# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# INTRODUCTION

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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### List of Contributors

## Acknowledgments

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# Foreword

Minnesota is known for its lakes, rivers, forests and prairies, which host a diversity of treasured wildlife species. Minnesotans love the outdoors and demonstrate that consistently through their recreational pursuits and their support for investments in Minnesota's natural heritage. The Minnesota Department of Natural Resources (DNR) has a broad array of programs designed to work with Minnesotans to conserve and manage Minnesota's natural resources, and Minnesota's Wildlife Action Plan 2025-2035: Conserving Habitats and Biodiversity is an example of leadership in the arena of wildlife conservation.

Despite Minnesotans' great love for wildlife and many notable conservation successes, many vulnerable species need our active conservation attention due to decreasing numbers, shrinking habitat or other ongoing stressors they face. This Wildlife Action Plan is a roadmap and invitation for all Minnesotans to participate in the protection, restoration and recovery of our state's most vulnerable wildlife and their vital habitats. The Plan identifies 1,142 Species in Greatest Conservation Need, including about 550 animals and 600 plants and lichens. The Plan also describes the significance and conservation needs of 15 primary habitats essential to these species. These habitats, when healthy, not only benefit wildlife, but also provide an array of societal benefits such as flood control, clean water and outdoor recreation opportunities for wildlife viewing, hunting and fishing. Further, the Plan identifies ways in which Minnesotans can take action to assist vulnerable wildlife and plants.

Effective wildlife conservation in our state is realized through collaboration and partnership in the management of our lands and waters. The DNR manages more than 5.6 million acres of state-owned public lands, many of which support rare and threatened species. Minnesota's wildlife species use these lands, in addition to the lands managed and cared for by Tribal Nations, local governments, other state agencies, federal agencies, private landowners, and conservation organizations. To help facilitate coordinated conservation efforts across all of these lands, this Plan's Conservation Action Network and map of Conservation Opportunity Areas highlight biodiversity hotspots and places on the landscape, irrespective of ownership.

The need for sustained support for wildlife conservation cannot be overstated. Minnesota's Wildlife Action Plan unlocks vital federal funds for the conservation of rare, at-risk and vulnerable species. Since 2000, Minnesota has been awarded nearly $26 million from the federal government's State and Tribal Wildlife Grants Program, matched with state funds such as the Nongame Wildlife Fund and Reinvest in Minnesota. These funds support essential conservation actions including habitat restoration, direct conservation actions, surveys, monitoring and conservation outreach projects.

I hope that Minnesota's Wildlife Action Plan brings to light the many ways in which we can all work together to research, conserve, and protect our treasured wildlife heritage.

Sarah Strommen
Commissioner
Minnesota Department of Natural Resources

# Introduction

The Nongame Wildlife Program, part of the Minnesota DNR's Ecological and Water Resources division, focuses on conserving wildlife species that are not hunted or fished (nongame species). Its mission includes monitoring species groups and restoring declining populations, protecting and enhancing critical habitats, conducting scientific research, and connecting Minnesotans with wildlife through education and community engagement.

Over the past 50 years, Minnesota's Nongame Wildlife Program has made remarkable strides — helping to turn near-extinct species into wildlife success stories. The scope and reach of the program have grown from a single staff person with a shoestring budget to a well-established program with nongame wildlife specialists throughout the state dedicated to fostering wildlife diversity. The work of the past half century has led to a greater understanding of the interconnectedness of ecological systems. This has resulted in an increase in the breadth of what is considered nongame wildlife, expanded from mammals and birds to now include herptiles (e.g., frogs and turtles), fishes, and invertebrates such as butterflies and mussels. For the first time we have also included plants on the Species in Greatest Conservation Need list, an important step in prioritizing ecosystem level conservation efforts.

While the work of the past guides our future actions and provides a solid foundation from which to continue to build success, the changing landscape and increased stressors to all species and ecosystems present new challenges in uncharted territory. The need is urgent, and the issues are many, including developing secure funding structures, broadening public involvement, addressing fragmented habitats, adapting to climate change and uncertainty, identifying and preventing emerging diseases, and reinforcing research capacity.

These challenges are serious and complex; however, this Plan helps prioritize conservation needs, address challenges, consider innovative strategies, implement actions and measure successes, maintain existing partnerships and build new collaborations. This is the third iteration of our Plan which builds from the foundational components of the two previous Plans. While administered and led by the DNR Nongame Wildlife Program, this plan is truly Minnesota's Wildlife Action Plan. Highlighting our programmatic growth over the past 50 years is a sign of success in its own right but also a recognition that the need for collaborative conservation action has increased. This comprehensive Plan revision would have been impossible without the concerted effort of our many partners and conservation allies. Through the 2-year revision process the status and trends of over 7000 species native to Minnesota were assessed and we collaborated with over 60 conservation entities represented by over 300 experts and professionals.

This Plan is tangible, scalable and aspirational. For environmental conservation efforts to succeed and last, the data-driven information and conservation action recommendations in this Plan are just the beginning. We need to consider a multifaceted approach garnered by public support and informed decision makers, including access to long-term and stable funding mechanisms, using science-based recommendations to develop policy, investments in sensible technologies, increased cross-sector collaboration, inclusion of indigenous knowledge, and recognition of equity barriers. Some of these factors may appear to be outside of the scope of this 10-year Wildlife Action Plan, yet they shape the reality in which we live and have a dynamic impact on our collective ability to implement this Plan. As the name suggests, this Plan is grounded in action, let's get to work.

Kristin Hall, Nongame Wildlife Program Supervisor, Minnesota DNR

# How to Use Minnesota's Wildlife Action Plan 2025-2035

Minnesota's Wildlife Action Plan 2025-2035 has been designed in a modularized way with the information seeker — the reader — in mind. The Plan is optimized for online access, based on feedback we received in a State Wildlife Action Plan (SWAP) awareness survey (2023), in which user groups and partners expressed their suggestions to make the SWAP more accessible and searchable. The Plan will eventually be presented online in an interactive website that enables visitors to find, read, and download the information they seek. Presenting information in this way makes the large volume of information contained in the Plan more accessible and able to be applied into various conservation contexts – for researchers, teachers, land managers, interpreters, private landowners, and the public. Access to Plan information will be guided online along several primary pathways:

## By Topic or Chapter

If you are interested in learning about the Species in Greatest Conservation Need, refer to Chapter 2. If you are interested in Public Engagement, select Chapter 4, and so on.

## By Taxonomic Group

If you are interested in mammals, mussels, or plants, you can directly select to read about a group of species. These reports will bring together information about stressors and actions for these species.

## By Habitat

A landowner or land manager might like to learn about the forest or stream on their land. Information will be provided for 15 habitats, including a general description, primary stressors in those environments, associated native plant communities and SGCN, and conservation actions in that environment to benefit SGCN.

## By Geography

If possible, we envision the capability for people interested in a specific region within the state, such as a county or ecoregional section, to select those geographical areas on an interactive map to gain information about the habitats and associated species in that area.

## On a Map

A spatial data viewer will enable viewers to interact with several key spatial resources. The Conservation Action Network highlights the most important areas for biodiversity and connectivity. Conservation Opportunity Areas highlight places prioritized for on-the-ground partnerships. The viewer will also include layers depicting the habitats in the state, climate resources, and native plant communities.

This Plan will also be available as one document for those who wish to have a complete reference. The next section, Roadmap to the Eight Elements, explains where in the Plan each of the congressionally required elements of State Wildlife Action Plans can be found.

## Roadmap to the Eight Elements

State Wildlife Action Plans are required for states to secure State Wildlife Grants from the U.S. Fish and Wildlife Service under the State and Tribal Wildlife Grants Program, established in 2001. The plans have eight required elements, depicted in the table below along with where the material can be found within this Plan.

**Table of Eight Required Elements of State Wildlife Action Plans and where the material is found in this Plan.**

| Element and Description | Location in this SWAP |
|---|---|
| Element 1. Identify Species of Greatest Conservation Need (SGCN) including species that have low populations or are in decline. | Chapter 2 SGCN |
| Element 2. Identify the habitats essential to the conservation of those SGCN. | Chapter 3 Habitat |
| Element 3. Identify threats to SGCN and associated habitats. | Chapters 2 and 3 |
| Element 4. Identify the conservation actions needed to address those threats. | Chapters 2 and 3 |
| Element 5. Describe a plan for monitoring SGCN and their habitats, and the effectiveness of conservation actions in order to adaptively manage them | Chapter 5 Monitoring |
| Element 6. Review and revise the SWAP at least every 10 years. | Chapter 1 Foundation |
| Element 7. Develop, review, and implement SWAPs in conjunction with conservation partners including Tribes and federal, state, and local agencies that manage lands. | Chapter 1 Foundation |
| Element 8. Seek broad public participation in the development and implementation of the SWAP. | Chapters 1 Foundation and 4 Public Engagement |

# Executive Summary

Minnesota's Wildlife Action Plan 2025-2035: Conserving Habitats and Biodiversity, is Minnesota's third State Wildlife Action Plan (Plan or SWAP), updating information and strategies initiated in the 2005 and 2015 plans.

**The overarching goal of this Plan is to guide, facilitate, and inspire conservation actions that sustain the long-term health and viability of Minnesota's biodiversity, with a focus on species that are rare, declining, or vulnerable (Species in Greatest Conservation Need) and their habitats.**

State Wildlife Action Plans provide strategic guidance for conserving Species in Greatest Conservation Need (SGCN) and the habitats they depend on within each state. These non-regulatory Plans outline proactive and voluntary approaches to conservation designed for collaborative implementation by a broad range of partners within states. These Plans reflect a shared commitment to maintaining a healthy environment for animals, plants and people. By guiding conservation efforts before species become critically imperiled, SWAPs help prevent the need for federal or state listing of animals or plants as endangered and reduce reliance on costly, restrictive recovery measures.

State Wildlife Action Plans also enable states to access State Wildlife Grant funds, the primary federal source dedicated to conserving non-hunted or fished wildlife species. In Minnesota, these funds are essential for the conservation of roughly 75% of the vertebrate species including amphibians, birds, fish, mammals, and reptiles. When including invertebrates such as insects, spiders, and mussels, State Wildlife Grant funding supports conservation actions for approximately 96% of all animal species in the state.

**Vision: working together to conserve Minnesota's rare, declining, and vulnerable species and their habitats**

## Three Primary Plan Goals

This Plan is organized around three primary goals, each presented in its own chapter. For each goal, a set of strategies is described and supported by a set of potential conservation actions. The goals are:

1. **Species:** Conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions.
2. **Habitat:** Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN.
3. **Public Engagement:** Inspire, motivate, and empower Minnesotans to engage in conservation actions that support SGCN and their habitats.

### Species in Greatest Conservation Need

SGCN are animal and plant species that are vulnerable or at risk of decline or extirpation and species of stewardship or tribal significance in Minnesota.

To identify these species, we completed a large-scale systematic conservation status assessment for the more than 7,000 species in the state for which there was sufficient information. We evaluated rarity, trends, and threats, following an internationally adopted process, to generate conservation assessment (S-rank) scores that classify species from secure to highly imperiled. These standardized evaluations then formed the foundation for revising our state list of SGCN, now in this update, totaling 1,142 species. For the first time, we have included plants and lichens, which together account for 599 of the SGCN species.

Another 860 plant and animal species were identified as Species in Need of Information (SNI), species believed to be rare in Minnesota, but for which we do not have enough information to categorize them as SGCN.

Throughout this Plan, we highlight key stressors — factors that pose challenges to vulnerable plant and wildlife species — and outline actions to address them, focusing conservation efforts where they are needed most. We profile 24 stressors following an international threats classification system, adapted to Minnesota's species groups and habitats described in the sub-chapters below. Among these, climate change receives additional attention, with dedicated strategies and resources for climate adaptation presented in Chapter 6: Implementation.

The species goal is advanced through three strategies:

1. **Survey, monitor and research** to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

2. **Collaborate to deliver conservation actions** that support resilient populations of SGCN and their habitats in partnerships with agencies, Tribes, non-governmental organizations, private landowners, and others.

3. **Develop and share informational material** to guide conservation actions for SGCN, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management practices.

Conservation actions under these strategies are described in sub-chapters for eight groups of species: amphibians, reptiles, birds, fishes, mammals, aquatic invertebrates, terrestrial invertebrates, and plants and lichens.

## Habitat

Habitat loss and degradation are primary mechanisms for species declines. Directing conservation efforts at the habitat, community, and ecosystem levels is fundamental to conserving SGCN. The habitat chapter outlines five strategies to guide habitat conservation for Minnesota's biodiversity:

1. **Protect, buffer, and connect** high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

2. **Restore, enhance, and maintain** lands and waters to benefit habitat quality for SGCN, biodiversity, and ecosystem resilience.

3. **Collaborate** with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

4. **Survey, monitor and research** SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to stressors, natural disturbances, conservation actions, and climatic conditions.

5. **Connect** to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN.

Fifteen primary habitat types are described in sub-chapters that provide conservation context, an assessment of the stressors, and actions nested under strategies to address those stressors.

## Public Engagement

The Plan's third goal for public engagement emphasizes the role that all Minnesotans can play in natural resource stewardship. This chapter articulates seven strategies for inspiring, motivating, and empowering Minnesotans to support conservation of SGCN and their habitats. The importance and rationale for each strategy is discussed, accompanied by a set of recommended actions to implement it. The strategies are:

1. **Develop and distribute informational resources** and media on SGCN, their habitats, and threats.
2. **Support environmental education** on SGCN and their habitats on a statewide level.
3. **Provide and promote wildlife viewing opportunities** and programs that inspire curiosity, caring, and connection with Minnesota's SGCN.
4. **Foster responsible recreation practices** that reduce recreational effects on SGCN and their habitats while allowing for safe and satisfying access to the outdoors.
5. **Engage and empower communities** to improve wildlife habitats where they live, work, and recreate.
6. **Offer participatory science programming** for Minnesotans to take part in conservation volunteerism that addresses SGCN data needs.
7. **Cultivate financial support** for the conservation of SGCN through the development and promotion of public funding opportunities and public-private partnerships.

Following these three main goals in the Plan, two additional chapters provide tools and approaches in support of the overall goals: Chapter 5: Monitoring and Research and Chapter 6: Implementation.

## Monitoring and Research

Though discussed throughout the Plan, Chapter 5: Monitoring and Research emphasizes the critical role of surveys, monitoring, and research in generating foundational ecological data. These activities support surveillance and conservation effectiveness monitoring and help assess the effects of stressors on Minnesota's plant and animal species, habitats, and ecological communities. The chapter defines these tools and explains their application within the framework of the State Wildlife Action Plan. It features a range of projects and programs led by the DNR and its partners, spanning diverse species, habitats, and conservation strategies. The chapter concludes with a practical guide on study design and key statistical principles essential for collecting rigorous, defensible, and repeatable scientific data. These principles are especially valuable in the context of adaptive management, where objectives and scientific understanding evolve over time through iterative learning and refinement.

## Implementation

The Implementation Chapter contains information for conservation practitioners about the Conservation Action Network, Conservation Opportunity Areas, and the topic of Climate Adaptation.

**The Conservation Action Network (CAN)** is a mapped resource identifying core areas in Minnesota for habitat quality, biodiversity (high numbers of SGCN), and locations of SGCN. It also delineates buffers and corridors that protect and connect these areas, while facilitating adaptation to climate change by identifying areas that support habitat resilience and facilitate species movements across the

landscape. The purpose of the CAN is to guide and prioritize conservation actions given limited resources. Building on the Wildlife Action Network developed in the 2015 Plan, it was renamed as the Conservation Action Network to include plant SGCN.

**Conservation Opportunity Areas (COAs)** are places where partnerships focus on implementing on-the-ground conservation actions to benefit SGCN and their habitats. These locations are based on the core areas of high biodiversity, highest quality habitats, and corridors identified by the CAN. However, many COAs extend beyond these core areas to include sites where established partnerships are actively collaborating on habitat management projects that support SGCN. Formerly named Conservation Focus Areas under the 2015 Plan, the updated name — Conservation Opportunity Areas — reflects the expanded boundaries that capitalize on partnership opportunities and increase the breadth of ecological benefits at the landscape scale.

**The Climate Adaptation** section provides resources to understand trends in Minnesota's climate and to support managers in facilitating adaptative practices in the ecosystems they oversee.

In summary, this Plan provides information, strategies, and example actions to benefit Minnesota's biodiversity, its Species in Greatest Conservation Need, and the habitats that sustain them. Designed for all Minnesotans, this Plan should help us achieve our vision of conserving Minnesota's rare, declining, and vulnerable species and their habitats. Our success depends on strong, collaborative partnerships statewide including private landowners; the 11 federally recognized Tribes within Minnesota's borders; local, state, and federal land managers; academic institutions; non-governmental conservation organizations; and others. We appreciate your interest and participation in the conservation of these valuable and vulnerable species of animals, plants, and their habitats.

*Photo: common loons, Carol Henderson*

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## CONSERVING HABITATS AND BIODIVERSITY

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Cover Photos: Biologists visiting Uncas Dunes Scientific and Natural Area, Leslie Parris; Young birdwatcher at Urban Bird Festival, Mississippi Gateway Park, Grayson Smith, USFWS

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# Chapter 1: Foundation

## The Significance of State Wildlife Action Plans

State Wildlife Action Plans (SWAP) provide strategic guidance for conserving rare, declining, and vulnerable animal and plant species and the habitats they depend on within each state. These plans also serve a critical function by unlocking access to U.S. Fish and Wildlife Service (USFWS) State Wildlife Grant (SWG) funds, the primary source of federal funding dedicated to the conservation of non-hunted or fished wildlife species. In Minnesota, game and sportfish receive targeted federal support through separate programs, but species with take restrictions account for only about 25% of the state's vertebrates (an additional 18% of vertebrate species are unregulated game or fish). This means that SWG funds are essential for the conservation of 57-75% of Minnesota's vertebrate species, including amphibians, birds, fish, mammals, and reptiles. When invertebrates such as insects, spiders, and mussels are included (3,789 species assessed for this Plan), the coverage of SWG funding extends to approximately 96% of Minnesota's animal species. These figures highlight the vital role that SWAPs and SWG play in supporting biodiversity conservation across Minnesota.

Across the nation, SWG funds have distributed over $1.4 billion to 56 states, territories, commonwealths and the District of Columbia since 2000. Minnesota has received nearly $26 million from 2002 through 2024. These critical funds have supported wildlife conservation projects dedicated to conserving rare and declining species across the state. Examples include surveys of rare salamanders and fish, restorations of native prairies and oak savannas, and propagating rare mussels for reintroduction.

State Wildlife Action Plans are non-regulatory guides that outline proactive and voluntary approaches to conserving wildlife, designed for implementation by broad arrays of partners within states. These plans reflect a shared commitment to maintaining a healthy environment that includes all animals and plants. By guiding conservation efforts before species become critically imperiled, SWAPs help prevent the need for listing animals or plants as endangered and reduce reliance on costly, reactive, and restrictive measures to recover species from the brink of extinction.

**Species in Greatest Conservation Need (SGCN) are animal and plant species that are vulnerable or at risk of decline or extirpation and species of stewardship or tribal significance in Minnesota.**

State Wildlife Action Plans focus on Species in Greatest Conservation Need (SGCN); their habitats; the threats they face; and the conservation actions needed to support their survival, including monitoring and research. These elements are core requirements of each Plan (see Roadmap) and among them, habitat conservation warrants particular emphasis. As our knowledge of species ecology and conservation challenges deepens and as the SGCN list continues to grow, it becomes increasingly clear that species-by-species conservation efforts are often impractical. In many cases the most effective conservation strategies will occur at the ecosystem level, where actions can benefit multiple species simultaneously.

The conservation of Minnesota's SGCN depends on strong, collaborative partnerships across the state, including private landowners; the 11 federally recognized Tribes within Minnesota's borders (Tribes); local, state, and federal land managers; academic institutions; and non-governmental conservation organizations. This Plan serves as a resource to inform and support the collective efforts of this diverse community of people committed to safeguarding Minnesota's SGCN and their habitats.

## Goals of Minnesota's Wildlife Action Plan 2025-2035

### Vision

Working together to conserve Minnesota's rare, declining, and vulnerable species and their habitats.

### Overarching Goal of the SWAP

To guide, facilitate, and inspire conservation actions that sustain the long-term health and viability of Minnesota's biodiversity, with a focus on species that are rare, declining, or vulnerable (Species in Greatest Conservation Need, SGCN) and their habitats.

### Three Primary Goals

#### Goal 1. Species

Conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions. (see Chapter 2: Species in Greatest Conservation Need)

#### Goal 2. Habitat

Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN. (see Chapter 3: Habitats)

#### Goal 3. Public Engagement

Inspire, motivate, and empower Minnesotans to engage in conservation actions that support SGCN and their habitats. (see Chapter 4: Public Engagement)

*Photo: Young birdwatcher at Urban Bird Festival, Mississippi Gateway Park, Grayson Smith, USFWS*

# Building on the Strengths of the 2005 and 2015 Plans

Minnesota published two previous ten-year State Wildlife Action Plans; this document represents the third version and is consistent with the earlier versions. Each of the earlier plans provided valuable guidance that continues to inform conservation efforts today. This updated Plan builds upon those foundations by incorporating current approaches, new information, and refined strategies. The key strengths of the previous plans are briefly summarized below.

## 2005-2015 Plan: Tomorrow's Habitat for the Wild and Rare

### Species in Greatest Conservation Need Identification and Distribution

Minnesota's initial State Wildlife Action Plan, Tomorrow's Habitat for the Wild and Rare (DNR, 2005) established criteria to objectively identify Species in Greatest Conservation Need. A total of 292 SGCN were identified, including 189 vertebrates and 103 invertebrates.

### Habitat Focus

The 2005 Plan identified that the primary threat to SGCN was the significant loss and degradation of habitat. It emphasized that effective conservation depends on the ability to identify and protect the habitats these species require. The Plan identified 16 key habitats and associated SGCN with key habitats.

### Ecoregional Profiles

To provide greater specificity, the Plan also included summaries for each of Minnesota's 25 ecoregional subsections, as defined by the state's Ecological Classification System. Each subsection profile featured maps illustrating the distribution of key habitats and SGCN richness by township, summaries of the key habitats used by SGCN and which habitats are most important to the greatest number of SGCN. In addition, ten-year goals, management challenges, strategies, and conservation actions were outlined for each subsection.

## Minnesota's Wildlife Action Plan 2015-2025

### Species in Greatest Conservation Need Update

For Minnesota's second Plan, Minnesota's Wildlife Action Plan 2015-2025 (DNR, 2015), technical advisory teams conducted a comprehensive review and update of the 2005 SGCN list, adding 111 species and removing 59 species, resulting in a revised total of 346 SGCN. Stressors affecting each species were assessed to determine which SGCN would benefit from a habitat-based conservation approach and which required more targeted actions.

### Wildlife Action Network

For species that would most benefit from a habitat-based approach, the 2015 Plan introduced the Wildlife Action Network (WAN), a map to illustrate the distribution of high-quality habitats for both terrestrial and aquatic SGCN. To prioritize the implementation of on-the-ground conservation efforts, sites within the WAN were assigned priority rankings based on five metrics, including SGCN population viability and species richness.

### Conservation Focus Areas

Acknowledging the limited fiscal and human resources available to implement conservation objectives, a prioritization system was developed to guide habitat conservation efforts more effectively. The WAN rankings helped identify 37 Conservation Focus Areas (CFAs), specific locations for partnerships and funding to support habitat restoration and management efforts across organizational and jurisdictional boundaries. The CFA approach has been an effective strategy for fostering partnerships and leveraging shared resources to address the habitat needs of SGCN across Minnesota.

## Strategies, Stressors, and Actions

Strategies for implementation of the Plan are described within each of the chapters that address the three primary goals (Chapter 2: Species in Greatest Conservation Need, Chapter 3: Habitats, and Chapter 4: Public Engagement).

Stressors, or threats, are factors that create conservation challenges for habitats or species. These are first explained in Chapter 2: Species in Greatest Conservation Need, then specifically elaborated within each of 15 habitat sub-chapters and 8 species group sub-chapters. Stressors are depicted with a set of icons that are used to connect to Conservation Actions.

Potential Conservation Actions are described in each sub-chapter to illustrate ways to implement strategies. Actions in the species and habitat sub-chapters are related to stressors with the use of icons.

## Monitoring and Research

Chapter 5: Monitoring and Research emphasizes the critical role of surveys, monitoring, and research in generating foundational ecological data. These activities support surveillance and conservation effectiveness monitoring and help assess the effects of stressors on Minnesota's plant and animal species, habitats, and ecological communities. The chapter defines these tools and explains their application within the framework of the State Wildlife Action Plan. It features a range of projects and programs led by the DNR and its partners, spanning diverse species, habitats, and conservation strategies. The chapter concludes with a practical guide on study design and key statistical principles essential for collecting rigorous, defensible, and repeatable scientific data. These principles are especially valuable in the context of adaptive management, where objectives and scientific understanding evolve over time through iterative learning and refinement.

*Photo: Biologists visiting Uncas Dunes Scientific and Natural Area, Leslie Parris*

## Implementation

Chapter 6: Implementation explains in detail three elements that assist in our delivery of the Plan in Minnesota: the Conservation Action Network, Conservation Opportunity Areas, and Climate Adaptation.

## Conservation Action Network

The 2025 Conservation Action Network (CAN) is a mapped resource representing important areas to the SWAP, including core areas of high biodiversity (high numbers of SGCN), highest quality habitats and landscapes, and buffers and corridors to further protect and connect core areas ( Figure 1.1). Three main steps were implemented in developing the CAN. First, core areas were identified from over XX GIS map layers representing SGCN concentrations, high quality or rare plant communities, and significant landscapes. Then, connectivity analyses of forests and prairies were conducted to identify the best paths of connection between core areas represented in the CAN. Finally, the network was scored using a subset of layers to prioritize where multiple layer features overlap.The purpose of the CAN is to guide and prioritize conservation actions given limited resources. It also addresses the growing effects of climate change by identifying areas that allow for essential ecosystem processes, habitat resilience, and the movement of species across the landscape.

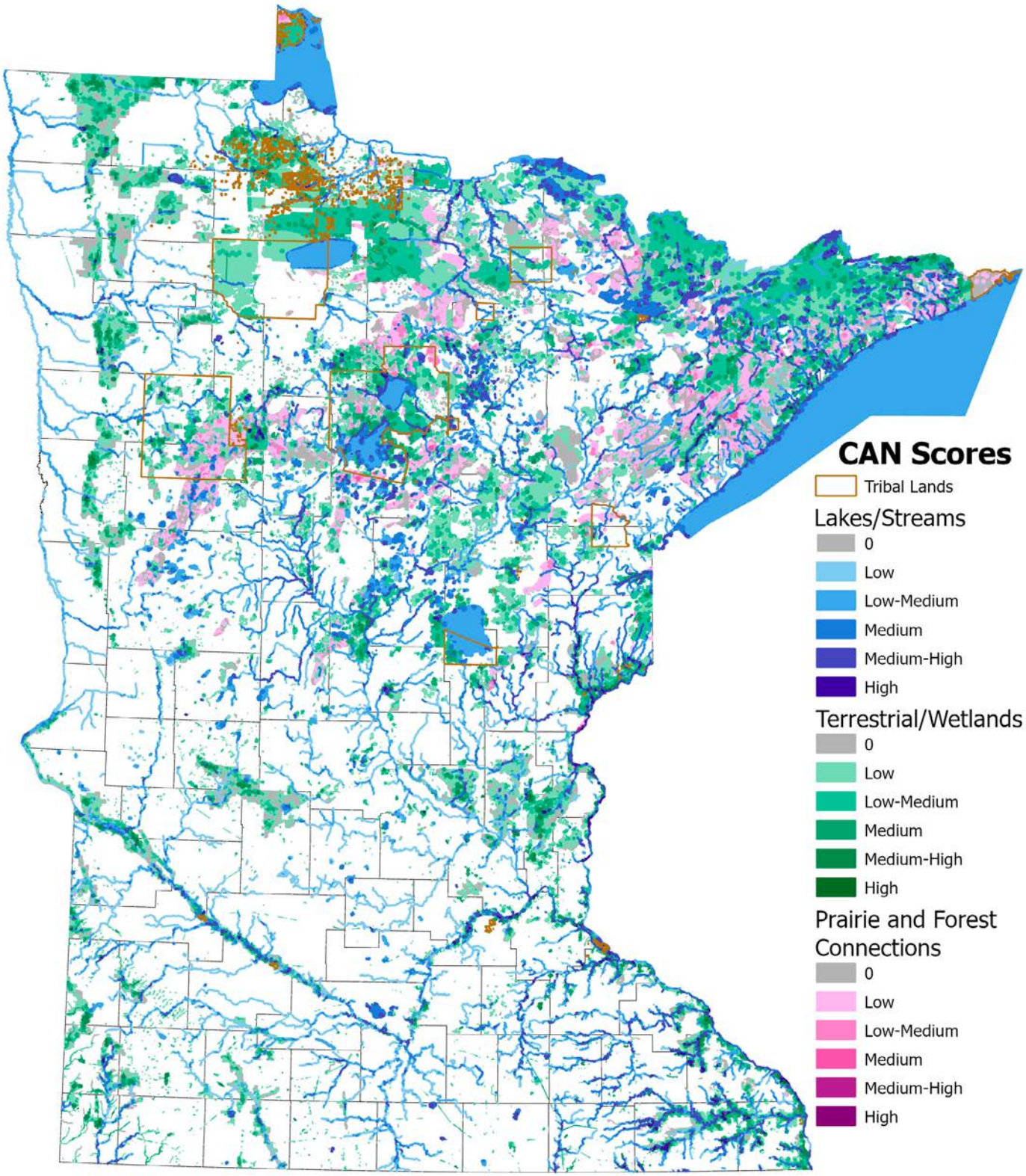


Figure 1.1 The Conservation Action Network (CAN) is built from a series of data layers including richness of Species in Greatest Conservation Need, areas of outstanding biological significance and places with strong landscape connectivity. A higher CAN score represents areas where more of the source layers overlap and indicates the highest priority for conservation actions.

## Conservation Opportunity Areas

Conservation Opportunity Areas (COAs) are based on the Conservation Action Network, with many expanded a bit beyond the CAN to incorporate established partnerships that are can actively collaborate to deliver habitat management projects to benefit SGCN (see Figure 1.2). These partnership efforts present unique opportunities to capitalize on established working relationships and shared conservation goals.

COAs are not meant to represent all of the important areas in the CAN for SGCN. The goal is to identify the highest priority areas for conservation work to occur within the larger partnership framework that exists within a COA. This allows our COA Coordinators to focus their efforts and capitalize on existing partnerships that are already addressing similar habitat concerns.

Potential projects within the COAs will be prioritized based on their location related to the priority areas designated by the CAN. Focusing habitat management, restoration, and protection within the CAN will enhance core areas of habitat and connections between habitats. This focus will also allow land managers/owners to incorporate existing partnerships while focusing their efforts on priority areas. This will increase efficiency by facilitating the coordination of management, prioritizing outreach efforts, and targeting technical assistance.

Conservation Opportunity Areas may contain multiple partnership groups that are actively collaborating on project implementation. Each of these groups may have a slightly different approach to their efforts and/or a slightly different set of habitat types in which they work. Rather than having a set of standards that each COA must meet to be considered active, the 2025 Minnesota Wildlife Action Plan will consider a COA active if there is at least one partnership group present, regularly meeting with the intent of implementing habitat improvement projects.

It is hoped that the COA approach will increase the number of active partnership groups that the COA Coordinators can engage with as well as the coordination of those partnership groups across a broader geographic area.

## Climate Adaptation

The Climate Adaptation section presents scientific data, concepts, and strategies to support effective conservation in the face of a changing climate. While climate change was prominently featured in the 2015 Plan, current trends in temperature and precipitation continue to intensify, as clearly illustrated through updated charts and statistics. The effects of rising temperatures and shifts in rainfall patterns, including increased flooding, shorter winters, and altered growing seasons, are being felt across all ecosystems. The climate-related stressors are addressed throughout the habitat sub-chapters, as they influence nearly every aspect of ecological function. Climate stress also interacts heavily with many other stressors, such as the spread of invasive species, fire regime alterations, and the emergence of diseases and pathogens.  In this section of Chapter 6: Implementation, we provide background information, actionable strategies, and illustrate case studies to help conservation practitioners better understand and incorporate climate adaptation into their work.

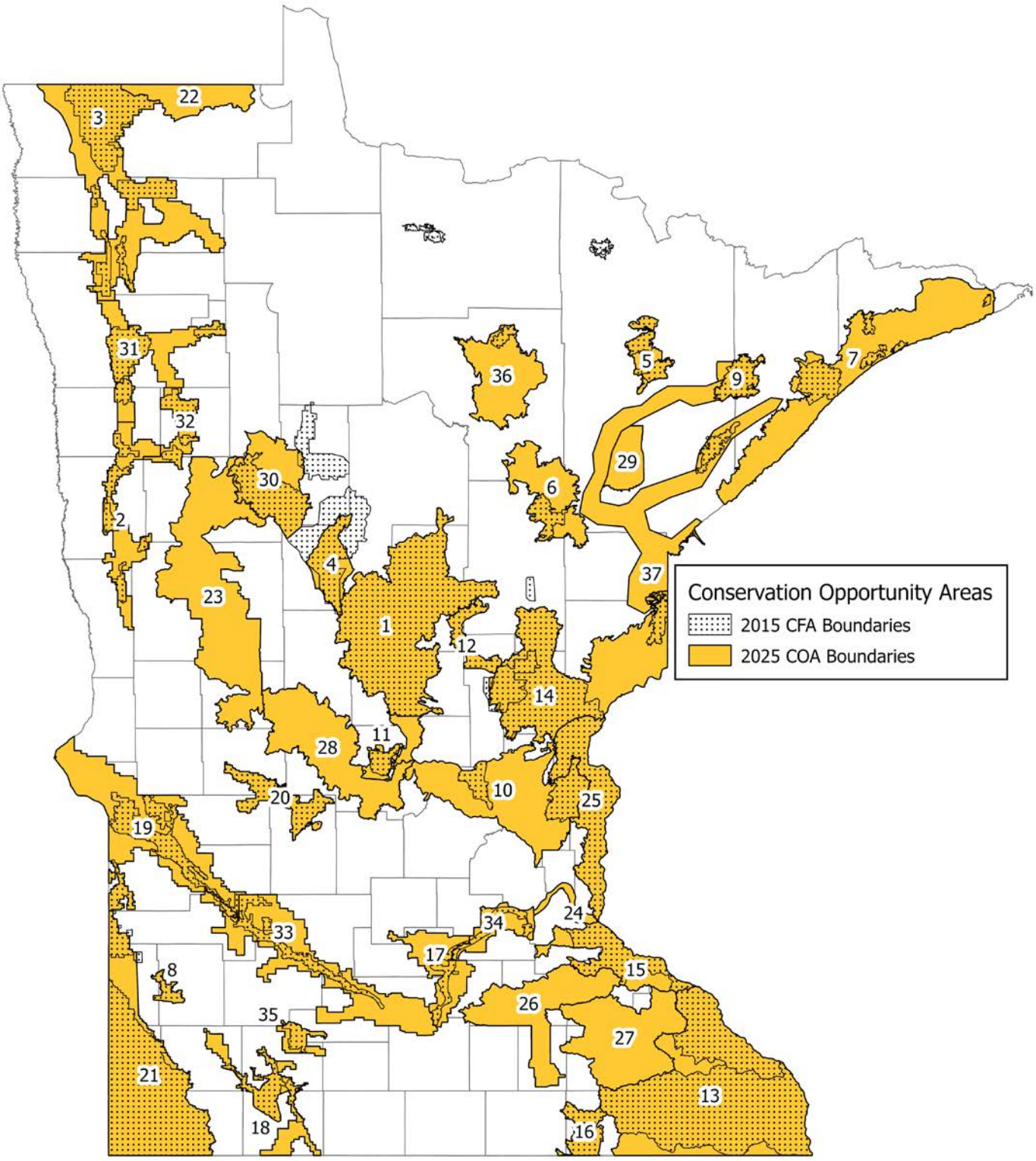


Figure 1.2. Map of Conservation Opportunity Areas (COAs) for 2025-2035, developed with input from internal and external partners to revise the 2015-2025 Conservation Focus Areas. After some COA's were added, some were merged, some were split, and some were removed altogether, the number of COA's remained at 37. Two additional COAs proposed in north central Minnesota require further consultation with Tribes for delineation and were not depicted on this map.

## Plan Revision Including Public and Partner Input

Minnesota DNR is committed to comprehensively reviewing and updating or revising our State Wildlife Action Plan at an interval not to exceed every ten years. Revisions are done following guidance documentation from the USFWS. For the 2025 revision, we examined Minnesota's entire Plan, completed updates and ensured that all 8 elements (see Roadmap to the Eight Elements) were properly fulfilled. The section below provides details about the 2025 revision, highlighting involvement by many partners (Element 7) and the public (Element 8). We plan to conduct another comprehensive review of the Plan within ten years by 2035.

A key emphasis of this revision of the State Wildlife Action Plan (the Plan) has been broad engagement across a diverse array of people to help shape its content and enhance its relevance for on-the-ground conservation. Contributors to the preparation of this Plan include 317 people representing more 64 organizations (see List of Plan Contributors at the end of this document). This network of individuals and entities who contributed to the development of the Plan will also play a vital role in sharing its vision and connecting others to implement its conservation actions.

We began the revision of the Plan in 2022 with a survey of individuals who use the SWAP. We asked what they valued most about previous Plans and what they hoped to see most in the new revision. Of the 136 responses received, 89 came from DNR staff and 47 from a broad range of conservation partners, including conservation organizations, federally recognized Tribes, federal agencies, local governments, and academic institutions. The feedback showed overwhelming support for the SGCN list, which continues to serve as a cornerstone for conservation planning and implementation statewide. Respondents also emphasized the lasting value of the habitat-based information introduced in the 2005 Plan and interest in refreshing that information. From the 2015 Plan, they highlighted the following elements as especially helpful: the Wildlife Action Network, the identification of Conservation Focus Areas, and the Plan's clear orientation toward action. A new request for this revision was the development of an interactive, online version of the Plan to allow users to easily access and tailor information to their specific needs.

In 2023, we invited a broad coalition of partners including Tribal representatives, conservation organizations, government agencies, academics, educators, and staff from all DNR divisions to participate in the Plan revision process. This collaboration took shape through a series of seven in-person workshops held within each region of the state. Prior to the workshops, a questionnaire was distributed to gather specific input from potential participants. Through these workshops, a total of 161 participants, representing more than 25 organizations, contributed their perspective and expertise to help shape foundational content on the most critical stressors and actions to be highlighted in this updated Plan. During the workshops, participants shared insights about the stressors affecting vulnerable species and ecosystems, identified conservation actions to address those threats, and discussed barriers to effective implementation. They also worked together to propose solutions for overcoming those challenges, helping ensure that this Plan reflects both on-the-ground realities and shared conservation goals.

*Participants in Wildlife Action Plan Revision Workshop, Alison Cariveau*

Following the workshops, we assembled volunteer teams to assist in developing of content for the revised Plan. More than 210 individuals participated across 11 teams, contributing their expertise to identify Primary Stressors and Priority Conservation Actions for key habitat types and taxonomic groups of plants and animals. Contributions were made during online working meetings. In addition, many of these volunteers also assisted in drafting chapters, collaborating through shared online documents to ensure the Plan reflects a broad base of knowledge and practical experience.

We also engaged more than 50 technical species experts to support the conservation status assessment (S-rank) process for all regularly occurring animal and plant species in Minnesota with sufficient data. Relevant datasets were compiled, species were evaluated, and S-rank scores were assigned to inform the identification of SGCN (see Chapter 2: Species in Greatest Conservation Need) and Species in Need of Information (SNI; see New for 2025 section below). The draft lists of SGCN and SNI were subsequently reviewed by species experts, volunteer team members, and DNR staff, all of whom were invited to provide feedback and comments.

To gather additional input for the development of Chapter 5: Public Engagement, including strategies to meaningfully engage Minnesotans in the stewardship of the state's rich natural resources (see New for 2025 section below), two final workshops were held in December 2024 and January 2025. These events brought together a total of 90 participants from 29 organizations, including strong representation of environmental educators and conservation outreach professionals, to identify barriers to reaching Minnesota's increasingly diverse population and to explore strategies for more effective engagement with local partners and communities. Follow-up meetings were held with a smaller working group, during which participants collaborated to craft the public engagement strategies and actions presented in this Plan.

To ensure input from Tribal Nations, we maintained regular communication with representatives from Tribal natural resource departments, meeting with them in some cases, and inviting their review of various sections of the Plan, including the draft list of draft SGCN.

The final stage of the public review involved posting the full draft Plan online for 21 days during July and August 2025, during which comments were collected through an online submission form. A second form was used to incorporate review by DNR employees during the same timeframe. All comments were reviewed and tracked in a spreadsheet. If changes were requested, we implemented the change if appropriate and replied via email to the requestor to explain if and how the requested changes were implemented.

# New for 2025

For the 2025-2035 Plan we have added several main new elements.

## Conservation Status Assessments

We employed a systematic, nationally standardized approach to assess the conservation needs of over 7,000 species of animals and plants in Minnesota, often referred to as S-ranks (see Chapter 2: SGCN). This method offers a repeatable approach for future reassessments and provides consistent, comparable information to support conservation at regional, national, and international conservation scales.

## Plants and Lichens

For the first time, the list of SGCN has been expanded to include plants and lichens (see Chapter 2: SGCN). This reflects a growing recognition of the need for closer integration between plant and animal conservation efforts, as encouraged by national initiatives such as the Restoring America's Wildlife Act, which also recognized the importance of plants. While plants and fungi are not currently eligible for SWG funding, their inclusion in this Plan lays the groundwork for a more comprehensive biodiversity conservation strategy. Plants are foundational to ecosystems and form the structure of habitats, serve as essential resources for specialist animal species, and provide critical ecosystem services that support life across the landscape.

## Species in Need of Information

Through the systematic review of all Minnesota plant and animal species with available data, it became evident that an additional classification of species was needed. Species in Need of Information (SNI) are those for which insufficient data currently exist to determine whether they warrant designation as SGCN (see Chapter 2: SGCN). This new category highlights the need for targeted survey and monitoring efforts to fill critical information gaps.

## Species of Tribal Significance

We introduced new criteria for identifying SGCN to include species of cultural significance to Tribes in Minnesota, recognizing the deep and enduring connections that Tribal Nations have with the plants and animals with whom we share the land. This addition allows Tribes to nominate species they consider vulnerable, even if those species do not meet the biological criteria for SGCN designation. As a result, wild rice *(Zizania palustris)* and snowshoe hare *(Lepus americanus)* were added to the list. Wild rice — *Manoomin* in Ojibwe and *Psin* in Dakota — is a culturally and spiritually important food traditionally harvested by Indigenous peoples, and it is vulnerable to many disturbances in the waters where it grows. Snowshoe hare – Waabooz in Ojibwe - is a culturally important prey species valued for its meat and fur, particularly in winter, and which is much reduced in population size and extent. In addition, there is concern about its status in the future due to less extensive snow cover in shorter, milder winters under our warming climate.

*Snowshoe hare, Julia Geschke*

## Public Engagement

In this Plan revision, the topic of public engagement was significantly expanded into a full chapter including seven strategies and many recommended actions. Chapter 5: Public Engagement highlights the vital role people play in conservation. It reflects the DNR's Nongame Wildlife Program commitment to better understanding and connecting with Minnesotans and our partners in conservation science, outreach, and education. This chapter emphasizes the importance of sharing information broadly and expanding the community of individuals and organizations actively working to conserve SGCN and their habitats.

## Conservation Action Network

Although not new to this Plan, the Conservation Action Network (CAN), formerly known as the Wildlife Action Network (or WAN), has been renamed to better reflect our expanded commitment to biodiversity conservation, including plant species as SGCN. The content of the CAN also has been updated with current data and new connectivity analyses. For complete information about the CAN, see Chapter 6: Implementation.

## Conservation Opportunity Areas

As with the Conservation Action Network, this component is not new in the 2025 Plan but has been renamed from Conservation Focus Areas to Conservation Opportunity Areas (COAs; see Figure 1.2). Updated and expanded boundaries to COAs were informed by extensive input gathered during in-person regional workshops, ten targeted mapping meetings with local partner groups, DNR staff, and external regional partners across the state. These discussions brought up the need to expand existing boundaries to capitalize on current partnership opportunities and to increase ecological connectivity. The new name, Conservation Opportunity Areas, better reflects these expanded boundaries and the broader, landscape-scale conservation opportunities they represent. It also aligns more closely with where partners are located, thereby facilitating collaboration and providing connectivity among core areas of the CAN. For more information refer to Chapter 6: Implementation.

# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## SPECIES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

## Acknowledgements

We would like to thank more than 300 people who contributed to the development of this State Wildlife Action Plan (SWAP) throughout our revision process over the past two years (see List of Plan Contributors). Everyone's varied perspectives and expertise has improved the plan and will carry on into the next ten years of conservation action for Minnesota's biodiversity and vulnerable wildlife. A specific thank-you to members of the Nongame Wildlife Program core team who facilitated teams, developed content, and pulled together this huge resource: Alison Cariveau (lead), TJ Boettcher, Daren Carlson, Mags Edwards, Julia Geschke, Benjamin Gieseke, Kristin Hall, Chris Jennelle, Tim Mitchell, Elizabeth Nault-Mauer, Jessica Ruthenberg, and Jim Wanstall. Special appreciation also to Lee Pfannmuller, Bridget Henning-Randa, Bob Dunlap, and April Rust who contributed so much to this revision. We thank numerous taxonomic experts and all the volunteers who participated in eleven revision teams; please see the full List of Plan Contributors.

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This document contains maps that are available in alternative formats to individuals with disabilities by calling (651) 259-5149 or emailing the SWAP Coordinator at alison.cariveau@state.mn.us.

Cover Photos: Blanding's turtle and research intern, by Andrew Herberg; Golden-winged warbler, a stewardship species, Bob Dunlap

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# Chapter 2: Species in Greatest Conservation Need

## Overview

This chapter gives an overview of Species in Greatest Conservation Need (SGCN), animal and plant species that are vulnerable or at risk of decline or extirpation, or species of stewardship or Tribal significance in Minnesota. We also introduce Species in Need of Information (SNI), species believed to be rare in Minnesota, but for which we do not have enough information to categorize them as SGCN. Also new this year is the inclusion of plants and lichen to the SGCN and SNI list. Although plants are not eligible for funding under State Wildlife Grants, plant Species in Greatest Conservation Need are included here to build the basis for a broader conservation strategy.

SGCN include species that are very imperiled, such as those that are facing extirpation or even extinction. All species listed as endangered, threatened, or special concern by the state or federally are included as SGCN. The federal listing of threatened and endangered species, administered by the U.S. Fish and Wildlife Service under the U.S. Endangered Species Act, provides legal protection to species across their entire national or regional ranges. Minnesota maintains its own list of endangered, threatened, and special concern species under state law, reflecting conservation status specifically within the state's borders (Minnesota's endangered, threatened, and special concern species). Per Minnesota Statute Ch. 84.0895, endangered species are those threatened with extinction throughout all or a significant portion of its range in Minnesota, threatened species are those likely to become endangered within the foreseeable future throughout all or a significant portion of its range within Minnesota, and species of special concern are extremely uncommon in the state or have unique habitat requirements (Status definitions). Legal protections exist for endangered or threatened species, with the goal of preventing the extinction of species. Many of these species also have species-specific plans directing conservation efforts for their recovery. The DNR endangered species program is responsible for administering a permitting program to ensure that activities that may cause take of (harm to) state endangered or threatened species are not detrimental to the species. The DNR cooperates with USFWS on the protection and conservation of federally listed species.

**SGCN are animal and plant species that are vulnerable or at risk of decline or extirpation, or species of stewardship or Tribal significance in Minnesota.**

In addition to these imperiled species, SGCN include species that are more common. An important function of the State Wildlife Action Plan (SWAP) is to identify early conservation actions for at-risk species that can reduce their need for listing as endangered or threatened species and improve the probability of their recovery to sustainable levels. Designating more abundant species as SGCN highlights their declines or significant threats, ensuring that conservation measures can be implemented early — before populations become so depleted that recovery efforts are more costly and less likely to succeed.

Topics in this chapter include the Goal, three Strategies, and how these relate to conservation actions. We also touch on the evolution of SGCN across the three Plan iterations and the current definition of SGCN. We explain the conservation status assessment (S-rank process) underlying this Plan's list of SGCN and explain our approach to discussing stressors (threats) relating to species and their habitats. We provide a summary table of the 2025 list of SGCN and SNI sorted by taxonomic groups. This is then followed by a set of 8 sub-chapters for amphibians, birds, fishes, mammals, reptiles, aquatic invertebrates, terrestrial invertebrates, and plants (with lichens).

## Building on the two Prior Plans

The definition of Species in Greatest Conservation Need has remained consistent across Minnesota's SWAPs, with minor additions and updates in selection processes over time.

### 2005-2015 Tomorrow's Habitat for the Wild and Rare

Minnesota's original State Wildlife Action Plan, Tomorrow's Habitat for the Wild and Rare, defined Species in Greatest Conservation Need as "animals whose populations are rare, declining, or vulnerable to decline and are below levels desirable to ensure their long-term health and stability." The criteria for SGCN included species whose populations were rare, declining, or vulnerable to decline, species at risk because of dependence on rare, declining, or vulnerable habitats, species subject to other threats that make them vulnerable, species with certain characteristics that make them vulnerable, or species whose Minnesota populations are stable but are declining in a substantial part of their range outside of Minnesota. In addition, federally or state-listed species, species with global conservation status of G1-G3, species of concern by regional lists such as the USFWS Region 3 Species of Concern, were also included. Vagrant and extirpated species not expected to return within 10 years were excluded. The selection process identified 292 SGCN, including 189 vertebrates and 103 invertebrates (DNR, 2005). These were then related to 16 key habitats as well as to 24 ecoregional subsections.

### Minnesota's Wildlife Action Plan 2015-2025

In Minnesota's Wildlife Action Plan 2015-2025, technical advisory teams updated the 2005 list, adding 111 species and removing 59, for a new total of 346 SGCN (DNR, 2015). This included 185 vertebrate and 161 invertebrate species. Unique life history traits were identified along with the primary threats, or stressors, to the long-term sustainability of each species (Appendix C of 2015-2025 Plan). In addition, the distribution and abundance of "viable/persistent" SGCN populations were mapped for 156 SGCN with sufficient data and used to develop the Wildlife Action Network.

# SWAP Species Goal

Conserve rare, declining, and vulnerable wildlife and plant Species in Greatest Conservation Need (SGCN) through targeted actions.

## Species Strategies

1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnerships with agencies, Tribes, non-governmental organizations, private landowners, and others.

3. Develop and share informational material to guide conservation actions for SGCN, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management practices.

### Strategy 1: Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

The Plan is an informational resource that provides a science-based framework to guide applied conservation strategies and actions. Surveys, monitoring, and research are essential for improving our understanding of the status of animal and plant populations, as well as their vulnerability to a variety of threats. Surveys often focus on questions of rarity and are used to evaluate how extensively a species is distributed within the state. Monitoring builds on this by tracking changes in species' abundance or distribution over time, often requiring long-term efforts across broader areas to determine meaningful trends. Research further contributes by examining the causes of SGCN population decline and by evaluating the effectiveness of conservation practices intended to benefit them. Together, well-designed surveys, monitoring programs, and research projects deepen our knowledge of species-specific habitat requirements and the environmental conditions that support thriving populations. For more information on this strategy, see Chapter 5: Monitoring and Research.

### Strategy 2: Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnerships with agencies, Tribes, non-governmental organizations, private landowners, and others.

Collaboration is essential to the successful conservation of SGCN animals and plants. The number of at-risk species and the scale of their conservation needs are too great for any single entity to address alone. As documented in the stressor sections, human activities — both past and present — have profoundly shaped and degraded many of Minnesota's ecosystems. This reality underscores the importance of working together to protect, restore, enhance, and maintain the habitats that remain, while optimizing their conditions to support vulnerable species.

While the DNR serves as the lead facilitator for efforts guided by this Wildlife Action Plan, implementation of actions depends on the work of numerous entities across the state each year. The DNR Nongame Wildlife Program plays a key role in facilitating partnerships with a broad array of collaborators to ensure conservation is approached collectively. Coordinated action among municipalities, soil and watershed conservation districts, private landowners, Tribes, other state agencies, national agencies,

*Photo: Mussel research team, DNR Center for Aquatic Mollusk Programs*

educational institutions, and non-profit organizations will be the most effective. In fact, the majority of our conservation work is accomplished through these partnerships.

Conservation Opportunity Areas (COAs) are places where on-the-ground conservation actions are concentrated to benefit SGCN and their habitats. COAs build on the Conservation Action Network, which depicts areas of high biodiversity and high habitat quality, linking them with buffers and corridors. They are delineated to encourage partnerships and to focus collaborative efforts on habitat conservation projects that provide the greatest benefit to SGCN. For more information, see the Conservation Opportunity Areas section in Chapter 6: Implementation.

While actions that are specifically related to developing partnerships will be listed under Strategy 2, collaboration as an approach can apply to all actions in the Plan, as all conservation actions would benefit from broader implementation by partners.

*Photo: Producers and agency partners at Redwood River Farms on field tour in the Prairie Coteau Conservation Opportunity Area, TJ Boettcher*

### Strategy 3. Develop and share informational material to guide conservation actions for SGCN, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management practices.

This Plan is designed to put science into action. It identifies threats, outlines conservation actions, and provides case studies of successful conservation programs and links to existing resources. However, there is still a great demand for information to guide conservation practitioners across the state. In some cases, research or investigations are needed to develop management guidelines, avoidance measures, or habitat best management practices (see Chapter 5: Monitoring and Research). In other cases, valuable findings from the research community or applied conservation practice need to be translated into practical tools and resources that can readily be applied. Expanding efforts to investigate, synthesize, and publish recovery and management guidance for additional SGCN represents a significant opportunity.

There are also opportunities to expand information for a greater number of SGCN. Species accounts, such as the DNR's Rare Species Guide, currently provide information only for state and federally listed species. Recovery or action plans, such as the Wood Turtle Conservation Plan for Minnesota, serve as excellent resources, but plans of this kind currently exist for only a small number of species in Minnesota.

This strategy also emphasizes effective communication to ensure that more people are aware of available informational resources. Workshops, field trips, webpages, webinars, and one-pagers can be valuable tools for sharing new research, threat assessments, or best management practices as they emerge. This approach parallels Strategy 5 in Chapter 3: Habitats and Strategy 1 detailed in Chapter 4: Public Engagement.

## Conservation Actions

Strategies are implemented by conservation actions, which are described in the SGCN sub-chapters. Conservation actions are also described in the habitat sub-chapters, so referring to these sections in tandem is recommended; for example, looking at the lakes and river chapters when reading about fish will provide more comprehensive information. Conservation actions are related to stressors through a set of icons, as depicted in the stressor section below.

## Species in Greatest Conservation Need - Definition

The definition of Species in Greatest Conservation Need (SGCN) for this 2025-2035 Plan is consistent with the prior versions of Minnesota's Wildlife Action Plan, with the addition of Tribally nominated species of cultural significance. **SGCN are animal and plant species that are vulnerable or at risk of decline or extirpation, or species of stewardship or Tribal significance in Minnesota.**

This set of species provides focus to the entirety of the State Wildlife Action Plan. SGCN are native species whose populations are rare, declining, or vulnerable to decline and are below levels desirable to ensure their long-term health and stability in our state. Also included are species for which Minnesota has stewardship responsibility - those for which populations in Minnesota represent a significant portion of their North American population, or species for which Minnesota populations are stable while populations outside of Minnesota have declined or are declining in a substantial part of their range.

Tribally nominated species of cultural significance were included as criteria for identifying SGCN in this Plan, recognizing the deep and enduring connections that many Ojibwe and Dakota people have with the plants and animals with whom we share the land. Including tribal significance as a factor for designating SGCN status enabled the 11 federally recognized Tribes within Minnesota's borders (Tribes) to nominate species they consider vulnerable even if those species would not otherwise be selected via the other SGCN selection factors. In 2025, this resulted in the addition of the snowshoe hare (*Lepus americanus*) and wild rice (*Zizania palustris*). Snowshoe hare – Waabooz in Ojibwe - is a culturally important prey species valued for its meat and fur, particularly in winter. There are concerns over its reduced population size and range extent, as well as its future status with less extensive snow cover in shorter, milder winters under our warming climate. A special challenge for the Waabooz is the change in its fur color and the potential for phenological mismatch, when the timing of its color change does not match up with the presence of snow. The Waabooz was in the 99th percentile for climate vulnerability in the Aanji-bimaadiziimagak o'ow aki Climate Change Vulnerability Assessment (Great Lakes Indian Fish and Wildlife Commission (GLIFWC) Climate Change Team, 2023). Wild rice, manoomin (in Ojibwe) or psin (in Dakota), is an important food that is traditionally harvested and vulnerable to many disturbances in the waters in which it is found. It should be noted that many other tribally important species such as moose, elk, and wolf were already included in the SGCN list, and that Tribes independently maintain resources regarding species of importance.

### SGCN include:

- **Federally-listed species** protected under the Endangered Species Act (including Endangered, Threatened, candidate, or recently de-listed species)
- **State-listed species** on Minnesota's state list of endangered, threatened, or special concern
- **Species that are rare, declining or vulnerable to threats**, as determined through the species conservation assessment (S-rank) process, including species with s-rank of critically imperiled (S1) and imperiled (S2) and some vulnerable

(S3) species if there were sufficient additional factors for concern (see below for more information)

- **Stewardship Species** - Species for which populations in Minnesota represent a significant portion of their North American population or whose Minnesota populations are stable, while populations outside of Minnesota have declined or are declining in a substantial part of their range

- **Tribally Significant Species** - Species of cultural significance to Tribes in Minnesota which are believed to be vulnerable to decline

*Photo: Golden-winged warbler, a stewardship species, Bob Dunlap*

## Species in Need of Information - Definition

New for the 2025 Plan, we have added another category known as Species in Need of Information (SNI). **SNI are species believed to be rare in Minnesota, but for which we do not have enough information to categorize them as SGCN**. Species were designated as SNI if they are thought to be a potential future SGCN, and there is a desire to conduct surveys or monitoring for them within the next ten years. A designation of SNI enables State Wildlife Grant funds to be allocated toward survey or monitoring for those species.

## Species List Development

Updating the SGCN list for the 2025-2035 SWAP included a few steps. First, we implemented a standardized, repeatable, comprehensive conservation status assessment for all regularly occurring species in our state for which we had sufficient data (see Conservation Status Assessment section below). Second, we established criteria for the SGCN list based on the S-ranks as well as additional factors, including plants and lichens in the SGCN list process for the first time. Third, we defined a list of Species in Need of Information (SNI).

### Conservation Status Assessments

As a foundation to updating the SGCN list for this Plan, we conducted conservation status assessments for over 7,000 species of animals and plants found in Minnesota. We followed the NatureServe Conservation Status Assessment process, a rigorous and repeatable method adopted widely by states and provinces throughout North America (Faber-Langendoen et al., 2012; Master et al., 2012). For species for which there was sufficient information, we generated numeric conservation status ranks from 1 (critically imperiled) to 5 (secure); additional species that were identified as non-native or vagrant, or for which there was insufficient information, were given non-numeric ranks (see Conservation Status Rank box for rank definitions). Assessments are done globally (G-ranks), nationally (N-ranks), and sub-nationally (S-ranks). We calculated S-ranks for the species in Minnesota.

Prior to calculating S-ranks, we requested and incorporated species observation data from partners, including academic institutions, other governmental entities, non-profit organizations, Tribes, and community science driven databases. These datasets were compiled for use in assessing the conservation status factors. Using the NatureServe S-rank Calculator, we calculated preliminary S-ranks based on rarity, trends, and threats. These preliminary ranks were reviewed by taxonomic experts to assess

any data deficiencies, discrepancies, or gaps, and add additional information particularly regarding threats based on expert knowledge. S-ranks were then revised and reviewed once again after those updates were completed. Once the S-rank was established, species were then assessed for SGCN and SNI designation. Information compiled for status assessments and SGCN identification will also be used in the state's endangered and threatened species list revision process.

## Conservation Status Ranks

Conservation Status Ranks indicate the risk of extinction for species (NatureServe Conservation Status Assessment). S-ranks consider species status within Minnesota. Each species received one of these ranks:

SX – Presumed Extirpated – Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.

SH – Possibly Extirpated – Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20-40 years despite some searching and/or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.

S1 – Critically Imperiled – At very high risk of extirpation in the jurisdiction due to very restricted range, very few population occurrences, very steep declines, severe threats, or other factors.

S2 – Imperiled – At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.

S3 – Vulnerable – At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.

S4 – Apparently Secure – At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.

S5 – Secure – At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little or no concern from declines or threats.

SU – Unrankable – for species that we have compiled data and considered, but there is inadequate information available to rank.

SNA – Not Applicable – for species that are not an appropriate target of conservation efforts, such as non-native species or vagrants.

SNR – Species Not Ranked – for species we know have occurred in Minnesota but we have not considered in this effort due to lack of information, e.g., all of our species of ants.

S_M – Migratory species that regularly occur in Minnesota, but do not breed here are ranked, but will be given a modifier (e.g., S2M).

The conservation status assessment process incorporated eight status factors in three categories, highlighting three main ways in which species may become vulnerable:

- **Rarity** assesses the distribution of the species in the state, tabulating the number of known occurrences. It is based on range extent, area of occupancy (the subset of that range containing occurrences), population size (when known), and number of occurrences. Range extent and area of occupancy represent the idea that when occurrences occur over a large spatial extent they are less vulnerable to threats such as development, fire, or climate. Occurrences are areas where species have been detected and are not necessarily analogous to populations; whereas the definition of an occurrence is consistent across taxa, what comprises a population varies greatly. For most vertebrates and plants, a population generally refers to a group of occurrences within a certain distance from each other in which multiple occurrences have been documented across multiple years; for birds, this definition also includes occurrences over consecutive years given the comprehensive data available from multiple sources. For most invertebrates, for which survey effort has been inconsistent or altogether lacking, populations are more difficult to define and as such we did not assess this metric for most invertebrate species. Finally, although infrequent, the number of occurrences with good viability was incorporated when known.

- **Trends** in population size, abundance, occurrences, or area of occupancy are considered, both long-term and short-term. Long-term refers to the period since European colonization, roughly 200 years. Short-term trends are considered 10 years or three generations, whichever is longer, up to a maximum of 100 years. When state level trends are available, these are used. If state-level trends are not available, regional trends are applied, and continental trends are used only when more localized data are unavailable. There is always uncertainty in assuming that continental or regional trends accurately reflect trends within Minnesota. Population trends are central to assessing species status, but they are known only for few species. When trends in population or abundance are unavailable, changes in area of occupancy are sometimes considered as a surrogate.

- **Threats** were assessed for direct and indirect effects on species. We considered 10 threats from the IUCN threats classification system (level-one threats), such as development or climate change, which we describe in detail in the Stressors section below (of IUCN's 11 level-one threats, we omitted "geological events"). Each threat was assessed by taxonomic expert panels for scope and severity. Scope describes the extent to which a threat overlaps with the species' occurrences, such as the proportion of the population affected by a particular threat. For this, we provided reviewers with information on the proportion of the species' range intersecting mapped threat layers when available. Severity refers to the degree to which a threat harms the species, such as the proportion of the exposed population that may suffer mortality due to that factor.

*Photo: Blanding's turtle and research intern, by Andrew Herberg*

## SGCN and SNI Selection

We developed a flowchart (in supplemental material at end of chapter) to determine whether species meet criteria for inclusion on our SGCN list, summarized as:

- SGCN include species ranked in Minnesota as Critically Imperiled (S1) or Imperiled (S2) in our conservation status assessments, species ranked globally as G1, G2, or G3 (Vulnerable), those federally listed as Endangered or Threatened under the Endangered Species Act (or recently de-listed or candidate species on the five-year work plan for listing), and those state listed in Minnesota as Threatened, Endangered, or Special Concern in 2013 and thought to remain on the future state list.
- In addition, other species (particularly those that ranked as Vulnerable, S3) were considered for inclusion on the SGCN list, particularly if they met some of these additional factors:
  - On the 2015 SGCN list or meet the 2015 criteria including for stewardship species
  - On the 2022 Midwest Regional SGCN (RSGCN) list, which are species classified as SGCN by at least one Midwest Association of Fish and Wildlife Agencies (MAFWA) state and meet regional stewardship criteria (% distribution in MAFWA states, core population in MAFWA states, etc.) and conservation concern criteria (federal listing, state listing, imperiled state and global NatureServe conservation status ranks, etc.)
  - On the Superior or Chippewa National Forest Regional Forester Sensitive Species (RFSS) list.
  - Tribally significant species (based on expert knowledge and recommendations by Tribes in Minnesota)

It can be noted that species ranked as vulnerable (S3) were sometimes included as SGCN and sometimes not, and this was a discretionary point in the selection process. The type of data available varied considerably across taxonomic groups, such that different considerations were made for species in different groups. For instance, trend data were available for many bird species, but few others. Some birds, despite having declining trends, were not included as SGCN due to high abundances that likely buffer them from major population declines over the next ten years. However, abundance and trend data are not available for many other species, and in those cases other factors might have been applied to the process of SGCN selection. For instance, habitat specialization was used as a criteria for including species of bees as SGCN and threats weighed heavily in the assessments for reptiles and amphibians.

Also of note, species ranked as Possibly Extirpated (SH) or Presumed Extirpated (SX) were sometimes included as SGCN or SNI, another discretionary point in the selection process. These species were included on the SGCN and SNI lists for a variety of reasons, including a high likelihood that breeding populations may be established in Minnesota over the next ten years; conservation actions (such as research and monitoring to confirm extirpation, or captive breeding and reintroductions) may target these species over the next ten years; or species are listed at the state or federal level. For animal species, this resulted in twenty-six SH species selected as SGCN, one SX species selected as SGCN, and two SH species selected as SNI (see Appendix B.) The majority of these are invertebrates. Six SH plant species and six SH lichen species were also designated SGCN, with an additional 68 SH plant and lichen species as SNI.

Draft lists of SGCN and SNI were widely circulated for review: within the DNR, to experts invited to provide S-rank comments, and to participants of the plant or animal SGCN volunteer teams assembled through regional workshops. If the state's list of threatened and endangered species changes during the term of the 2025 SGCN List, we will update the SGCN list and materials to reflect those updates accordingly.

## 2025 Species List

The 2025-2035 SGCN list contains 1,142 species (see Figure 2.1), along with 860 SNI species (Figure 2.2). Plants comprise 448 of the SGCN, followed by lichens (151 species), butterflies and moths (122), and bees (117). Together, plants and lichens comprise 52% of the SGCN list. Vertebrates, including amphibians, birds, fishes, mammals, and reptiles, total 166 species and represent 15% of the list. Refer also to Table 2.1 for a summary of SGCN and SNI species by taxonomic groups. See Appendix B for the full list of SGCN and SNI animals, plants and lichens. For invertebrates, the class and order, if appropriate, for each group is provided in the Aquatic Invertebrate and Terrestrial Invertebrate sub-chapters.

Among the 71 species previously identified as SGCN but not included in this Plan's list, some were removed due to more favorable assessments, some due to extirpation, and some were changed to SNI to better reflect a need for further information; please reference Appendix C for information on each species.

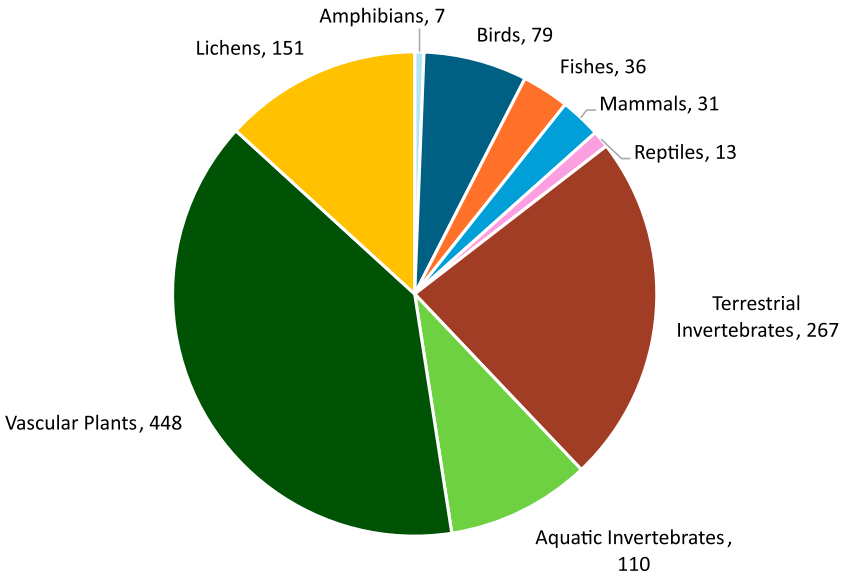


Figure 2.1 Numbers of Species in Greatest Conservation Need by species group. Each species group is described in a subchapter.

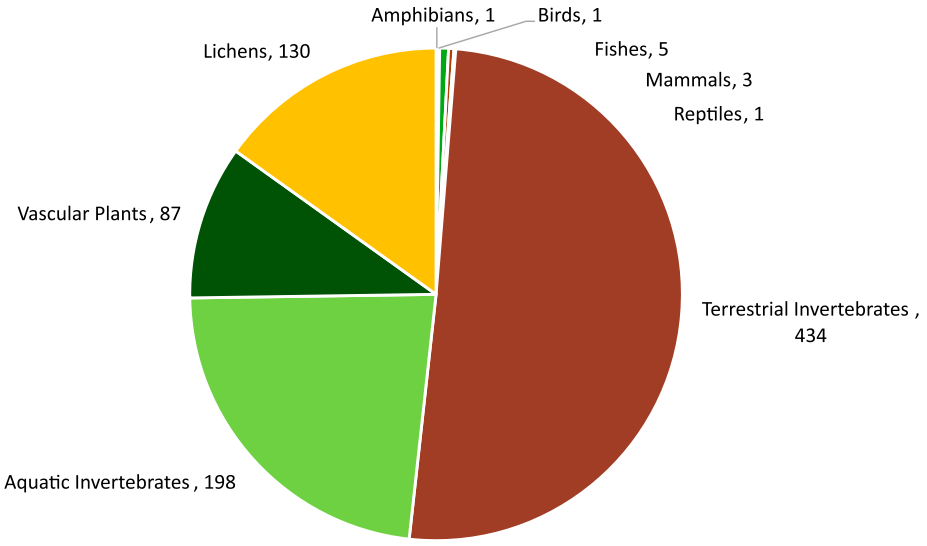


Figure 2.1 Numbers of Species in Greatest Conservation Need by species group. Each species group is described in a subchapter.

**Table 2.1. Numbers of Species in Greatest Conservation Need (SGCN) and Species in Need of Information (SNI), the number of species assessed and the number of species that changed status from 2015, grouped first by vertebrate species, terrestrial invertebrates, aquatic invertebrates, plants, and lichen.**

| Species Group | No. of SGCN | No. of SNI | No. of Neither | Total Assessed | No. of SGCN removed | No. of SGCN added | No. of SNI added | % SGCN | % SNI |
|---|---|---|---|---|---|---|---|---|---|
| Amphibians | 7 | 1 | 14 | 22 | 1 | 0 | 1 | 32% | 5% |
| Birds | 79 | 1 | 366 | 446 | 21 | 8 | 1 | 18% | 0% |
| Fishes | 36 | 5 | 124 | 165 | 8 | 2 | 5 | 22% | 3% |
| Mammals | 31 | 3 | 52 | 86 | 1 | 5 | 3 | 36% | 3% |
| Reptiles | 13 | 1 | 17 | 31 | 2 | 0 | 1 | 42% | 3% |
| Bees | 117 | 125 | 273 | 515 | 0 | 112 | 125 | 23% | 24% |
| Beetles | 12 | 10 | 68 | 90 | 1 | 4 | 10 | 13% | 11% |
| Butterflies, Moths | 122 | 257 | 1708 | 2087 | 6 | 95 | 257 | 6% | 12% |
| Flies | 0 | 5 | 62 | 67 | 0 | 0 | 5 | 0% | 7% |
| Grasshoppers, Crickets | 0 | 6 | 5 | 11 | 0 | 0 | 6 | 0% | 55% |
| Millipedes | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0% | 100% |
| Snails | 9 | 23 | 120 | 152 | 0 | 4 | 23 | 6% | 15% |
| Spiders | 7 | 4 | 517 | 528 | 6 | 3 | 4 | 1% | 1% |
| Springtails | 0 | 3 | 0 | 3 | 0 | 0 | 3 | 0% | 100% |
| True Bugs, Cicadas, Leafhoppers | 2 | 8 | 2 | 12 | 2 | 1 | 8 | 17% | 67% |
| Caddisflies | 38 | 63 | 213 | 314 | 3 | 17 | 63 | 12% | 20% |
| Dragonflies, Damselflies | 25 | 8 | 112 | 145 | 20 | 5 | 8 | 17% | 6% |
| Mayflies | 8 | 83 | 72 | 163 | 0 | 8 | 83 | 5% | 51% |
| Mussels | 32 | 1 | 18 | 51 | 0 | 3 | 1 | 63% | 2% |
| Shrimp | 0 | 1 | 8 | 9 | 0 | 0 | 1 | 0% | 11% |
| Stoneflies | 5 | 34 | 37 | 76 | 0 | 5 | 34 | 7% | 45% |
| Plants | 448 | 87 | 1932 | 2467 | 0 | 447 | 87 | 18% | 4% |
| Lichens | 151 | 130 | 757 | 1038 | 0 | 151 | 130 | 15% | 13% |
| TOTAL | 1142 | 860 | 6477 | 8479 | 53 | 870 | 842 | - | - |

## Species-Habitat Associations

To associate SGCN with habitat types, species experts classified the SGCN by habitat types they use based on professional knowledge (see Figure 2.3). Habitats were distinguished as primary or secondary for vertebrate species and some invertebrate species. Primary habitats were those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats were used by the species less frequently. Animals with more general habitat requirements were associated with multiple habitat types, while specialists were associated with one or a few. Some animals were only assigned secondary habitat associations, such as for several mammals that associate with specific features of habitats (e.g. wolf focused on prey) rather than particular habitat types. Plants were only associated with a primary single habitat type. A detailed table associating each animal SGCN with the Plan's 15 habitat types can be found in Appendix D. Appendix E lists the plant SGCN associations with primary habitats.

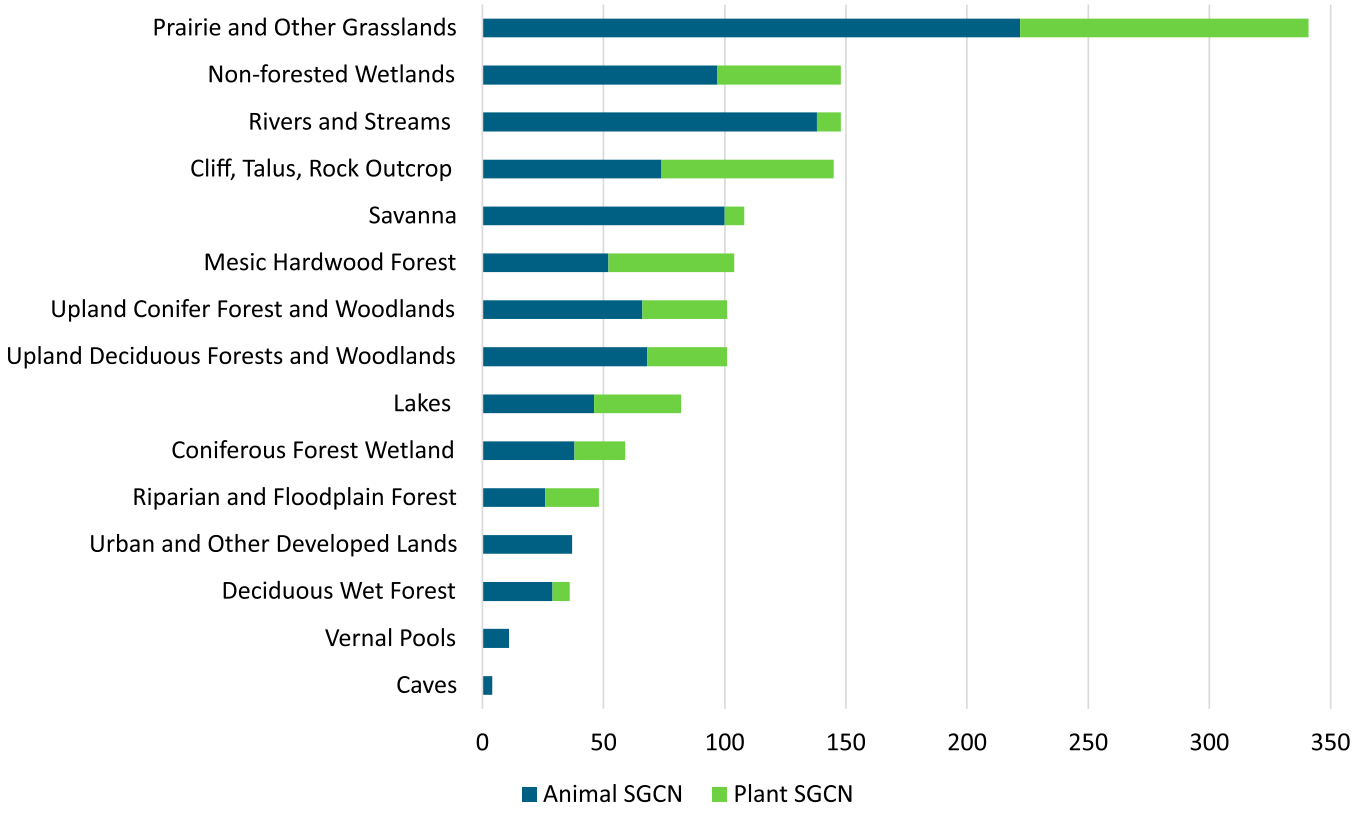


Figure 2.3 Numbers of Species in Greatest Conservation Need (SGCN) Associated with Habitat Types, including both primary and secondary habitat associations for animals. Plants were not associated to Urban and Other Developed Lands, Vernal Pools, or Caves habitat types.

## Stressors and Actions

Throughout Minnesota, over time, habitats have been lost and degraded due to pressures that result from human inhabitation, subsistence, livelihoods, and recreation. **Thus, habitat loss or alteration is the primary threat for most, if not all, SGCN**. However, an approach has been taken at the international level to classify threats, or "stressors" as we call them in this Plan, to shine light on more of the proximate activities that continue to degrade our habitats or affect our SGCN directly. See also Chapter 3: Habitats.

We identify stressors as a way to direct conservation attention to where it is needed most. Potential conservation actions are explicitly linked to address the stressors, presented as a set of conservation opportunities. Stressors are factors that pose challenges to vulnerable plant and wildlife species, either directly or indirectly. An example of a direct threat is the stressor of "wind and solar energy" causing collisions for birds and bats with wind turbines. Other stressors may operate indirectly, such as through habitat conditions (e.g., the stressor of "problematic native species" reduces streamside sandy nesting habitat due to expansive cover by reed canary grass). Many stressors operate both directly and indirectly, such as roads, trails, and railroads causing both vehicular strikes for animals (direct) and habitat fragmentation (indirect).

It should be noted that sometimes factors or activities labeled as "stressors" can also be applied to advance conservation goals. Broad language such as "livestock management" and "fire management" is an attempt to remind readers of this: that these practices may sometimes be stressors but in other cases are applied as conservation tools. It is a matter of "how" and "where" these practices take place that determines if they are advancing ecosystem health and resilience as conservation actions (such as prescribed fire) or if they put stress on the ecological community, habitat, or species (such as a catastrophic wildfire following a long period of fire suppression). Throughout the Plan you will find language clarifying when a stressor may be a challenge and when it can be applied as part of a conservation solution.

We base the stressors listed in this Plan on an internationally employed threats lexicon developed by the International Union for the Conservation of Nature (IUCN) Species Survival Commission and the Conservation Measures Partnership (Salafsky et al., 2024). First developed in 2008 (Salafsky et al., 2008) and updated in 2024, this hierarchical system describes 11 Level 1 (higher level) threats and within those, 41 Level 2 (more specific) threats. We have selected a subset of 24 of these to discuss in relation to the species and habitats in Minnesota. We have shortened and re-named some for ease of understanding (see Table 2.2). We employ a set of icons throughout the Plan to depict stressors visually and to connect them to Actions. Please note that in the production phase of preparing this document for publication, we plan to replace some icons with customized ones, such as for timber harvest, to better convey the nuance and complexity of those stressors. Also note that within each habitat or species sub-chapter, we include only the primary stressors pertinent to that habitat or species group, omitting others to maintain focus.

**Table 2.2. Stressor icons and names referenced throughout this SWAP, along with threat level information from the IUCN classification (Salafsky et al., 2024).**

| ICON | STRESSOR NAME | LEVEL1_2 | LEVEL 1 THREAT (IUCN CLASSIFICATION) |
|---|---|---|---|
| | Development | 1 | Residential, Commercial, & Recreation Areas |
| | Crop Production | 2_1 | Agriculture & Aquaculture |
| | Tree Plantations | 2_2 | Agriculture & Aquaculture |
| | Livestock Management | 2_3 | Agriculture & Aquaculture |
| | Mining and Quarrying | 3_2 | Energy Production & Mining |
| | Wind and Solar Energy Infrastructure | 3_3 | Energy Production & Mining |
| | Roads, Trails, and Railroads | 4_1 | Transportation, Service, & Security Corridors |
| | Utility Corridors | 4_2 | Transportation, Service, & Security Corridors |
| | Shipping Lanes | 4_3 | Transportation, Service, & Security Corridors |
| | Hunting and Collecting Animals | 5_1 | Biological Resource Use & Control |
| | Gathering Plants and Fungi | 5_2 | Biological Resource Use & Control |
| | Timber harvest | 5_3 | Biological Resource Use & Control |
| | Fishing | 5_4 | Biological Resource Use & Control |
| | Recreation | 6_1 | Human intrusions & disturbance |
| | Fire Management | 7_1 | Natural System Management & Modifications |
| | Dams and Water Management | 7_2 | Natural System Management & Modifications |
| | Invasive Species (Problematic Non-native Species) | 8_1 | Invasive/Other Problematic Species, Genes & Pathogens |

| ICON | STRESSOR NAME | LEVEL1_2 | LEVEL 1 THREAT (IUCN CLASSIFICATION) |
|---|---|---|---|
| | Problematic Native Species | 8_2 | Invasive/Other Problematic Species, Genes & Pathogens |
| | Diseases and Pathogens | 8_4 | Invasive/Other Problematic Species, Genes & Pathogens |
| | Water-borne Pollution | 9_1 | Pollution |
| | Air-borne Pollution | 9_3 | Pollution |
| | Light and Noise Pollution | 9_4 | Pollution |
| | Changes in Temperature related to Climate | 11_2 | Climate Change |
| | Changes in Precipitation and Hydrology related to Climate | 11_3 | Climate Change |

## Species Sub-chapters

Information on Species in Greatest Conservation Need and Stressors is presented in 8 sub-chapters, one for each of the following groups of species:

1. Amphibians
2. Reptiles
3. Birds
4. Fishes
5. Mammals
6. Terrestrial Invertebrates
7. Aquatic Invertebrates
8. Plants and Lichens

Each of these species group sub-chapters includes the following information:

### Overview

Each sub-chapter begins with several paragraphs that summarize relevant information about each taxonomic group of species, including unique aspects of the species, the depth of information available, and/or the ecological importance of the species.

### SGCN and SNI Summary Information

A brief summary of the number of SGCN and SNI identified is provided and the reader is directed to Appendix B for more extensive detailed information.

### Species-Habitat Associations

A summary of the associations of SGCN with the 15 habitat types is provided. Details on the habitat associations for each SGCN is provided for animals in Appendix D and for plants in Appendix E.

### Stressors

As noted above, the primary stressors that may affect SGCN in each group are identified and briefly described. Each stressor is depicted by an icon (illustration) to help the reader connect content from stressor to actions.

### Priority Species Conservation Strategies

In each sub-chapter we reference the three

Strategies for implementation, using these to group Potential Conservation Actions.

## Potential Conservation Actions

Conservation Actions, organized under Strategies, address primary stressors and are tagged by stressor icons to relate them. Frequently a conservation action can address more than one Stressor. In those cases, Conservation Actions are identified by multiple Stressor Icons.

## Case Studies

Case studies are provided throughout the plan to showcase examples of successful conservation approaches, highlight key partnerships, and provide additional links to key resources related to the species group in that sub-chapter. Case studies include a brief summary of the project as well as links to read additional information. It should be noted that although some active partnerships are described in the narrative; these are not an exhaustive list but rather given as examples of programs that may interest readers and expand the implementation of conservation actions.

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## Supplemental Material - Species Designation Flowchart

To support the Species in Greatest Conservation Need (SGCN) and Species in Need of Information (SNI) designation process, we developed a flowchart to help determine whether species meet criteria for inclusion on our SGCN or SNI lists. The instructions for following the flowchart are below, and the flowchart is illustrated on the next two pages, split into two panels for readability.

The flowchart begins on the far left at the yellow star. It is designed to process one species at a time, answering the questions until one of three boxes is reached: SGCN, SNI, or Neither. Some boxes in the flowchart are colored gray. These indicate questions that are more subjective. Taxa experts can use their knowledge of each species to answer these questions. Additionally, there are three boxes with dashed arrows pointing out from them. These indicate a potential path to follow, and experts choose which path to take using their judgment.

**Box A. Native and Regularly Occurring.** Verifies that species are native and regularly occurring (not vagrants). Species not meeting these criteria are eliminated from consideration.

**Box B. Federal Status.** Identifies species federally listed under the Endangered Species Act (ESA) as endangered or threatened, recently de-listed, or on the five-year work plan for listing. These are automatically SGCN.

**Box C. Extirpated Species.** If a species received an S-rank of SX, indicating it is Presumed Extirpated, then it does not need to be included as an SGCN just because it meets ESA criteria. Continue to Box M.

**Box D. State Listed.** Includes species from the 2013 Minnesota State list of endangered, threatened, and special concern species. Use in conjunction with Box E.

**Box E** verifies the species is likely to remain on the next Minnesota state list; if so, these are SGCN. If not, continue to box F.

**Box F. Imperiled S1 and S2 Species.** Identifies species that in our 2025 conservation status assessment (S-rank process) received ranks of S1 (Critically Imperiled) or S2 (Imperiled). These will become SGCN unless they are not thought to merit SGCN status due to factors in gray boxes G, H, and I.

**Box G.** If a species was classified as an S1 or S2 in Minnesota only because it is at the edge of its range, go to Box K.

**Box H.** If a species was classified as S1 or S2 because it is under-surveyed (not truly rare), go to Box I.

**Box I.** Re-evaluate the S-rank. In this case, it is more appropriate that the species have an S-rank of SU. Change S-rank if needed and go to Box O.

**Box J. S3, S4, and S5 Species.** Most species that received S-ranks of S3, S4, and S5 will not become SGCN, but some species can be qualified based upon additional factors.

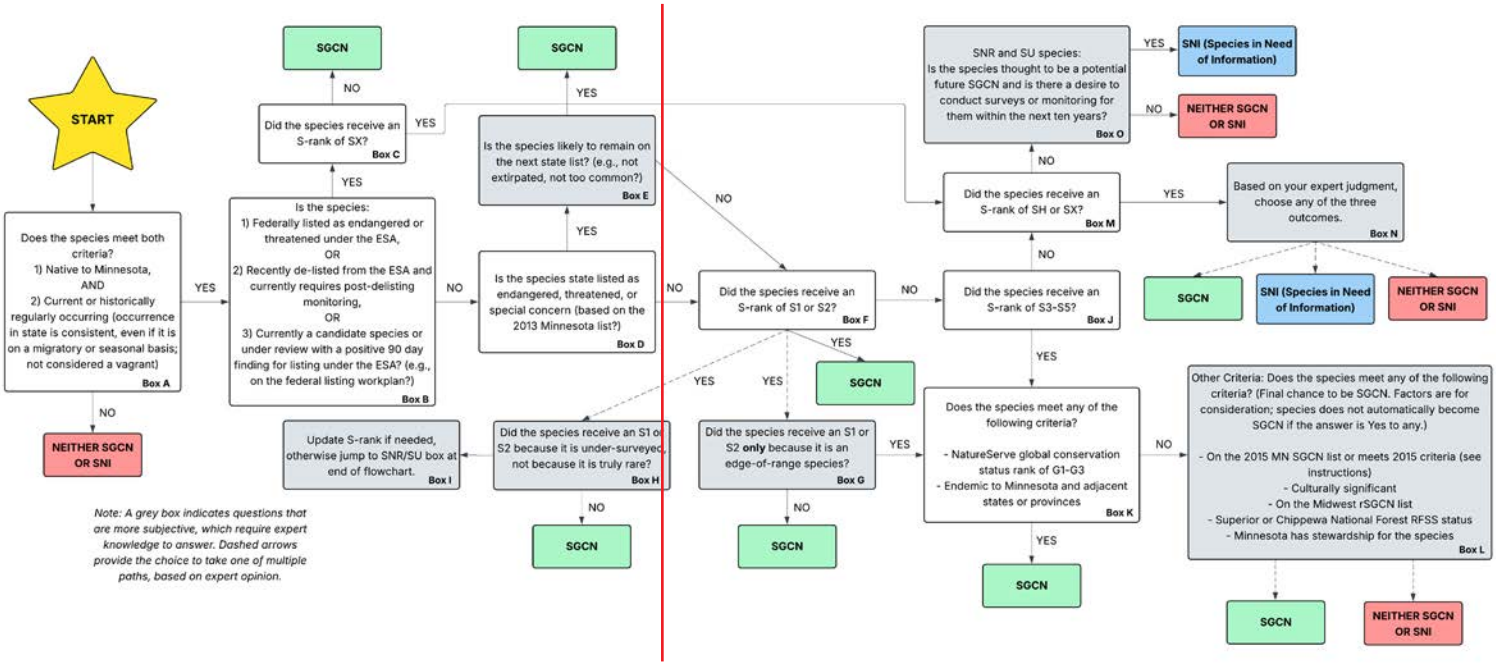
**Box K. Global Status and Endemism.** If a species has a global conservation rank of G1, G2, or G3, it is a SGCN. If a species is endemic to Minnesota and adjacent states, it will be designated as a SGCN. These criteria apply to species from Boxes G and J.

**Box L. Other Criteria.** This box represents additional criteria to consider, including being a SGCN in 2015 or meeting the 2015 criteria for SGCN status, thought to have cultural significance, designated within the 2022 Midwest Regional SGCN list, included on the Superior or Chippewa National Forest's Regional Forester Sensitive Species list, or if Minnesota has stewardship of the species. Based on expert judgment, a species can be designated SGCN or Neither from this box. Some experts may feel that meeting just one of the criteria is important enough to call the species a SGCN. Or, they may want a species to meet several criteria to call it a SGCN. There may be cases where a species meets one or more criteria, but experts don't believe they are important enough to necessitate SGCN designation.

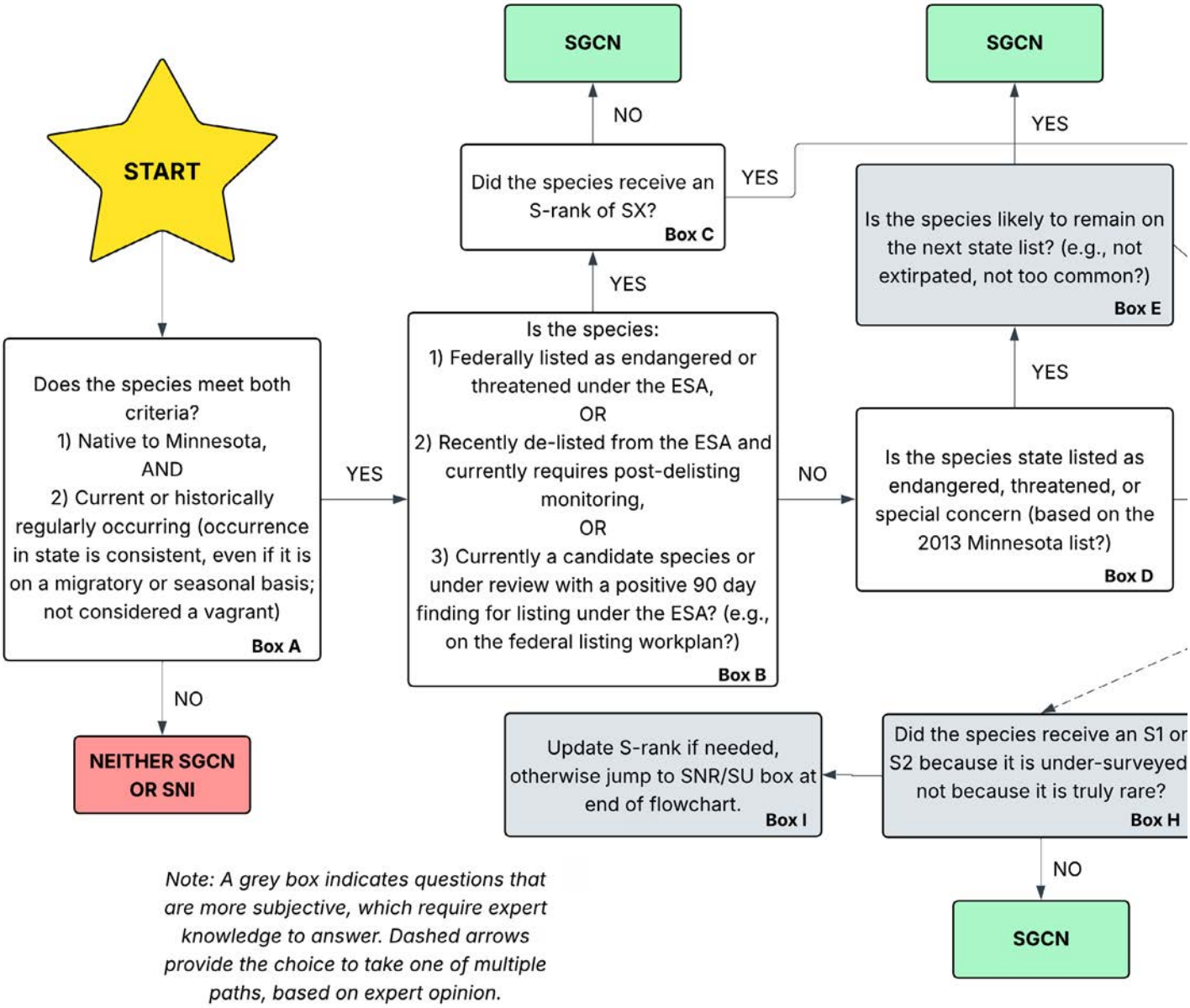
**Box M. Extirpated Species.** If a species was ranked Possibly Extirpated (SH) or Presumed Extirpated (SX), go to Box N.

**Box N.** Based on your expert opinion, you can choose to make SH and SX species SGCN, SNI, or Neither. Most SH are likely to become SGCN.

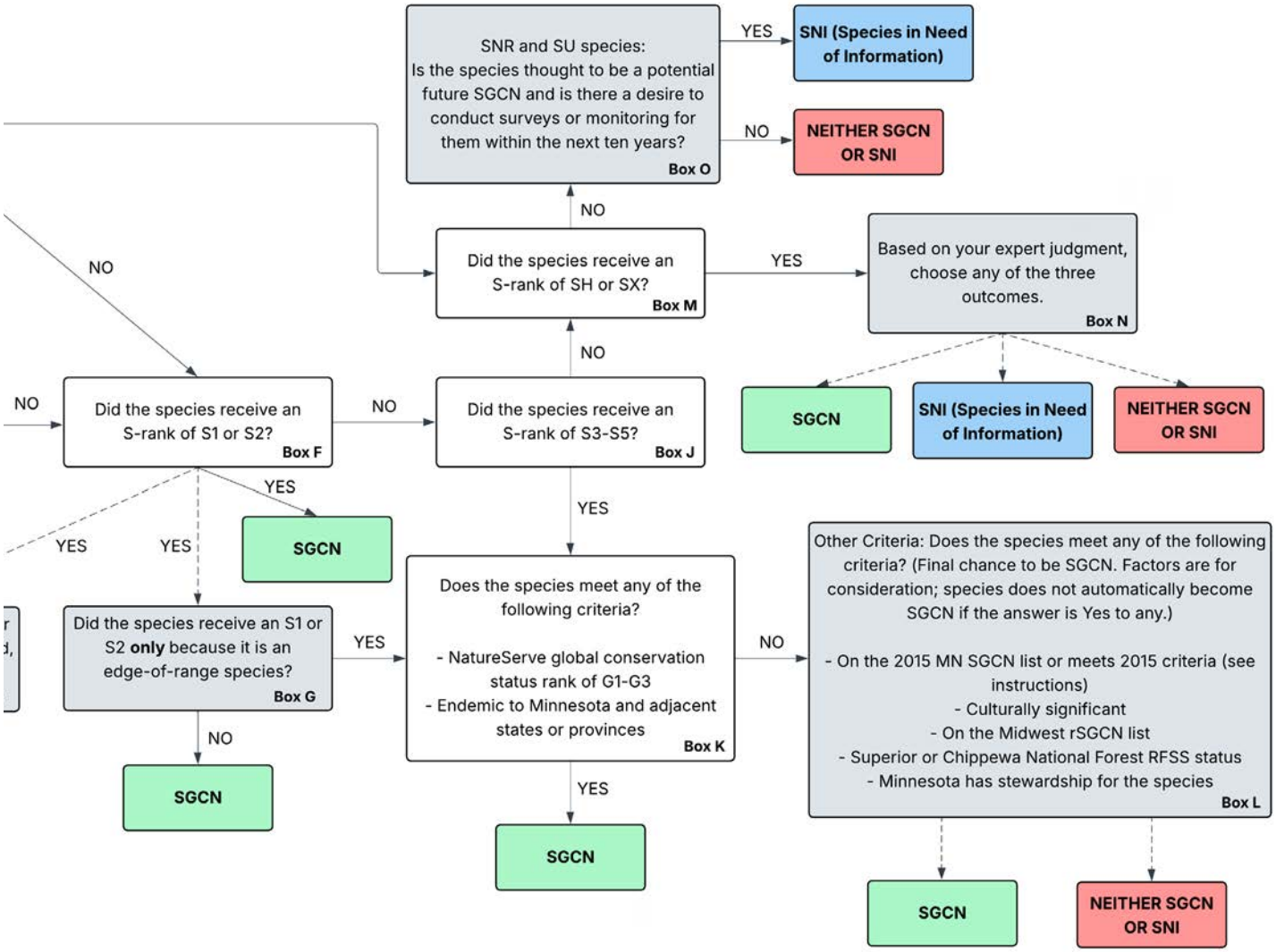
**Box O. Species Lacking Information.** Unrankable Species (SU) for which we have compiled data and considered, but there is inadequate information available to rank, and Species Not Ranked (SNR) for species we know have occurred in Minnesota but we have not considered in this effort due to lack of information, can be designated as Species in Need of Information (SNI) if they are thought to be a potential future SGCN and there is a desire to conduct surveys or monitoring for them within the next ten years. A designation of SNI enables State Wildlife Grant funds to be allocated toward survey or monitoring efforts for those species.




**Chapter 2 Supplement Figure A. Species Designation Flowchart (Full), with red line indicating where the figure is split into the next two figures.**




**Chapter 2 Supplement Figure B. Species Designation Flowchart (Left Side).**




**Chapter 2 Supplement Figure B. Species Designation Flowchart (Right Side).**

# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# AMPHIBIANS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Great plains toad, Jeff LeClere; Mudpuppy, Jeff LeClere; ; Spotted salamander, Andrew Herberg; Pickeral frog, Jeff LeClere

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# Amphibians

## Overview

Minnesota is home to 22 species of amphibians – 14 frogs and toads, and 8 salamanders. In 1944 Walter Breckenridge published Reptiles and Amphibians of Minnesota, marking the state's beginning of modern herpetology. At the time only 13 species of frogs and toads and 5 species of salamanders had been documented in the state. Breckenridge's publication was considered Minnesota's standard herpetological reference until Amphibians and Reptiles Native to Minnesota was published by Oldfield and Moriarty in 1994, followed by an update in 2014 (Moriarty & Hall). In the late 1970s, the Minnesota DNR's Nongame Wildlife Program was established and has coordinated breeding frog call surveys and funded studies on Northern leopard frogs and Blanchard's cricket frogs. The Minnesota Biological Survey, initiated in 1987, surveyed counties across the state targeting rare wildlife and collecting records on common species. Their work has helped establish Minnesota's list of amphibian SGCNs and has added thousands of records of amphibians to the DNR's Natural Heritage database.

Amphibians are the most threatened vertebrate group worldwide due to the compounding effects of habitat conversion, contaminants, invasive species, disease, and climate change, with 40% of species at risk of extinction (Campbell et al., 2024; Luedtke et al., 2023). This is especially concerning given the wide range of benefits amphibians provide. In their ecosystems, amphibians function as both predator and prey, assist with energy and nutrient flow between terrestrial and aquatic systems, and enhance soil aeration and productivity (IUCN SSC Amphibian Specialist Group, 2024). Amphibians also decrease the transmission of dangerous pathogens to humans through their predation on mosquitoes and flies and are frequently used to further the field of human medicine (IUCN SSC Amphibian Specialist Group, 2024). They are often sensitive indicators of environmental contaminants and serve as gauges of environmental health.

Lastly, encountering amphibians in the wild at a young age can foster a positive attitude toward conservation. Many people have fond memories of catching frogs in a local pond or finding a salamander under a log on a hike through the forest. These moments can be the first spark that instills an interest in conservation action.

*Photo: Spotted salamander, Andrew Herberg*

Despite all of this, lack of funding for amphibian conservation is a persistent issue (Bishop et al., 2012). Many amphibian species in Minnesota live cryptic lives and are not frequently encountered, so people might not even know they have some living in their own backyard. Our frogs, toads, and salamanders use a variety of terrestrial and aquatic habitats and exhibit a multitude of life history strategies. Therefore, we need to take a wide range of conservation actions to address the stressors detailed below, including monitoring and public engagement efforts, such as the Minnesota Frog and Toad Calling Survey (see inset) that actively involves citizen scientists in the goal of learning more about our amphibian fauna. The Minnesota Herpetological Society is another important venue for public education and promoting the study and conservation of both reptiles and amphibians. On a larger scale, Midwest Partners in Amphibian and Reptile Conservation (PARC) is an important network dedicated to the conservation of reptiles and amphibians that provides an avenue for collaborative conservation initiatives, outreach and education resources, and more.

## Case Study: Engaging the Public in Frog and Toad Monitoring

A volunteer-based community science program, the Minnesota Frog and Toad Calling Survey monitors the distribution and abundance of all 14 of Minnesota's frog and toad species across the state. Over 100 routes along roads have been established, each with approximately 10 stops where volunteers stop to listen and record the species that are calling. Routes are sampled three times during the breeding season to cover the breeding seasons of all species. The original survey ran from 1994 through 2017, collecting thousands of records. The survey was re-launched in 2023 with updated tools and protocols and continues to develop and grow. The survey not only provides critically important information on a group of species that is often overlooked, but it has become a vital part of many volunteers' spring season. As one volunteer, Nick Krueger, reflected: "The frogs and toads add to the diversity of nature here, but they're also part of the beauty for us, the beauty of the soundscape. It's good to take time to be amazed at the world."

One of our rarest frogs, the Blanchard's cricket frog, has a unique history in Minnesota. Thought to have been lost from Minnesota by the late 1980s, the species was rediscovered in the late 1990s. Upon rediscovery, the Blanchard's cricket frog remained at very low population levels until new populations began to turn up in the 2010s and 2020s (Moriarty & Hall, 2014; Smith, 2018). As a state-listed, protected species, it is critical for regulators and scientists to understand occurrence and occupancy patterns for this tiny frog. Given the challenges with fitting surveys for Blanchard's cricket frogs into busy workloads, DNR staff searched for alternative methods to track what we hope is this species' recovery. From this need was born a partnership between DNR Nongame Wildlife Program staff and a community science, non-profit organization called HerpMapper. HerpMapper is designed to gather and share information about amphibian and reptile observations across the planet. The Blanchard's Cricket Frog Survey asks Minnesotans to help find and document Blanchard's cricket frogs on the HerpMapper website or smartphone app. This effort combines community science with cutting edge species study and recovery efforts to help this enigmatic rare species click-and clack their way across Minnesota again.

*Photo: A family participating in the Frog and Toad Calling Survey*

## SGCN and SNI Summary Information

Seven amphibian species have been designated Species in Greatest Conservation Need (SGCN) - two frogs, one toad, and four salamanders. Four of these are state-listed as Species of Special Concern, and one, Blanchard's cricket frog (*Acris blanchardi*), is State Endangered. Most of the amphibian SGCN species are also Midwest Regional SGCN and have documented declines and significant stressors affecting populations across their range in Minnesota. One species that was listed as a SGCN in the 2015 State Wildlife Action Plan (SWAP), the Eastern red-backed salamander (*Plethodon cinereus*) was removed given that populations currently appear to be stable in Minnesota's northern forests. One species, the Western tiger salamander (*Ambystoma mavortium*), has been designated a Species in Need of Information (SNI). The Western tiger salamander is visually similar to the Eastern tiger salamander (*Ambystoma tigrinum*), and their ranges overlap in Minnesota. More research, likely using molecular techniques, is needed to determine the extent of Western tiger salamander populations across the state. A complete list of both SGCN and SNI species can be found in Appendix B.

## Habitat Associations

The amphibian SGCN utilize a variety of habitats, but all are associated with some type of aquatic habitat due to their life histories. Table 2.3 provides a summary of their association with the habitats discussed in the 2025-2035 SWAP. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Detailed tables associating each SGCN with the primary 15 habitats in the 2025-2035 SWAP can be found in Appendix D.

**Table 2.3. Numbers of Amphibian Species in Greatest Conservation Need (SGCN) associated with each of the habitat types (only showing habitats with amphibian SGCN associations).**

| Habitats | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Prairie and Other Grasslands | 1 | 0 | 1 |
| Upland Conifer Forest and Woodland | 0 | 3 | 3 |
| Upland Deciduous Forest and Woodland | 3 | 0 | 3 |
| Mesic Hardwood Forest | 3 | 0 | 3 |
| Deciduous Wet Forest | 0 | 3 | 3 |
| Riparian and Floodplain Forest | 2 | 0 | 2 |
| Non-forested Wetlands | 4 | 1 | 5 |
| Rivers and Streams | 3 | 0 | 3 |
| Lakes | 2 | 1 | 3 |
| Vernal Pools | 3 | 0 | 3 |
| Urban and Other Developed Lands | 0 | 1 | 1 |

Minnesota's seven amphibian SGCN were associated with an average of four primary habitats each. Several species use upland habitats in addition to wet habitats, and overall amphibians are associated with 11 of the primary 15 habitats. The habitat associated with the greatest number of species was non-forested wetlands supporting five of the seven SGCN.

The Great Plains toad (*Anaxyrus cognatus*) is the only amphibian SGCN that is primarily associated with open grassland habitats. It may be found in remnant prairies, wet meadows, and even agricultural fields, where it breeds in shallow wetlands and flooded fields that form after heavy rain in the early summer. The toads spend much of their time in underground burrows throughout the rest of the year.

Blanchard's cricket frogs are strongly associated with permanent water bodies like lakes, ponds, streams, and rivers, utilizing both the aquatic habitat and the adjacent shoreline. Pickerel frogs (*Lithobates palustris*) are found in similar habitats, though prefer cool streams and often forage in wet meadows and grasslands in the summer.

Three of the salamander SGCN – spotted (*Ambystoma maculatum*), four-toed (*Hemidactylium scutatum*), and Eastern newt (*Notophthalmus viridescens*) – are strongly associated with mature forest habitats. They primarily occupy deciduous forests but will also occur in mixed deciduous-conifer forest types. These species rely on forested wetlands such as vernal (springtime) pools for spring breeding. Eggs are laid in or near the water, and larvae remain in the pools until metamorphosis occurs. Four-toed salamanders typically lay their eggs in moss hummocks adjacent to open water.

Eastern newts use a wide range of aquatic habitats, including lakes, ponds, and streams. Their unique life history includes the development of egg to larvae in aquatic habitat followed by a lengthy terrestrial juvenile stage that lasts a few years. Upon reaching maturity, adults undergo additional transformations as they revert to being primarily aquatic. To read about a study monitoring four-toed salamanders in relation to forest management activities on, see the Case Study: Four-toed Salamanders and Forest Management in the Vernal Pools Sub-chapter of Chapter 2.

The mudpuppy (*Necturus maculosus*) is Minnesota's only fully aquatic salamander and is restricted to medium or large rivers and lakes. They take cover under submerged rocks or logs, which are important components of their habitat. Females attach their eggs to the underside of such structures and guard them until they hatch.

*Photo: Mudpuppy, Jeff LeClere*

## Primary Stressors for Amphibians

Stressors are factors that pose direct or indirect challenges to vulnerable plant and wildlife species. Habitat loss and degradation are generally considered the primary threat for most SGCN, and some stressors reduce the quality of those habitats. Other stressors may operate more directly on the SGCN, such as disease and pathogens. In some cases, stressors may operate both directly and indirectly. For example, roads, trails, and railroads can directly harm SGCN through vehicular strikes, or operate indirectly through habitat fragmentation and reduced landscape connectivity. The stressor list below is adapted from an internationally recognized threats classification developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For more information, see the "Stressors" section of Chapter 1: Species in Greatest Conservation Need.

It is important to note that some factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this species group is included below, followed by a set of conservation actions addressing those stressors.

### Development

Development for residential communities, recreation, or commercial and industrial areas can eliminate, degrade and fragment amphibian habitat. This leads to a variety of negative effects that influence survival and reproduction of amphibians, such as desiccation (loss of moisture), reduced reproductive output, exposure to higher temperatures, reduced dispersal ability, increased exposure to contaminants, and reduced foraging success (Eakin et al., 2019; IUCN SSC Amphibian Specialist Group, 2024). It also makes traversing the landscape more difficult and dangerous (see also Roads, Trails, and Railroads).

### Crop Production

Conversion of amphibian habitat to agriculture eliminates, degrades and fragments amphibian habitat. This can lead to a variety of negative effects on amphibians, including desiccation, reduced reproductive output, exposure to higher temperatures, reduced dispersal ability, and reduced foraging success (IUCN SSC Amphibian Specialist Group, 2024). Drainage also plays a key role in row crop agriculture but has adverse effects on aquatic and terrestrial habitats that amphibians depend upon (Blann et al., 2009; Schottler et al., 2013; Schulz et al., 2015). The loss of wetlands due to agricultural practices can eliminate important wetland habitats, resulting in wetlands being separated beyond the species' normal dispersal distance. The presence of grassland and wet meadow habitats between wetlands provides cover and foraging habitat for dispersing frogs, improving the potential for successful migration.

### Livestock Management

Grazing by livestock can help to maintain open canopy habitats for dependent amphibian species. Nevertheless, the overall effects of livestock operations depend on management details such as stocking rates and whether livestock have direct access to water bodies. Amphibians are generally sensitive to water quality parameters such as levels of dissolved oxygen and nitrate concentration. Amphibians may be affected by livestock operations where waterways are not buffered, which affects shoreline habitat as well as water quality from manure, fertilizer, pesticide, and sediment runoff (Howell et al., 2019).

## Mining and Quarrying

Mining and quarrying may cause changes in habitat, such as in water chemistry, hydrology (the movement, and distribution of water), or the physical structure of wetlands, which could affect amphibian species composition and abundance.

## Wind and Solar Energy Infrastructure

There is insufficient research on how wind and solar facilities affect amphibians and what measures might be effective to reduce any negative effects. Wind and solar farms may affect amphibians through physical habitat alteration and noise and light pollution (de Oliveira et al., 2025; Chock et al., 2020).

## Roads, Trails, and Railroads

The proliferation of roads fragments and destroys amphibian habitat. This reduces the dispersal capabilities of individuals and may result in genetic isolation of populations on either side of the road. Many amphibian species attempt to cross roads, especially during breeding seasons, and experience high levels of road mortality. Roads also increase human access to natural habitats and increase the spread of invasive species that may degrade the habitat or outcompete native amphibian species (Andrews et al., 2008, Schmidt & Zumbach, 2008). Research by Fahrig et al. (1995) indicated that traffic mortality had a significant negative effect on local frog and toad populations.

## Utility Corridors

Amphibians are underrepresented in studies addressing direct and indirect effects and response thresholds to pipelines and powerlines (Richardson et al., 2017). There are existing and proposed transport pipelines in Minnesota with potential to affect amphibians via habitat loss, degradation and fragmentation (Brown et al., 2023). Amphibians may also be affected in the event of pipeline spills (see Water-borne Pollution).

## Hunting and Collecting Animals

In Minnesota, frogs, toads, and salamanders are classified under “protected wild animals.” A person may not take, buy, sell, transport, or possess a protected wild animal unless allowed by the game and fish laws (M.S. 97A). There are stricter rules for state endangered or threatened species (M.S. 84.0895). Minnesota fishing regulations allow people with a fishing license to take, use, buy, and sell an unlimited number of frogs up to 6” long for bait, except for the state-endangered Blanchard’s cricket frog. A special license is needed to take frogs for any purpose other than bait. Current fishing regulations do not allow taking of any native salamander species as bait.

Even though these rules are in place, illegal collection still occurs. People might not be aware of the rules or purposefully break them. Anecdotal reports of tadpoles mixed with minnows at bait shops indicate that there are cases where unintentional movement of frogs occurs. It is very difficult to monitor illegal take and appropriately enforce the rules.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Depending on the way in which it is designed, timber harvest could have negative effects on forest-dwelling amphibians, especially SGCN salamanders. Timber harvest can alter microhabitats (increased temperature, decreased moisture), increase soil compaction and desiccation if applied outside of frozen ground conditions, and reduce habitat complexity (Rothermel & Luhring, 2005; Rittenhouse et al., 2008; Todd & Rothermel, 2006; Semlitsch et al., 2009). Clearcuts are often the most damaging; some studies suggest it may take decades for populations to recover after a clearcut (Pough

et al., 1987; deMaynadier & Hunter, 1995). However, silvicultural practices that leave adequate microhabitat structure and adequate buffers may be able to mitigate effects, and long-term effects of forest harvesting on amphibians vary (deMaynadier & Hunter, 1995).

Forest-dwelling salamanders like spotted salamanders, four-toed salamanders, and eastern newts prefer high levels of canopy cover, up to 90% (Faccio, 2003). One study found that spotted salamanders were absent where forest cover was reduced to below 30%, and eastern newts were absent where forest cover was reduced to below 50% (Gibbs, 1998). In Minnesota, forests are regenerated after timber harvest, meaning loss of canopy cover at a site is not permanent. However, it can take decades for a harvested site to develop mature forest habitat characteristics. While more generalist, highly-mobile amphibians (such as northern leopard frog or gray treefrog) may be able to more readily recolonize forested habitat as it regenerates and develops suitable understory conditions, SGCN forest-dwelling salamanders have limited dispersal ability and adjacent source populations may not be present to assist with recolonization (Loehle et al., 2021).

Most woodland salamanders require both forested upland and wetland habitat to complete their life cycles. Many small wetlands (i.e. vernal pools) are undocumented and unprotected; initial checks using aerial imagery coupled with on-the-ground verification may be helpful in planning management appropriately to prevent negative effects on these critical habitats during timber harvest operations.

*Photo: Four-toed salamander, Andrew Herberg*

## Fishing

Mudpuppies (a species of salamander) are occasionally caught by anglers, and may be killed accidentally, or purposefully by individuals who mistakenly believe mudpuppies are poisonous or venomous. Reports submitted to the DNR indicate that most mudpuppies are released unharmed.

Fish releases into wetlands and shallow lakes (e.g. release of unused bait fish) — particularly previously fishless water bodies — is known to reduce abundance, density, and/or species richness of amphibians; these effects can be from fish that are either native or non-native and are not limited to predatory fish (Hecnar & M'Closkey, 1997; Herwig et al., 2013; Holbrook & Dorn, 2015).

## Recreation

Recreation can have a have a wide range of effects on amphibian species depending on the type of activity, although more research is needed on this topic. Motorized and non-motorized forms of recreation such as riding off-highway vehicles, bikes, or horses, particularly beyond designated trails, can destroy sensitive habitat or run over small, slow-moving amphibians. The presence of people or vehicles may alter amphibian behavior, leading to increased time spent under cover or away from favored areas, and indirect effects such as introduction of pathogens, invasive species, or trash can also affect habitat conditions (Amphibian and Reptile Conservation Trust, 2021).

## Fire Management

Fire suppression increases the growth and spread of woody vegetation in open upland habitats used by some amphibian species like the Great Plains toad. It can also lead to larger wildfires due to a buildup of vegetation on the landscape. Amphibians are slow-moving and may find it difficult to escape wildfires if they are on the surface; however, since many amphibian species utilize underground burrows, most individuals might be able to avoid harm.

More research is needed on the response of amphibians to fire on the landscape (Hossack & Pilliod, 2011).

## Dams and Water Management

Water management is comprised of many diverse actions such as water level manipulation, dams, drainage, dredging, water deposition and transfer, and more. These can greatly alter hydrology, stream geomorphology (physical features), and water quality which in turn can affect amphibians. Dredging and even beneficial practices like stream restoration often involve construction, heavy equipment use, and excavation which can result in direct injury or mortality of amphibians. Increased drainage can cause downstream flooding and high flows, erosion, and runoff of chemicals and nutrients (Schottler et al., 2013). Dams reduce connectivity to key habitats and separate populations so they can no longer breed with each other. Water management can convert or degrade wetland and lake habitats. Ephemeral prairie wetlands have been drained for row crop production, severely reducing native breeding habitats for the Great Plains toad. Removal and placement of dredged material should avoid potential negative effects on amphibian SGCN, such as the Blanchard's Cricket Frog. Placing dredge spoil materials into breeding sites and/or altering the hydrology associated with overwintering sites could be detrimental to local populations.

## Invasive Species (Problematic Non-native Species)

In Minnesota, the American bullfrog is considered to be non-native and invasive outside of the extreme southeastern corner of the state. Populations occur in many other counties, likely due to intentional releases. This could eventually displace other native amphibian species in aquatic habitats throughout Minnesota due to predation and competition for resources, if left unchecked (Bucciarelli et al., 2014; Moriarty & Hall, 2014).

Research has found that invasive plants such as buckthorn reduce hatching success and larval survival of some amphibians and may contribute to amphibian declines (Sacerdote & King, 2014).

## Problematic Native Species

The introduction of fish into previously fishless wetlands and shallow lakes can reduce abundance, density, and/or species richness of amphibians (Hecnar & M'Closkey, 1997; Herwig et al., 2013; Holbrook & Dorn, 2015). Fish can be introduced through ditches, floodwaters, or by release of bait.

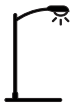
## Diseases and Pathogens

Infectious diseases are one of the top causes of amphibian decline globally (IUCN SSC Amphibian Specialist Group, 2024). Ranavirus is transmitted through contaminated water, physical contact, and ingestion of infected tissues and may present as abnormal behavior, lethargy, swelling, fluid accumulation, and skin hemorrhage or ulcers (Cornell University, 2025a). Chytridiomycosis is caused by the waterborne fungus *Batrachochytrium dendrobatidis* and infects the keratin layer of the skin, causing weight loss, lethargy, skin shedding, red skin, and abnormal behavior (Cornell University, 2025b). Another more recently discovered fungus, *Batrachochytrium salamandrivorans*, has decimated salamander populations in Europe. It also infects the skin, causing reddening and ulcers, as well as lethargy and weight loss (Cornell University, 2025c). This fungus has not yet been found in North America, but if it does spread here, it could have major effects on our salamander populations. Of note, one of Minnesota's SGCN, the eastern newt (*Notophthalmus viridescens*), has been found to be highly susceptible to the fungus in research trials (Cornell University, 2025c). Major contributors to the spread of pathogens like these include the pet trade, biological supplies industry, and people using contaminated equipment or footwear. Challenges to

addressing this threat include lack of funding and the high workload and short response window needed to research amphibian diseases.

## Water-borne Pollution

Amphibians are very susceptible to water-borne pollutants, including salt from roads and water softeners, endocrine disrupters, hormones from birth control, herbicides, fertilizers, and more. These can affect the growth, development, and survival of eggs and larvae through direct and sublethal effects that influence survival (Ocampo et al., 2022; Thompson, 2022; Benli, 2024; Tornabene et al., 2024). Frog malformations have been a topic of concern in Minnesota after high rates of malformed frogs were found in a variety of ponds and wetlands in the 1990s. The cause of malformations is likely related to combinations of chemical, biological and physical factors (U.S. Geological Survey, 2001). Effects associated with acid rain include direct toxicity and developmental abnormalities, as well as indirect effects on food availability and aquatic vegetation (Croteau et al., 2008).



## Light and Noise Pollution

Reproductive behaviors of amphibian species can be altered by artificial lights at night. Studies have found that artificial light can inhibit amphibian movement to and from breeding areas and decrease mating call activity (Longcore & Rich, 2004). A quick increase in the amount of light can cause a reduction in vision that can last for minutes or hours (Longcore & Rich, 2004).

Noise pollution is also problematic for frogs and toads, which rely on acoustic communication. Noises from many sources (urbanized areas, traffic, energy production) influence calling activity, alter mate selection, and cause physiological changes such as increased stress, suppressed immune function, and coloration change (Zaffaroni-Caorsi et al., 2022).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency & Minnesota Department of Commerce, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

Amphibians are micro-habitat specialists and thus are very sensitive to changes in temperature. Current studies generally suggest that extreme heat stress can suppress amphibian immune responses. Elevated temperatures can also alter microbial communities in amphibian skin and gut, which

may reduce resistance to pathogens. Studies also suggest that increasing temperatures may cause reductions in body size, which may then lower reproductive success (Sheridan & Bickford, 2011; Hernández-Pacheco et al., 2020).

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

More specifically, amphibians are very sensitive to changes in precipitation and moisture. Droughts can suppress amphibian immune responses (Rollins-Smith & Le Sage, 2023). Blanchard's cricket frogs are negatively affected by river flooding in the winter because they cannot survive inundation in anoxic (low oxygen) water for more than 24 hours nor in initially oxygenated water past 10 days (Irwin et al., 1999). If precipitation increases due to climate change and results in the inundation of overwintering sites, Blanchard's cricket frog mortality will also increase. In the long-term, climate change could result in drastic changes to the landscape. Extensive periods of drought and/or elevated temperatures could eliminate shallow wetlands critical as amphibian breeding sites and recruitment of young (McMenamin et al., 2008).

*Photo: Great plains toad, Jeff LeClere*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan, to conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions, three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnerships with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management practices.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with not applicable (NA) in the stressor column.

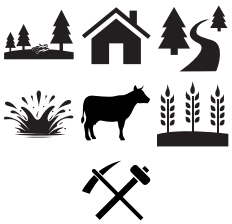
## Potential Conservation Actions for Amphibians

### 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

| Stressor | Action |
|---|---|
| | Develop citizen science programs to safely identify stretches of road that are mortality hotspots for amphibians, especially during spring and fall breeding migrations. |
| | Conduct effectiveness monitoring to assess responses of SGCN to specific management activities to refine evidence-based management recommendations and avoidance measures for SGCN (Binley et al., 2025), such as monitoring the effects of forest management activities on the populations of forest species. |
| | Support research on effects of recreation on SGCN amphibians, including thresholds for response and avoidance of significant adverse effects. Prioritize specific recreation types and habitats based on assessment of need in environmental review. Identify sensitive areas and avoid promoting recreational use and development in those areas. Enforce closures in sensitive areas. |
| | Monitor the status of bullfrog populations to help establish where they may be a problem for native species in central and northern Minnesota. |
| | Prioritize amphibian disease monitoring to understand effects on populations and to facilitate early detection of *Batrachochytrium salamandrivorans* (Bsal) if it arrives in North America. Increase capacity of amphibian disease surveillance and response through collaboration between the DNR and external partners, such as the USGS National Wildlife Health Center and its Wildlife Health Information Sharing Partnership (WHISPers) and the North American Bsal Task Force. |

| Stressor | Action |
|---|---|
| | Investigate mudpuppy mortality events. Conduct surveys to better understand mudpuppy habitat use. Work with state and federal partners to develop and test hypotheses related to stressors. Engage citizens by soliciting reports of amphibian mortality events. |
| NA | Engage the public in community science to help survey and monitor amphibians. Example opportunities include: Minnesota Frog & Toad Calling Survey and Minnesota Amphibian & Reptile Survey. |
| NA | Resurvey/monitor amphibian SGCN populations whose last observations in the Natural Heritage Information System (NHIS) database are over 10 years old to confirm continued presence of the species, assess population status, and identify specific conservation needs. |
| NA | Conduct wetland surveys focusing on identifying and mapping ephemeral wetlands like vernal pools (Hofmeister et al., 2022). Create a citizen science program or app for reporting locations of ephemeral wetlands. |
| NA | To help address data gaps which hinder conservation, support continued research on efficacy of tools like environmental DNA (eDNA) to augment standard survey and monitoring techniques for rare SGCN amphibians such as spotted salamanders and mudpuppies in various environments. |
| NA | Increase collaboration with universities to further research and monitoring of selected amphibian SGCN. |

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

| Stressor | Action |
|---|---|
| | Work with MnDOT, cities, and counties to develop under-road wildlife crossing tunnels and surmountable curbs in areas close to amphibian breeding sites such as ponds and vernal pools, especially those identified as road mortality hotspots. Consider additional options such as road closure or speed reduction during amphibian breeding seasons and signage informing drivers of amphibian crossings (Gunson et al., 2016; Marcelino et al., 2024). |
|  | Maintain vegetated buffers comprised of locally native vegetation adjacent to waterways. Avoid or reduce mowing, burning, grazing or chemical application on these buffers. Support and promote state and federal programs incentivizing buffers and other best practices for lakes, streams, wetlands and ponds (Semlitsch & Bodie, 2003). |
| | Promote protection and restoration of native shoreline habitats (Restore Your Shore; Rivers and Streams). |
| | Encourage collaboration among all stakeholder groups and across ownerships to promote effective management for the health and resilience of forests and their ability to provide ecological, wildlife habitat, and other values. |

| Stressor | Action |
|---|---|
| | Work with road authorities to implement culvert designs that improve stream connectivity and aquatic organism passage (Hernick et al., 2019). |
| | Restore wetlands to benefit a variety of amphibians, including seasonal and temporary wetlands that do not sustain fish. |
| | Support intra and inter-agency drainage teams focused on evidence-based best practices such as:<br>• Control drainage to strategically manage water levels and mimic natural drainage and adapt to climate change to improve water quality, reduce flooding and support ecological functions<br>• Restore and protect wetlands for water filtration, flood control and wildlife habitat<br>• Reduce runoff<br>• Incorporate native perennial plantings and cover crops<br>• Establish shallow drainage systems to help maintain wetlands<br>• Establish two-stage ditches designed to slow and filter runoff, reduce erosion and improve water quality<br>• Restore river and stream connectivity via properly designed passage structures and removing dams |
| | To mitigate effects of dams and changes in water management regimes, focus on dam removal and stream restorations that avoid or minimize unintended negative effects – for example, employ special precautions and conduct at a time of year that is less detrimental to stream-dwelling amphibians. Stream restoration should include naturally associated off-channel habitats (e.g. oxbows) and stream bank specifications conducive to rare amphibians, where indicated. Because SGCN amphibians can co-occur with SGCN from other wildlife groups it is important to consider their needs as well for a more integrated approach. |
| | Incentivize renewable energy that “piggybacks” on existing infrastructure versus developing new facilities on currently undeveloped sites (e.g. example, atop buildings, parking lots and ramps, etc.). Explore examples from other countries. |
| | Limit creation of new utility line corridors in important wetland and shallow lake areas. Develop best management practices for creation and maintenance of utility lines. Reduce chemical vegetative control methods. |
| | Maintaining and improving landscape connectivity is a key strategy to support amphibians in the face of climate change. For example, maintaining and restoring a diverse set of interconnected, healthy aquatic and terrestrial habitats and ensuring there are safe movement corridors that may also allow them to track shifting conditions (Uden et al., 2014; Souza et al., 2023). SGCN such as Blanchard’s cricket frog (Badje et al., 2021) and Great Plains toad (Bragg, 1940) are among the many amphibian species that would benefit from improved dispersal options to access overwintering, migration, and breeding habitats. For a given amphibian SGCN, ensure that uplands adjacent to their aquatic habitats are equally suitable and permeable (Youngquist & Boone, 2014). |

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

| Stressor | Action |
|---|---|
| | Increase enforcement of nongame illegal take issues; educate conservation officers on the issues and increase monitoring of important areas for poaching. |
| | Increase public awareness of state rules and regulations around take, possession, purchasing, and selling of native amphibian species and the reasons for these laws. Promote alternatives to appreciate Minnesota's amphibians in their native habitats. |
| | Educate land managers, including private landowners, about habitat needs of rare forest species. |
| | Increase public education and outreach about how releases of captive animals (including wild-caught individuals) can spread disease. |
| | Increase public education and outreach about best management practices for artificial lights at night, such as suggested by Dark Sky International. Advocate for increased regulation of light and noise pollution, especially near important amphibian breeding sites. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## BIRDS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Birds

## Overview

Birds are perhaps the most popular and intensively studied animals in Minnesota and throughout the world. Most species are easily visible, display beautiful plumages, and communicate with unique calls and songs. From Native Americans who first occupied North America to the European settlers who arrived, people have observed, listened, consumed, collected, studied, and written about birds for hundreds of years. Indeed, Minnesota has a spectacular legacy of information regarding our avifauna, beginning with the oral legends of Native Americans (e.g. Adikwan, 2019) to articles, pamphlets, peer-reviewed papers, and numerous books describing their life history, distribution, and abundance.

Minnesota is fortunate to have the recent Minnesota Breeding Bird Atlas, a project led by the National Audubon Society, which documents the breeding status and locations of all birds nesting in Minnesota at a local scale and provides in-depth species accounts (Pfannmuller et al., 2017). Earlier foundational works include the two-volume tome by T.S. Roberts in 1932, followed with books by Green and Janssen (1975), Janssen (1987; 2019), and Pfannmuller, Niemi, and Green (2024). Multiple other accounts, projects, journal articles, and publications by resource agencies and the Minnesota Ornithologists' Union supplement these sources and provide a wealth of information on the 452 species that have been reported in the state (MOU, 2024). These include the Blueprint for Minnesota Bird Conservation, the North American Bird Conservation Initiative, the Minnesota National Forest Breeding Bird Monitoring Program, and the Audubon Christmas Bird Count. The North American Breeding Bird Survey (BBS) has monitored the population trends of North American birds since 1967 providing an abundance of valuable data on the status of all birds for more than 50 years.

*Photo: Black-backed woodpecker, Julia Geschke*

This information is now augmented by eBird data collected by recreational birders and compiled by the Cornell Laboratory of Ornithology, which has recently produced information for state-level eBird Status and Trends. Some birds, such as colonial nesting waterbirds, secretive marshbirds, raptors, and nocturnal birds will likely still require additional efforts to track their numbers. It is important to find cost-effective and efficient means to monitor of all these types of species throughout the future.

Given the depth of attention they have received over the years, our knowledge of bird trends is relatively well-developed. Nationally, pervasive and significant declines of birds have been noted. One study of more than 650 North American species estimated a 29% reduction in numbers since 1970, with declining trends showing for many common birds (Rosenberg et al., 2019). Recent continent-wide assessments found prominent declines in the most abundant species and in regions where they were most abundant (Dupont et al., 2025 and Johnston et al., 2025). The State of the Birds Report indicates long-term trends of -43% for grassland birds, -33% for shorebirds, and -27% for forest birds (North American Bird Conservation Initiative, 2025).

We noted during the species conservation status assessment (S-rank) process that many bird species are experiencing declines, extending beyond those listed as SGCN. To inform the S-rank process, we reviewed or estimated breeding bird relative abundance trends using data from BBS and eBird. From BBS data, 158 species had sufficient records in Minnesota to estimate ("estimable") long-term trends (1972–2021), and 160 species had sufficient records in Minnesota for short-term trends (2000–2021; Table 2.4). From eBird, 220 species had sufficient records in Minnesota to estimate short-term trends between 2012 and 2022 (Table 2.4). While we used a more conservative 95% confidence level to declare significant declines using BBS data, we used the 80% confidence level for eBird data. The 80% level is justified for eBird data because: (1) using a 95% interval would make many intervals so wide as to appear uninformative given the relatively shorter time series of data available in eBird compared to BBS, (2) the goal of eBird trend estimates are to detect emerging population signals that could indicate conservation concerns and serve as actionable early-warning indicators, (3) eBird status and trends are global, covering areas with varying amounts of data (Cornell Lab of Ornithology eBird Status and Trends: Methods and Data Products).

BBS results showed that 42% of species with estimable long-term trends were in significant decline at the 95% confidence level, and 39% of species with estimable short-term trends were also in significant decline (Table 2.4). Importantly, while many of these species are SGCN, declines were also widespread among non-SGCN species: 37% were significantly declining in the long term and 33% in the short term. Similarly, eBird results showed that 40% of species with estimable short-term trends were in significant decline at the 80% confidence level (Table 2.4), with 40% of non-SGCN species also showing significant declines. While population declines in SGCN species are expected, these findings demonstrate that declines are pervasive across the broader bird community. Notably, even species considered sufficiently abundant to be excluded from the SGCN list — such as aerial insectivores (e.g., swallows) — are undergoing statistically significant declines that warrant attention.

Examples of species with significant population declines occur in a variety of habitats such as the eastern screech owl (*Megascops asio*) in Upland Deciduous Forest and Woodland, eastern whip-poor-will (*Antrostomus vociferus*) in Savanna, Connecticut warbler (*Oporornis agilis*) in Coniferous Forest Wetlands and purple martin (*Progne subis*) associated with Lakes (Pfannmuller et al., 2024). In addition, some groups of species may warrant additional concern.

Grassland bird species with especially steep declines include bobolink (Dolichonyx oryzivorus), grasshopper sparrow (Ammodramus savannarum), and western meadowlark (Sturnella neglecta). In a recent analysis, these species showed declines in BBS surveys in Minnesota that include habitats with variable quality and protection as well as in high-quality permanently protected prairies as documented in the DNR-led project: Sustaining Prairies in a Changing Landscape (SPICE, see Case Study). Seven of the 11 prairie obligate bird species for which data were sufficient to determine trends were found to have declining trends, and similar in magnitude, in both the BBS and SPICE results (see Table 2.5). Aerial insectivores are another group that have been showing steady and widespread declines causing concern. Drivers of declining trends are numerous (see Stressors section below) but most studies cite habitat loss and degradation. A sound understanding of threats to these species is made more difficult due to the migratory nature of many of our species encountering differing conditions across their life cycles and across continents. An ongoing concern is how well species will adapt to the stress caused by changing climatic conditions and even potential extirpation of many of our northern boreal forest species as temperatures continue to rise (National Audubon Society

2019; see Case Study later in this chapter). Despite these pervasive threats, there are remarkable success stories. Due largely to targeted conservation efforts some species, such as the trumpeter swan (*Cygnus buccinator*) (see inset), peregrine falcon (*Falco peregrinus*), and bald eagle (*Haliaeetus leucocephalus*), have recovered from the brink of extirpation in Minnesota. It is not uncommon nowadays, for example, to see a bald eagle not only over a lake in the dense forests of northern Minnesota, but also in the center of the Twin Cities or in the agricultural landscapes across southern and western Minnesota.

**Table 2.4. Counts of Minnesota breeding bird trends from BBS data in the long-term (1972-2021) and short-term (2000-2021) for both SGCN and non-SGCN assigned species, as well as counts of Minnesota breeding bird trends from eBird data in the short-term (2012-2022). Significant declines for BBS data were established at the 95% confidence level and for eBird at the 80% confidence level.**

| Number of Bird Species Trends | BBS Long-term Total | BBS Long-term Declining | BBS Short-term Total | BBS Short-term Declining | eBird Short-term Total | eBird Short-term Declining |
|---|---|---|---|---|---|---|
| Total Estimable | 158 | 67 | 160 | 62 | 220 | 92 |
| SGCN | 31 | 20 | 32 | 20 | 60 | 34 |
| Non-SGCN | 127 | 47 | 128 | 42 | 160 | 58 |

**Table 2.5. Obligate grassland bird declines in abundance detected in Minnesota, based on transects from the North American Breeding Bird Survey (BBS) in the Minnesota prairie region (Bird Conservation Region 11; except for Henslow's Sparrow for which data in BCR 11 were insufficient and BBS from all of Minnesota were used) and the DNR's Sustaining Prairies in a Changing Environment (SPICE) long-term monitoring project. Of the 11 grassland-obligate bird species (based on Vickery et al., 1999) for which data were sufficient to determine trends, 7 had declining trends for the period of 2008 to 2024, generally similar in magnitude for BBS and SPICE.**

| Bird Species | SGCN | Breeding Bird Survey | SPICE Survey |
|---|---|---|---|
| bobolink (*Dolichonyx oryzivorus*) | Y | Decline of 4% | Decline of 1% |
| dickcissel (*Spiza americana*) | N | Increase of 21% | Increase of 11% |
| grasshopper sparrow (*Ammodramus savannarum*) | Y | Decline of 4% | Decline of 7% |
| Henslow's sparrow (*Centronyx henslowii*) | Y | Probably Stable | Increase of 17% |
| LeConte's sparrow (*Ammospiza leconteii*) | Y | Decline of 7.5% | Decline of 10% |
| marbled godwit (*Limosa fedoa*) | Y | Increase of 1% | Increase of 1% |
| northern harrier (*Circus hudsonius*) | Y | Decline of 7% | Decline of 5% |
| savannah sparrow (*Passerculus sandwichensis*) | N | Decline of 6% | Decline of 7% |
| sedge wren (*Cistothorus stellaris*) | Y | Decline of 3% | Decline of 6% |
| upland sandpiper (*Bartramia longicauda*) | Y | Decline of 1% | Decline of 12% |
| western meadowlark (*Sturnella neglecta*) | Y | Decline of 3% | Decline of 2.5% |

## Species Information

The 2025-2035 list of Species in Greatest Conservation Need identified 79 Minnesota bird species as SGCN and one species, the Eastern Screech Owl, as a SNI (Species in Need of Information). A total of 21 species were removed from the SGCN list in the 2015-2025 SWAP primarily because their numbers have increased and/or they are now known to be more common and widespread than biologists thought in 2015 (see for example Case Study box below). Eight species were added: canvasback (Aythya calisineria), bufflehead (Bucephala albeola), buff-breasted sandpiper (Calidris subruficollis), solitary sandpiper (Tringa solitaria), great gray owl (Strix nebulosa), American barn owl (Tyto furcata), American three-toed woodpecker (Picoides dorsalis), and Swainson's thrush (Catharus ustulatus).

Five of the bird SGCN were assigned a Presumed Extirpated S-rank (SH): Sprague's pipit (*Anthus spragueii*), burrowing owl (*Athene cunicularia*), Baird's sparrow (*Centronyx bairdii*), horned grebe (*Podiceps auritus*), and king rail (*Rallus elegans*). All of these species are listed as State Endangered. Bird species were considered extirpated if there are not any regular breeding populations in the state (i.e., breeding in the same location in successive years). Notably, several of these species have been documented as nesting in Minnesota in recent years. There is a chance that populations may become established in the state over the next ten years, and conservation actions may be taken to support these species.

Among the 79 Minnesota birds that are designated SGCN, the piping plover (*Charadrius melodus*) is federally endangered, the red knot (Calidris canutus) is federally threatened, and the golden-winged warbler (Vermivora chrysoptera) is under review for federal listing. Nine species are state listed sted as Endangered, two as Threatened, and 19 listed as Special Concern. A complete list of SGCN and SNI species can be found in Appendix B.

*LeConte's sparrow, Bob Dunlap*

## Case Study: The Successful Recovery of the Trumpeter Swan in Minnesota

When Roberts compiled his treatise on Minnesota birds in 1932, he wrote, "The days of the Trumpeter Swan as a bird of Minnesota have long since passed." Unfortunately, this large white bird was an easy target for the state's early European settlers and market hunters. The young birds were tender and tasty while the older birds were either shot for sport or for their skin and feathers. By 1932 only 69 birds were believed to remain, surviving in the remote mountain valleys of Montana, Idaho, and Wyoming. These birds, along with those from a breeding population found in Alaska in the 1950s, became breeding stock for introductions farther east, in areas formerly occupied by the species, including the LaCreek National Wildlife Refuge in western South Dakota.

*Photo: Trumpeter swan, Beau Liddell*

Interest in reintroducing trumpeter swans to Minnesota began in 1966 by the Hennepin County Park Reserve District (now Three Rivers Park District). Their initial efforts to establish a breeding population by releasing adult birds secured from Montana failed. The tide turned when the district initiated its own captive breeding program, caring for the young cygnets and not releasing them until they were two years old. The first release of young raised by this program occurred in 1978, and the first successful nesting occurred in 1979. By 1996, more than 245 young birds had been raised and were successfully nesting within the park district and beyond. The park district's program continued for another thirteen years, until it was retired in 2009. In 1982, the DNR's Nongame Wildlife Program outlined an initiative to build on the work of the park district by reintroducing birds in northwestern, north-central, and south-central Minnesota, working collaboratively with state and federal agencies, provinces, universities, tribes, and the Trumpeter Swan Society. Together, these two initiatives by the Park District and DNR were so successful that by 2019, the Minnesota Waterfowl Breeding Population Survey generated a statewide population estimate of 23,200 swans. It is now common to find breeding pairs of trumpeter swans in wetlands across the state. (Excerpted from Pfannmuller et al., 2024.)

## Habitat Associations

SGCN birds rely upon many different habitats across Minnesota. Table 2.6 provides a summary of their associations with the 15 habitats discussed in the 2025-2035 SWAP. Three habitats that provide primary habitat for the largest number of SGCN are prairie and other grasslands (22 SGCN), followed by non-forested wetlands (18 SGCN), and lakes (18 SGCN). Collectively, forested habitats (upland, lowland, and riparian) provide primary habitat for 27 bird SGCN. Primary habitats are those where the species is found most consistently; the species is most reliant on the habitat and, should the habitat be degraded or lost, it would have the greatest effect on the species. Secondary habitats are those where a species can be found some of the time, but less frequently than a primary habitat. Some species, especially those with more general habitat requirements, may be assigned to multiple primary or secondary habitats. A complete list of all primary and secondary habitats for each SGCN can be found in Appendix D.

**Table 2.6. Numbers of Bird Species in Greatest Conservation Need associated with each of the habitat types.**

| Habitats | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Prairie and Other Grasslands | 22 | 7 | 29 |
| Savanna | 3 | 4 | 7 |
| Upland Conifer Forest and Woodland | 7 | 9 | 16 |
| Upland Deciduous Forest and Woodland | 4 | 8 | 12 |
| Mesic Hardwood Forest | 6 | 2 | 8 |
| Deciduous Wet Forest | 0 | 5 | 5 |
| Coniferous Forest Wetland | 9 | 3 | 12 |
| Riparian and Floodplain Forest | 3 | 3 | 6 |
| Non-forested Wetlands | 18 | 12 | 30 |
| Rivers and Streams | 1 | 0 | 1 |
| Lakes | 18 | 6 | 24 |
| Vernal Pools | 0 | 1 | 1 |
| Cliff, Talus, and Rock Outcrops | 2 | 0 | 2 |
| Urban and Other Developed Lands | 3 | 6 | 9 |

## Primary Stressors for Birds

Stressors are factors that pose direct or indirect challenges to vulnerable plant and wildlife species. Habitat loss and degradation are generally considered the primary threat for most SGCN, and some stressors reduce the quality of those habitats. Other stressors may operate more directly on the SGCN, such as disease and pathogens. In some cases, stressors may operate both directly and indirectly. For example, roads, trails, and railroads can directly harm SGCN through vehicular strikes, or operate indirectly through habitat fragmentation and reduced landscape connectivity. The stressor list below is adapted from an internationally recognized threats classification developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For more information, see the "Stressors" section of Chapter 1: Species in Greatest Conservation Need.

It is important to note that some factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this species group is included below, followed by a set of conservation actions addressing those stressors.

### Development

Collisions with towers and buildings, especially windows, are a well-documented threat to bird populations (e.g. Loss et al., 2015; Loss et al., 2014). Birds often mistake reflective glass that mirrors vegetation or sky as open habitat, leading them to fly directly into it, often resulting in injury or death. Long-distance migratory species are particularly vulnerable to these collisions (Arnold & Zink, 2011; Machtans et al., 2013). Among the 10 migrants that were disproportionately vulnerable to building collisions was the Minnesota SGCN, the black-throated blue warbler (*Setophaga caerulescens*; Runwal, 2020). Communication towers also pose a significant hazard, especially during migration on foggy nights or when cloud ceilings are low (Loss et al., 2015).

Birds that nest or feed along lake and river shorelines are especially vulnerable to the increasing rate of shoreline development and habitat degradation. These areas are considered prime real estate for summer homes and recreational use, leading to widespread alteration. A recent report estimates that Minnesota has lost 40-50% of its natural shoreline and continues to lose an additional 1 to 2% per decade (Minnesota Natural Shoreline Partnership, 2023). This ongoing loss affects species like the common loon (*Gavia immer*) that requires undisturbed shorelines for nesting. Additionally, during migration, many migrants depend on shoreline habitats rich in insects to refuel, making these areas essential stopover habitat.

The loss and degradation of forests, especially across the intensively developed Eastern Broadleaf Forest Province, is a notable factor in the decline of forest-dependent bird species such as the cerulean warbler (*Setophaga cerulea*), Acadian flycatcher (*Empidonax virescens*), and eastern whip-poor-will (Pfannmuller et al., 2024).

In addition, unsupervised domestic and feral cats can pose a serious threat to local bird populations. Annual bird mortality caused by cats is estimated at 1.4 to 4 billion birds in the U.S. alone, though these figures include significant uncertainties (Loss et al., 2013a). Feral cats in particular may be a greater threat than free-roaming domestic cats (Loss et al. 2015; 2022).

## Crop Production

Grassland birds, including sedge wrens (Cistothorus stellaris), bobolinks, grasshopper sparrows, and short-eared owls (*Asio flammeus*) are affected by loss of habitat caused by conversion to rowcrop agriculture on the landscape. Since 1970, birds dependent on grassland habitats have declined an average of 43% as the Great Plains continues to lose approximately 1 to 2 million acres of grassland per year (State of the Birds Report). Additionally, areas with cover crops can function as population sinks when birds build nests in them, but the crop is terminated before young have hatched and left the nest.

In addition to habitat loss, extensive tiling of agricultural lands increases runoff to wetlands embedded in the agricultural landscape. Spring and summer storms increase runoff, which can suddenly flood the nests of waterfowl, shorebirds, and rails. Over time, the resulting sediment load can accumulate and gradually fill in wetlands (see also Dams and Water Management stressor below).

## Tree Plantations

Tree plantations typically support lower plant species diversity and reduced structural complexity, resulting in lower-quality habitat for forest-dependent birds. The lack of a well-developed understory, for example, can significantly reduce the suite of forest bird species, often reducing it to 6 to 15 species that primarily occupy the conifer canopy. In contrast, plantations that include deciduous shrubs and saplings may support an average of 20 to 35 bird species (Green, 1995).

## Livestock Management

Grazing by large ungulates, especially bison, was historically an important natural disturbance that helped maintain grassland habitats and the bird species that depend on them. Bison played a vital role in sustaining prairie ecosystems through selective grazing, wallowing behavior that disturbed soil and created new microhabitats (Ratajczak et al., 2022), and dung that attracted insects, providing a key food source for many grassland birds. Today, livestock have replaced bison as the dominant ecological force shaping the structure and composition of Minnesota's one million acres of pastures and hayfields (USDA, 2022).

Depending on how grazing is managed, it can have both negative and positive effects on the abundance and diversity of grassland birds. Intensive grazing often has harmful consequences, including the reduction of vegetative cover needed by ground-nesting species, which increases the risk of nest predation; trampling of nests by livestock; and the spread of non-native plant species that degrade native vegetation used for feeding and nesting (Wuerthner, 2012). Bird abundance is especially sensitive to grazing in riparian (riverbank) habitats (Barzan et al., 2021). Grassland species known to respond negatively to intensive grazing include northern harriers (Circus hudsonius), short-eared owls, and Henslow's sparrow (*Centronyx henslowii*) (Bock et al., 1993). Some studies have also found that cattle grazing may be more detrimental to bird populations than grazing by sheep or mixed livestock herds (Barzan et al., 2021).

Livestock grazing can also benefit grassland conservation by creating favorable conditions for certain grassland bird SGCN species. For example, moderate to heavy grazing that produces short-grass prairies or grasslands can support species like the chestnut-collared longspur (*Calcarius ornatus*) (Lebbin & Fenwick, 2010). However, very few grassland bird species in Minnesota's tallgrass prairie ecosystem are strictly dependent on short-grass conditions. In these landscapes, the absence of grazing can actually reduce habitat suitability for birds. Moderate grazing helps maintain the vegetative and structural diversity that many bird species, such as grasshopper sparrows and western meadowlarks, thrive upon (Barzan et al., 2021). Creating a mosaic of grass height and structure

across singular operations will support habitat heterogeneity (variety) for a greater diversity of grassland birds. A recent study concluded that rotational cattle grazing provides similar benefits to breeding birds as bison grazing. The authors concluded that the rotational cattle or bison grazing system used was less important to grassland bird diversity and abundance than other factors such as stocking rate, soil composition, precipitation, topography and woody vegetation (Boyce et al., 2021). Grazing on private "working lands" also helps to maintain grassland habitats and prevents conversion to other land uses.

## Mining and Quarrying

Habitat loss is the primary negative effect of mining and quarrying operations. This has been especially evident along the former Lake Agassiz beach ridges in northwestern Minnesota. The beach ridges not only support some of the best and largest remnants of native prairie in the state that provide habitat for many declining grassland birds, they also are a significant source of sand and gravel to growing communities in the Red River Valley (DNR, 1997). Potential effects on birds in sensitive wetlands from proposed mines have been raised as a concern. Although peat mining in Minnesota is limited in scope to a small percentage of area (approximately 8,000 acres in active leases in 2025, of an estimated 7 million acres [State mineral leases]), peat mining can alter hydrology and other attributes of peatland habitats valuable to some SGCN species.

## Wind and Solar Energy Infrastructure

Renewable energy site development can negatively affect birds through habitat degradation and direct collision (also see discussion of window and tower collisions under the Development stressor). Loss and his colleagues (2013b) estimated between 140,000 and 328,000 birds are killed annually at wind turbines across the contiguous United States. Based on data collected at wind turbines supported by a single vertical tower they demonstrated that mortality increases with the height of the turbine hub. Mortality also differed geographically with the lowest risk in the Great Plains.

## Roads, Trails, and Railroads

Bird species that depend on large tracts of habitat that are not fragmented (e.g. American goshawk [*Astur atricapillus*] and red-shouldered hawk [*Buteo lineatus*]) can be affected by creation of new roads which decrease the amount of unfragmented forest and increase the level of disturbance in nesting areas, especially during the breeding season. Ortega and Capen (2002) found that habitat quality for a suite of forest-interior songbirds may be higher when territories are located more than 150 meters (492 feet) from a road. While smaller in width and often unpaved, trails can also pose problems. The higher the density of trails in an area, the more invasive plant species can be spread due to increased human access during and after trail building. These invasive species may outcompete native plant species and degrade habitat.

Vehicle collisions pose another threat to birds that use roadside fence lines, utility lines, and poles as perches. Car collisions have been noted as a significant cause of mortality for species such as the loggerhead shrike (*Lanius ludovicianus*) and red-headed woodpecker (*Melanerpes erythrocephalus*) (Pfannmuller et al., 2024).

## Utility Corridors

Grassland bird species and forest interior songbird species can be affected by the creation and maintenance of utility and service corridors that traverse large tracts of habitat. As these areas are cleared regularly and kept in an early state of succession, they can create habitat sinks that bring in breeding birds that are then

more prone to nest predation or nest failure when the area is sprayed or cleared during the breeding season. Mortality can also result from collision with the lines. Powerlines, for example, present a risk to waterfowl when situated between feeding and roosting areas. This is especially true for lines near lakes, rivers and wetlands. Less agile birds, such as American white pelicans (*Pelecanus erythrorhynchos*), are particularly susceptible to collision with overhead lines located near waterbodies (APLIC, 2012). Mortality can result from the collision with wires or from electrocution from both wires and poles (Loss et al., 2015).

Pipelines used to transport oil and gas fragment habitats across the state and pose a risk of spills, which can lead to water-borne pollution.

## Hunting and Collecting Animals

Lead poisoning in birds resulting from the consumption of lead shot is well-documented (Tranel & Kimmel, 2009; Haig et al., 2014; Pain et al., 2019). It can result from ingesting spent lead shot or from ingesting food that contains lead shot. Among bird species documented with lead poisoning in Minnesota are bald eagles and trumpeter swans. Data from the Raptor Rehabilitation Center at the University of Minnesota document that over 150 bald eagles are admitted each year. Between 80-90% of these birds have some level of lead in their blood; 25-30% have lead toxicity and either die or are euthanized. Many more bird species are susceptible to the effects of lead poisoning by consuming lead shot, including many SGCN. A few examples include bufflehead (*Bucephala albeola*), canvasback (*Aythya valisineria*), Northern pintail (*Anas acuta*), Northern harrier (*Circus hudsonius*) and American goshawk (Kimmel & Tranel, 2007; Pain et al., 2009). Lead shot use has been banned in some areas in Minnesota, including federal Waterfowl Protection Areas, National Wildlife Refuges, state Scientific and Natural Areas (SNA) that regularly allow hunting, and in state parks and SNAs that hold special hunts. Lead shot may be used in all other areas, including most state Wildlife Management Areas (WMAs).

Although falconry is also tightly regulated by Minnesota rules and federal regulations, concerns remain regarding the illegal take of young raptors from nests.

## Timber Harvest

Forest management at the landscape scale includes timber harvest as a tool for maintaining a diversity of forest composition, age classes, and patch sizes. At a site-level, timber harvest can change species composition, seral stage, and habitat structure. Forest-dependent birds, including woodpeckers, owls and hawks, grouse, and warblers, can be affected positively or negatively depending on the specifics of the timber harvest. Some species would not be present in Minnesota's dense northern forests without the presence of large disturbances such as fire, timber harvest and windstorms. Changes that increase the amount of young forest (approximately 20 years old) benefit some species including song sparrows, indigo buntings, American goldfinches, chestnut-sided warblers, and veerys. Rarely are these Species of Greatest Conservation Need, although golden-winged warblers (*Vermivora chrysoptera*) may be found in young aspen stands. Changes that decrease the amount of older forests (i.e., stands that have more complexity in their structural layers and more diversity in the forest canopy) negatively affect forest birds dependent on these forest components, including such SGCN as the American goshawk, boreal chickadee (*Poecile hudsonicus*), Swainson's thrush, and black-throated blue warbler.

Numerous studies document the relationship between forest cover and bird distribution and abundance in Minnesota forests. The most comprehensive studies have been conducted by the University of Minnesota's Natural Resources Research Institute's Avian Ecology

Lab (e.g. Niemi et al., 2016). Most logging occurs during the winter months to reduce the potential for impacts on roads and trails. Winter harvesting, however, can affect resident species that often begin nesting in late winter, such as the American goshawk and great gray owl. When spring and summer timber harvests occur, they can destroy nests, kill nestlings, and cause birds to abandon their territories. Regardless of the time of year harvesting occurs, rare species need to be considered when silvicultural practices are implemented at either the site or landscape level.

*Photo: Black-throated blue warbler, Bob Dunlap*

## Fishing

Waterbirds and fish-eating raptors can all be affected by lead fishing tackle, and by fishing lines left behind by anglers. The effects of lead sinkers and jigs have been most extensively studied in loons and swans but also documented in multiple waterfowl species, colonial waterbirds, bald eagles and osprey. In addition to common loons, other SGCN species that have been documented ingesting lead sinkers include the American black duck (*Anas rubripes*) and black-crowned night-heron (*Nycticorax nycticorax*) (Rattner et al., 2008; Grade et al., 2018; Slabe et al., 2019).

Fish consumption by some waterbirds is often perceived by the angling public to be a threat to local fish populations. Although double-crested cormorants (*Nannopterum auritum*) are the most commonly perceived threat, one SGCN, the American white pelican, is also frequently implicated. Field studies, however, have shown that pelicans forage primarily on fish that have little economic value.

## Recreation

The effect of recreational activities depends on factors such as their proximity, duration, intensity, frequency, visual screening, and time of the year as well as individual species sensitivity and habituation. Nature-based recreational activities, such as cycling, hiking, and boating, can negatively affect birds by affecting reproductive success, causing behavioral changes, or decreases in populations (Steven et al., 2011). Wave actions from recreational boats, for example, can disrupt nesting areas for overwater and shoreline nesting species while high levels of boating traffic also can disrupt waterbird and shorebird nesting activity. Recreational vehicles can cause nest abandonment, nest desertion, and reduced nest survival (Barton & Holmes, 2006; Spaul & Heath, 2016). Human activity near or within colonial waterbird nesting sites may result in colony abandonment or reduced nesting success, especially when events occur early in the nesting season (Vennesland, 2010).

## Fire Management

Many forest birds utilize large open habitats created by recent fires; some would not be present in Minnesota's dense northern forests without the presence of fire or other large disturbances (such as timber harvest and windstorms). A field study of the response of forest birds to the Little Sioux fire on the Superior National Forest reported a variety of species attracted to the 15,000 acre burn including the killdeer (*Charadrius vociferus*), Northern flicker (*Colaptes auratus*),

Eastern bluebird (*Sialia sialis*), and indigo bunting (*Passerina cyanea*) and three SGCN including the black-backed woodpecker (*Picoides arcticus*), red-headed woodpecker and American kestrel (*Falco sparverius*), the latter two being more common in agricultural regions farther south in Minnesota (Niemi, 1978).

Disturbance (fire or grazing) is critical to maintaining suitable habitat for many grassland birds; without disturbance grasslands become shrublands and forests. Although grassland bird species each require vegetative cover that may differ in composition, density, and height at different times of year, they each depend on some level of active management, from greater prairie-chickens (*Tympanuchus cupido*) and upland sandpipers (*Bartramia longicauda*) to western meadowlarks and grasshopper sparrows (Wilsey et al., 2019).

## Dams and Water Management

Wetland/marsh birds, shorebirds, and waterbirds are all affected by changes in water management regimes. Dams, for example, may permanently flood seasonal wetlands that provide nesting, feeding and resting areas, eliminate the periodicity of floods and droughts that may provide critical signals to birds, and destroy the connectivity of associated wetland habitats in a large wetland complex (Abreu et al., 2020). Stream channelization projects can affect avian habitats by increasing downstream sedimentation and bank erosion and decreasing in-stream riffles and pools and stream-side vegetation. For example, habitat improvement projects that stabilize eroding stream banks, may eliminate microhabitat features that are critical to Louisiana waterthrushes (*Parkesia motacilla*) in southeastern Minnesota (Stucker & Cuthbert, 2000).

The installation of underground tiles and the construction of ditches to remove water from poorly drained soils provide many benefits to agricultural production but also cause significant environment effects. With approximately 19,150 miles of drainage ditches and an extensive, untallied system of subsurface tiles (Minnesota Board of Soil and Water Resources), the hydrology, water quality, and abundance of wetland habitats across much of Minnesota's original prairie landscape have been negatively affected (University of Minnesota Extension). Removing water from poorly drained soils not only results in the loss of wetland habitats, including wet meadows, that provide habitat for LeConte's sparrows (*Ammospiza leconteii*), yellow rails (*Coturnicops noveboracensis*), and sedge wrens, but can also cause higher flows into streams after high rainfall events. For example, decades ago, extensive tiling in southwest Minnesota caused untimely surges in water levels during the nesting season, ultimately leading to the demise of many waterbird nesting colonies and waterfowl nesting populations. Fortunately, many best management practices and water management options now are available to help mitigate many of these effects.

## Invasive Species (Problematic Non-native Species)

Grassland species are negatively affected by the spread of non-native plant species in their habitat, including common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*Frangula alnus*), and invasive honeysuckle species (*Lonicera spp.*). Although many studies investigating the effects of common non-native shrubs such as buckthorn (*Rhamnus cathartica* and *Frangula alnus*), and non-native honeysuckles (e.g. *Loricera tatarica*) have been equivocal, others have pointed to "altered nest site availability, habitat heterogeneity, and food supplies" (Nelson et al., 2017) and increased predation (Schmidt & Whelan, 1999). The increasing prevalence of garlic mustard (*Alliaria petiolata*) in riparian and floodplain forests decreases the diversity of native flora, instead creating a dense carpet of herbaceous vegetation and potentially affecting riparian species like the Louisiana waterthrush (Stucker pers. comm.).

Thick stands of purple loosestrife (*Lythrum salicaria*) can similarly affect wetland SGCN such as black terns and least bitterns. Many of the most widespread species, such as smooth brome (*Bromus inermis*) and Kentucky blue grass (*Poa pratensis*), can outcompete native vegetation resulting in a decline in vegetative diversity. Although some grassland birds will use these habitats, studies have shown that "non-native vegetation cover is correlated with reduced nesting success and post-fledging survival" (Bernath-Plaisted et al., 2023). One hypothesis for the observed decline is that non-native plants attract fewer insects (Narango et al., 2018).

Ground nesting forest birds are negatively affected by non-native, European earthworms used as bait for fishing (Loss & Blair, 2011). The worms' consumption of leaf litter and other organic materials reduces the amount of ground cover and plant diversity, increasing the vulnerability of ground-nesting species.

Several non-native invasive forest insects and diseases can cause defoliation and mortality. Currently the most significant threat is from the emerald ash borer (Agrilus planipennis), which has affected 6,100 acres in central Minnesota. Like many forest disturbances, some birds will benefit from the increase in dead trees (such as woodpeckers; Koenig et al., 2013) while others that depend on a healthy tree canopy may decline. Given the current distribution of emerald ash borer in Minnesota, this could affect such SGCN as the cerulean warbler and Acadian flycatcher. Neither species is entirely dependent on ash, but it is a canopy tree in many of the forests they inhabit. The fungal disease oak wilt (*Bretziella fagacearum*) is now common throughout southeastern and east-central Minnesota. Because oaks decay very slowly, the dead oaks will provide benefits to some birds for many years. Ultimately, however, the loss of oaks will result in the absence of acorns, an important food source for many birds, such as wood ducks, turkeys and blue jays and the SGCN, red-headed woodpeckers who are especially dependent on hard mast during the winter months (Frei et al., 2020).

Waterbird and marshbird nesting habitat also can be diminished by the spread of non-native vegetation. Non-native species such as common reed (*Phragmites australis* subsp. *australis*), can crowd out native vegetation and reduce accessibility and availability of open water habitat, especially for birds that utilize short wetland grasses (Benoit & Askins, 1999).

Two birds are officially classified as invasive species in Minnesota, the European starling (*Sturnus vulgaris*) and the Mute Swan (*Cygnus olor*). Starlings can cause damage to agricultural crops and aggressively compete with native birds for nesting cavities. Mute swans are also fiercely competitive with other waterbirds, including trumpeter swans, aggressive to people, and consume huge amounts of native aquatic vegetation daily (Pfannmuller et al., 2024).

## Problematic Native Species

In Minnesota, open sand and gravel beaches are a rare resource so species that share that habitat are often in competition for nest sites. Common terns, a state threatened species, compete for these sites with ring-billed gulls (*Larus delawarensis*) and ground-nesting double-crested cormorants. Because adult gulls and cormorants arrive on the breeding grounds weeks before the terns, the prime nesting sites are already occupied. Intensive management efforts are underway at most Minnesota's tern breeding colonies to deter the gulls and cormorants (Pfannmuller et al., 2024).

*Photo: Common tern colony on Interstate Island*

Three native forest insects can affect large tracts of songbird breeding habitat in northern Minnesota. The eastern larch beetle (*Dendroctonus simplex*) has caused the death of mature tamaracks in more than 1.1 million acres since 2001. Many birds that are found in conifer dominated peatlands are likely affected by this loss. The forest tent caterpillar (*Malacosoma disstria*) and spruce budworm (*Choristoneura fumiferana*) can also affect broad swaths of forest land, but their negative effects are more short-lived. Some birds positively respond to this sudden increase in insect populations. Cuckoos are best known for their voracious appetite for tent caterpillars, but the list of avian predators includes at least two SGCN, evening grosbeaks (*Coccothraustes vespertinus*) and Philadelphia vireos (*Vireo philadelphicus*), while several warblers, including the SGCN warblers, bay-breasted (*Setophaga castanea*) and Cape May (*Setophaga tigrina*), are well-known consumers of spruce budworm.

## Diseases and Pathogens

Birds are subject to a variety of diseases and pathogens that cause disease. Many birds naturally carry these diseases while showing few, if any, of the symptoms until they are stressed and lose their resilience. Many of the stressors listed above, such as problematic non-native species and habitat loss that causes overcrowding on migratory stopovers, can instigate an outbreak. Bird flu, caused by the H5N1 virus, has resulted in the death of at least 11,000 wild birds nationally since 2022 (Yates, 2025), with die-offs most pronounced in waterfowl. The virus's effect on Minnesota SGCN is unknown. It has generated widespread concern because of its effect on both high-density domestic poultry operations and backyard flocks. In just a two-month period, from December 2024 through January 2025, 41.4 million domesticated chickens were culled nationwide because of the flu.

West Nile Virus can affect many bird species but members of the Corvidae bird family are especially susceptible. Transmission was so high in the eastern United States in the early 2000s that some local populations of American crows declined nearly 70% (Reed et al., 2009); although not as severe, declines were also noted in Minnesota. West Nile Virus has been documented in 250 bird species including the SGCN American goshawk, Northern harrier and Cape May warbler (Taieb et al., 2020). The virulent Newcastle disease has been reported in several bird species, including the SGCN the American white pelican (Wisconsin DNR), but double-crested cormorants and pigeons appear to be most susceptible. Without precautions they can spread the disease to poultry farms where chickens are considered the most vulnerable. The most recent outbreak in Minnesota was in 1992 when more than 20,000 cormorants collectively died in North Dakota, South Dakota and Minnesota (DNR, 2025). Pelicans commonly co-nest with cormorants and were likely part of the loss documented in 1992. Another pathogen, avian botulism, occurs world-wide and affects many birds but predominantly waterfowl and other species common to wetland habitats. Shallow waters with low oxygen levels are most susceptible. It is not spread from bird to bird but by the consumption of aquatic invertebrates that carry the toxin or by birds that filter bottom sediments or organic materials where the toxin is embedded. Ultimately resulting in the bird's paralysis, thousands, often millions, of birds

succumb to the disease each year (Gutierrez-Arnal & Marin, 2024). Botulism outbreaks are expected to only increase in frequency and magnitude with warming temperatures (Lafrancois et al., 2011).

## Water-borne Pollution

Many water-borne pollutants that have been banned or strongly regulated for years, such as PCBs (polychlorinated biphenyls), dioxins and dibenzofurans, are persistent chemicals that have remained in the environment for decades. Their continued presence in fish-eating birds in the Great Lakes Basin was recently documented and included evidence of reduced reproductive success, physical deformities, and compromised immune function (Grasman et al., 2025). Other sources of water pollutants including "wastewater, heavy metals, chemicals, plastics, water from agricultural fields, and oil spills are considered among the most important factors responsible for mortality and population declines in freshwater birds (Shahid & Nadeem, 2021). One impactful water pollution event occurred in 2010 when the Deepwater Horizon oil rig exploded in the Gulf of Mexico, an area of coastal waters where at least one Minnesota SGCN, the common loon, winters (see Minnesota Common Loon Restoration Project Case Study in the Lakes sub-chapter). New concerns also are being raised about the effects of PFAs (perfluoroalkyls), brominated flame retardants and neonicotinoids and their persistence in aquatic environments.

## Air-borne Pollutants

Mercury's effect on fish-eating birds (waterfowl, shorebirds, loons, and wading birds) has been well-documented (Seewagen, 2010). Airborne mercury enters aquatic ecosystems primarily through atmospheric deposition, where it settles onto land and water bodies via rain, snow, or dry particles, and is carried into water bodies by rain events. Deposition of mercury on soil and foliage also affects terrestrial species. Recent studies that examined approximately 50% of the songbirds in the U.S. and Canada documented reproductive problems attributed to mercury exposure in 41% of the species (Evers & Cristol, 2020). The risks are highest among birds that consume predatory invertebrates such as spiders.

Among grassland birds, the major population declines that began in the 1960s were coincident with a period of agricultural intensification across the Great Plains, including heavy pesticide use (Stanton et al., 2018). Studies have consistently demonstrated the negative effects of aerially applied pesticides on birds, including mortality, reduced reproductive success, and disrupted migratory behavior (Bernath-Plaisted et al., 2023). Carbamates and organophosphates have been the most widely studied pesticides. As their use has decreased there is growing concern about the use of neonicotinoids (Stanton et al., 2018). Studies conducted to date point to both lethal and sublethal effects (e.g. declines in reproductive success, growth, chick survival, etc.) from ingesting seeds treated with neonicotinoids (Wood & Goulson, 2017). Reductions of arthropod food resources for grassland birds have been associated with soybean aphid insecticide applications up to 5 days after spraying (Goebel et al., 2024).

## Light and Noise Pollution

Nearly half of the United States land surface has light-polluted skies (Falchi et al., 2016). Sources of light pollution at night include interior and exterior lights on homes, buildings, billboards, parking lots, and streets as well as lighted sports fields, industrial plants, and airports (DarkSky International, 2025). Studies also point to the ecological effects created during the daytime by polarized light that reflects off surfaces such as asphalt roads, glass panes, and solar panels (Chock et al., 2020; Horvath et al., 2009). Because most of the nation's large urban areas (with multiple artificial light sources every night), are embedded in the

Temperate Deciduous Forest biome, biota occupying temperate forests are the most vulnerable to these effects (Aubrecht et al., 2010).

Effects of light pollution include disrupting the behavior of amphibians whose breeding calls are delivered at night, drawing nocturnal insects to artificial lights that increase their predation risk, and disorienting birds using environmental cues to guide nocturnal migration (DarkSky International, 2025). Bright day and dark night cycles synchronize the internal clocks of plants and animals; alterations to these cycles can affect hormone production, reproductive behavior, neural activity, and metabolic functions (Bumgarner & Nelson, 2021).

Noise pollution from aircraft, vehicles, boats, and other human causes is pervasive. Anthropogenic (human-caused) noise was detected in 36% of national parks surveyed (Buxton et al., 2019), and 12% of wilderness areas had anthropogenic noise levels 3 decibels higher than levels predicted to occur naturally (Buxton et al., 2017). Exposure to elevated noise levels can change the spatial distribution and movement patterns of wildlife, cause avoidance of feeding and nesting areas, and interrupt sleeping patterns and communications (Kok et al., 2023).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency & Minnesota Department of Commerce, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

Many bird species will be affected by habitat shifts and alterations due to warming temperatures and the accompanying effects. Warmer winters may change the diversity, distribution and abundance of birds that overwinter in the state, with fewer Canadian species moving south and more short-distance migrants remaining through the year.

Predictive models developed by the National Audubon Society (2019) forecast the most significant negative effects on Minnesota's avifauna will fall on boreal forest species (see Climate Change Profile). More than 21 of the 27 species the models predict will be extirpated in the state should the temperature rise by 1.5 degrees Celsius are restricted to Minnesota's northern forest (Pfannmuller et al., 2024). Even more species are lost should the temperatures rise even further. The breeding range of most

of these species is predicted to move farther north across Canada, providing suitable habitat is available.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Increased flooding and high winds will negatively affect ground-nesting waterfowl, waterbirds, and shorebirds by eroding nesting habitat and flooding nests. Nesting failures in canopy dwelling waterbirds (herons and egrets) could increase given the vulnerability of their highly exposed nests. Flash floods, tornados and hail can cause adult and chick mortality, blow down nests in trees and shrubs, flood ground nests or nests embedded in wetland vegetation, delay migration, and alter habitat.

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). Droughts will likely decrease insect abundance and increase the occurrence of fires, especially in northern counties. Grassland birds, wetland birds, and waterbirds may be negatively affected if habitat quality degrades and food supplies decline. Drought conditions and low water levels also are predicted to increase the spread of infectious diseases and pathogens that affect birds. For more information and resources for climate-adapted management strategies, see the Climate Section in Chapter 6: Implementation.

## Case Study: Modeling Climate Effects on Breeding Birds

In 2019 the National Audubon Society (NAS) published a report titled Survival by Degrees: 389 Bird Species on the Brink. The report documented a comprehensive effort to model changes in the distribution of 640 North American birds that could result from warming temperatures. More than 70 data sources and over 140 million bird records were used as input, along with information on vegetative cover, land use, and climate. Using the most current climate modeling methods available at the time, the researchers assessed the distributional changes to birds under three global warming scenarios based on the 2014 Intergovernmental Panel on Climate Change. They include a 1.5°C warming above preindustrial levels (which is considered imminent between 2030 and 2052 if no climate change mitigation measures are taken); a 2°C warming (which could happen as soon as 2050); and a 3°C warming scenario (which could occur by 2080). These models are predictive models, meaning that they may or may not occur.

Distribution maps for each species for each of the three warming scenarios are available and can be used to assess effects at the national, regional and state level. Pfannmuller et al. (2024) assessed the predicted results for Minnesota species. They designated a species as extirpated at a given warming scenario when the NAS models portrayed the absence of any current or newly available "thermal breeding range" for the species in Minnesota. At the lowest warming scenario (1.5oC), the models predicted the extirpation of 27 breeding birds from Minnesota. The vast majority of these species are dependent on the northern boreal forests of the Laurentian Mixed Forest Province. They include such SGCN as the spruce grouse (*Canachites canadensis*), great gray owl, olive-sided flycatcher (*Contopus cooperi*), and Cape May warbler. At the 2oC warming scenario Minnesota may lose a total of 41 breeding birds including the SGCN American goshawk, evening grosbeak, and LeConte's sparrow and a total of 66 species at the 3oC warming scenario including the SGCN lesser scaup (*Aythya affinis*), red-necked grebe (*Podiceps grisegena*), and Franklin's Gull (*Leucophaeus pipixcan*).

*Photo: Great gray owl, Bob Dunlap*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan, to conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions, three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with "NA" in the stressor column.

## Potential Conservation Actions for Birds

### Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

| Stressor | Action |
|---|---|
| | Increase monitoring of grassland birds on both public and private lands to improve our understanding of statewide population levels. Conduct response/effectiveness monitoring to assess their response to different grassland management regimes, including prescribed burning, grazing, and prairie restoration efforts. Rigorous effectiveness monitoring is necessary to develop improved evidence-based management recommendations and avoidance measures for SGCN (Binley et al., 2025) as part of adaptive management. This information can then be used to help devise and guide new options for incentivizing bird-friendly management. |
| | Monitor population trends of rare forest species, including the effect of forest management activities on forest birds. Quantify spatial use needs and territory size requirements of birds to help guide management decisions. |
| NA | Promote participatory science opportunities such as the Minnesota Loon Monitoring Program, and eBird. See Chapter 4: Public Engagement and the DNR's Wildlife Diversity and Community Science webpage for more bird-related opportunities. |
| NA | Actively support and promote continued funding for long-term bird monitoring programs, including the Minnesota National Forest Breeding Bird Monitoring Program, the Hawk Ridge Bird Observatory, Minnesota Breeding Bird Atlas, North American Breeding Bird Survey, and monitoring surveys conducted by the DNR to track the status of colonial waterbirds, waterfowl, and upland game birds. |

## Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.

| Stressor | Action |
|---|---|
| | To reduce window collisions, apply decals to windows or use UV paint visible to birds. Require or incentivize collision mitigation for new construction builds. Increase public outreach/ education on collision prevention. The American Bird Conservancy and Audubon's Bird Friendly Buildings initiative provide more details. |
| | Protect and restore shoreline habitat. Advocate for stricter community planning and zoning. Increase public outreach about the value of natural shorelines and provide guidance for shoreline owners. Provide guidance regarding artificial nesting platforms, such as for loons. |
| | Encourage agricultural producers to enroll in conservation programs that incentivize integrating bird conservation efforts into their working farms or ranches such as by restoring and managing grasslands, improving water quality, reducing erosion and sedimentation, and conserving ground and surface water. Promote conservation grazing and prairie restorations on both public and private lands with incentives to accommodate Best Management Practices proven to benefit native birds, especially SGCN. Add buffers around agricultural fields. Encourage cover crop and no-till farming practices. Support private lands biologists to assist landowners in enrolling in Farm Bill and other similar programs and learning about conservation easements. Encourage livestock producers to explore other creative options such as Audubon's Conservation Ranching Program, a collaborative effort between the National Audubon Society and ranchers to protect and restore grassland habitats for declining bird populations. This program focuses on sustainable ranching practices, particularly rotational grazing, and provides a market connection for "bird-friendly" beef and bison. Additional opportunities to link agricultural production with bird conservation can be found at the Natural Resources Conservation Service and the Board of Soil and Water Resources. |
| | Integrate habitat requirements into permits for mining and quarrying. Work with appropriate government agencies to restrict mining and quarrying in areas of known and historical leks (grouse/prairie chickens). |
| | Consider requiring native vegetation in energy development areas and prohibiting renewable energy development in remnant prairie areas. Influence wind farm siting to avoid flyways. Advocate for policies to improve reporting of mortality and implementation of mitigation strategies required under state and federal laws. Seek collaborative opportunities to work with wind energy companies to publicly acquire habitat adjacent to wind towers for conservation. |
| | Minimize new roads and trails and damaging recreational activities in important habitats, including Important Bird Areas delineated by Audubon Minnesota. |
| | Co-locate utilities when possible to reduce negative environmental effects and consider wildlife in siting plans. Mow utility areas outside the breeding and nesting season. Avoid routing lines near or across lakes where feasible. Provide technical guidance to utility companies related to reducing avian collisions with powerlines (such as by marking lines). Support research related to reducing avian collisions with powerlines |

| Stressor | Action |
|---|---|
| | Encourage collaboration among all stakeholders and across ownerships to promote effective management for the health and resilience of forests and their ability to provide ecological, wildlife habitat, and other values. Aim to provide diversity across the landscape and over time. Explore opportunities to emphasize connectivity and corridor creation. Encourage use of best management practices such as winter harvest; the maintenance of snags, downed logs, and leave trees; and protecting sensitive areas to incorporate species-specific bird habitat requirements, including forest structural and age-class diversity. |
| | When conflicts arise regarding the effects of fishing-eating birds on local fish populations, apply science-based decision making to conflict resolution processes. Ensure mitigation strategies sustain regional populations and avoid effects on non-target species. Monitor effects of any management actions. Provide educational opportunities related to "nuisance" species. |
| | For shorebird and colonial waterbird SGCN, consider restricting recreational access to significant locations during breeding season and peak migration. Seasonal beach restrictions protect nesting and foraging areas of sensitive birds such as piping plovers and common terns (Hillman et al., 2015). Wildlife sanctuary signage placed around breeding habitat reduces recreational disturbance to these sites. Local support from landowners, conservation partners and enforcement officers is important in supporting these closures. |
| | Consider establishing and enforcing no wake zones around key nesting areas, especially for colonial nesting waterbirds, and conduct public outreach to promote wildlife-friendly boating behavior. |
| | Integrate seasonal timing of water management, especially wetland drawdowns, relative to the bird nesting season. Provide sufficient water levels, especially in non-forested wetlands that support bird SGCN, from spring through July. Encourage the application of best management practices for installing new or upgrading old drainage systems (Board of Soil and Water Resources and the Natural Resources Conservation Service). |
| | Support Lights Out programs. Advocate for mandates and bylaws to change city lighting (downward facing and off after a certain time). Promote artificial light guidance from the International Dark Sky Association and implement their best practices for wildlife-friendly outdoor lighting. |
| | Leave some dense vegetation structure in conifer forests to provide thermal refuges for spruce grouse. |
| | Increase buffers around wetlands and increase the size of wetlands to mitigate wind and water level rise. Provide more upland nesting habitat on higher ground. Protect lake shoreline habitat. Create artificial nesting habitat. Stop island erosion and flooding. |
| | Continue and support efforts to provide suitable nesting habitats for common terns with actions that reduce the access of other waterbirds, such as ring-billed gulls and double-crested cormorants, that compete for the limited nesting habitat that is available. |
| | Increase the use of prescribed fire. Proactively apply prescribed fire and grazing in ways that sustain native ecosystems and support SGCN birds while also avoiding or minimizing negative effects on them through factors such as timing, intensity, acreage, and leaving unburned areas for escape cover. When developing grazing and burn plans, consider the requirements of SGCN. Aim to provide diversity across the landscape and over time (see also Prairies and Other Grasslands sub-chapter). |
| | Support and promote efforts to control problematic non-native species, placing a special emphasis on restoration of native vegetation in grasslands and wetlands. |

## Strategy 3. Develop and disseminate informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.

| Stressor | Action |
|---|---|
| | Provide land managers (including private landowners) with information on bird-friendly landscape design, yard certification, and forest management. Audubon's "How to Make Your Yard Bird-Friendly", National Wildlife Federation's "Create a Bird-Friendly Habitat", and the "Forestry for Minnesota Birds" guide offer suggestions. Support programs providing financial incentives for woodland owners to create bird-friendly habitat, such as the Sustainable Forest Incentive Act which provides payments to landowners to keep woodlands undeveloped. |
| | Share information with land managers, including private landowners, about habitat needs of rare forest species. |
| | Promote the use of non-lead fishing tackle options to anglers and increase public outreach on negative effects on wildlife. Encourage anglers to recycle lead tackle at hazardous waste facilities and/or encourage local communities to hold tackle collections days. The Minnesota Pollution Control Agency has additional information and suggestions. |
| | Promote non-toxic ammunition options to reduce exposure of wildlife and humans to lead. For example, the Non-Toxic Working Group of the Minnesota Chapter of the Wildlife Society, along with partners, distributes information and holds hands-on demonstration events to inform and encourage the use of copper ammunition for hunting. |
| | Initiate an information campaign to raise awareness of the effects of seed coatings on the health and sustainability of grassland birds. |
| | Support Lights Out programs. Advocate to change city lighting practices (downward facing and off after a certain time). Promote artificial light guidance from the International Dark Sky Association and implement their best practices for wildlife-friendly outdoor lighting. |
| | Support and promote efforts to control problematic non-native species, placing a special emphasis on restoration of native vegetation in grasslands and wetlands. |
| | Promote programs such as Audubon's Bird City Minnesota which helps birds by restoring, protecting and improving bird habitat; reducing threats such as window collisions and toxins; and engaging people in learning about and helping birds thrive. |

## Case Study: Linking Grassland Birds to Profitable Livestock Production

*Photo: Bobolink, Bob Dunlap*

A monitoring team was launched by the Land Stewardship Project and the Minnesota Institute for Sustainable Agriculture in the 1990s to create a set of sustainability indicators to link healthy grassland habitat to profitable livestock production. At the core of the team were six farm families in southeastern Minnesota who used rotational grazing for dairy and beef production and wanted to learn more about its effect on the land and its wild inhabitants. Farmers worked with University of Minnesota environmental scientists, an economist, a sociologist, and experts from the Minnesota DNR and the U.S. Fish and Wildlife Service, to develop indicators that could be easily implemented while carrying out livestock management. The farmers learned the basics of monitoring soil health, water quality, forage viability, birds, and frog and toad populations.

By far the most popular, and effective, indicator for the farmers was the presence of grassland birds. It became a user-friendly method for the farmers to link the productivity of their pastures, and their animals, with the presence of species that rely on healthy, heterogeneous, grassland habitat. Because it can be worked into chores like moving cattle and fixing fences, birding is a handy way to gauge some of the key effects a farmer is having on the land. Indeed, by the third year of the monitoring initiative, bird sightings were among the first items farmers mentioned during their monthly reports. When they got together, they were not bragging about their corn yields, milk production, or improvements in soil structure. Instead, they were quick to share the number of successful bluebird or bobolink nesting they had observed. As they became more aware of the birds on their farms, the farmers took the next step: they started wondering what effects their livelihoods were having on the life cycles of their feathered neighbors. They began discussing with wildlife biologists concerns they had about nesting disruptions caused by haying, pasture clipping, and even grazing.

Although several farmers observed that cattle were sometimes able to graze a paddock with an active nest without destroying the eggs or nestlings, it became clear that the hay fields and managed pastures could become avian "population sinks," rather than "population sources." As a result, several farmers reduced or delayed pasture clipping to allow fledglings to become more mobile before the mower disrupted the nests. Dairy producer Art Thicke also eliminated clipping on some of his paddocks one year and found, "You couldn't tell where you clipped and where you didn't." In other words, despite the lack of clipping, the cows still found the grass palatable.

A management technique that improved nesting success was the establishment of rest areas within their grazing paddocks. One year, each farm held one paddock out of grazing from the beginning of the season until at least the end of July. The densely vegetated rest areas provided a place for birds to nest undisturbed by cattle or machines. They also allowed birds disturbed in adjoining paddocks to retreat to the lush cover and re-nest. Farmers noticed greater concentrations of bobolinks and dickcissels in the rest areas during the first year of the experiment. As an added bonus, the rested paddocks gave the vegetation an opportunity to mature so it could re-seed directly or through the livestock's digestive systems. Allowing the longer growing period also increased the plant's root structure, thus improving soil structure, which is important when a farm is exposed to extreme drought or precipitation events.

These management practices both benefit the farm financially, as well as improve the environment. In short, more bobolinks can equal more beef. If the farmers had been told right out of the gate that their farming methods were threatening grassland bird species, defenses would have gone up, reducing opportunities to implement even minor management changes. But monitoring took them through a process starting with newfound knowledge and ending with appreciation and action that improved grassland bird habitat without negatively affecting their profits (DeVore, 2003).

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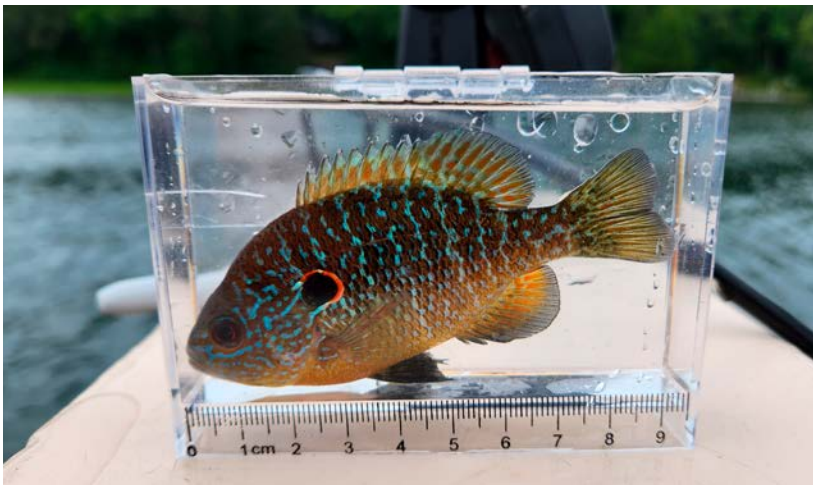
# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# FISHES



DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Brook trout in spawning season colors; Northern sunfish, Tony Long; Least darter, Tony Long; DNR fisheries specialist Hannah Anema with paddlefish caught during monitoring

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# Fishes

## Overview

Minnesota is well known for its excellent aquatic habitats and fisheries. Considered a top destination for fishing, the state provides quality fishing opportunities on 4,500 lakes managed for fishing and 16,000 miles of fishable rivers and streams. Fishing is a major recreational activity for adults and families throughout the state with approximately 26% of the Minnesota population age 16 and older participating in the year 2022. In addition to attracting Minnesota residents to quality lakes and rivers across the state, over 500,000 nonresidents also participated (University of Chicago, 2022). Yet, of the 165 fish species that are known to occur in the state, a relatively small percentage are targets of most angling expeditions.

This chapter focuses on Minnesota fishes that are Species in Greatest Conservation Need. These rare, declining, or vulnerable species are found throughout nearly every aquatic habitat in the state. These habitats and the fishes that depend on them experience cumulative effects of multiple stressors: loss of connectivity, changes in land use, altered surficial hydrology (distribution and movement of water), invasive species, erosion and sedimentation, disease, climate change and degraded water quality (Aadland, 2015; Walsh et al., 2011). Many SGCN fish species are migratory, moving among large rivers, tributary streams and connected lakes and are affected by alterations to multiple kinds of aquatic habitats. Large river species such as lake sturgeon (*Acipenser fulvescens*), paddlefish (*Polyodon spathula*) and skipjack herring (*Alosa chrysochloris*) have historically been affected by loss of connectivity due to dams and their impoundments that prevent upstream movement. Stream dwelling SGCN such as gravel chub (*Erimystax x-punctatus*), slender madtom (*Noturus exilis*), and hornyhead chub (*Nocomis biguttatus*) are especially affected by land use and hydrologic alterations that increase sediment loads in streams and result in the burial of coarse gravel substrates that these fishes depend on for spawning habitat and the aquatic invertebrates that they feed on. Lake dwelling SGCN species such as least darter (*Etheostoma microperca*), pugnose shiner (*Miniellus anogenus*) and northern sunfish (*Lepomis peltastes*) depend on native aquatic vegetation and are adversely affected by alterations to natural shorelines, invasive plant and animal species, and increased nutrient loads.

*Photo: Northern sunfish, Tony Long*

Overall, however, the loss of connectivity, much of it historic, may be the most significant stressor to fish communities across Minnesota. Aadland (2015) evaluated the effects of barriers to connectivity on fish distributions upstream and downstream of 32 dams in the Mississippi, Minnesota, St. Croix, St. Louis, Missouri, and Red River watersheds. “On average, species richness declined by 41% for complete barriers, 37% for near-complete barriers and 20% for barriers that are/were inundated at bankfull flows. A detailed assessment of the Cottonwood River Watershed indicated that a single barrier near the mouth of the river caused a watershed-wide loss of species richness.” Fish that were most vulnerable to the loss of connectivity were species that are imperiled or intolerant of the habitat conditions created by barriers, including 9 fish SGCN (see Dams and Water Management stressor).

Many of the stressors that negatively affect fish communities influence one or more aspects of water quality such as turbidity (cloudiness), oxygen levels, sediment loads, the presence of pollutants, invasive species, or increasing water temperatures. Minnesota's list of impaired waters is a good resource regarding water quality throughout the state's rivers, streams, and lakes. As of 2024, the total number of impaired water bodies was 2,798; impaired waters were most prevalent in the southern counties.

## Summary of Fish SGCN and SNI

A total of 36 fish species have been designated Species in Greatest Conservation Need (SGCN); this represents nearly 22% of the 165 fish species that have been documented in Minnesota. One SGCN, the Topeka shiner (*Miniellus topeka*), is listed as a federally endangered species. This small minnow is restricted to small prairie streams that are within the Missouri River watershed in southwestern Minnesota. Four fish SGCN have been classified as State Endangered Species (skipjack herring, crystal darter (*Crystallaria asprella*), pallid shiner (*Hybopsis amnis*), and slender madtom (*Noturus exilis*); five have been classified as State Threatened (gravel chub, plains topminnow (*Fundulus sciadicus*), black buffalo (*Ictiobus niger*), pugnose shiner. and paddlefish); and 21 species are state listed as Special Concern.

Five species listed as SGCN in the 2015-2025 SWAP were removed for the 2025-2035 plan update. The American eel (*Anguilla rostrata*) was deemed a temporary resident and, therefore, not a conservation target. Four species were removed because their state populations are considered secure: (kiyi (Coregonus kiyi), blue sucker (*Cycleptus elongatus*), yellow bass (*Morone mississippiensis*) and pugnose minow (*Opsopoeodus emiliae*). Five fish were designated Species in Need of Information (SNI): Nipigon cicso (*Coregonus nipigon*), shortjaw cisco (*Coregonus zenithicus*), shoal chub (*Macrhybopsis hyostoma*); pygmy whitefish (*Prosopium coulterii*), and ninespine stickleback (*Pungitius pungitius*). See Appendix B for a complete list of SGCN and SNI.

## Habitat Associations

The 2025-2035 SWAP uses the Strahler Stream Order (SSO) method to classify streams and rivers (see Rivers and Streams sub-chapter of Chapter 2). Streams without any tributaries are assigned an SSO of 1; the stream order increases when tributaries combine into larger streams. Table 2.7 gives the number of fish SGCN associated with various types of habitats as either primary or secondary habitat. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Detailed tables associating each SGCN with the primary 15 habitats in the 2025-2035 SWAP can be found in Appendix D.

**Table 2.7. Numbers of Fish Species in Greatest Conservation Need associated with each aquatic habitat type.**

| Habitats | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Riverine Streams (SSO 1-4) | 13 | 4 | 17 |
| Riverine Rivers (SSO 5-6) | 7 | 15 | 22 |
| Riverine Large Rivers (SSO 7-8) | 11 | 2 | 13 |
| Riverine Large Rivers: Backwaters | 3 | 0 | 3 |
| Riverine Coldwater Specialist | 3 | 0 | 3 |
| Lakes Shallow | 0 | 6 | 6 |
| Lakes Not Shallow | 8 | 3 | 11 |
| Lakes Coldwater Specialist | 5 | 0 | 5 |

As illustrated in Table 2.7, most fish SGCNs depend on small streams as primary habitat (SSO 1-4); these species also use a variety of secondary riverine habitats. Among the large river (SSO 7-8) SGCN, five species are entirely restricted to this habitat: skipjack herring, bluntnose darter (*Etheostoma chlorosoma*), pallid shiner, black buffalo, and paddlefish. Riverine coldwater specialists include three fish SGCN: longnose sucker (*Catostomus catostomus*), slimy sculpin (*Cottus cognatus*) and brook trout (*Salvelinus fontinalis*). Eight SGCN fish select shallow lakes as their primary habitat. Five are coldwater specialists in lakes: slimy sculpin, spoonhead sculpin (*Cottus ricei*), lake chub (*Couesius plumbeus*), deepwater sculpin (*Myoxocephalus thompsonii*), and brook trout.

*Photo: Least darter, Tony Long*

## Primary Stressors for Fishes

Stressors are factors that pose direct or indirect challenges to vulnerable plant and wildlife species. Habitat loss and degradation are considered the primary threat for most SGCN, and some stressors reduce the quality of those habitats. Other stressors may operate more directly on the SGCN, such as disease and pathogens. In some cases, stressors may operate both directly and indirectly. For example, roads, trails, and railroads can directly harm SGCN through vehicular strikes, or operate indirectly through habitat fragmentation and reduce landscape connectivity. The stressor list below is adapted from an internationally recognized threats classification developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For more information, see the "Stressors" section of Chapter 1: Species in Greatest Conservation Need.

It is important to note that some factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this species group is included below, followed by a set of conservation actions addressing those stressors.

### Development

Development in and around aquatic ecosystems can degrade habitat, reduce habitat connectivity, degrade water quality, and alter the local hydrology. Elimination or degradation of natural shorelines can alter runoff or discharge patterns that increase nutrients, sediments, and pollutants in waters. Some of these changes are prevalent when natural stream banks have been channelized or stabilized with rocks or cement, or lake shores are stabilized with rocks or converted into sand beaches. Impervious surfaces, such as parking lots, streets, and rooftops decrease the amount of rainwater that can replenish local soils, leading instead to increased runoff to aquatic habitats that carries sediment, pollutants, and debris. The loss of riparian vegetation (plants along the river corridor or riverbank) can increase the amount of sunlight and water temperatures (USGS, 2012). Over time, urbanization can affect species richness and composition, decreasing the ratio of native to non-native species as some non-native species, such as common carp (*Cyprinus carpio*), are more tolerant of decreased water quality conditions (Pandit et al., 2024).

### Crop Production

Many activities associated with intensive agriculture pose threats to aquatic systems and fish communities. Changes to sediment dynamics, water quality, nutrient or chemical runoff, and drainage practices are some of the potential stressors resulting from this activity (Schottler et al., 2014). Stream channelization, wetland drainage, and the loss of surrounding floodplain and riparian cover all increase inputs of pesticides, herbicides, sediment and nutrients into adjacent water bodies. This can lead to algal blooms that deplete oxygen in the water column and negatively affect sensitive fish that require well oxygenated water to survive. Drainage from fields reduces the natural absorption of the landscape for heavy rain events and increases sheet flow. Agricultural practices such as the installation of wells or drain tiles can also change the flow of groundwater to streams and lakes and are often associated with straightening of the channel (Blann et al., 2009). These changes result in flashy hydrology (rapid increases to high levels of flow) and incised channels that cause streams to function poorly (Blann et al., 2009). Smaller headwater

streams are disproportionately affected by agricultural practices (Wohl, 2017). Fish SGCN that depend on cold, clear waters, such as brook trout and the longnose sucker, as well as the federally endangered Topeka shiner, are affected by row crop agriculture operations.

## Livestock Management

Livestock operations have the potential to affect fish communities in several ways. Pastures that are intensively grazed can lead to erosion along the banks of rivers, streams, and lakes, particularly if livestock have unlimited access to these aquatic habitats. In addition, stream bottoms can become disturbed and lose shade-providing cover through herbivory and trampling (Storch, 1979). It may only take a few weeks of overgrazing to completely destroy years of effort to restore a stream and/or riparian habitat. Inappropriate grazing can cause water temperatures to rise, sediment loads to increase, and water quality to decline. If stockyards are not managed appropriately, runoff can affect water quality in ground water and adjacent wetlands and streams. Fish SGCN that respond positively to the implementation of best management practices include the Topeka shiner and plains topminnow (*Fundulus sciadicus*).

*Photo: Topeka shiners, Andrew Herberg*

## Mining and Quarrying

If gravel or sand mining were to be permitted in rivers, it could negatively affect fish by either destroying the bottom sediments, as well as increasing turbidity. Two Minnesota fish SGCN that are especially vulnerable to such activities include the crystal darter and the Western sand darter (*Ammocrypta clara*). Both species inhabit the sandy bottoms of large rivers.

Taconite mining, a major industrial and economic activity throughout northeastern Minnesota for decades, is a potential threat to fish populations. Federal studies associated with historic taconite operations at Silver Bay, along the north shore of Lake Superior, demonstrated effects on fish populations largely caused by the discharge of tailings (over 60,000 tons per day for 25 years in the 1950s to 1980s) that increased water turbidity and established an entire new delta of tailings along the shoreline (WTIP, 2024). Although mining operators and permitting agencies have learned a great deal about how to prevent and/or mitigate these threats, concerns remain.

## Roads, Trails, and Railroads

Railroads can present an overlooked threat to aquatic organisms as derailments resulting in the release of toxic substances into lakes and rivers can cause fish kills. Although the vast majority of derailments happen in shipping yards, a relatively small number of derailments result in contaminant spills that can cause disproportionate environmental damage. In 2015, a train derailment spilled approximately 20,000 gallons of ethanol into the Mississippi River. Although no fish kills were observed, ethanol can deplete oxygen levels in the water (Pheifer, 2015). A train derailment near Superior, Wisconsin in 1992 spilled 22,000 gallons of chemicals including liquid benzene and toluene into the Nemadji River, killing thousands of fish (Rodstein, 1992).

Roads, trails, and railroads can be a source of erosion, sedimentation and pollution into lakes, especially when not properly managed during construction. Further, they can reduce connectivity with crossing structures such as culverts that are insufficiently sized or placed and prevent regular access and movement for fish. Connectivity is especially important for providing fish access to important habitats such as thermal refugium (water at appropriate temperature) and spawning habitat. Once restoration efforts have occurred in one part of a lake (e.g. along the shoreline or along an inflowing stream), recolonization of these improved habitats depends on the ability of fish to safely and easily access the restored areas. Finally, impervious surfaces, such as tarred roads, parking lots, and trails, adjacent to lakes can lead to increased turbidity and runoff, including the addition of road salts to de-ice surfaces that can increase a lake's salinity.

## Shipping Lanes

Maintaining shipping lanes and navigation channels to accommodate commercial boat traffic is essential for economic trade. The Duluth harbor on Lake Superior handles approximately 35 million tons of cargo each year (including iron ore, grain, coal, and cement; Duluth Seaway Port Authority). Farther south, the Mississippi River moves approximately 589 million tons a year, which accounts for 92% of all U.S. agricultural exports (Waterways Council, 2023). Maintaining these shipping lanes and navigation channels for ships and barges is a priority both for the industries that ship cargo and for the U.S. Army Corps of Engineers who is responsible for dredging. Nevertheless, these activities may directly or indirectly lead to connectivity loss, habitat alteration, water quality changes, and altered hydrology, which all affect fish communities. Routine dredging of river channels, as well as near ports on large lakes, to accommodate commercial boat traffic creates disturbances that prevent natural channel formation, movement, and sediment transport. Field studies in Mississippi River pools that are dredged to maintain a navigation channel for barges and small ships demonstrated numerous effects. Most important was the loss of habitat heterogeneity (variety) as large, deep pools replace shallower ripple and run stretches of river, and the loss of habitat structure as gravel, logs, and other natural debris is removed. Effects on the fish community include a decrease in species richness and abundance, the replacement of fish dependent on flowing water with fish more suited to still water, and the replacement of habitat specialists, such as darters, with invasive habitat generalists, such as common carp (Freedman et al., 2012).

Nutrient cycling also is limited in dredged channels because the river has limited access to floodplain habitats that offer an exchange of terrestrial and aquatic nutrients (Schramm et al., 2015). Channel dredging creates constant disturbance that prevents natural channel formation, movement, and sediment transport. Impounded sections of river upstream of locks and dams trap sediment and create warmer water temperatures (Poff & Zimmerman, 2010). Wakes and turbulence from barges can cause excess sedimentation (Spear et al., 2024). All these changes influence the composition of the river's fish community.

Shipping in the Great Lakes does not pose a direct threat to Lake Superior's fish but the ships themselves are a vector for the introduction of invasive species when they release their ballast water. As of April 2010, 89 non-native aquatic species had already been introduced into Lake Superior. Among the long list of non-native species are the following fish: ruffe (*Gymnocephalus cernuus*), round goby (*Apollonia melanostomus*), sea lamprey (*Petromyzon marinus*), alewife (*Alosa pseudoharengus*), and rainbow smelt (*Osmerus ordax*). Fortunately, changes to ballast water regulations have reduced the rate of invasive species introductions by an estimated 85% since 2006 (Ricciardi & MacIsaac, 2022). Many biologists consider aquatic invasive species the biggest threat to the Great Lakes (Lake Superior Binational Program, 2014; see also Non-native Invasive Species).

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest conducted in riparian forests along rivers or streams, can affect fish if proper care is not taken. For example, harvesting can increase stream discharge, inputs of fine sediments, and water temperatures while decreasing macroinvertebrate diversity and inputs of leaf litter and wood (Merten et al., 2010). This same study, which examined the response of fish to experimental riparian forest harvest in a northern hardwood forest in Minnesota, found that summer air temperatures near harvest sites have the largest effect on the fish community, illustrating the importance of the shade provided by tree and shrub canopies along riparian corridors. Partial harvesting in riparian zones, however, may not affect stream fish communities (Chizinski et al., 2010).

## Fishing

Stocking fish for angling can affect non-stocked native fish communities already present (Eby et al., 2006). Species assemblages can change which, in turn, affect trophic levels of the food web as many of the fish introduced, such as northern pike and largemouth bass, are top predators. Some of these introductions may be intentional management actions by resource agencies, some may be "unauthorized" by anglers, or accidental introductions by emptying bait buckets (Vander Zanden et al., 2004). Natural dispersal also occurs. Whether these introduced fish replace native species depends on a variety of factors (Eby et al., 2006). Even smaller, nongame fish could be affected by introductions, intentional or otherwise, as they may experience increased predation and/or increased harvest pressure for use as bait fish. Smallmouth bass are one example of an introduced fish that can outcompete or prey on native fishes (Loppnow et al., 2013). Native to the Mississippi River, they are commonly introduced to lakes and river systems beyond their natural range. Lake trout, for example, no longer show up in fisheries surveys in Little Trout Lake or Beast Lake in Voyageurs National Park, following unauthorized smallmouth bass introductions (R. Maki, pers. comm.) Stocked fish can also have effects on water quality, such as the resuspension of sediments caused by common carp, which were intentionally stocked to provide angling opportunities for food fish (Moyle, 1986). Unless otherwise authorized, the release of live bait, bait water, and fish into any Minnesota waters is illegal (Minnesota Rules 6262).

## Recreation

A global review of 94 studies designed to assess the ecological effects of water-based recreational activities on freshwater ecosystems found that boating and shoreline use consistently had negative effects, with the strongest observed on invertebrates and plants — organisms whose declines can indirectly affect fish populations (Schafft et al., 2021). In addition, recreational boats can significantly contribute to the introduction of invasive species such as Eurasian watermilfoil (*Myriophyllum spicatum*) and zebra mussels (*Dreissena polymorpha*), both of which can negatively affect fish populations. Bait bucket releases can also be a risk for spreading invasive species or fish diseases.

## Fire Management

Fire can be a stressor for fish populations in landscapes where fire is prevalent. Field studies, however, documenting the response of fish to fire are minimal (Dunham et al., 2003). The most significant stressor is the fire retardant that is aerially sprayed to suppress wildfires. Fire retardant comprised of water and ammonium phosphate that is aerially sprayed to suppress wildfires when input accidentally or incidentally into streams can result in fish kills (Buhl & Hamilton, 2000).

## Dams and Water Management

Dams cause fundamental changes to the ecology of river systems. Aadland (2015) noted that a total of "1,078 dams are fragmenting Minnesota streams" in addition to countless smaller dams and impassable culverts and other barriers to fish passage. Among the changes are interrupted sediment transport, altered nutrient dynamics, decreased fish species diversity upstream of the dam, and the propagation of fish diseases and parasites (Aadland, 2015). Although freshwater fish migrations are generally shorter than those observed for anadromous fish such as salmon, migrations may be necessary for spawning, for reaching optimal foraging areas, to respond to seasonal changes in habitat needs, or to move from drought-stricken waters or waters where water quality has declined. Aadland (2015) noted migration may be particularly important in northern latitudes, such as Minnesota, where severe winters may cause low oxygen levels, extremely cold-water conditions, and ice cover resulting in increased stress, disease, and mortality.

*Photo: DNR fisheries specialist Hannah Anema with paddlefish caught during monitoring*

Lock and dam operations block the migration and movement of many large fish species, including the SGCN skipjack herring, lake sturgeon, and paddlefish. Many smaller SGCN also face barriers to migration and reduced habitat connectivity when dams and other barriers are installed including the Western sand darter, slimy sculpin, crystal darter, gravel chub, Mississippi silvery minnow (*Hybognathus nuchalis*), and gilt darter (*Percina evides*) (Aadland, 2015). Restricted fish movement further affects native mussel populations by restricting the movement of host fish that are necessary to the reproduction of mussels for carrying and dispersing mussels' larval glochidia (microscopic early stage of life). Dams along the Mississippi River caused the near extirpation of two mussel species from Minnesota (ebonyshell (*Fusconaia ebena*) and elephant ear (*Elliptio crassidens*)). The upstream transport of goods on barges also facilitates the movement of undesirable and deleterious species like invasive zebra mussels that can attach to barges. Impounded sections of river located upstream of locks and dams are often reservoirs for invasive species, allowing them to persist where they would otherwise not occur in naturally flowing river reaches (Johnson et al., 2008). This is especially true for zebra mussels (Stoeckel et al., 2004). Commercial traffic also has been shown to increase suspended sediments and turbidity (Smarts et al., 1985, Spear et al., 2024).

As noted under the stressor Crop Production, extensive efforts to improve drainage for agricultural purposes is a major stressor on fish communities. Straightening stream channels, establishing and deepening ditches, and the installation of tiling systems, have extensively altered the hydrology of Minnesota's western and southern counties (Blann et al., 2009). Fish that depend on cold, clear waters, such as brook trout and the longnose sucker as well as the federally endangered Topeka shiner are affected by these alterations.

## Invasive Species (Problematic Non-native Species)

As noted under the Shipping Stressor, at least 89 non-native species have been introduced into Lake Superior, and an uncounted number in Minnesota's other lakes and rivers. Among fish these include the common carp, ruffe, sea lamprey, round goby, freshwater tubenose goby (*Proterorhinus semilunaris*), white perch (*Morone americana*) as well as other invertebrates and plants. Invasive aquatic plants, for example, such as Eurasian watermilfoil and curly-leaf pondweed (*Potamogeton crispus*), can grow into dense canopies of aquatic vegetation that block sunlight and reduce oxygen levels leading to fish kills. Dense beds of vegetation also provide shelter to smaller fish, reducing predation levels by larger fish and altering the balance of fish trophic levels; they also reduce the overall diversity of native plants, fish, and aquatic invertebrates (Minnesota Aquatic Invasive Species Research Center (MAISRC)). The movement of several invasive carp species (e.g. silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), black carp (*Mylopharyngodon piceus*) and bighead carp (*Hypophthalmichthys nobilis*)) up the Mississippi River is especially concerning. Silver and bighead carp are filter feeders that feed on microscopic plants and animals that many native fish depend on for food; grass carp are voracious feeders of plants that provide habitat for many young fish; black carp (not yet observed in Minnesota) eat mollusks, competing with native invertivores and further threatening native mussels (MAISRC). Upstream movement of invasive carp is related to local hydrologic conditions and passable dams (Fritts et al., 2024). Invasive carp reproduction has not been detected in Minnesota to date but has been detected further downriver (up to Pool 16) where abundance is higher (DNR, 2025). Notably, native fish conditions have been affected in the Illinois River where there is a very high abundance of silver carp (Irons et al., 2007). Recently, another invasive fish, goldfish (*Carassius auratus*), has become established in many metro area lakes and ponds. They are commonly introduced by pet owners. Their quick rate of reproduction can quickly result in thousands of goldfish disturbing sediments and competing with native fish for food and space (DNR, 2021).

## Diseases and Pathogens

Diseases and pathogens that affect fish may be naturally occurring or novel; however, the severity of a disease and its population-level effects may be responsive to water quality changes, altered hydrology, and land use changes. The Minnesota DNR provides a complete description of 12 common diseases that affect Minnesota fish. Disease, low oxygen levels, and industrial spills are believed responsible for most fish kills that occur on lakes and ponds (DNR). There is considerable concern about a deadly invasive fish virus, viral hemorrhagic septicemia (VHS) which is present in Lake Superior but has not yet been detected inland.

## Water-borne Pollution

The effects of water-borne pollutants, especially agricultural pesticides, are well-known and widely investigated (Ali et al., 2020). Polychlorinated biphenyls (PCBs), dioxins, per- and polyfluoroalkyl substances (PFAs) as well as toxins from algae can also accumulate in fish and negatively affect their health (see Minnesota Department of Health: Contaminants in Fish). Minnesota's Fish Consumption Guidance, which initially focused on mercury and PCB contamination, has now been updated to include guidance for waterbodies with high levels of PFAs. Even microplastics, which may be coated with toxic substances, are now showing up in fish in Lake Superior (Hemphill, 2021; Durenberger-Grunow, 2022). The effect of microplastics and other newly emerging contaminants on fish requires further study.

Nonpoint source pollution, including phosphorus, nitrogen, sediment, bacteria, and other contaminants generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. As runoff flows, it picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, groundwater, and estuaries (EPA NPS Webpage). These nonpoint source pollutants represent the largest combined contribution (an estimated 86%) to the state's water pollution (MPCA Water Quality Initiatives). Water quality measured by nutrients and contaminants has been shown to decline with higher agricultural or urban development in the watershed. Some key effects include excess algal growth, reduced plant diversity, and reduced diversity in fish and invertebrate communities. (DNR Water quality non-point sources). The feeding behaviors of common carp and fathead minnow (*Pimephales promelas*) may further exacerbate eutrophication, particularly in shallow lakes, by resuspending sediments and releasing nutrients (Breukelaar et al., 1994; Zimmer et al., 2006).

## Air-borne Pollution

Mercury may be the best-known contaminant in Minnesota fish populations. Its main source is industrial waste and coal-combustion for power generation. Once released, it is converted into methylmercury by microorganisms in soil and waters. Unfortunately, it can be harmful to humans but also to wildlife and fish. It is bioaccumulated in higher trophic (food web) levels; predatory fish, such as walleye, or long-lived fish, such as lake sturgeon, carry much higher concentrations. The Minnesota Department of Health's Fish Consumption Guidelines provide the angling public with information on fish mercury levels as well as other contaminants.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (MPCA & MDOC, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, see the Climate Adaptation section in Chapter 6: Implementation.

In the Western Great Lakes region, changing hydrology and air and water temperatures are observed to be some of the largest climate change impacts affecting inland fisheries (Paukert et al., 2021). In Minnesota, air temperatures are increasing, with the largest increases observed in winter and nighttime temperatures (Climate Trends). Among the

documented or expected changes to fish habitat in Minnesota lakes include: 1) increasing water temperature; 2) changing duration and/or timing of ice cover; 3) an extension of the open-water season; 4) changes in water clarity; and 5) increased algal productivity. As a result, coldwater fish populations in many Minnesota lakes will be increasingly stressed. Cisco and brook trout populations will likely be lost in lakes where water temperatures increase while warm-water species increase in abundance. Natural reproduction, recruitment and growth rates of coolwater species may be negatively affected. Unfortunately, warmer temperatures can exacerbate stressors, such as land use and invasive species, resulting in even more complex effects on fish populations. In Minnesota, increased warmer temperatures already are causing longer periods of lake stratification (layering of water of different temperatures layering) which, in turn, decrease the abundance of cisco populations (Jacobson et al., 2012; 2019).

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. In response, water quality and habitat characteristics of lakes are changing (Jacobson et al., 2019; Jane et al., 2021). Climatologists predict changes in both the timing and intensity of precipitation events which can affect connectivity, lake size and depth, and habitat diversity; it can also disrupt spawning cues (Paukert et al., 2021). In the Midwest, decreased precipitation can increase the salinity of waters while decreasing water levels. Changes in water flow can affect upstream and downstream migrations of fish and decrease water quality as water levels lower causing more turbid conditions. Formerly shallow lakes may become more turbid as nutrient runoff increases with the increase of extreme precipitation events that oscillate with drought conditions (Paukert et al., 2021). The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation section in Chapter 6: Implementation.

## Case Study: Restoration of Lake Sturgeon to the Red River of the North

Lake Sturgeon (*Acipenser fulvescens*) were extirpated from the Red River Basin in the mid-1900s. Through partnerships with the Rainy River First Nations, USFWS, White Earth Band, Red Lake Band, North Dakota Game and Fish and South Dakota Fish and Parks, the Red River Basin Lake Sturgeon Restoration Plan was implemented. The plan includes targeted stocking efforts, fish passage barrier removal efforts and population monitoring. Within the basin, 48 of 72 major fish barriers have been modified since 2002, which allows lake sturgeon and 70 other fish species and mussels to move more freely through the connected waterways. In 2022, the first natural spawning event in over 100 years occurred in the system. To learn more, see: Red River of the North sturgeon restoration.

*Photo: Lake sturgeon spawning in the Red River*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan, to conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions, three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with not applicable (NA) in the stressor column.

## Potential Conservation Actions for Fishes

### Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

| Stressor | Action |
|---|---|
| | Conduct water quality and fish community surveys in rivers, streams, and lakes. |
| | Monitor fish health and transmission pathways for diseases and pathogens. Examples requiring careful consideration and protective strategies include inter-basin water transfer and importation of bait. |
| NA | Conduct rigorous effectiveness monitoring to assess responses of SGCN to specific management activities in order to develop improved evidence-based management recommendations and avoidance measures for SGCN (Binley et al., 2025) as part of adaptive management. |

## Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.

| Stressor | Action |
|---|---|
| | Treat and slow stormwater runoff. Encourage best practices, updating, and compliance for the management of subsurface sewage treatment systems (septic systems). Look for opportunities to reduce impervious surfaces; install rain gardens. Create appropriately sized culverts to mimic natural conveyance or meet management goals. |
| | Encourage or incentivize agricultural best management practices (BMPs) across Minnesota landscapes. Examples include minimizing disturbance by grazing operations such as with cattle exclosures along streams, rivers and lakes; protecting and restoring riparian corridors (especially floodplains and unique habitats thereupon), best management practices for erosion control and nutrient reduction, and approaches to drainage that have reduced effects or provide habitat benefits. |
| | Implement Minnesota Forest Resource Council's forest management guidelines for establishing riparian management zones and filter strips. |
| | Restore stream habitat and connectivity. Examples may include floodplain restorations, including oxbow systems, and aquatic connectivity projects, such as dam removal or modifications and road crossing remediations. Other activities may include stream habitat restorations. Projects within this general activity class should consider other co-occurring aquatic SGCNs and their required habitat features. The potential for invasive species movement (e.g, invasive carp, sea lamprey) should be considered when siting and designing connectivity projects. |
| | Prevent introductions of invasive species through outreach, regulations, deterrents where appropriate, and watercraft inspection. Carefully consider effects on native species before stocking non-native species. Manage existing invasive species populations using best practices, mitigating where possible any effects on native species. Support research into better tools for prevention and management. |
| | Create and maintain vegetated buffers comprised of locally native vegetation adjacent to waterways. Avoid or reduce mowing, burning, grazing or chemical application in buffers. Support and promote programs incentivizing buffers and other best practices for streams, rivers and lakes. |
| | Protect high quality intact fish habitats and restore watersheds. For coldwater streams, enhance connectivity and riparian buffers to slow the rate of temperature change in the water as ambient temperatures rise. Protect groundwater inputs. Protect coldwater springs and seeps. |
| | In anticipation of greater frequencies of both floods and droughts, replace undersized culverts and road-crossings with those that are designed to hold up under flooding events and also optimize aquatic connectivity during low flow periods (see Case Study in Climate Section of Chapter 6: Implementation). Employ culvert design to help support safe, effective wildlife passage based on tested designs. |

## Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.

| Stressor | Action |
|---|---|
| | Develop and disseminate educational materials on the significance of aquatic connectivity to fish populations. |
| | Examine ways to reinforce to the angling public the effects on native fish populations of releasing live bait fish or other live fish into any waters of the state. |
| | Continue to support work to educate the angling and boating public about the negative effect of problematic non-native invasive aquatic species and the importance of removing all visible plants from boats before leaving a water access; draining water from the boat, livewell, motor, and bait containers; disposing of unwanted bait into the trash; and drying boats before moving them to other water bodies (see Aquatic Invasive Species). Continue boat checks at major public accesses. |
| | Increase public awareness regarding the presence and effects of viral hemorrhagic septicemia (VSH) and the importance of removing all visible plants from boats before leaving a water access; draining water from the boat, livewell, motor and bait containers; disposing of unwanted bait into the trash; and drying boats before moving them to other water bodies (Viral Hemorrhagic Septicemia Virus). Education at public accesses in Lake Superior are of primary importance. |

## Case Study: Brook Trout

Brook Trout are one of two salmonids native to Minnesota. Following European settlement, widespread land use changes degraded coldwater stream habitat, especially in southeast Minnesota and contributed to declining populations of native fishes such as Brook Trout and Slimy Sculpin (Thorn & Ebbers, 1997). Most populations of native Brook Trout were presumed extirpated. Poor land use practices also caused excessive flooding and erosion of important farmland and stimulated the implementation of many conservation practices beginning in the 1930s (Thorn et al., 1997). Expansion of conservation practices reduced flooding and erosion and improved instream habitat. Expanding conservation practices across several decades may have also increased infiltration as groundwater-fed baseflow in many streams and rivers has increased in the Midwest (Juckem et al., 2008; Ayers et al., 2019). In the hope that some native populations persisted through this time period, Hoxmeier et al. (2015) conducted the first expansive genetic survey of remaining Brook Trout populations and identified some populations that were not associated with known hatchery populations, suggesting that native "heritage" Brook Trout still persist in the region. Since about 2020, fisheries managers have been aggressively surveying and prioritizing candidate streams for restoration and reintroduction of native Brook Trout, and we now have robust populations of this SGCN in the state.

*Photo: Brook trout in spawning season colors*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# MAMMALS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Mammals

## Overview

Minnesota is home to 74 native mammal species with established breeding populations. This includes a recent immigrant to the state, the North American evening bat (*Nyticeius humeralis*). Three species were historically present but are now considered extirpated from Minnesota: free-ranging American bison (*Bos bison*); caribou (*Rangifer tarandus*); and North American least shrew (*Cryptotis parva*). Other mammalian wanderers from adjacent states make an occasional appearance in Minnesota and there are several mammal species whose distributions approach the state borders. Excluded from this list are humans, two non-native rodent species that have established populations in the wild, the brown rat (*Rattus norvegicus*) and house mouse (*Mus musculus*), and several domesticated mammals that have become feral.

Among the mammals identified as Species in Greatest Conservation Need (SGCN), most Minnesotans will recognize the large and conspicuous gray wolf (*Canis lupus*) and moose (*Alces alces*). However, they may not know much about the smaller mammals on this list, such as prairie vole (*Microtus ochrogaster*), northern bog lemming (*Mictomys borealis*), or smoky shrew (*Sorex fumeus*). Seven of the eight species of bats found in the state are included but go largely unnoticed due to their nocturnal habits. These range from the more numerous big brown bat (*Eptesicus fuscus*) that frequents buildings to more secretive species such as the silver-haired bat (*Lasionycteris noctivagans*) and tricolored bat (*Perimyotis subflavus*).

*Photo: Canada lynx, Anya Auerbach*

For thousands of years mammals in Minnesota provided food and materials for clothing, tools, and shelter to the Ojibwe and Dakota people. Tribes in Minnesota maintained important relationships with American bison, American black bear (*Ursus americanus*), wolf, wapiti (elk; *Cervus canadensis*), snowshoe hare (*Lepus americanus*), North American beaver (*Castor canadensis*), and common muskrat (*Ondatra zibethicus*) (Swanson, 1940).

The arrival and expansion of European settlers caused one of the major stressors to some Species in Greatest Conservation Need through their unregulated take and market hunting that fed rapidly growing urban populations. In addition to the decimation of bison, current SGCN that declined during this period include elk, Canada lynx (*Lynx canadensis*), gray wolf, and American badger (*Taxidea taxus*) (Swanson, 1940). Although tightly regulated hunting and trapping seasons now help to maintain sustainable populations of these species, concern regarding their status remains. Like all SGCN taxa today, the loss and degradation of habitat is a primary threat that impedes the ability these species to recover from historic losses.

With exploration and settlement of the Minnesota Territory came accounts of the region's abundant wildlife. However, by the time scholarly publications first described the mammals present in this region, they recognized that losses were already occurring due to changing conditions associated with "encroachments of civilization" (Herrick, 1892). Subsequent accounts of the mammals of Minnesota included observations of the effect of human activities, such as tree harvest, pest removal, or fur-trapping, that benefited some mammals while decimating others (Surber, 1932; Gunderson & Beer, 1953; Hazard, 1982). Change has continued to occur since the last comprehensive account of Minnesota's mammals was published in 1982. Statewide surveys, beginning in the late 1980s by the Minnesota Biological Survey, have made significant contributions to our knowledge of the distribution and abundance of many mammal species found in the state.

Long an iconic symbol of Minnesota's Northwoods, one prominent SGCN is the moose. The state's moose population has experienced a 60% population decline since 2006 in northeast Minnesota. The state population estimate in 2006 was 8,840 animals; by 2025 it had declined to 4,040. The latter number actually was an increase above the lowest population estimate in the year 2018 of 3,030 animals (DNR Aerial Moose Survey). Heat stress, increased winter ticks, and introduction of parasites carried by white-tailed deer (brainworms and liver flukes) whose ranges are increasingly overlapping are key effects from a changing climate. During summer heat, moose experience elevated body temperatures that sometimes persist until the next day and reduce their ability to forage (Carstensen et al., 2024). Effects of warming temperatures on other mammalian SGCN associated with Minnesota's boreal forests, such as the Canada lynx and snowshoe hare, have also been noted and are discussed in the following pages.

*Photo: Snowshoe hare, Julia Geschke*

## SGCN and SNI Summary Information

This chapter provides information on 31 mammals that were designated as Species in Greatest Conservation Need (SGCN). In addition, three species were designated as Species in Need of Information (SNI): prairie shrew (*Sorex haydeni*), North American evening bat (*Nycticeius humeralis*), and long-tailed weasel (*Neogale frenata*). One species on the 2015 SGCN list, the North American least shrew (*Cryptotis parvus*), was removed as it is extirpated from the state. The mountain lion (*Puma concolor*), which received a Presumed Extirpated S-rank (SH), was retained on the SGCN list as there have been sightings of vagrant individuals in recent years. Five new SGCN species were added: gray wolf, northern flying squirrel (*Glaucomys sabrinus*), snowshoe hare, rock vole (*Microtus chrotorrhinus*), and Eastern woodland jumping mouse (*Napaeozapus insignis*).

Among the newly added SGCN, snowshoe hare - *Waabooz* in Ojibwe - was Tribally-nominated due to its cultural significance to Native Americans within Minnesota, declines in parts of its range, and anticipated effects of climate change on the species through warming winters and reduced snow duration and depth. Snowshoe hare is a culturally important prey species valued for its meat and fur, particularly in winter. There are concerns over its reduced population size and range extent, as well as its future status with less extensive snow cover in shorter, milder winters under a warming climate. A special challenge for the snowshoe hare is the change in its fur color and the potential for phenological mismatch, when the timing of its color change does not match up with the presence of snow. The *Waabooz* was in the 99$^{th}$ percentile for climate vulnerability in the Aanji-bimaadiziimagak o'ow aki Climate Change Vulnerability Assessment (Great Lakes Indian Fish and Wildlife Commission [GLIFWC] Climate Change Team, 2023).

The range of the Northern flying squirrel appears to be retracting as Southern flying squirrels (*Glaucomys volans*) expand northward, possibly due to changes in climate and habitats that are bringing the two species into contact. The rock vole and Eastern woodland jumping mouse both have distributions limited to far northeastern Minnesota, where they appear to occur in small, isolated populations that could be vulnerable to local habitat alteration. Gray wolves are federally listed as threatened in Minnesota and endangered in the remaining contiguous 48 states where they are found. The Minnesota population remains vulnerable to the same threats as elsewhere in its range.

Federally listed SGCN include one species as endangered, northern long-eared bat (*Myotis septentrionalis*), and two threatened, the Canada lynx and gray wolf. In addition, at the state level, two species are state threatened, plains spotted skunk (*Spilogale interrupta*) and northern pocket gopher (*Thomomys talpoides*); 19 species are state listed as Special Concern. A complete list of both SGCN and SNI species can be found in Appendix B.

In light of recent field studies (see Case Study box) that suggest large regional population declines for both migratory and cave-using populations of bats (Boman, pers. comm.), seven of the eight bat species found in Minnesota are considered SGCN: little brown bat (*Myotis lucifugus*), Northern long-eared bat, tricolored bat, big brown bat, hoary bat (*Lasiurus cinereus*), silver-haired bat, and Eastern red bat (*Lasiurus borealis*). The evening bat, first confirmed in Minnesota in 2016, is a Species in Need of Information as few individuals have been confirmed in the state. Minnesota participates with several other states in regional conservation efforts for bat conservation, including the Lakes States Forest Management Bat Habitat Conservation Plan (ICF, 2023).

## Case Study: Declines in Minnesota's Bats

Bats are a unique group of SGCN mammals in Minnesota, occupying both terrestrial and aerial habitat as the only mammals capable of true flight. Historically, bats have been understudied across the globe compared to other mammal groups, largely due to their cryptic nature, nocturnal activity, and limited technology for studying movements of such small animals. Since the early 2000s, research has expanded exponentially across the continent in response to a deadly bat-specific disease known as White-Nose Syndrome (WNS, Frick et al., 2010). The disease is caused by a non-native fungus, Pseudogymnoascus destructans, that grows in cold and humid environments (Gargas et al., 2009), such as the conditions found in caves and mines where bats hibernate. The fungus colonizes the tissues of hibernating bats leading to frequent arousals and energy expenditure, premature loss of critical fat reserves, and mortality rates exceeding 75% two years after infections are documented (Blehert et al., 2009).

In Minnesota, the disease was first confirmed at Soudan Underground Mine in the winter of 2016. Similar to trends throughout North America, severe declines for multiple hibernating bat species were documented throughout the state within five years of confirmation of the disease in hibernacula. By winter of 2019, the population of bats overwintering in Soudan had declined by over 90% just three years after WNS was documented in the mine. This population continued to decrease until reaching a 98% decline by 2024. At the southern border of Minnesota, Mystery Cave also observed declines of 94% a few years after the disease was confirmed, following a similar timeline as the Soudan Mine farther north. All known and accessible hibernacula have documented evidence of WNS. As of 2025 Minnesota is considered the western border of the endemic zone (i.e. the zone where the fungus is consistently present which stretches east to the Atlantic coastline and south to Arkansas, Tennessee, and North Carolina (USGS).

*Photo: DNR biologist surveying hibernating bats for White-Nose Syndrome*

SGCN such as the little brown bat, Northern long-eared bat, and tricolored bat have been heavily affected by the disease. The fourth cave-hibernating species in Minnesota, the big brown bat, appears to be less susceptible to mortality from the fungus (Frank et al., 2014), and their populations have experienced lower mortality. Little brown bats make up a large portion of the bat declines in hibernacula; they were once the most common bat species in the state and across their known range throughout North America. Northern long-eared bats and tricolored bats were often encountered in Minnesota caves and mines, though in lower numbers compared to little brown bats (Nordquist and Birney, 1985). After WNS infections, these species are encountered much less often during monitoring surveys, particularly the Northern long-eared bat. Due to these declines, the Northern long-eared bat was uplisted from federally threatened to endangered in 2022 (USFWS, 2022); the tri-colored bat and little brown bat are both also being considered for federal listing in 2025.

The need to monitor bat populations through time in response to WNS has generated improved tools for bioacoustics, allowing biologists to record bat vocalizations, also known as bat calls, and to assess changing activity through time. This development has increased the ability to monitor migratory bat species that travel long distances longitudinally, are not known to aggregate in colonies, and are difficult to survey with traditional methods. As their name suggests, migratory bats do not overwinter or use caves in Minnesota, instead they move to areas with milder climates (Hayes et al., 2015). As a result, they do not enter hibernation for any prolonged period (which is when the fungus infests the host bat) and their immune

system is able to combat the WNS fungus. However, a disparate threat has emerged for these species that also causes high mortality rates with negative effects for migratory bat populations.

Migratory SGCN bat species, such as hoary bats, silver-haired bats, and Eastern red bats, are frequently found dead below wind turbines (Arnett et al., 2008). As a long-distance migrating species, hoary bats comprise the largest portion of fatalities at turbines (Kunz et al., 2007). In 2017, Frick et al. predicted that the estimated mortality in North America per megawatt (installation capacity levels in 2014) for hoary bats could threaten population viability and pose risk of extinction for this species. With the use of bioacoustics and improved monitoring protocols, evidence of summertime region-wide decline for hoary bat populations was confirmed in the Pacific Northwest (Rodhouse et al., 2019).

In Minnesota, bioacoustic monitoring was conducted from 2010-2019 by the U.S. Forest Service, Camp Ripley, and Minnesota Biological Survey (DNR). Bioacoustic monitoring uses special detection devices to record and analyze the ultrasonic calls that bats emit to navigate and locate food, enabling researchers to identify which species are present and to assess their abundance. Call abundance for WNS-affected species such as little brown bats and Northern long-eared bats declined 84% after 2015, closely following trends observed in winter hibernaculum (Figure 2.1, Herberg et al., 2020 and Melissa Boman, DNR, pers. comm.). The data collected by these partners also documented a large decline (greater than 78%) in the abundance of migratory Lasiurus, the hoary bat and Eastern red bat in Minnesota in the years following 2014 (Figure 2.1, Herberg et al., 2020). Unexpectedly, these trends were similar to cave hibernating species experiencing high mortality from WNS. Statewide, total call abundance declined by 54% from a peak in 2015. Big brown bats and silver-haired bats were combined into one category due to overlapping call parameters. This group composed the largest portion of call files (23%) and did not follow overall trends for steep declines. Due to high levels of interactions between migratory bats and wind turbines, these acoustic data suggest additional monitoring is needed to track migratory bat population trends as wind energy development expands nationwide. For all bat species in Minnesota, more information is needed on summer roosting requirements, important gathering areas, migratory pathways, and management actions that can benefit populations.

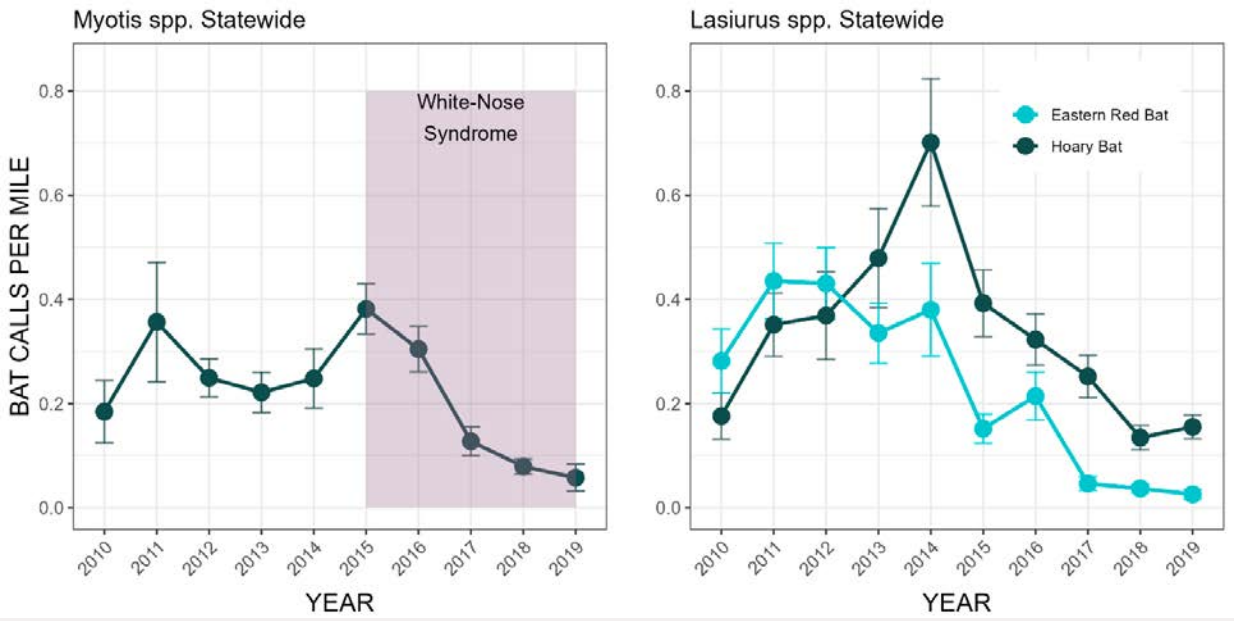



Figure 2.1 Graphs indicating population levels of bats in Minnesota for the years 2010-2019, based on bioacoustics data (bat calls). The left panel shows Myotis bats (Northern long-eared bat and little brown bat) that overwinter in Minnesota and the onset of white-nose syndrome in the state. The right panel shows data for two migrating bats for the same timeframe, also showing strong declining trends (Herberg et al., 2020 and Melissa Boman, DNR, pers. comm).

## Habitat Associations

Mammal SGCN occupy diverse habitats including grasslands, wetlands, brushlands, peatlands, forested uplands and lowlands, and transitional habitats. Some species are found in a variety of habitats due to their mobility and life history traits. Large predators, such as mountain lions (*Felis concolor*), range widely in search of prey. Bats' ability to fly considerable distances allows them to utilize multiple habitats for foraging, rearing pups, and hibernating. Other SGCN mammals are strongly associated with a narrow range of habitat conditions, including the rock vole and Northern bog lemming.

A summary of mammal SGCN associations with the 15 primary habitat types in the SWAP are listed in Table 2.8. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. The mountain lion was only assigned secondary habitat associations, with 12 habitat types, due to its ranging nature. No mammal species were officially associated with vernal pools, although vernal pools are visited by some mammals. A complete list of all primary and secondary habitats for each SGCN can be found in Appendix D.

Prairies and other grasslands are the primary habitat for a large number of SGCN mammals. The extensive loss and degradation of this habitat across western and southern Minnesota is responsible for the declining populations and vulnerability of so many species. Many of these SGCNs are small to mid-sized mammals that are limited to grassland habitats. These mammals include the white-tailed jack rabbit (*Lepus townsendii*), American badger, prairie vole, northern grasshopper mouse (*Onychomys leucogaster*), plains pocket mouse (*Perognathus flavescens*), and Richardson's ground squirrel (*Urocitellus richardsonii*).

The important ecological roles that small and mid-sized mammals play in grassland systems were summarized by Ayodele (2025) and highlighted by the DNR Prairie Wildlife webpage. They include nutrient cycling, soil disturbance, grazing, dispersal of seeds and mycorrhizal fungi, and serving as both predators and prey for other animals. SGCN mammals can be vital to populations of SGCN from other groups. For example, Richardson's ground squirrels are associated with the population health of key SGCN predators such as the burrowing owl (*Athene cunicularia*) and Swainson's hawk (*Buteo swainsoni*) (Houston & Bechard, 1984; Conway, 2018), while white-tailed jackrabbit's selective grazing activities play an important role in the distribution of grassland plants while their burrows can act as seed pits or refuges (Schlater et al., 2021). Both these SGCN species have experienced population declines. White-tailed jackrabbit populations, for example, have significantly declined over the past century, primarily from eradication efforts (e.g., hunting and poisoning) aimed at reducing crop damage in the early 1900s (Brown et al., 2018) and from the loss of the species' preferred habitats, including grasslands, pastures, hayfields, and small grains. Today, the species' population is only a fraction of what it was throughout its range compared to the previous century (Brown et al., 2020) and it is rarely seen in Minnesota (DNR ARS 2024). Despite this decline, little research on the species has been conducted (Schlater et al., 2021).

**Table 2.8. Numbers of Mammal Species in Greatest Conservation Need associated with each habitat type.**

| Habitats | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Prairie and Other Grasslands | 12 | 1 | 13 |
| Savanna | 5 | 13 | 18 |
| Upland Conifer Forest and Woodland | 12 | 7 | 19 |
| Upland Deciduous Forest and Woodland | 11 | 10 | 21 |
| Mesic Hardwood Forest | 8 | 7 | 15 |
| Deciduous Wet Forest | 7 | 6 | 13 |
| Coniferous Forest Wetland | 1 | 6 | 7 |
| Riparian and Floodplain Forest | 9 | 2 | 11 |
| Non-forested Wetlands | 4 | 2 | 6 |
| Rivers and Streams | 0 | 9 | 9 |
| Lakes | 0 | 9 | 9 |
| Cliff, Talus, and Rock Outcrops | 2 | 12 | 14 |
| Caves | 4 | 0 | 4 |
| Urban and Other Developed Lands | 2 | 14 | 16 |

*Photo: Richardson's ground squirrel, Amy Westmark*

A variety of forests provide habitat for many SGCN mammals that have more general habitat requirements. These include many large SGCN mammal species such as gray wolves, moose, and elk, which have had a long history of importance to human communities as apex predators and game species. As a result, these mammals are well studied. Primarily found in the forested regions of Minnesota, many of these species are considered boreal species, with the majority of their populations occurring to the north in Canada or to the west in montane regions. They survive, in part, because these regions have been relatively undisturbed compared to the Great Plains and Eastern Deciduous Forest Biomes.

Minnesota forests also provide primary habitat for two small mammal SGCN species: rock vole (only in upland conifer and upland deciduous forests and cliff, talus, rock habitats); woodland vole (*Microtus pinetorum* (mesic, deciduous wet, and riparian forest habitats). Several small SGCN mammals rely on peatland habitat or mature conifer habitats with rich, damp forest floors that are often covered in sphagnum and ericaceous (acidic-soil loving) plants including the northern bog lemming (*Mictomys borealis*), smoky shrew, and Eastern heather vole (*Phenacomys ungava*).

Eight species of bats occur in Minnesota, seven of which are SGCN, equally divided into two groups that use different strategies for surviving long winters without insects. Migratory bat SGCN (hoary bats, Eastern red bats, and silver-haired bats) leave the state in early fall and head towards regions with milder weather. Evening bat, the only bat species not designated a SGCN, are likely to migrate out of the state, but little is known about overwintering habits in the northern Midwest. Cave-wintering bats (little brown bats, big brown bats, tricolored bats, and Northern long-eared bats) hibernate underground for the duration of winter until warm spring weather brings reliable insect hatches. All of the species use forested habitats during the spring, summer, and fall months, many using trees for pup-rearing.

## Primary Stressors for Mammals

Stressors are factors that pose direct or indirect challenges to vulnerable plant and wildlife species. Habitat loss and degradation are generally considered the primary threat for most SGCN, and some stressors reduce the quality of those habitats. Other stressors may operate more directly on the SGCN, such as disease and pathogens. In some cases, stressors may operate both directly and indirectly. For example, roads, trails, and railroads can directly harm SGCN through vehicular strikes, or operate indirectly through habitat fragmentation and reduced landscape connectivity. The stressor list below is adapted from an internationally recognized threats classification developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For more information, see the "Stressors" section of Chapter 1: Species in Greatest Conservation Need.

It is important to note that some factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this species group is included below, followed by a set of conservation actions addressing those stressors.

### Development

Development can cause habitat loss and fragmentation and makes traversing the landscape more difficult and dangerous for mammals of all sizes (see also Roads, Trails, and Railroads). This stressor is only projected to increase in the coming years with projections of urban land use increasing by a factor of 1.8 to 5.9 between the years 2000 and 2100 (Gao & O'Neil, 2020). Hanson et al. (2024) reviewed the effects of urbanization on mammals including changes in the diversity and abundance of species and changes in daily activity patterns. In some urban areas, mammals may actually thrive while in others the effects of urbanization are neutral or negative. Several factors may be involved, including city-wide landscape factors such as housing density and overall structure. One of the most common behavioral changes is increased activity during nighttime hours to avoid humans and/or predators. Overall, there is a direct relationship

between the density/intensity of urbanization and the effects on mammal communities (Hanson et al., 2024). Maintaining natural areas near development sites is key to preserving the local mammal diversity, especially for species that cannot prosper in densely populated areas.

## Crop Production

Small grassland mammals are affected by conversion of habitat to rowcrop agriculture. In general, studies have consistently demonstrated that more intensive agricultural practices, including more intensive use of herbicides and pesticides, and more narrow specialization of crop production, reduces the availability of terrestrial invertebrates and subsequently, those higher tropic levels that depend on their abundance, especially small mammals (Balestrieri et al., 2019).

Some agricultural producers view small burrowing animals, such as Richardson's ground squirrels, Franklin's ground squirrels (*Spermophilus franklinii*), American badgers, and Northern pocket gophers as pests. The burrowing nature of these species is concerning to some agricultural producers and results in removal of these animals, including by shooting, trapping, and poisoning.

## Livestock Management

As Minnesota's wolf population has increased so have the conflicts with livestock operations. Wolves do kill and/or injure livestock such as cattle, sheep, poultry and occasionally pets. Among livestock, the wolves primarily attack young animals. The number of animals taken is low and affects less than 1% of all farms in the state, but the financial impact on individual operators can be substantial. Farmers do have the legal authority to kill wolves without a permit if they are "posing an immediate threat to livestock, a guard animal, or a domestic animal located on property owned, leased or occupied by the owner of the livestock, guard animal, or domestic animal" (M.S. 97B.645). During the past ten years the average number of complaints regarding by the USDA Wildlife Services Gray Wolf Depredation Management Program was 174 per year. In 2024 the number increased to 252. Biologists attributed the increase to the lack of snow cover, which made it more difficult for wolves to catch their primary prey, white-tailed deer (Stanley, 2025). The USDA's Wildlife Services Program works closely with livestock owners to address concerns and to implement changes that help deter and prevent wolf access to young livestock. Landowners also can be compensated for their losses; from about 2010 to 2020 an average of $135,000 per year was paid to farmers from Minnesota's Wolf Compensation Fund.

Following the reintroduction of elk to northwestern Minnesota in 1935, their populations also have increased, as have conflicts with livestock operations. Most of the damage is in the northwest counties but lone animals occasionally wander outside of the primary range and do damage elsewhere. As the USDA Wildlife Services office reports, "damage typically involves consumption of or damage to stored and stockpiled livestock forage" but can frequently include "damage to infrastructure such as livestock fences (Minnesota Department of Agriculture, 2025)". Like wolves, these conflicts are mitigated with a combination of compensation for fence and crop damage (managed by the MNDA) and abatement (managed by the DNR).

Smaller mammals, on the other hand, may respond differently to livestock grazing operations depending upon how it is managed. For example, SGCN mammals that require very short grasslands (e.g. Richardson's ground squirrel) may benefit from more intensive grazing whereas others (e.g. Franklin's ground squirrel) are associated with taller grasslands.

## Mining and Quarrying

Sand and gravel quarries and taconite mining, all significant industrial activities in Minnesota, affect mammals not only by the loss of habitat but also by the increase in noise near these operations. The effects of noise pollution on mammals have received increased attention in past years, interfering with intra and inter-specific communication and inducing stress responses (Arcangeli et al., 2022; refer to Light and Noise Pollution Stressor). One SGCN, the northern grasshopper mouse, is found on sites with coarse or gravelly soils which include both active and inactive quarry sites. Despite its affinity for this habitat, active quarrying can disturb or destroy their burrows.

## Wind and Solar Energy Infrastructure

Migratory, foliage and tree-roosting bats, including SGCN bat species such as hoary bats and eastern red bats, are frequently found dead below wind turbines (Arnett et al., 2008). Although variable in timing, most mortality occurs during late summer and fall, corresponding with migration and mating seasons. Estimates place the loss at approximately 888,000 bats per year (Smallwood, 2013). To date, lighting and noise appear to not influence the level of mortality. Although several other factors that have been investigated, including tree bats' attraction to large structures resembling trees as well as factors that influence their foraging and mating behavior (e.g. tall trees are an attractant for mating), many questions remain (Guest et al., 2022). Overall, collisions with wind turbines are considered a major, but not the only, factor contributing to the widespread decline of bat populations.

## Roads, Trails, and Railroads

Mammals are susceptible to collisions with vehicles on roadways. Some studies have reported that carnivores are less affected than omnivores and herbivores while nocturnal species, which are more difficult to see, are more seriously affected. Among SGCN, moose are at some risk for vehicle collision as they use roads and trails for their own travel and as salt licks in the winter. Predators, such as wolves, do utilize secondary roadways and trails in efforts to hunt moose and deer in northeastern Minnesota. Indeed, research in Minnesota on Canada lynx found road and train collision-related mortality (Moen et al., 2005).

In addition to direct mortality, and the effect of roads, trails, and railroads in fragmenting habitats, these travel corridors can introduce other disturbances that also affect mammals (see Recreation and Light and Noise Stressors). Finally, construction and maintenance of bridges can affect bats that use bridge spans for roosting sites.

## Utility Corridors

Corridors cleared for utility lines and pipelines may have different effects on different mammals. Species that depend on forest habitats, such as squirrels and mustelids (weasel family), usually avoid forest corridors. Conversely, the absence of woody cover in many corridors allows predators to more efficiently hunt for prey. They also are attractive to species such as white-tailed deer who, despite being more visible to predators, often forage along these utility lines. These openings allow more sunlight to reach the ground and allow fruit bearing shrubs and other lowland plants to grow, which provide food for many mammal species. However, if utility corridors are heavily treated with herbicide to reduce woody plant growth, that benefit is not realized.

At the landscape scale, habitat fragmentation is a major concern, especially for species that depend on large habitat areas or species that can utilize smaller tracts if they are interconnected. Corridors also create edge habitats which can negatively affect small

forest-dwelling mammals by increasing predation. A recent and detailed analysis of the effects of linear infrastructure on vertebrates found the effects on mammals were more nuanced than previous studies had suggested; they depend on both the biological traits of each species and the overall environmental context (de Jonge et al., 2022). Carnivorous mammals were more abundant near infrastructure while non-carnivorous species "consistently display avoidance responses."

## Hunting and Collecting Animals

The tradition of hunting large mammals such as deer, elk, and moose, is sustainably managed through the establishment of strict regulations and seasons. Small mammals, however, do not receive the same focused management attention and can be affected by deliberate trapping or shooting. For example, while Northern pocket gophers are rare, the Plains pocket gopher is very abundant and is unprotected, meaning that hunting and trapping is not limited. The collection of bounties for some animals, including gophers, ground squirrels, and woodchucks, may contribute to their decline. Most natural resource professionals, however, doubt their effectiveness in reducing populations. Although the state no longer pays bounties, counties and townships still maintain that authority (Sec. 348.13 MN Statutes). Payouts are usually based on the number of feet or tails that are collected, creating a small financial incentive. Today, Northern pocket gophers are very rare or extirpated from Minnesota. Several other SGCN such as Richardson's ground squirrels, Franklin's ground squirrels and American badgers, are still considered pests. Their burrowing nature concerns some agricultural producers, resulting in their continued persecution.

*Photo: Northern flying squirrel, Levi Moxness*

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Indeed, a recent modeling exercise that examined 41 years of forest management on native wildlife habitat in Minnesota found that over that time span "35.5% of species experienced significant improvement in habitat, 29% significant reductions, and 35.5% nonsignificant change. The extent of habitat (acreage) increased for 100% of species, but the quality declined for 63% of species (Zobel et al., 2021).

Timber harvest activities benefit at least one SGCN mammal, the moose. The young regenerating forests that follow a stand's harvest, creates young, regenerating forests that serve as foraging habitat.

Bats, however, may not all benefit from timber harvest. A modeling exercise in Indiana examined the effects of different harvest scenarios on two bats, including the Minnesota SGCN, the Northern long-eared bat. Overall, suitable habitat for the species was negatively correlated with timber harvest intensity. Illustrating the importance of planning forest management activities to simulate the range of natural disturbance regimes, the models documented the bat's preference for forest edges for nocturnal foraging while preferring mature, intact forests for daytime roosting (Pauli et al., 2015).

The snowshoe hare also is affected by forest management activities relating to their foraging and sheltering needs, particularly those that decrease structural diversity in the forest. In Superior National Forest, snowshoe hare foraging habitat generally includes upland forest 3-15 years old or over 60 years old or lowland forest greater than 10 years old (USDA Forest Service – Region 9, 2004). A study in northeastern Minnesota found higher densities of snowshoe hare in regenerating-young forest (7-30 years since harvest) and coniferous forest than in other forest types (McCann & Moen, 2011). A study by the Leech Lake Band of Ojibwe Division of Resource Management found that snowshoe hare populations were restricted to northern white cedar stands that maintained old growth characteristics. The hares could not expand much beyond these stands because much of the surrounding forest lacked horizontal structure that provides hiding cover from predators (Tanya Roerick, Leech Lake Band of Ojibwe, pers. comm.). Effects on smaller mammals, such as shrews, and voles, are less well known. Nevertheless, species that prefer the structural complexity of mature forest stands, including two non-SGCN species, the fisher and marten, benefit from timber harvest strategies that strive to retain these features (Suffice et al., 2023).

## Recreation

A recent, thorough review of the literature on the effects of recreational activities on mammals by Sganzerla and colleagues (2025) found that most studies have focused on large, charismatic mammals that rarely are of conservation concern. Only in recent years has this bias begun to be addressed. Although most of the 209 articles they reviewed analyzed the effects of recreational activities on foot (i.e. hiking and skiing), 74% of those reported at least one negative effect, including avoidance behavior, changes in habitat use, and physiological responses such as stress. Motorized vehicles, aerial disturbances and water-based disturbances were more likely to cause a significant response than hiking.

Regarding Minnesota's mammalian SGCN, recreation is not considered to be a major concern for moose (Larson, pers. com.). Field studies in Colorado focused on winter recreational activities found Canada lynx did not consistently avoid areas of low or moderate dispersed recreation but did avoid some areas with high levels of motorized recreation. When the level of recreational activity was high, lynx were more active during the nighttime hours (Miller, 2019). Finally, in a wilderness setting in Alaska, wolves were found to reduce their presence up to 6 km away from areas of high human use (Thompson et al., 2025). In Minnesota, the Voyageurs National Park Wolf Project has found that wolves are attracted to areas of human development because of the high concentration of white-tailed deer but still avoid any encounters with people while hunting (Johnson-Bice et al., 2023).

Bats can be negatively affected by recreation in caves, both by physical disturbance during hibernation and by spread of the fungus (*Pseudogymnoascus destructans*) that causes White-nose syndrome (WNS). When people

visit caves where bats roost their activities can increase the noise levels and cause local changes in air flow and temperature that wake the bats, causing them to disperse and deplete their energy reserves during a critical time. This is when cave bats are most susceptible to WNS. Even climbing activities outside of the cave, but near its opening, can disturb roosting bats inside the cave. Pounding or chiseling the rock, placement of climbing gear in rocks and crevices, and high noise levels all create disturbances that can negatively affect bats (Schorr et al., 2025).

## Fire Management

Proper fire management in grasslands is especially important for mammalian SGCN. Nearly 38% (12 species) of the SGCN depend on prairie and other grasslands as their primary habitat. Species such as the western harvest mouse (*Reithrodontomys megalotis*), plains pocket mouse, and prairie vole depend on upland prairies. When such sites become overgrown with non-native invasive plants and woody vegetation due to fire suppression they no longer provide suitable habitat. Fire helps to create a dynamic mosaic of forest ages and vegetative cover that is critical to many species such as moose. Fires create openings and young, regenerating forest stands that provide important habitat to SGCN that utilize fire-dependent upland conifer and upland deciduous forests in Minnesota. In the absence of fire, timber harvests can be planned to help create this habitat mosaic.

## Dams and Water Management

Tile drainage to convert wet grasslands and pastures to farmland is the major effect of water use management on grassland-dependent mammalian SGCN. Loss of habitat remains the primary threat to all grassland species.

## Diseases and Pathogens

Moose are severely affected by brainworm (*Parelaphostrongylus tenuis*), causing abnormally high mortality in Minnesota populations. Brainworm is carried by white-tailed deer, who have increased their range north into what previously was solely moose territory. Deer are usually not affected by the worm. In moose, on the other hand, *P. tenuis* damages the brain and spinal cord, causing weakness and disorientation. Although less pervasive than brainworm, other parasites that affect moose, occasionally causing death, include liver flukes (*Fascioloides magna*) and hydatid cysts (*Echinococcosis granulosis*) that are found in the animal's lungs or liver (Carstensen et al., 2017a). Moose can also be affected by chronic wasting disease (CWD), which could be a growing risk if expanding elk and deer populations bring it into moose range.

Gray wolves can be affected by several diseases and parasites. These include parvovirus, canine distemper, canine adenovirus, and mange, which may reduce pup survival and limit population growth (Carstensen et al., 2017b).

Bat populations of multiple species have been decimated by White-nose syndrome, caused by a fungus (*Pseudogymnoascus destructans*) that wakes bats up from hibernation and reduces their energy stores so they eventually die from starvation or dehydration. In Minnesota, the disease was confirmed at Soudan Underground Mine in the winter of 2016. Species such as the little brown bat, northern long-eared bat, and tricolored bat have been heavily affected statewide with population declines greater than 90% (Bowman, pers. comm; see Case Study: Bat Declines).

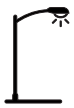
## Water-borne Pollution

Aerial applications of herbicides and pesticides that end up in local wetlands, streams, and rivers can potentially affect mammal SGCN, especially in agricultural regions where their use may be intensive. There

also is growing concern about the effects of microplastics on wildlife. Although most studies have focused on aquatic species, microplastics have been found in some terrestrial mammals including voles and foxes (Jeong et al., 2024).

## Air-borne Pollution

The effects of aerially applied herbicides and pesticides are of greater concern to mammals, especially on grassland species. A study in Europe examined the presence of 140 currently used pesticides and banned or restricted pesticides (i.e. legacy pesticides) in the hair of small mammals and found 112 of the compounds in the hair samples with a total of 32 to 65 chemicals found per individual specimen. The detection and quantity of chemicals found in the specimens directly correlated with the amount of pesticide sold. Little is known about the relative contribution of different pathways of exposure (e.g. direct contact, consumption of treated seeds, or ingestion of soil invertebrates). Some of these chemicals have also been reported in the body tissues of bats. As the authors note, the ubiquity of exposure raises concern not only about acute exposure but about chronic exposure as well (Fritsch et al., 2022). Although this study did not assess the pesticides' effects on small mammals, they are widely recognized as causing neurological symptoms such as tremors and convulsions; gastrointestinal symptoms such as vomiting; and death.



## Light and Noise Pollution

Nearly half of the United States land surface has light-polluted skies (Falchi et al., 2016). Sources of light pollution at night include interior and exterior lights on homes, buildings, billboards, parking lots, and streets as well as lighted sports fields, industrial plants, and airports (DarkSky International, 2025). Studies also point to the ecological effects created during the daytime by polarized light that reflects off surfaces such as asphalt roads, glass panes, and solar panels (Chock et al., 2020; Horvath et al., 2009).

Several studies have documented the effects of anthropogenic (human caused) light on mammals, the majority of which are nocturnal. Bats, for example, can delay their nighttime emergence from daytime roosts and caves, sometimes even abandoning the site (Jagerbrand & Spoelstra, 2023). Individual species, however, may response differently to lighting conditions. Foraging activity by big brown bats and little brown bats was reduced by nighttime lights while biologists found that eastern red bats and hoary bats responded neither positively nor negatively (Seewagen et al., 2023). Many other mammals decrease their activity in the presence of light and/or change the spaces in which they move (Jagerbrand & Spoelstra, 2023). In addition to these observed effects, biologists know that bright day and dark night cycles synchronize the internal clocks of animals. Alterations to these cycles have been shown to affect hormone production, reproductive behavior, neural activity, and metabolic functions (Bumgarner & Nelson, 2021).

Noise pollution from aircraft, vehicles, boats, and other human causes is pervasive. Anthropogenic noise was detected in 36% of national parks surveyed (Buxton et al., 2019), and 12% of wilderness areas had anthropogenic noise levels 3 decibels higher than levels predicted to occur naturally (Buxton et al., 2017). Exposure to increasing noise levels can change the spatial distribution and movement patterns of wildlife, cause avoidance of feeding and nesting areas, and interrupt sleeping patterns and communications (Kok et al., 2023).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months.

Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al. 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Increasing temperatures and prolonged 'hot' temperature events negatively affect moose (*Alces alces*) health in particular. As temperatures rise, moose experience elevated internal body temperatures and these "hot" moose are more likely to die than moose with fewer "hot" episodes (Carstensen et al., 2024). Shorter winters with less snow cover may also affect Canada lynx (*Lynx canadensis*) and snowshoe hare (*Lepus americanus*). University Minnesota-Duluth mammal researcher, Ron Moen also predicts steep declines and even potentially extirpation from Minnesota over the coming 50 - 100 years for four species of shrews and moles, nine species of rodents, the snowshoe hare, moose and three carnivores dependent on the north woods (NRRI, 2018). Small mammals such as mice and voles are prey for predators of all sizes and require subnivean zones (under the snow) to survive, helping to create a balance between population sizes of prey species and predator species. Milder winters with limited snow cover and earlier snow melt due to higher-than-normal temperatures create more hospitable environments for some parasites like winter tick (*Dermacentor albipictus*), which can lead to increased tick loads on moose and potentially to moose mortality. Milder winters also can promote the northward range expansion for other parasites and their hosts, as well as insect populations that may adversely affect moose health.

Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, see the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation

is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies see the Climate Adaptation section in Chapter 6: Implementation.

In the north woods, the lack of winter precipitation (i.e., snow) or an early snow melt creates a better environment for parasites such as winter tick, which can cause moose mortality. Drier conditions could potentially create a less hospitable environment for other parasites and their vectors, such as brainworm (*Parelaphostrongylus tenuis*) and gastropod hosts.

*Photo: Moose, Colin Canterbury, USFWS*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan, to conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions, three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnerships with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management practices.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with not applicable (NA) in the stressor column.

## Potential Conservation Actions for Mammals

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

| Stressor | Action |
|---|---|
| | Conduct more studies to better understand the conditions that attract bats to wind turbine sites. |
| | Conduct more research on bat locations and response to timber harvest. Quantify spatial use needs and territory size requirements. |
| | Investigate options to reduce the effects of aerially applied pesticides and herbicides on grassland dependent small mammal SGCN. |
| | Continue important research and collaborative studies to investigate the effects of a changing climate on mammalian SGCN and to develop potential mitigation strategies, such as the Nature Conservancy's establishment of conifer strongholds that could benefit conifer-dependent SGCN, including moose. |
| | Determine moose habitat use/response prior to, during, and after landscape-level habitat management activities. Assess juxtaposition and patch size of key habitat types to ensure adequate forage and thermal cover (winter and summer) are available to inform forest management and promote moose population growth. |

| Stressor | Action |
|---|---|
| NA | Investigate the causes of declines in mammal SGCN, investigating threats, habitat characteristics and effectiveness of conservation measures. Conduct rigorous effectiveness monitoring (Ayodele, 2025) to assess responses of SGCN to specific management activities in priority habitat types to enable the development of improved, evidence-based management recommendations and avoidance measures for SGCN (Binley et al., 2025) as part of adaptive management. |
| NA | Support and develop opportunities for community scientists to engage in bat monitoring. Examples would be acoustic monitoring such as the North American Bat Monitoring Program, and bat box monitoring. |
| NA | Increase the number of bat caves that are monitored each winter to help ensure their protection and the sustainability of the wintering bats they provide habitat for each year. |
| NA | Improve moose population surveys by exploring improved/new methods and tools (e.g., thermal plane) and by applying advanced analytical methods. Monitor calving and calf survival with new tools (e.g., thermal plane) to improve population estimates. |
| NA | Assess fecundity (fertility) and recruitment of young moose to improve population modeling and info management activities and conduct research to understand predator-prey interactions among moose, deer, wolves, bear, etc. |

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

| Stressor | Action |
|---|---|
| | Install bat boxes using recommended guidelines to provide suitable roosting habitat for bats in urban or rural areas, particularly when bat colonies are excluded from building roosts (Boman, 2023; Boman et al., 2024). |
| | Retain wild areas for mammal SGCN that cannot thrive in developed areas. |
| | Promote and support restoration of prairie and grassland acres through innovative financial incentives, technical assistance, and engagement. |
| | Encourage non-lethal techniques for livestock owners to manage wolves. The DNR Wolf Plan includes a wolf livestock depredation toolbox which includes non-lethal techniques aimed at minimizing wolf depredation. |
| | Build better captive elk farm fences to keep wild elk from breaking in to help prevent the spread of diseases such as chronic wasting disease and bovine tuberculosis. |
| | Reduce overgrazing and implement conservation grazing methods that benefit the farmer and wildlife simultaneously. These include: flash grazing, where livestock graze intensively on small areas for a short period of time, patch burn grazing, the use of prescribed fire to attract cattle to highly palatable vegetation or other methods of adaptive grazing management that are suited to each farmer's conditions and that have been evaluated for their effectiveness. |

| Stressor | Action |
|---|---|
| | At active quarry sites that support populations of the northern grasshopper mouse, inform operators of the species' presence and work to find solutions that allow mining operations and species protection to continue simultaneously. Explore ways to restore expended mine pits to promote recolonization of affected SGCN. |
| | Encourage best management practices that reduce mortality such as reducing blade rotation when wind speeds are low and bats are more active (e.g. late summer and fall) and delaying turbine activation when bat activity is high (Mathewson, 2023). |
| | Promote wildlife safe road crossing programs. Advocate for safe crossings when providing technical guidance on roadway projects. |
| | Minimize new roads and trails and damaging recreational activities in important habitats for mammal SGCN. |
| | Co-locate utilities when possible to reduce environmental effects and consider wildlife in siting plans. Avoid routing lines near or across lakes where feasible or along known mammalian travel corridors. |
| | Consider implementing habitat enhancements for snowshoe hare. This could include increasing structural diversity in the forest by creating slash piles during or after timber harvest, dropping trees to leave as coarse woody debris, planting conifers to increase trees with low hanging branches that offer cover, protecting areas that have structural diversity and provide snowshoe hare habitat, and maintaining advanced regenerating forest on the landscape. |
| | Implement best management practices for bats such as winter harvest, protecting hibernacula entrances and maternity roost trees, and retaining older trees and standing snags for habitat including potential future roost trees; see Lakes States Forest Management Bat Habitat Conservation Plan (ICF, 2023). |
| | To manage for the wide array of forest-dependent SGCN, as well as forest-specialist furbearers like marten and fisher, leave some old forest patches or corridors within harvested areas. Overall protection of old growth forests can help provide habitat for wildlife associated with old forests (see Managing Old Growth Forests). |
| | Support collaborative efforts to implement the large-scale habitat management necessary to sustain moose in Minnesota, such as working with the Moose Habitat Collaborative, Grand Portage Band of Lake Superior Chippewa, 1854 Treaty Authority, Fond du Lac Band of Lake Superior Chippewa, The Nature Conservancy, Ruffed Grouse Society and Woodcock Society, Lake, St. Louis, and Cook Counties, and USFS Superior National Forest. |
| | Increase the use of prescribed fire. Proactively apply prescribed fire and grazing in ways that sustain native ecosystems and support SGCN mammals while also avoiding or minimizing negative effects on them through factors such as timing, intensity, acreage, and leaving unburned areas for escape cover. When developing grazing and burn plans, consider the requirements of SGCN. Aim to provide diversity across the landscape and over time (see also Prairies and Other Grasslands sub-chapter). |
| | Restrict entry to known hibernation sites during the winter months and, where possible, restrict climbing and other recreational activities immediately outside of caves where bats are known to hibernate. |

| Stressor | Action |
|---|---|
| | Encourage the application of best management practices for installing new or upgrading old drainage systems to help reduce the conversion of wet prairies and grasslands to cropland (Board of Soil and Water Resources and the Natural Resources Conservation Service). |
| | Protect bats from human disturbance and spread of White-nose Syndrome by increasing the number of caves that are gated and monitored. |
| | Designate specific areas of northern Minnesota as core moose areas and consider how to reduce transmission of brainworm from white-tailed deer. Integrate deer management as part of a comprehensive moose management strategy as outlined in the Minnesota DNR Moose Research and Management Plan (2011). |
| | Implement best practices for wildlife-friendly outdoor lighting, such as turning off lights when they are not needed, using timers or motion detectors, shielding lights pointed downward, and employing lights in the warmer part of the spectrum. For more detailed information, refer to solutions advised by conservation organizations such as DarkSky, the Xerces Society and National Audubon's Lights Out Program. |

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

| Stressor | Action |
|---|---|
| | Engage in education and outreach to raise awareness of persecuted SGCN mammals and provide information on their ecological roles. |
| | Initiate a public information campaign to raise awareness of the effects of aerial pesticide and herbicide applications on SGCN mammals. |
| NA | Develop and promote accessible opportunities for the public to report observations of priority SGCN. |
| NA | Update the Minnesota Moose Research and Management Plan with input from partners (also see Strategy 2 above). |
| NA | Design and implement education and outreach activities that raise awareness of bats and their ecological roles and unique adaptations. |

## Case Study: Minnesota Department of Transportation Develops a New Tool to Identify Bats in Culverts and on Bridges

Minnesota Department of Transportation (MNDOT) takes its responsibility to protect state endangered, threatened and special concern species seriously. Knowing that the Northern long-eared bat is already an endangered species at the federal and state level, and that two other bat species (little brown myotis and tri-colored bat) are under consideration for federal listing, staff began to investigate how their construction and maintenance activities on bridges and culverts could affect these species. These transportation structures have long been known to provide roosting habitat for bats. Given the devastating declines that bats have experienced due to white-nose syndrome, attention has focused on additional measures to protect their declining populations. For example, a recent study in Iowa (Bektas et al., 2018) examined factors that increase a bridge's suitability as a bat roosting site. Among the factors that increased suitability were the bridge's proximity to wetlands (important foraging habitat) and the bridge's height and depth (higher and deeper were most suitable). When there is evidence that bats are using a bridge for roosting habitat (e.g. presence of guano), MNDOT staff must assume that state and federal listed species are present. Physical inspection of the site, however, can cause the very disturbance that staff are trying to avoid. Lacking any other evidence to identify the presence of state or federally listed species, engineers must implement costly measures to protect the bats if a new bridge is being constructed or an old bridge is being maintained or upgraded. A new study by MNDOT begun in 2024 is aimed at addressing this challenge. Researchers are investigating the utility of analyzing the DNA present in bat guano as a means of identifying whether state or federally listed species are present and if special provisions are necessary to protect these species (MnDOT, 2024).

*Photo: little brown bat, Bob Dunlap*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# REPTILES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Reptiles

## Overview

Despite its cold climate, Minnesota is home to a diverse assemblage of reptile species – 9 turtles, 16 snakes, and 3 lizards. In 1944 Walter Breckenridge published Reptiles and Amphibians of Minnesota, marking the state's beginning of modern herpetology. Breckenridge's publication was considered Minnesota's standard herpetological reference until Amphibians and Reptiles Native to Minnesota was published by Oldfield and Moriarty in 1994, followed by an update in 2014 (Moriarty and Hall). In the late 1970s, the Minnesota DNR's Nongame Wildlife Program was established, and has since funded studies on wood turtles (*Glyptemys insculpta*), Blanding's turtles (*Emydoidea blandingii*), timber rattlesnakes (*Crotalus horridus*), gophersnakes (*Pituophis catenifer*), five-lined skinks (*Plestiodon fasciatus*), and more. The Minnesota Biological Survey, initiated in 1987, surveyed counties across the state targeting rare wildlife and collecting records on common species. Their work has helped establish Minnesota's list of reptile Species in Greatest Conservation Need (SGCN) and has added thousands of records of reptiles to the DNR's Natural Heritage database.

Reptiles play an important role as both predator and prey in their ecosystems. Snakes eat many mammal species that humans consider pests and reduce numbers of disease-carrying ticks attached to those mammals (Kabay et al. 2013). Turtles create and modify habitats as they dig burrows or nests, and function as seed dispersers (Lovich et al. 2018). Conservation and research initiatives targeting reptile species have historically been underfunded and underrepresented despite the ecological importance of these species and particular life history requirements that make them vulnerable to decline, such as low reproductive rate, reliance on rare habitat types, and sensitivity to changes in temperature (Gibbons, 1988; Todd et al., 2010; Christoffel & Lepczyk, 2012; Tingley et al., 2016). In part, this may be due to traits that make them more difficult to study, including the rarity and cryptic nature of many species (Crane et al., 2021) and the fear and disdain that members of the public often feel towards snakes, lizards, and turtles relative to charismatic bird and mammal species (Olson & Pilliod, 2022). SGCN reptiles need focused attention to ensure their long-term conservation. The Minnesota Herpetological Society is an important venue for public education and promoting the study and conservation of both reptiles and amphibians. Herpmapper, a community science platform designed to gather reptile and amphibian observations worldwide, hosts the Amphibian & Reptile Survey of Minnesota, which provides information on Minnesota's herpetofauna and collects observations of Minnesota's herpetofauna, including turtle road crossing and mortality hotspots through the Minnesota Turtle Crossing Tally and Count Project. On a larger scale, Midwest Partners in Amphibian and Reptile Conservation (PARC) is an important network dedicated to the conservation of reptiles and amphibians that provides an avenue for collaborative conservation initiatives, outreach and education resources, and more.

*Photo: Plains hognose snake, Bob Dunlap*

## SGCN and SNI Summary Information

The 2025 SGCN list includes 13 reptiles (46%) of the 28 reptiles in the state and one Species in Need of Information (SNI), the Southern map turtle (*Graptemys ouachitensis*). The SGCN include 8 snakes, three turtles, and two lizards. Four species are state listed as Threatened, and six as Special Concern species. Two species, the Blanding's turtle and wood turtle, are presently under consideration for federal listing. Two species that were on the 2015 list were not included on this update, the Northern ring-necked snake (*Diadophis punctatus*), which is now thought to have a stable population in Minnesota, and massasauga (*Sistrurus catenatus*), due to extirpation. A complete list of both SGCN and SNI species can be found in Appendix B.

## Habitat Associations

Reptile SGCN utilize a variety of habitats, but the highest number of species were associated with savanna, prairie and other grasslands, upland deciduous forest and woodland, and cliff, talus, and rock outcrops (see Table 2.9). Cliff, talus, and rock outcrops provide rock surfaces essential for basking and thermoregulation in snakes and lizards, while rock and talus crevices provide important shelter and nesting sites.

Table 2.9 summarizes the association of reptile SGCN with the habitat types identified in the SWAP. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D.

**Table 2.9. Numbers of Reptile Species in Greatest Conservation Need associated with each of the 15 main habitat types (only showing habitats with reptile SGCN associations).**

| Habitats | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Prairie and Other Grasslands | 11 | 0 | 11 |
| Savanna | 12 | 0 | 12 |
| Upland Conifer Forest and Woodland | 3 | 1 | 4 |
| Upland Deciduous Forest and Woodland | 9 | 1 | 10 |
| Mesic Hardwood Forest | 5 | 1 | 6 |
| Deciduous Wet Forest | 3 | 1 | 4 |
| Riparian and Floodplain Forest | 2 | 1 | 3 |
| Non-forested Wetlands | 1 | 5 | 6 |
| Rivers and Streams | 3 | 0 | 3 |
| Lakes | 1 | 0 | 1 |
| Vernal Pools | 0 | 1 | 1 |
| Cliff, Talus, and Rock Outcrops | 8 | 0 | 8 |
| Urban and Other Developed Lands | 0 | 5 | 5 |

Across their entire range, common five-lined skinks are typically found in woodlands. However, in Minnesota they are primarily associated with limestone and granite rock outcrops and bluff prairies. Another lizard SGCN, the six-lined racerunner (*Aspidoscelis sexlineatus*), is also found in prairie, savanna, and rocky habitats, usually in areas with sand or gravel.

The North American racer (*Coluber constrictor*) utilizes dry habitats including edges of deciduous woodlands, prairies, rock outcrops, and old crop fields. Plains hog-nosed snakes (*Heterodon nasicus*) are a prairie species that prefer sandy or gravelly areas to burrow in. The closely related Eastern hog-nosed snake (*Heterodon platirhinos*) also prefers sandy or loamy soil, but occupies a wider range of habitats including grasslands, open woodlands and forest edges, and river shorelines and floodplains. The smooth greensnake (*Opheodrys vernalis*) is associated with prairies and meadows, edges of mixed forests, and the edges of marshes and bogs. The gophersnake prefers open landscapes like prairies, savannas, pastures, and old cropland, as well as rocky bluff habitats. The lined snake (*Tropidoclonion lineatum*) can be found in open prairies with large amounts of exposed rock. The timber rattlesnake requires hillsides with bluff prairies and rock outcrops, where they breed and overwinter in dens. Nearby forests, forest edges, and open fields are used as feeding grounds in the summer. The western ratsnake (*Pantherophis obsoletus*) is a woodland species and prefers forested uplands and valleys with rivers and rock outcrops.

Blanding's turtles prefer open areas with shallow, slow-moving water, like marshes, ponds, bogs, small streams, and ditches. During the winter, they overwinter at the bottom of these bodies of water. Blanding's turtles also utilize upland forested habitat as travel corridors between wetlands, foraging opportunities, and nesting, with some females traveling over a mile to nest (Piepgras & Lang, 2000). Wood turtles utilize rivers and adjacent floodplains and uplands, primarily in forested areas. They nest on sandbars and riverbanks but may also nest in human-altered habitats such as agricultural fields or sand and gravel mines. The smooth softshell is found in large rivers with moderate to fast currents that have sandy or muddy bottoms, which they burrow in during the winter.

*Photo: six-lined racerunner, Bob Dunlap*

## Case Study: Wood Turtle Nest Success

As part of a USFWS Competitive State Wildlife Grant, the Minnesota DNR Nongame Wildlife Program and collaborators undertook a project in northeastern Minnesota to identify threats to wood turtles and effective conservation actions to address those threats. One area of focus was nest success. Biologists monitored wood turtle nests and found that 5% of nests were successful, with predation the primary cause of nest failure. Badgers were responsible for 85% of predated nests, followed by raccoons, ravens, skunks, and foxes. Different nest protection methods were trialed, including an electric fence around a nest site, nest boxes which completely enclose a nest site with a small opening at the bottom for turtles, and deploying nest cages over individual nests. The different nest protection methods have pros and cons in terms of amount of effort and logistics of working in remote areas. Overall, nest success increased to 50% with nest protection efforts. Nest protection has been a successful conservation action, and these efforts have led to a minimum of 630 wood turtle hatchlings.

*Photo: Wood turtle hatchling, Gaea Crozier*

The real measure of success will be finding out if these conservation actions are having an effect on the overall wood turtle population. To answer that question, biologists have established long-term monitoring sites with a mark-recapture methodology. The goal is to monitor the sites every 5 years to obtain information on abundance, age-class structure, and sex ratio. Some long-term monitoring sites are controls, where no conservation actions are occurring. Other long-term monitoring sites are treatments, with conservation actions like nest protection and enhancing nesting habitat by removing encroaching vegetation and creating nest sites that are more safe from flooding. If these conservation efforts are successful, biologists expect to see an increase in turtles in the younger age classes in the coming years in the treatment monitoring sites. See Brown et al., 2025 for more information.

## Primary Stressors for Reptiles

### Development

Development can cause habitat loss and fragmentation and makes traversing the landscape more difficult and dangerous for reptiles (see also Roads, Trails, and Railroads). Development also can increase the abundance of mesopredators (mid-sized), such as raccoons, badgers, foxes and skunks, which prey on reptiles (Gelvin-Innvaer et al., 2025). Free-roaming cats are non-native predators on snakes and lizards including the common five-lined skink (COSEWIC, 2007). That effect has been often has been overlooked and warrants further attention as an additive stressor (Lloyd, 2012; Hall, 2019). Erosion control materials including rip rap and mesh, such as those used in construction of roads and to stabilize stream banks, can pose hazards as well, ensnaring snakes, lizards and turtles. (Stuart et al., 2001; Barton & Kinkead, 2005; Walley et al., 2005; Kingsbury & Gibson, 2012).

### Crop Production

Row crop agriculture has converted native prairie and grasslands that reptiles like Blanding's turtles, gophersnakes, and plains hog-nosed snakes depend on (Congdon et al., 2008; Moriarty & Hall, 2014). Suitable nesting habitat may be a limiting factor for some SGCN reptiles (MWPARC, 2010). Cultivated fields often become the only remaining option for nesting, yet these open, disturbed soils can also be "ecological sinks." For example, female Blanding's turtles have been found to preferentially select bare crop fields for nesting over naturally occurring nest sites (Mui et al., 2016). As crops grow, they shade nests from the sun's warmth which affects egg development, can lead to skewed sex ratios and reduce nest success (Freedberg & Pappas, 2011). Reptiles, such as snakes and turtles, are also injured and killed by farming equipment (Kapfer et al., 2008, Saumure & Bider, 1998; Saumure et al., 2007). Nests and eggs may be subject to destruction from mid-season tillage, and soil compaction from heavy equipment that could make it difficult for hatchlings to emerge from the nest (Dowling et al., 2010; Henning & Hinz, 2016; Chessman, 2017; King et al., 2025.) Agricultural chemical application also poses threats to turtles and their unhatched eggs. Turtles are long-lived and therefore may also be prone to bioaccumulation of toxins that could have lethal and/or sublethal effects (DNR, 2020). Last, row crop agriculture can negatively affect water quality, hydrology, and plant communities of wetlands, streams, and shallow lakes that SGCN turtles rely on and some SGCN snakes like gophersnakes use in parts of Minnesota for thermoregulation, foraging, and travel (DNR unpubl. data.)

SGCN reptiles use haylands and other managed grassy areas to meet a variety of needs, including for nesting and foraging (Knoot & Best, 2011; Dowling et al., 2010; Wittenberg, 2012; DNR, 2020). Haying for livestock forage and mowing, such as for roadside maintenance, filtration and buffer strips, or firebreaks, pose significant risks of injury and mortality to rare reptiles, especially turtles and snakes (Dalrymple & Reichenbach, 1984; Durbian, 2006; Wiese, 2016). The nesting period is the most vulnerable period for Blanding's turtles (Henning & Hinz, 2016; King et al., 2025). Wood turtles may also be at risk when foraging in uplands (Saumure et al., 2007; DNR, 2020).

### Mining and Quarrying

Hard rock mining operations may remove or degrade rock outcrop habitats and put reptiles at direct risk of harm by equipment during active mining, although these areas can also in the long term provide alternative outcrop habitat. Sand and gravel quarries can attract nesting turtles, increasing the risk of turtles being injured or killed and nests being destroyed by heavy equipment and blasting as part of mining operations (Zagorski et al., 2019; DNR, 2020).

## Wind and Solar Energy Infrastructure

Solar farms shade nesting and basking areas for Blanding's turtles, including agricultural lands which may be the only available nesting areas in the vicinity of the turtle's aquatic habitat. Additionally, unless fence design specifically incorporates periodic openings to accommodate turtles, fencing around solar facilities can block turtle movements and habitat use (MWPARC, 2010).

Easements for wind energy facilities often preclude acquisition and easement protections of adjacent open lands for conservation which in turn affects reptiles dependent on those habitats. (See also Prairies and Other Grasslands chapter).

## Roads, Trails, and Railroads

Roads can fragment reptile habitat and create a hazard for species that need to cross this barrier to reach habitats necessary for their survival and reproduction. Transportation infrastructure and vehicles affect reptiles in many ways (Andrews et al., 2006). Road mortality poses a major threat to snakes and turtles including Blanding's turtles (King et al., 2025; MWPARC, 2010) and gophersnakes (Kapfer et al., 2008). Railroads have also been documented as a mortality risk (King et al., 2025). Roads can attract cold-blooded reptiles seeking a warm surface to raise their body temperature. Gravel roads and sparsely vegetated road shoulders with disturbed soils may attract nesting turtles which increases risks to breeding females, their nests, and hatchlings from traffic and roadway maintenance (Jones et al., 2024). The turtles' slow movements and habit of withdrawing into their shells when perceiving a threat, such as an oncoming vehicle, further adds to the risks of crossing a road (Gooley, 2010).

## Utility Corridors

Directional boring and trenching for utilities (cable and pipelines) can affect reptiles directly and indirectly. Extensive excavation may destroy reptile nests and hibernation dens. Availability of suitable hibernacula (shelter) can be a limiting factor for snakes in northern latitudes including gophersnakes ("bullsnakes") (Johnson et al., 2022; Kapfer et al 2008; Martino et al., 2012) that overwinter in deep burrows. The DNR has

*Photo: Gophersnake, Bob Dunlap*

documented Blanding's turtles overwintering in stream banks, including concentrations of many turtles in burrows that extend deep into the banks at least 10 feet (DNR unpubl. data). Such sites could be subject to utility boring (e.g. at stream crossings). Unfortunately, overwintering locations are not universally documented for all Blanding's turtle populations which hinders environmental review.

## Hunting and Collecting Animals

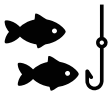
In Minnesota, taking, importing, transporting or selling any state endangered or threatened reptile is prohibited without a state permit (M.S. 84.0895) (e.g, timber rattlesnake, Blanding's turtle, wood turtle, and western ratsnake; MN Rules chapter 6134). Native turtles may not be sold as pets in the state. Although state residents with a fishing license and recreational turtle license may harvest common snapping turtles and western painted turtles for their personal use, commercial harvesting of these species was prohibited beginning in January 2024. The statute has exemptions that provide for the take of painted and snapping turtles by minors to continue the long-standing tradition of summer turtle races in small towns in Minnesota (M.S 97C.605). Once collected, and the races are over, the turtles cannot be released to the wild; their long-term care is the responsibility of the collector.

These rules and regulations provide a strong network of protection for Minnesota's native reptile species although illegal collection still occurs and poses a risk factor especially for imperiled species in Minnesota (DNR, 2020; Christman et al., 2024). Occasionally, a threatened turtle species gets entered illegally in a race (DNR unpubl. data).

Concerns also remain regarding the persecution and killing of species people perceive to be harmful to themselves, their livestock, or their pets. The timber rattlesnake is considered especially vulnerable. Because of the species' low reproductive rate, irregular reproduction, and high juvenile mortality (DNR, 2009), the loss of even a single adult can significantly affect a local population (Brown, 1993). Another concern is when citizens are fearful of a snake, remove it from their home site and release it elsewhere, it may decrease its long-term survival.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. The wood turtle is a forest-dependent SGCN reptile that is affected by a variety of factors related to forest management including timber harvest, road development, forest type conversion, and herbicide application, which may harm wood turtles directly and degrade their habitats (Tingley & Herman, 2008; DNR, 2020). Blanding's turtles are also vulnerable to these forest management activities as they make upland forest movements in the spring and summer related to breeding, foraging, and nesting (Piepgras & Lang, 2000, Refsnider & Linck, 2012), as well as hatchling movements in fall from nest site to overwintering habitat (Nyhus, 2020). However, canopy openings created by timber harvest may benefit both these turtle species as well as other SGCN reptiles requiring open sites for thermoregulation (Hughes & Litzgus, 2019; Auge et al., 2023). Forest management practices that reduce fuel load can help to prevent catastrophic mid-summer fires which can be lethal to forest-dwelling turtles.



## Fishing

Turtle bycatch and ingestion of fishing tackle can have individual and population level effects (Borkowski, 1997; Barko et al., 2010; Midwood et al., 2015; Steen & Robinson, 2017). Anglers may unintentionally attract and concentrate predators like raccoons by leaving discarded fish cleaning remains and

live bait, which can pose a significant threat to SGCN turtles, particularly hatchlings (see Problematic Native Species; Recreation).

## Recreation

Recreation can have numerous direct and indirect effects on rare, sensitive reptiles and their habitats (Northeast Blanding's Turtle Working Group, 2022). Snakes, for example, can be physically harmed by people when they are encountered during outdoor activities, due to widespread fear of snakes. Rare turtle species, like the wood turtle and Blanding' turtle, are vulnerable to a range of recreational activities, including all-terrain vehicle trails and canoe routes located near nesting locations. Off-highway vehicle parks established on sandy areas can pose risks to snakes and turtles that depend on these areas. Recreational sites located on or near sandy shorelines where turtles nest can create a range of disturbances. Garbage left behind at these locations can attract predators to nearby nest sites. Motorized vehicles can cause direct mortality to slow-moving turtles and snakes and inadvertently destroy nests. An increase in human traffic on land also increases the chances turtles are picked up and removed from the local population. A 20-year field study in Connecticut documented a decline in two wilderness wood turtle populations after opened to recreational use (Garber & Burger, 1995).

Larger loose rock is an important habitat component for some SGCN reptiles, such as five-lined skinks (Lang, 1982; Quirt et al., 2006). Rock collecting and recreational cairn building increase disturbance and affect reptile habitat (Schlesinger & Shine, 1994; Hecnar & M'Closkey, 1998; Goldingay & Newell, 2006).

In the water, motorized watercraft can cause direct injury, mortality, disturbance and habitat degradation for turtles (Lester et al., 2013, Selman et al., 2013; Smith et al., 2018).

Summer turtle races are local community events that result in the permanent removal of turtles from their populations, as required by state law. Despite providing recreational opportunities, turtles collected for the races likely undergo stress and become more prone to disease and injury (Heeb et al., 2024).

## Fire Management

Fire suppression increases the growth and spread of woody vegetation in open upland habitats that are critical for many reptiles. Encroachment of trees and shrubs affects reptile species adapted behaviorally and physiologically to open habitats such as prairies and grasslands, including prairie rock outcrops. For example, woody species reduce suitability for Blanding's turtle nesting and egg development, primarily due to shading (MWPARC, 2010). It may also reduce the ability of hatchling Blanding's turtles to orient towards water after they emerge from the nest (Pappas et al., 2009). For wood turtles, early spring and late fall wild fires can be beneficial by increasing herbaceous (non-woody) vegetation for foraging and openings for nesting. Common five-lined skink populations of the Upper Minnesota River Valley have been affected by woody encroachment on prairie outcrops, a required habitat (Gelvin-Innvaer et al., 2025). Trees like red cedar can shade basking areas for timber rattlesnakes, reducing reproductive success by limiting the number of days with high ground temperatures that females need to incubate young (DNR, 2009). (See also Prairies and Other Grasslands and Cliff, Talus and Rock Outcrop habitat sub-chapters).

Prescribed fire is a valuable tool to maintain open upland habitats for nesting and basking to benefit SGCN such as five-lined skink, Blanding's turtle, and many SGCN snakes. Prescribed fire also may help create quality foraging habitat (i.e., flush of herbaceous vegetation and berries post-fire). However, many prairies and grasslands now exist as small and isolated patches which make managing both for vegetation and sensitive wildlife a challenge. Fire can cause injury or mortality when it is not applied with the life histories and risk factors of rare, sensitive reptiles in mind.

For example, adult female Blanding's turtles have been injured and killed by prescribed burning conducted during their nesting periods in May and June when they were trapped away from aquatic refuge. Spring burning in native prairies and wet meadows has resulted in injury and mortality of Blanding's turtles (Lang, 2004). Fire can also cause direct mortality of prairie snakes and lizards (Setser & Cavitt, 2003, Schultz & Caven, 2021). During early spring emergence, snakes typically remain near their hibernation dens, and when temperatures are cool, they are less able to escape quickly if threatened by fire.

## Dams and Water Management

Turtles can be affected by a wide variety of water management when that occurs without considering turtle requirements and vulnerabilities. Examples include dams, water drainage and drawdowns, stream channelization, excavation/dredging culvert installation and even construction activities associated with stream restoration. The creation of physical barriers and changes to water flow that result in loss of feeding and nesting habitat, and changes to water quality are among the documented effects (Barcenas-Garcia et al., 2022). Water appropriations and drawdowns that reduce water levels during critical low water periods pose another threat especially when there are no accessible alternative habitats or when turtles are inactive during overwintering (Hall & Cuthbert, 2000; MWPARC, 2010; DNR 2020; NatureServe, 2025).

Turtles face direct risk of injury and mortality from heavy equipment operation in waterbodies. Currently, there is no corroborated evidence that proposed actions to mitigate the effects of dredging and other excavation to turtles effectively results in avoidance of turtle injury or mortality (Barcenas-Garcia et al., 2022). Dredging during the turtles' active season and posting spotters during dredging are not proven to be reliably effective measures due to the turtles' cryptic coloring, insufficient water clarity that obscures vegetation, and the tendency of many freshwater turtles to "hide" in place within their shells rather than to evade direct threats.

*Photo: smooth softshell (left) and spiny softshell (right), Jeff LeClere*

## Invasive Species (Problematic Non-native Species)

Invasive, non-native species can alter open habitats that are critical for reptiles, including rare species (Gibbons et al., 2000). Prairies and grasslands dominated by dense stands and thick thatch layers of smooth brome (*Bromus inermis*) are unsuitable for nesting and successful hatching by Blanding's turtles (L. Gelvin-Innvaer, pers. comm.). Bluff prairies overgrown with buckthorn (*Rhamnus cathartica* and *Frangula alnus*) negatively affect timber rattlesnakes in southeastern Minnesota (DNR, 2009) and five-lined skinks on rock outcrops along the Upper Minnesota River Valley (Gelvin-Innvaer et al., 2025). (See sub-chapter on Cliff, Talus and Rock Outcrops).

## Problematic Native Species

Reptiles are affected by nest predation from mesopredators like raccoons, badgers, foxes, and skunks. Mesopredators also injure and kill juveniles and adults. Although an important component of native ecosystems, the populations of these native predators can be artificially elevated and concentrated through factors such as habitat fragmentation, constructed trails, and attractants such as garbage and discarded bait. Human-subsidized nest predators have been identified as major factor in Blanding's and wood turtle declines (DNR, 2020). Dense stands of native and non-native reed canary grasses (*Phalaris spp.*) in floodplains reduce the availability of sandy nesting areas used by wood turtles (DNR, 2020).

## Diseases and Pathogens

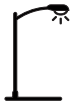
North American reptiles face a variety of risks from diseases, pathogens, and parasites (Gibbons et al., 2000). For example, snake fungal disease has been found in several species that are known to occur in Minnesota, including milk snakes, black rat snakes, and timber rattlesnakes. Caused by a fungus (*Ophidiomyces ophiodiicola)* it can spread internally, causing eye infections and pneumonia, and externally, causing lumps or ulcerations. Mortality can occur (Cornell College of Veterinary Medicine, 2021). Turtles are also carriers of various pathogens and can be affected by a variety of diseases, including metabolic bone syndrome. Emerging diseases such as *Emydomyces testavorans* and *Emydoidea herpesvirus 2* are of particular concern for turtles, including Blanding's turtles (Woodburn et al., 2019, Andersson et al., 2021). Turtles also are well-known carriers of *Salmonella* bacteria which is easily transmitted to people who handle them. Overall, there is a lack of focus on and awareness of releasing and transporting captively held species without rigorous precautions and criteria.

## Water-borne Pollution

Freshwater turtles are bioindicators of environmental pollution due to their longevity, ecological diversity, and trophic positioning (higher in food web). Mercury contamination has been studied the most extensively (Dias et al., 2025) although other environmental pollutants can also have direct and indirect effects on reptiles (Gibbons et al., 2000). In general, insufficient research on the direct, indirect, and synergistic effects of pesticides and herbicides on reptiles hampers informed proposal review and technical guidance.

## Air-borne Pollution

Airborne mercury enters aquatic ecosystems primarily through atmospheric deposition, where it settles onto land and water bodies via rain, snow, or dry particles, and then can be washed into water bodies. Otherwise, chemical application on uplands often is via aerial spraying. As noted above, several life traits of freshwater turtles make them suitable bioindicators of environmental pollution (Thompson et al., 2018; Dias et al., 2025) and effects on reptiles are vastly under researched.



## Light and Noise Pollution

Apart from sea turtles, where light pollution has shown to negatively affect hatchling movements, reptiles have rarely been the subject of field research addressing the effects of light or noise pollution. However, some studies suggest that freshwater turtles like the Blanding's turtle orient toward dark horizons upon hatching to help them disperse from nests into wetlands (Pappas et al., 2009).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (MPCA & DOC, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al. 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

Reptiles depend on external conditions to regulate their body temperatures, which influences their activity and metabolism. Substantially warmer winters have implications for Minnesota's reptiles which have evolved long dormancy periods for winter survival. Although reptiles must have overwintering sites below the frostline to avoid freezing, those sites must also be sufficiently cool for them to maintain a reduced metabolic state during dormancy. Later freezes and earlier winter thaws affect reptile activity periods and have implications for technical guidance to help ensure their conservation. Warmer temperatures during their nesting season may cause skewed sex ratios for Blanding's turtles and Southern map turtles due to temperature dependent sex determination (Gutzke & Packard, 1987; Vogt, 2018) which will affect population structure and reproductive output.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Flooding can be detrimental to species like turtles, which may be killed, washed downstream, buried under sand, or experience nest failure (Climate trends affecting lakes and rivers). Flooding also can cause erosion and incising of stream banks that degrade a stream's natural connections to floodplains and cause the loss of meanders and other natural features favored by Blanding's and wood turtles. Steep, high stream banks also hamper turtle access to terrestrial habitats. Increased flooding often results in more proposals for riprap, other hardened infrastructure, and drainage systems which can pose risks to turtles and otherwise alter their native habitats.

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). Droughts may especially affect reptile species associated with water, like Blanding's (Anthonysamy et al., 2013) and wood turtles. Longer term, drought can also alter terrestrial habitats and food chains for all reptiles. For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

*Photo: Timber rattlesnake, Amod Zambre*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan, to conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions, three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnerships with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management practices.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with not applicable (NA) in the stressor column.

## Potential Conservation Actions for Reptiles

### Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

| Stressor | Action |
|---|---|
| | Research responses of reptiles to solar facilities and measures to make solar facilities more reptile-friendly (Hernandez et al., 2014). |
| | To address road mortality, develop or collaborate with existing citizen science programs to identify stretches of road that are mortality hotspots (e.g. the Minnesota Turtle Crossing Tally and Count). Once identified, use these data to work with MnDOT to develop and apply effective mitigation strategies such as safe under-road passages to help reduce collisions, which benefits wildlife and motorists. |
| | Conduct rigorous monitoring to assess responses of SGCN to management activities such as prescribed fire, conservation grazing, timber harvest and water management. Apply findings to develop improved evidence-based management recommendations to avoid or reduce the risk of effects on SGCN (Binley et al., 2025). Graduate research projects could help address needs for intensive research. |
| | Research and apply reptile-friendly solutions for controlling invasive vegetation like smooth brome, reed canary grass, and buckthorn. |

| Stressor | Action |
|---|---|
| | Prioritize research and monitoring on snake fungal disease as well as diseases putting Blanding's turtles and other turtle species at risk such as adenoviruses and *Emydomyces testavorans* (Fredrickson et al., 2024). |
| NA | Resurvey/monitor reptile SGCN populations whose last observations in the Natural Heritage Information System (NHIS) database are over 10 years old to confirm continued presence of the species, assess population status, and identify specific conservation needs. |
| NA | To help address data gaps which hinder conservation, support continued research on efficacy of tools like environmental DNA (eDNA) and camera traps to augment (not replace) standard survey and monitoring techniques for rare SGCN reptiles in various environments, such as Blanding's and wood turtles (Kranz, 2023; Davis et al., 2025). |
| NA | Support more in-depth research of Blanding's turtle populations to help answer key conservation questions such as:<br>• Habitat use and movements of hatchlings<br>• Response to nesting habitat creation and management<br>• Response to stream restoration (including construction phase)<br>• Response to different grassland and forest management regimes |

*Photo: North American racer, Jeff LeClere*

## Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.

| Stressor | Action |
|---|---|
| | To address habitat fragmentation from development, protect key areas through land acquisition, conservation easements, and other protected designations. Conserve, reconstruct and manage suitable nesting habitats for SGCN reptiles. |
| | Reducing landscape fragmentation by increasing buffering, connectivity, and conditions similar to native remnant habitats can help reduce effects of native and non-native predators on rare sensitive prey species (Schneider, 2001). |
| | To help avoid entanglement by reptiles and other wildlife and effects on their habitats, consider these practices (DNR, 2004): A) Use biodegradable netting, preferably natural materials with short degradation periods. Erosion control blankets should be limited to bio-netting or natural netting types due to the risk of entanglement and death of small animals. Avoid photodegradable materials (break down in sunlight), as they do not degrade properly when covered/shaded, and products containing plastic mesh netting or other plastic components. B) Avoid mulch products that contain synthetic (plastic) fiber additives near waterbodies. Identify acceptable materials in Category 3N or 4N mulches. See Standard Specifications for Construction - MnDOT . |
| | When possible, restore agricultural lands to high quality reconstructed prairie. |
| | When haying and mowing, promote and apply measures such as found in the Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States (Kingsbury & Gibson, 2012) and Mowing Guidelines in Rare Turtle Habitat (MANHESP, 2009) which can be adapted to accommodate larger turtles like the Blanding's turtle. These include mowing when reptiles are less active (November to February) and mowing at high blade settings. |
| | Apply current guidelines for solar facility fencing to allow access for SGCN turtles (DNR, 2023). |
| | Work with wind energy companies and conservation partners to reduce restrictions of wind easements on land acquisition and conservation of adjacent lands that reptiles and other wildlife depend upon. |
| | Using the best available information, establish safe under-road passages and surmountable curbs to aid safe wildlife crossings for the benefit of wildlife and motorists (Markle & Stapleton, 2022, Markle et al., 2025). Avoid creating new roads in important areas for reptiles such as adjacent to water bodies as well as identified crossing hotspots for turtles (Congdon & Keinath, 2006) and snakes. |
| | Encourage collaboration among all stakeholders and across ownerships to promote effective management for the health and resilience of forests and their ability to provide ecological, wildlife habitat, and other values. |
| | Consider temporarily closing off key nesting areas for reptile SGCN during critical periods (e.g. nesting, emergence). Consult the Northeast Blanding's Turtle Working Group Guidelines for Recreational Area Development and Maintenance (2022). |

| Stressor | Action |
|---|---|
| | When planning prescribed burns, research whether any SGCN reptiles are known or potentially occur on the parcel. Burns should be conducted at times and under conditions when specific rare reptiles are less likely to be on land and access to water refuges remain available (Congdon & Keinath, 2006). Consult guidelines regarding prescribed fire and reptiles (MWPARC, 2008b) with appropriate modifications for target species of concern. Also consider how annual weather variation and climate change affect reptile activity, phenology, and access to safe refuge. Develop more comprehensive prescribed burn guidance based on scientific literature and expertise that considers factors such as fire frequency, intensity, timing, acreage, configuration of treated area, buffers around hibernacula, and access to fire refuge and escape routes in a landscape context (Kapfer et al., 2008). Where prescribed fire poses a significant risk, consider other forms of beneficial habitat disturbance such as conservation grazing. Managing for a mosaic of grassland structure and leaving unburned refuges may also benefit SGCN turtles and snakes in those habitats (Setser & Cavitt, 2003). |
| | Replace dams and restore streams in a way that minimizes negative effects and increases benefits to turtles during demolition and construction as well as final restoration design. Consider turtle phenology (seasonal behaviors) for the given area and life history characteristics. Time water drawdowns and ditch cleaning at a time of year less likely to affect turtles. Employ measures such as temporary barriers to keep turtles out or temporary drainage prior to excavation to encourage turtles to move to safety or to be more visible for active rescue. Avoid dredging where endangered or threatened turtles occur unless or until rigorous empirical research clearly identifies measures that will result in effective avoidance of injury or mortality. |
| | Manage water levels and conduct riverine management and restorations with SGCN turtles to address their requirements and include measures to avoid take (Congdon & Keinath, 2006). |
| | Protect nests of rare reptile species from native and non-native predators. Manage human-subsidized predators, like raccoons, especially near nesting areas (MWPARC, 2008a; Golba, 2024). |
| | Disinfect shoes and gear before traveling to a new outdoor site, whether you are a field biologist, land manager, or outdoor enthusiast. Use scrub brushes and immerse items in disinfectant such as 1% solution of Virkon Aquatic, 3% solution of bleach, or 70% solution of ethanol (Olson et al., 2021; Rzadkowska et al., 2016; Bletz et al., 2023.) |
| | Create buffer zones around bodies of water to reduce water-borne pollutants. Increase native plantings and add filtration ponds. |
| | Create buffer zones along rivers and streams to reduce the effect of flooding on shoreline habitat. Increase the availability of flood-safe nesting habitat. |
| NA | Headstarting of Blanding's turtles and wood turtles in suitable habitats with compatible management of habitat and mesopredators to boost recruitment in populations with age ratios heavily skewed to older individuals (Golba, 2024). |
| NA | Implement the Minnesota Wood Turtle Conservation Plan. |

### Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.

| Stressor | Action |
|---|---|
| | Increase public education and outreach about how releases of captive reptiles (including wild-caught individuals) can spread disease and introduce non-native species. |
| NA | Public outreach about turtle by-catch and what to do if you accidentally hook a turtle. |
| NA | Increase enforcement of nongame illegal take issues; educate conservation officers on the issue and monitor key areas for poaching. Develop effective solutions for masking rare reptile locations on websites like iNaturalist. Collaborate with initiatives like Collaborative to Combat the Illegal Trade in Turtles (CCITT) for effective approaches (Christman et al., 2024). |
| NA | Increase public awareness of state rules and regulations around take, possession, purchasing, and selling of native reptile species and the reasons for these laws. Promote alternative ways to appreciate Minnesota's reptiles in their native habitats. |
| NA | Outreach/education to reduce persecution of venomous and non-venomous snakes via interpretive programs, handouts, social media posts, and other communications. Increase public understanding and appreciation of snakes and how to co-exist with them. |
| NA | Educate land managers, including private landowners, about habitat needs of rare forest species. |
| NA | Develop and implement a state conservation plan for Blanding's turtles. |
| NA | Revise and develop comprehensive best management practices (BMPs), including but not limited to required avoidance measures, for listed reptiles. Prioritize Endangered and Threatened species that are often flagged in internal or external project reviews. These BMPs should be based on the best available updated scientific/technical information, vetted by species experts; be date versioned and in digital format; address the range of practices/actions that affect the species and that commonly arise in reviews; address relevant variation in habitat use and phenology across that species' Minnesota range as it relates to technical guidance for the species (e.g. critical periods, avoidance periods, activity); and be linked from the species' Rare Species Guide account on the DNR website. |

## Case Study: Listed Turtle Environmental DNA Project

Rare reptiles can be particularly difficult to detect, which can hinder conservation and environmental review. Although conventional survey methods like visual encounter surveys or trapping are the "gold standard", they can be costly and time-consuming. Therefore, scientists from the DNR Nongame Wildlife Program and MnDOT Office of Environmental Stewardship identified a need for additional tools to augment (not replace) standard monitoring methods. Environmental DNA (eDNA) is an emerging technology that holds promise as a rapid, coarse survey tool to help detect rare wildlife. Water samples can be analyzed for DNA shed by animals into their environment to detect their presence, without needing to directly observe or capture them. These scientists championed a proposal to assess the efficacy of eDNA for detecting Blanding's turtles and wood turtles across their ranges in Minnesota. MnDOT accepted and funded the proposal which led to contracting an expert research team from the University of Illinois. A Minnesota Technical Advisory Panel comprised of representatives from several DNR divisions, MnDOT, the Mille Lacs Band of Ojibwe, and the Minnesota Zoo provided additional guidance and input. This project, which is wrapping up in 2025, has demonstrated that environmental DNA is a rapid, sensitive, and cost-effective tool for monitoring these species under certain conditions. Their final report provides guidance on methodology and recommendations for next steps to further refine its use (Kranz 2023; Davis et al. 2025).

*Photo: Blanding's turtle, Bob Dunlap*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# AQUATIC INVERTEBRATES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Higgins eye mussels, DNR Center for Aquatic Mollusk Programs; Zebra clubtail, Jeff Fischer; Eurylophella funeralis, a species of spiny crawler mayfly, Dave Funk;. Headwaters Chilostigman caddisfly, Kyle Johnson

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# Aquatic Invertebrates

## Overview

This sub-chapter highlights different groups of aquatic invertebrates, including mussels and aquatic insects, a few groups of which have been well-surveyed in Minnesota, but the majority of which have not. Mussels have been well-investigated, primarily by the DNR's Center for Aquatic Mollusk Programs (see Mussels of Minnesota). Some groups of aquatic insects have been surveyed by researchers at several universities, the Minnesota Pollution Control Agency, and the Minnesota Dragonfly Society, including dragonflies (Anisoptera) and damselflies (Zygoptera), caddisflies (Trichoptera; Houghton et al., 2022), mayflies (Ephemeroptera), and stoneflies (Plecoptera).

Aquatic invertebrates play an important role in freshwater ecosystems by acting as intermediaries between primary producers (algae, plants, fungi, bacteria) and secondary consumers (fish). It is estimated that aquatic invertebrates are responsible for processing 20-73% of the leaf litter that enters a stream (Covich et al., 1999). Aquatic macroinvertebrates also increase the amount of bioavailable nutrients dissolved in the water column through their feeding activities, burrowing in sediment, and excretion, which in turn accelerates the growth of benthic microbes, algae, and rooted macrophytes (aquatic plants) (Covich et al., 1999).

Preferred habitats vary by species. Some inhabit only water bodies with specific conditions (water depth, temperature, trophic state, flow rate, surrounding habitat type), while others inhabit a wider variety of water body types. The vast diversity of aquatic macroinvertebrate species and their different tolerance levels to biotic and abiotic environmental factors can serve as an important indicator of the biological condition of a water body.

Historical data on aquatic invertebrate populations is often absent or lacking in quality, which poses a challenge when trying to determine how aquatic invertebrate communities have shifted over time and what trends could be observed. Additionally, aquatic invertebrate assemblages vary greatly across different aquatic habitat types and seasonal periods, making it difficult to determine overall trends on a large spatial or temporal scale. Some studies for particular species groups that are considered less tolerant of lower water quality, such as caddisflies and mayflies, have shown overall losses in biodiversity in association with anthropogenic (human-caused) disturbances (Houghton & Dewalt, 2023, Stepanian et al., 2020). The paragraphs below provide some insights into the diversity of invertebrates in our state.

## Mussels

Mussels are relatively well-studied, and have been the focus of survey, research, and conservation work for many years in Minnesota. Efforts by DNR malacologists (mollusk scientists) to conserve freshwater mussels began with statewide inventory surveys from 1999-2010, completing surveys at more than 2700 sites. During this time, 16 quantitative, long term monitoring stations were established in rivers across the state to detect long-term trends in mussel populations. Those monitoring sites have been sampled at least three times as of this writing. Since 2004, DNR malacologists also studied the early life histories of freshwater mussels, determining host fish requirements, timing of larval brooding, and host-infection strategies for 20 species. This included several species whose hosts were poorly known or entirely unknown. For example, DNR malacologists were the first to identify the host of the endangered spectaclecase (*Cumberlandia monodonta*) despite nearly 100 years of study (see Case Study). Life history work was expanded to in situ culturing of native species

for reintroduction to suitable sites. In situ culture work has evolved, starting with culture cages for Higgins' Eye (*Lampsilis higginsii*) in the Mississippi River to having dedicated staff and full functioning hatchery space devoted to culturing mussels since 2016. Since 2016, the DNR has successfully reintroduced over 25,000 cultured juvenile mussels representing six species (black sandshell (*Ligumia recta*), plain pocketbook (*Lampsilis cardium*), mucket (*Ortmanniana ligamentina*), snuffbox (*Epioblasma triquetra*), Higgins' Eye, and spectaclecase into the Cannon, Cedar, and Mississippi watersheds. Efforts are currently underway to evaluate survival and growth of the reintroduced mussels and to look for signs of recruitment. Some of the priority mussel conservation goals for the DNR from 2025-2035 include a second round of statewide surveys to begin elucidating trends, examining mussel response to stream restoration efforts, and continuing to address mussel culture needs for state and federally listed mussels. The depth of the DNR's mussel conservation efforts would not be possible without the continuous support and collaboration from a wide variety of federal, state, tribal, local and private partners (U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, National Park Service, Illinois DNR and Natural History Survey, Iowa DNR, Wisconsin DNR, Minnesota Department of Transportation, Minnesota Zoo, Prairie Island Indian Community, Minneapolis Park and Recreation Board, Macalester College, University of Minnesota, Shedd Aquarium, James Ford Bell Museum of Natural History, Friends of the Hormel Nature Center, Mower County Soil and Water Conservation District, Daguna Consulting), and many volunteers.

Collectively, DNR malacologists have dozens of scientific publications and have participated in national-scale research projects examining causes of mussel declines and development of a mussel assemblage health index. DNR malacologists have also developed numerous outreach products including a mussel guidebook (updated version expected summer 2025), a Mussels of Minnesota poster, and a

*Photo: Higgins eye mussels, DNR Center for Aquatic Mollusk Programs*

mussel life cycle poster, all of which can be found on the DNR's Mussels of Minnesota website. The DNR's Clam Counter Minnesota (Google link; Apple link) mussel identification app became available in spring 2025 and is modeled after the Clam Counter app originally developed by the Toronto Zoo and Fisheries and Oceans Canada. The DNR's partners are also actively contributing to mussel conservation outreach, such as the Minnesota Zoo's "Show Us Your Mussels" Challenge" for high school students. These products, along with a variety of in-person outreach, press and news releases, informational videos, and social media efforts around the state, have helped Minnesotans grow to love mussels and appreciate the role they play in healthy aquatic ecosystems.

Native freshwater mussels are a diverse group of animals with over 300 species in the U.S. and 51 species in Minnesota representing families Unionidae and Margartiferidae. Of Minnesota's species, 33 are considered at risk to some degree with 6 extant species needing federal protection as endangered species: spectacle case; snuffbox; Higgins' Eye; sheepnose (*Plethobasus cyphyus*); winged mapleleaf (*Quadrula fragosa*); and salamander mussel (*Simpsonaia ambigua;* currently proposed for federal endangered status). Often the reasons for imperilment can be tied to damming large rivers for navigation and hydropower that affect all aspects of the mussel life cycle and biology. General habitat and water quality

degradation associated with industry and agriculture are linked to mussel declines (Bakshi et al., 2023). Despite intensive study, precise explanations for most mussel declines are unclear and declines are often described as enigmatic (Haag, 2012; 2019). Disease ecology of freshwater mussels remains understudied and effects of certain invasive species like Basket Clams (*Corbicula* spp.) need further evaluation (Haag, 2019; Richard et al., 2022). Fortunately, in Minnesota, *Corbicula* species are relatively uncommon when compared to other regions of the U.S. Many of the widespread mussel declines documented in Minnesota during the last 100 years seem to have stabilized in recent years as water quality standards have been implemented and large dams are no longer being built. However, many populations linger as shells of their former selves (Hornbach et al., 2019) while other populations in select high quality and connected habitats may be rebounding (DNR unpublished data). The last decade has seen some success in DNR hatchery rearing of extirpated species to re-establish populations in restored or recovered stream segments that historically supported those species. In cases where certain mussel species are extirpated upstream of dams, properly executed dam removals have benefitted those species by allowing downstream populations to naturally recolonize habitats upstream of the former dam (DNR unpublished data).

Mussels are effective filter feeders that occupy bottom sediments of lakes and rivers, often occurring in dense and diverse aggregations referred to as mussel beds. Mussel beds can be very productive at filtering nutrients, algae, and certain bacteria from the water. Mussel beds can also stabilize substrates and serve as habitats for other organisms like macroinvertebrates. Ecosystem services provided by freshwater mussels cannot be overstated (Vaughn, 2018). Freshwater mussels are mostly sessile (immobile) and may live in the same patch of sediment for their entire lives. Because of their limited mobility and tendency to live in flowing water, limiting any movement to a downstream direction, mussels rely on one or more host species, usually fish, to disperse their larvae to new areas. Host fish are often attracted by and enticed into eating a prey-like lure made by a female mussel. Upon attempting to eat the lure, fish are instead parasitized by a cloud of mussel larvae that develop and fall off weeks later wherever the fish happens to end up. Due to this complicated life cycle and being immobile residents of benthic sediments, mussels are particularly sensitive to stressors that reduce substrate stability, highly polluted water, and absence of host species. Taken together these attributes can make mussels indicators of overall stream and lake health in some systems.

## Snails

Aquatic snails have been studied in Minnesota for over 100 years and surveys have identified around 60 species. Most of these surveys occurred well over 20 years ago, and a concerted statewide aquatic snail survey has not been completed in decades. Because of the lack of recent survey effort, the distribution and abundance of most species is not well known, making assessment of conservation statuses and implementation of subsequent conservation actions difficult. This is further complicated by strong roots in morphological species concepts (based on appearance and structure rather than genetics) and a high degree of intraspecies shell variation having potentially led to an over description of some genera. Apparent difficulties with mitochondrial genetic testing have complicated modern understanding of taxonomic relationships for many aquatic snails, but genomic sequencing is promising. To begin addressing the above conservation issues during 2025-2035, the DNR is incorporating snails into statewide mollusk survey efforts, compiling existing snail survey data and specimens, and identifying partners to help address taxonomic uncertainties.

Native snails can range from a few millimeters to around 2.5 cm and occur in almost all aquatic habitats in Minnesota from small springs to large rivers to deep lakes. These snails graze algae, detritus, and other organic matter and are food items for other organisms like fish and some mammals. Historical threats were likely related to habitat loss or degradation from draining of wetlands for agriculture and subsequent sedimentation from fields in the prairie regions of Minnesota. Current threats faced by snails include invasive mollusk species, pollutants, and ongoing habitat degradation. Much of the snail toxicity literature often studies widespread and relatively tolerant snail species, although more recent studies have begun focusing on rarer and more sensitive species as culture techniques are developed (Barrick et al., 2024).

## Aquatic Insects

The diversity of insects in Minnesota is likely greater than the combined diversity of all other animals, but insects are among the least well understood. The Minnesota Pollution Control Agency, researchers at several universities, and the Minnesota Dragonfly Society have surveyed the state for some aquatic insect groups including dragonflies (Anisoptera) and damselflies (Zygoptera), caddisflies (Trichoptera; Houghton et al., 2022), mayflies (Ephemeroptera), and stoneflies (Plecoptera).

In the conservation status assessment process, we evaluated 826 species of aquatic invertebrates, but the true diversity could be orders of magnitude more (Jessica Petersen, DNR, personal communication). Other orders of insects that were not even evaluated during our conservation status assessment are hyper-diverse and we know essentially nothing about their diversity, including aquatic beetles (Coleoptera) and dobsonflies, alderflies and fishflies (Megaloptera).

Lacking basic biological information about so many species, each with a unique role in sustaining the health of natural communities, compromises the ability to address their conservation needs. There is an immediate need to document the diversity of insects in Minnesota before further losses are sustained and therefore go undocumented (Cardoso et al., 2020).

### Dragonflies and Damselflies

Despite being tropical in origin, over the past 300 million years dragonflies and damselflies (Odonata) have spread through our temperate climate all the way to the arctic. Minnesota's location in the center of the continent, our four recognized biomes, and our diversity of aquatic breeding habitats all lead to an interesting and diverse mix of Odonata species in the state. Despite being readily recognizable as dragonflies, even by lay-people, we do not have a deep historical record of Odonata species distribution in Minnesota. Prior to the formation of the Minnesota Odonata Survey Project (Minnesota State Wildlife Program Grant T-36-R-1, 2005-2012) there were counties in Minnesota which had zero records of dragonflies and damselflies, despite widespread aquatic breeding habitat. The MOSP, with the help of many volunteers, added thousands of new county records and nearly two dozen new state records for the Odonata in Minnesota. Not only were surveys of adult Odonata conducted in the field, every known museum collection in Minnesota was also investigated and catalogued. The Minnesota Dragonfly Society (MDS), a 501c3 tax exempt organization, was formed in 2013 as a volunteer organization to ensure the conservation of Minnesota's dragonflies and damselflies through education and research.

Very little formal work on the Odonata distribution in Minnesota has been done since the ending of the MOSP. Despite that, volunteers and enthusiasts continue to contribute to our Odonata knowledge in Minnesota, with several state records and many new county records added in the past years. Given Minnesota's geographical location and our abundance and diversity of habitats, it is highly probable that there are small populations

of other Odonata species yet to be found in Minnesota. Odonata Central and iNaturalist are tools readily used by citizen scientists to report new findings.

*Photo: Zebra clubtail, Jeff Fischer*

Minnesota has 154 Odonata species on its list, with 112 species of dragonflies (suborder Epiprocta) and 42 species of damselflies (suborder Zygoptera). Several of these records are represented by only one individual which could mean that those species are strays or that more survey work is needed. With a warming and changing climate, there is anecdotal evidence that we are seeing the expansion of more-southerly species into southern Minnesota.

The two general habitat types that hold the most Odonata SGCN species are boggy, northern waters and larger, clear rivers. The biggest threats, statewide, to all Odonata are human disturbances within sensitive watersheds or to the habitat, itself.

## Mayflies

Mayflies (Ephemeroptera) are an order of hemimetabolous insects (i.e. they have no pupal stage in the transition from larva to adults) which spend most of their lives in the water before emerging briefly as subimago (dun) or winged, sexually immature adults. Within hours of emerging from the water, the subimago molts to reach full reproductive maturity. In total, this winged adult phase of their lives can last anywhere from a couple of hours to a few days depending on the species and the sex of the individual. After mating, female mayflies disperse their eggs on the surface of the water or, in some cases, on substrates just beneath the surface of the water.

As aquatic nymphs, mayfly larvae can inhabit a wide variety of habitats, from fast flowing rocky-bottom streams to lakes and wetlands. While most mayfly species are collectors and/or scrapers of benthic algae and detritus for the duration of their development, mayflies have evolved a wide variety of feeding strategies and habitat preferences. Numerous mayfly genera burrow in fine sediments, while others are predators, shredders of organic material, or adept swimmers, able to respond quickly to changing stream conditions.

Mayflies play a vital role in maintaining healthy aquatic ecosystems. As aquatic nymphs, they help break down aquatic vegetation and detritus, contributing significantly to the recycling of nutrients. Mayfly nymphs are also a key food source for fish, other macroinvertebrates, and amphibians. As adults, mayflies provide nourishment for fish, birds, and many terrestrial insects, serving as an essential link in the transfer of nutrients between aquatic and terrestrial ecosystems.

*Photo: Eurylophella funeralis, a species of spiny crawler mayfly, Dave Funk*

Mayflies are familiar to many fishermen who target their emergence events, utilizing artificial flies to "match the hatch". More broadly, mayflies play a critical role in sustaining productive fisheries and healthy ecosystems, which are essential not only for biodiversity, but also for Minnesota's outdoor recreation economy. Recreational fishing and other aquatic activities supported by these ecosystems contribute significantly to the state's economy through tourism, equipment sales, licenses, and local businesses. Protecting mayfly populations helps ensure the long-term viability of these economic and recreational opportunities for communities across Minnesota.

Mayflies in Minnesota face a wide range of threats. Human development has altered much of the state's natural landscape, disrupting the specific habitat and chemical conditions which many mayfly species require to survive. Major threats include agriculture, urban development, mining, invasive species, and climate change. Of the 658 currently known and taxonomically valid mayfly species in North America, 159 have been documented in Minnesota. Among these, 14 species are considered vulnerable (S3), three are imperiled (S2), and two are critically imperiled (S1), indicating conservation concern for these populations. Eight species are designated SGCN and 83 as SNI. Further work is needed to better understand the health of many of Minnesota's mayfly species.

## Stoneflies

Stoneflies (Plecoptera) are an order of aquatic insects strongly associated with running, well-oxygenated freshwater during most of their life cycle. Their presence is often an indicator of good water quality, as many species have specific habitat requirements such as cold temperatures, stable stream substrates, and low pollution levels.

Stoneflies begin their lives as eggs which develop into aquatic nymphs, often after an extended period of limited development, or diapause. As nymphs, stoneflies adopt a wide variety of feeding strategies depending on the species, and stage of development. For example, stoneflies in the family Pteronarcyidae, shred and eat detritus and aquatic vegetation throughout their development, while many stoneflies in the family Perlidae transition from a diet of algae/detritus early in their development, to a diet of aquatic macroinvertebrates as larger and more mature instars. The winged adult phase of the stonefly life cycle is relatively brief, lasting only a few days in most cases and up to a few weeks in a few species.

Stoneflies play a vital role in maintaining healthy aquatic ecosystems. As aquatic nymphs, stoneflies help break down aquatic vegetation and detritus, while contributing significantly to the recycling of nutrients. Predatory nymphs help to regulate the productivity of some other aquatic macroinvertebrates and help to maintain the delicate balance of these aquatic ecosystems. Stoneflies, both as adults and nymphs, are a key food source for fish, other macroinvertebrates, amphibians and birds. Like other aquatic insects they often serve as an essential link in the transfer of nutrients between aquatic and terrestrial ecosystems.

Due to their stringent habitat requirements, stoneflies are often some of the most pollution sensitive organisms found in each stream or river. Across Minnesota, stoneflies face a wide range of threats. Human development has altered much of the state's natural landscape, disrupting the specific habitat and chemical conditions which many mayfly species require to survive. Major threats include agriculture, urban development, mining, invasive species, and climate change. Of the 70 stonefly species documented in Minnesota, 12 are considered vulnerable (S3), four are imperiled (S2), and one is considered critically imperiled (S1), indicating conservation concern for these populations. Further work is needed to better understand the health of many of Minnesota's mayfly species. Five are designated SGCN and 34 as SNI.

## Caddisflies

Caddisflies (Trichoptera) are a diverse order of insects that utilize aquatic habitats for much of their life cycle. The name trichoptera is derived from the Greek *trichos* (hair) and *pteron* (wing) which is in reference to the hair that covers the wings on adult caddisflies.

Larval caddisflies have a major role in aquatic ecosystems including rivers, streams, marshes, and lakes. While some individual species are uniquely adapted for specific habitat types, others are considered generalists and are found across a wide array of aquatic ecosystems. Caddisflies are major components of aquatic ecosystems and contribute towards the transfer of energy and nutrients throughout trophic levels within freshwater systems worldwide. Caddisflies also display a wide array of life history characteristics. Many caddisfly taxa produce shelters or cases to protect and disguise themselves from predators. These cases are constructed using materials from their surroundings that are fastened together by silk, and some species even produce nets that they use to filter flowing water as a passive source of food. While many species use silk to protect themselves or as a food source, there are also "freeliving" caddisflies, such as the *Rhyacophila* genera which do not build cases, and act as predators towards smaller aquatic fauna. Many taxa have very specific habitat preferences or tolerance/intolerance to specific pollutants and water chemistry parameters making them excellent indicators of watershed disturbance. The diversity of caddisflies, and their ingenious use of silk to fully optimize their unique life history strategies, makes caddisflies an invaluable group for water quality monitoring.

Out of more than 300 caddisfly species that were reviewed in this process, 48 were designated SGCN. Four have been given a rank of S1 (critically imperiled), 20 have been given a rank of S2 (imperiled), and 70 have been given a rank of S3 (vulnerable). These species have been highlighted in these S ranks for a variety of reasons, but most commonly due to rarity, sensitivity, or unique habitat preferences. In addition to the S1-S3 ranks more than 130 caddisfly species were designated an S4 (apparently secure) or S5 (secure) ranking due to generally stable, well-established populations throughout Minnesota. Lastly, ranks of SH (possibly extirpated), SU (unrankable), and SNA (not applicable) were assigned to 23, 56, and 6 species respectively. SH taxa are typically species with exclusively old records, where efforts have been made to search for these species and they have not been found. SU species lack sufficient information to rank (very low numbers of occurrences), while SNA species are reserved for non-native species, vagrants, or species that are unlikely to have ever existed in Minnesota.

*Photo: Headwaters Chilostigman caddisfly, Kyle Johnson*

There is a high level of variability in information for any given species of caddisfly within Minnesota. For some species, there may be very few occurrences from a localized area, whereas other species may have thousands of records across the state. In general, the larger bodied caddisflies are typically easier to identify, and more correlations can be drawn about their habitat preferences, range, and population stability. Conversely, smaller caddisflies such as the Microcaddisfly family Hydroptilidae have many species, and are difficult, if not impossible to identify depending on their life stages without the aid of genetic analysis. Short of specific studies designed to identify adults or fully mature larva of certain groups such as Hydroptilidae, little is known about these taxa as many of the broad scale sampling efforts that occur in the state do not capture the necessary details to identify some groups down to species.

## SGCN and SNI Summary Information

There are 110 SGCN aquatic invertebrates and 198 SNI aquatic invertebrates (see Table 2.10). See Appendix B for full list of species. This includes some state-listed species (24 caddisflies, 8 dragonflies and damselflies, 28 mussels) and federally listed species (5 mussels, with 1 additional proposed for federal listing).

**Table 2.10. Numbers of Aquatic Invertebrate Species in Greatest Conservation Need and Species in Need of Information by species group. Note that many of these groups are very under-surveyed.**

| Species Group | No. of SGCN | No. of SNI | Total Assessed | No. of SGCN removed from 2015 List | No. of SGCN added to 2015 List | No. of SNI added |
|---|---|---|---|---|---|---|
| Beetles (Class Insecta; Order Coleoptera) | 1 | 0 | 1 | 0 | 1 | 0 |
| Caddisflies (Class Insecta; Order Trichoptera) | 38 | 63 | 314 | 3 | 17 | 63 |
| Dragonflies and Damselflies (Class Insecta; Order Odonata) | 25 | 8 | 145 | 20 | 5 | 8 |
| Mayflies (Class Insecta; Order Ephemeroptera) | 8 | 83 | 163 | 0 | 8 | 83 |
| Mussels (Class Bivalvia) | 32 | 1 | 51 | 0 | 3 | 1 |
| Shrimp (Class Branchiopoda) | 0 | 1 | 9 | 0 | 0 | 1 |
| Snails - Aquatic (Class Gastropoda) | 1 | 8 | 67 | 0 | 1 | 8 |
| Stoneflies (Class Insecta; Order Plecoptera) | 5 | 34 | 76 | 0 | 5 | 34 |
| TOTAL | **110** | **198** | **826** | **23** | **40** | **198** |

## Habitat Associations

The range of wetlands, rivers, and streams that aquatic invertebrate SGCN inhabit is found in Table 2.11. The totals for each taxa listed below include both primary and secondary habitats for mussels (Bivalvia), caddisflies (Trichoptera), and mayflies (Ephemeroptera). For the other taxa (stoneflies (Plecoptera), aquatic beetles (Coleoptera), aquatic snails (Gastropoda) and dragonflies (Odonata), primary and secondary habitats were not delineated, only the habitats where the species occurred without ranking. Primary habitats are those where the species is found most consistently; the species is most reliant on the habitat and, should the habitat be degraded or lost, it would have the greatest effect on the species. Secondary habitats are those where a species can be found some of the time, but less frequently than a primary habitat. Some species, especially those with more general habitat requirements, may be assigned to multiple primary or secondary habitats. Table 2.11 does not include habitat associations for the one taxonomic group that is only represented by Species in Need of Information, shrimp (Branchiopoda). Appendix D provides a comprehensive list of the primary and secondary habitats utilized by each SGCN.

**Table 2.11. Numbers of Aquatic Invertebrate Species in Greatest Conservation Need and their associations across habitat types.**

| Habitats | Beetles (aquatic) | Caddisflies | Dragonflies and Damselflies | Mayflies | Mussels | Snails (aquatic) | Stoneflies | Total |
|---|---|---|---|---|---|---|---|---|
| Deciduous Wet Forest | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Coniferous Forest Wetland | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Non-forested Wetlands | 1 | 0 | 7 | 0 | 1 | 0 | 0 | 8 |
| Rivers and Streams (Total) | 0 | 33 | 12 | 8 | 31 | 0 | 5 | 94 |
| Streams | 0 | 19 | 10 | 7 | 10 | 0 | 5 | 51 |
| Rivers | 0 | 11 | 3 | 4 | 15 | 0 | 4 | 37 |
| Large Rivers | 0 | 5 | 1 | 0 | 29 | 0 | 0 | 35 |
| Lakes (Total) | 0 | 15 | 13 | 2 | 1 | 1 | 0 | 34 |
| Lakes Not Shallow | 0 | 13 | 10 | 2 | 1 | 1 | 0 | 27 |
| Lakes Shallow | 0 | 2 | 3 | 0 | 1 | 1 | 0 | 7 |
| Vernal Pools | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 |

Rather than broadly characterizing aquatic invertebrate SGCN as simply river species, the 2025-2035 SWAP uses the Strahler Stream Order (SSO) method to classify streams and rivers. Streams without any tributaries are assigned an SSO of 1; then the stream order increases when tributaries combine into larger streams. As illustrated in Table 2.11, the majority of aquatic invertebrate SGCN occur in small streams (SSO 1-4). The mussels are primarily found in riverine waters where their diversity is highest (see the Rivers and Streams sub-chapter) with 10 species found in smaller streams (SSO 1-4), 15 species in medium rivers (SSO5-6), and 29 species occurring in large rivers (SSO 7-8) (note: many species occur in more than one riverine habitat) (see Appendix D Animal SGCN Habitat Associations).

Minnesota is also home to the only known lake endemic mussel species, the lake floater (*Pyganodon lacustris*). It occurs primarily in silt or soft mud dominated substrates of backwater lakes that have little flow and are deep enough not to completely freeze over during the winter months. Some of the mussel SGCN are habitat specialists and examples include spectaclecase and salamander mussels which occupy crevices under boulders and slab rocks.

## Primary Stressors for Aquatic Invertebrates

Stressors are factors that pose direct or indirect challenges to vulnerable plant and wildlife species. Habitat loss and degradation are generally considered the primary threat for most SGCN, and some stressors reduce the quality of those habitats. Other stressors may operate more directly on the SGCN, such as disease and pathogens. In some cases, stressors may operate both directly and indirectly. For example, roads, trails, and railroads can directly harm SGCN through vehicular strikes, or operate indirectly through habitat fragmentation and reduced landscape connectivity. The stressor list below is adapted from an internationally recognized threats classification developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For more information, see the "Stressors" section of Chapter 1: Species in Greatest Conservation Need.

It is important to note that some factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this species group is included below, followed by a set of conservation actions addressing those stressors. Also please reference the Rivers and Streams sub-chapter for more about stressors and actions in that habitat.

### Development

Residential and commercial development can fragment and reduce suitable habitat available for insects and are among the most prevalent threats to aquatic invertebrates currently listed under the federal Endangered Species Act (Shirey et al., 2025).

### Crop Production

Many activities associated with intensive agriculture pose threats to aquatic macroinvertebrates. Some examples include stream channelization, draining of wetlands, loss of surrounding floodplain and riparian cover, and increased inputs of pesticides, herbicides, sediments, and nutrients (Houghton & Dewalt, 2023). Overapplication of fertilizer results in increased nutrient runoff into adjacent water bodies. This can lead to algal blooms that deplete oxygen in the water column and negatively affect sensitive aquatic invertebrates that require well oxygenated water to survive.

Flashy hydrology (rapidly rising and falling water levels) caused by tiled agricultural fields can cause bed erosion in streams (scouring) which limits freshwater mussel presence to only the most stable stream reaches. This is compounded when stream channels are straightened, facilitating water conveyance "too efficiently" (Blann et al., 2009). Small streams are affected to a greater degree than larger streams by agricultural practices (Wohl, 2017), which in turn affects the mussels in those systems. However, in large rivers wide scale conversion to intensive row crop agriculture has been shown to reduce mussel diversity when compared to natural land uses in Minnesota (Hornbach et al., 2019).

### Livestock Management

Direct links between cattle and effects on freshwater mussels are limited, but effects of cattle on stream habitat degradation are well documented. Cattle cause stream bank erosion, sedimentation, increased total suspended solids, increased nutrient loading, and increased coliform bacteria (O'Callaghan et al., 2018).

## Mining and Quarrying

Release of heavy metals into water bodies due to certain types of mining activities can result in bioaccumulation of heavy metals throughout the aquatic ecosystem and toxicity to sensitive species of aquatic invertebrates. Indirect effects may also occur through the decline in algal food sources in response to heavy metal exposure (Mebane et al., 2020).

If gravel or sand mining were to be permitted in rivers with mussels, it could cause displacement and/or reduction in habitat quantity or quality.

## Roads, Trails, and Railroads

Railroads can present an overlooked threat to aquatic organisms as derailments resulting in release of toxic substances into lakes and rivers can cause mussel kills. Although most derailments happen in shipping yards, a relatively small number of derailments result in spills of contaminants (less than one percent; AAR, 2024) and can cause disproportionate environmental damage. Several mussel species in Minnesota that are only found in a single river could be devastated by a train derailment.

Freshwater mussels are also very sensitive to salt, and heavily salted roadways are considered a threat in some instances (Bakshi et al., 2023).

## Shipping Lanes

Routine dredging of river channels to accommodate commercial boat traffic can create disturbances that prevent natural channel formation, movement, and sediment transport. Because freshwater mussels require stable river bottoms to burrow into, dredging can remove them from the sediments, bury them, or destabilize the sediments that remain. Increased water turbidity can also make it more difficult for these filter feeders to eat.

Nutrient cycling is limited in dredged channels because the river has limited access to floodplain habitats that offer an exchange of terrestrial and aquatic nutrients (Schramm et al., 2015). Lock and dam operations block the migration and movement of many fish species, especially those that migrate seasonally (e.g. skipjack herring, *Alosa chrysochloris*). Restricted fish movement further affects native mussel species that require those fish species to complete mussel life cycles and this has led to functional extirpation of two mussel species from Minnesota (elephant-ear (*Elliptio crassidens*) and ebonyshell (*Reginaia ebenus*)). The upstream transport of goods on barges facilitates the movement of undesirable and deleterious species like invasive zebra mussels (*Dreissena polymorpha*) that can attach to barges. Impounded sections of river upstream of locks and dams are often reservoirs for invasive species, allowing them to persist where they would otherwise not occur in naturally flowing river reaches (Johnson et al., 2008). This is especially true for zebra mussels (Stoeckel et al., 2004). Commercial traffic has been shown to increase suspended sediments and turbidity (Smarts et al., 1985; Spear et al., 2024). Elevated turbidity has been shown to negatively affect mussel reproduction (Gascho Landis et al., 2013, Gascho Landis & Stoeckel, 2015).

## Fishing

Many in Minnesota's large and diverse fishing community may know very little about the importance of aquatic invertebrates to the health and sustainability of good water quality and healthy fisheries. An engaged public would be a strong voice for water quality improvements.

## Recreation

Resuspension of sediments caused by recreational motorboat wakes from as few as 11 boats passing once per day was found to reduce filtration activity of native freshwater mussels by nearly 7% in a river in

Germany, although the effects were inversely related to water depth and primarily seen in water less than 2 meters deep (Lorenz et al., 2013). Elevated turbidity has been shown to negatively affect mussel reproduction (Gascho Landis et al., 2013, Gascho Landis & Stoeckel, 2015).

## Dams and Water Management

Dams block the migration and movement of many fish species, especially those that migrate seasonally (e.g. skipjack herring). Restricted fish movement further affects native mussel species that require those fish species to complete mussel life cycles and has caused functional extirpation of two species in Minnesota (Kelner & Sietman, 2000; DNR unpublished data). Since mussels are sessile and live in lake and river sediments, they rely on fish to transport their larvae upstream. Thus, dams severely limit upstream mussel dispersal. The population fragmentation associated with these barriers increases the chances of local mussel extirpations from stochastic (random) events (Haag, 2012). Impounded sections of river upstream of dams are often reservoirs for invasive species, allowing them to persist where they would otherwise not occur in naturally flowing river reaches (Johnson et al., 2008). Of specific importance to native mussels, impoundments and lakes upstream of flowing reaches often act as a continual source of zebra mussels that colonize downstream reaches (Stoeckel et al., 2004). Zebra mussel biofouling effectively cements native mussel shells to close causing suffocation and reduced host infestation success.

Flashy hydrology caused by impervious surfaces or tiled agricultural fields can cause streams to scour which limits freshwater mussel presence to only the most stable stream reaches. This is compounded when stream channels are straightened, facilitating water conveyance "too efficiently" (Blann et al., 2009).

*Photo: DNR biologists glue unique identification tags on black sand-shell mussels before release into the Cannon River, DNR Center for Aquatic Mollusk Programs*

## Invasive Species (Problematic Non-native Species)

Problematic non-native snail species such as the Chinese mystery snail (*Cipangopaludina chinensis* and *C. japonica*), banded mystery snail (*Viviparus georgianus*), faucet snail (*Bithynia tentaculata)*, and New Zealand mudsnail (*Potamopyrgus antipodarum*) outcompete native macroinvertebrate species for food and habitat.

Zebra mussels endanger native mussel species and riverine infrastructure by densely encrusting to hard surfaces. Native mussel species can become encrusted to the point of suffocation by zebra mussels but also may lose the ability to close which is a primary defense against predators and temporarily unfavorable water quality conditions. Since many mussel species use lures to attract host fishes, complete encrustation by zebra mussels will prevent deployment of those lures. Because both native mussels and zebra mussels are filter feeders, high density zebra mussel populations can outcompete native species for food.

## Diseases and Pathogens

While mussel diseases have not been identified specifically in Minnesota, rivers in the eastern U.S. (including in Wisconsin; Knowles et al., 2024) have documented various mussel specific pathogens that can negatively affect mussels in various ways (Richard et al., 2022).

## Water-borne Pollution

Some surfactants common in household products, like dish soap, are toxic to many aquatic mollusks (Gibson et al., 2016). Hydrobiid snails may be particularly sensitive to pollutants and at least one study has documented negative effects of copper, ammonia, and pentachorophenol (Besser et al., 2016).

Ammonia is very toxic to freshwater mussels, especially at the larval and juvenile life stages (Wang et al., 2007). Another study found that mussels are broadly sensitive to total nitrate, total phosphorus, and chloride and that current water quality standards may not sufficiently protect mussels from these pollutants in Minnesota (Bakshi et al., 2023).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al. 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). More frequent and prolonged droughts are expected to reduce stream flows and water levels. Some stream reaches may dry up entirely, resulting in the loss of aquatic invertebrates due to desiccation. Warmer summer air temperatures will further raise stream temperatures, especially during low-flow periods. Many mussel species are particularly vulnerable, with thermal limits generally ranging from 25–35°C depending on tolerance, rate of warming, and duration of exposure (Pandolfo et al., 2012). Notably, many Minnesota streams already reach or exceed 30°C, and impounded reaches near dams may experience even greater temperature stress.

Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since

2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Higher precipitation and extreme weather events can also severely affect mussel populations by increasing the sediment load to rivers and streams, suffocating mussels and burying mussel beds. An increase in nutrients and pollutants from surface runoff will decrease water quality and, depending on concentrations, kill or damage mussels. Extreme flooding can also scour the riverbed, displacing mussels and transporting them to less suitable habitat, damage mussel shells by impacts with swiftly moving debris, and cause mortality (Tarter et al., 2022).

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate sub-chapter in Chapter 6. Implementation.

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan (Conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions), three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with “NA” in the stressor column.

# Potential Conservation Actions for Aquatic Invertebrates

## Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

| Stressor | Action |
|---|---|
| | Monitor mussel populations including focus on species at risk for disease. Take samples and analyze mussels for pathogens. Document disease and pathogen spread and implement prevention measures where possible. |
| | Monitor population distribution of sensitive aquatic macroinvertebrate species in impaired water bodies. |
| | Gather information on aquatic invertebrate assemblages across different seasons in key water bodies to use as comparative benchmarks for future studies quantifying the effect of the changing climate. |
| NA | Conduct rigorous effectiveness monitoring to assess responses of SGCN and priority sensitive taxa to specific management activities to develop improved evidence-based management recommendations and avoidance measures for SGCN (Binley et al., 2025) as part of adaptive management. |

## Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.

| Stressor | Action |
|---|---|
| | Support implementation of actions that improve overall watershed health (see Watershed Health Assessment Framework). Improve water quality through excellent stewardship of the land upslope of streams to reduce sedimentation and point and non-point pollution. |
| | Work with farmers to implement practical solutions to reduce sedimentation and nutrient loading into streams (riparian buffers, cover crops, conserve wetlands, etc.). Implement regenerative and precision agriculture practices to minimize the use of pesticides, herbicides, and fertilizer, preventing subsequent runoff into adjacent water bodies. Develop best management practices with farmers and communicate them to landowners. |
| | Help develop incentives and alternative practices to reduce effects of drain tiles on streams and find practical yet more environmentally sound solutions for water storage and conveyance. |
| | Working with permitting agencies, ensure that mining operations that affect downstream waters or mining operations that occur within waters properly mitigate for effects on freshwater mussels (e.g. reducing effects on established mussel beds). Ensure proper mining standards are adhered to minimize risk of releasing heavy metals into adjacent water bodies. Perform proper remediation activities on affected water bodies to restore population of sensitive aquatic macroinvertebrate species. |

| Stressor | Action |
|---|---|
| | Work with the Army Corps of Engineers and others dedicated to problematic non-native species to reduce opportunities for invasive species to enter Minnesota waters and to mitigate the effects problematic species already present. |
| | Support projects that focus on stream restoration, dam removal and replacement with rock arch rapids, restoration of natural water connections, the installation of effective fish passages, and mussel species reintroductions when and where appropriate. |
| | Promote the establishment of riparian buffers, native plantings, filtration ponds, and wetland basins. Insure the proper treatment of wastewater and stormwater. Mitigate ammonia runoff and point sources, especially during spring and summer when juvenile mussels are most vulnerable. Investigate surfactant levels in lakes with high residential land use. Bolster water quality standards sufficiently to minimize effects on native mussels. |
| | Improve aquatic biodiversity and create a robust native community by stocking mussels when and where appropriate. |

## Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.

| Stressor | Action |
|---|---|
| | Develop best management practices and communicate them to farmers, landowners, and public regarding solutions to reduce sedimentation and nutrient loading into streams (e.g., riparian buffers, cover crops, conserve wetlands, regenerative and precision agriculture practices, reducing effects of drain tiles) to minimize effects of runoff into adjacent water bodies. |
| | Engage with community members who enjoy water bodies recreationally to increase awareness around the importance of healthy aquatic invertebrate communities to support the overall health of the aquatic ecosystem. |
| | Increase education and enforcement efforts for decontamination of aquatic vessels to prevent transport of invasive macroinvertebrate species to new water bodies. |
| | Continue to implement proven aquatic invasive species detection and prevention methods (e.g. Clean, Drain, Dry educational initiatives for boaters). |

## Case Study: Spectaclecase, an Example of Full-circle Conservation

Through decades of collaboration with many partners and funding from the State and Tribal Wildlife Grants Program, the spectaclecase is just one example of freshwater mussel conservation coming full circle in Minnesota. The spectaclecase is a long-lived (over 100 years) mussel found in cavities within piles of large boulders and slab rocks in a few locations in the Mississippi and St. Croix rivers in Minnesota. Given this unique and difficult-to-survey habitat, it is a challenging species to study, but survey data collected by the DNR and other agencies suggest that the species has declined. Spectaclecase currently occupies four HUC8 (a hydrologic unit code the typically describes a medium-sized river) basins in Minnesota (extirpated from 1). The Lower St. Croix basin is one of only a few strongholds currently remaining for this species across its range. Spectaclecase received protection under the Endangered Species Act (ESA) in 2012, and since then the DNR and its partners have been working to restore the spectaclecase populations in the Upper Mississippi River basin.

There are a number of reasons why mussel species are in decline but given freshwater mussels' need for host-fish to complete their life cycle, understanding specific host needs for a freshwater mussel species is critical to its conservation. Since the hosts for spectaclecase were unknown at the time of its listing under the ESA, host-fish identification was a high priority conservation action. The DNR and University of Minnesota (UM) spent many years conducting laboratory trials to identify the host for spectaclecase without any success. Then, after realizing that spectaclecase found upstream of the St. Croix Falls Dam were showing no signs of reproduction, the DNR and UM deduced that the absence of host-fish upstream of the dam could be the reason why spectaclecase were unable to reproduce. A search began for fishes that were missing upstream of the dam, and Mooneye, Goldeye, and American Eel were identified. Host-trials for these three species determined that Mooneye and Goldeye are indeed hosts for spectaclecase, and finding glochidia (larval mussels) on the gills of Mooneye in the wild corroborated the laboratory results.

Ever since appropriate hosts were identified in 2017, the DNR has been culturing spectaclecase, with the plan to reintroduce them into the Mississippi and St. Croix rivers to bolster populations. At the DNR's mussel facility in Lake City, the first few years of spectaclecase culture begins in a laboratory setting. Optimal flow rate, sediment type, sediment size, water temperature, and feeding regimes have been experimentally determined to maximize their survival and growth. The mussels continue growing in storage totes in the river for a few more years until they are big enough to tag and are more resistant to predation. The DNR's first spectaclecase cohort was produced in 2017 (130 individuals) and is planned to be reintroduced in 2025. In the coming years, they will be monitored for signs of growth, survival, and recruitment – which are indicators of a self-sustaining population and the ultimate sign of conservation success.

Next steps for the spectaclecase include continued culturing of additional cohorts to support genetic robustness. Additionally, the DNR plans to collaborate with partners to better understand their unique habitat requirements and incorporate creation of additional spectaclecase habitat into future stream restoration projects.

*Photo: Spectaclecase mussels, DNR Center for Aquatic Mollusk Programs*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# TERRESTRIAL INVERTEBRATES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Eucera albata, a long-horned bee, visiting purple prairie clover, Rachel Kranz; Regal fritillary on milkweed, Bob Dunlap; Dakota skipper, Bob Dunlap; Hairy-necked tiger beetle, Bob Dunlap

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# Terrestrial Invertebrates

## Overview

This sub-chapter highlights different groups of terrestrial invertebrates, including insects, spiders, and snails. Only a few of these species groups have been well-surveyed in Minnesota. For aquatic invertebrates, including mussels and insects such as dragonflies and caddisflies, please see the Aquatic Invertebrates sub-chapter. The paragraphs below provide insights into the diversity of invertebrates in our state.

## Insects

The diversity of insects in Minnesota is likely greater than the combined diversity of all other animals, yet we know very little about most insect species. Our conservation status assessment includes approximately 3,500 insect species, but the true richness is likely 30,000 or more species (Jessica Petersen, DNR, pers. comm). Insect groups for which we have the best statewide information include grasshoppers (Acrididae; Haarstad 1990), stink bugs (Pentatomidae; Koch et al. 2014), ground beetles (Carabidae; Gandhi et al. 2005), bees (Anthophila; Portman et al., 2023), butterflies and moths (Lepidoptera), and tiger beetles (Cicindelidae). These groups represent a tiny fraction of the full suite of insect species in Minnesota, leaving much yet to be discovered.

There are general concerns about declines in insects (Seibold et al., 2019), but long-term datasets to assess insect population trends are lacking. One exception is a recent analysis of butterfly monitoring projects, based on repeated transects in Midwest states (Illinois, Iowa, Michigan, Missouri, and Ohio), and North American Butterfly Association Fourth of July circle counts. Data from these and other programs were compiled into a study that estimated butterfly abundances among Midwestern species declined 17% from 2000 to 2020 (Edwards et al., 2025; State of the Butterflies Report). Nationally, 62 of 119 butterfly species (52%) showed declines, while only 25 (21%) showed increases (Edwards et al., 2025). Because population trend data are limited for most insects, other measures are sometimes used to indicate trends, such as range extent of the rusty patched bumble bee (*Bombus affinis*) and extent of occupied overwintering area of the eastern migratory monarch butterfly (*Danaus plexippus*).

Acknowledging that it is not feasible to survey all groups of insects for which we lack information, the following groups could be prioritized for future baseline surveys:

- Fireflies (Lampyridae) are completely missing from the Minnesota Species of Greatest Conservation Need list due to lack of preliminary surveys and understanding of their biodiversity.
- Hover flies (Syrphidae), to better understand biodiversity and contributions to pollination.
- Bee flies (Bombyliidae), to better understand biodiversity and contributions to pollination.
- Beetles, such as leaf beetles (Chrysomelidae) that require specific plant species for food or other critical resources, may be of conservation concern if their required plants are under threat.
- Robber flies (Asilidae) could be of conservation concern given that most are predators and some may be habitat specialists.
- Many bush crickets (Tettigoniidae) are likely habitat specialists and prairie endemics, but their diversity is poorly understood.
- A statewide survey of ants (Formicidae) is warranted, as ants are known to be indicators of functioning ecosystems (Underwood & Fisher, 2006).

Lacking basic biological information about so many species, each with a unique role in sustaining the health of natural communities, compromises our ability to address their conservation needs. There is an immediate need to document the diversity of insects in Minnesota before further losses are sustained and therefore go undocumented (Cardoso et al., 2020).

## Bees

Thanks to a statewide bee survey completed in 2022, we now know that Minnesota hosts over 500 native bee species, and around a dozen non-native species (Portman et al., 2023; see the Minnesota Statewide Bee Survey report). This preliminary list provides a baseline for conservation. This list is rapidly evolving, and updated to accommodate new findings, most recently to add two species that had not been documented in Minnesota in over 50 years. In addition, we are continuing to add more information about the 30% of bee species that are considered oligolectic, or specialists on a particular species or genus of plant pollen that they provide to their brood. These specialist species were designated as SGCN due to their being environmentally constrained to a limited resource, making them vulnerable to threats such as climate change, development, and natural system modifications. We know far more than we did 10 years ago about the bees of Minnesota, but we still have a lot to learn about population locations and their trends. See Native Bees of Minnesota for more information.

*Photo: Eucera albata, a long-horned bee, visiting purple prairie clover, Rachel Kranz*

Because bees rely on nectar and pollen from flowers, and most bee species gather plant pollen to feed their broods, bees are often considered the most important animal pollinators. Global threats to bees include loss or degradation of habitat, climate change, phenological mismatches between flower bloom time and bee flight period, insecticide exposure, parasites, pathogens and disease, and low genetic diversity (Lima et al., 2022). Pathogens, disease, and low genetic diversity are thought to be the primary threats to bumble bees (Cameron et al., 2011). There are several boreal species (e.g., *Osmia neactica*) on the southern edge of their range in Minnesota that are threatened by climate change and habitat modifications. The rusty patched bumble bee is now found in only a fraction of its historical range and was listed as federally endangered in 2017 (Rusty patched bumble bee status review). It has a relatively robust population in Minnesota, particularly in comparison to many parts of its former and current range. Rusty patched bumble bee is one of the preferred hosts of Ashton's cuckoo bumble bee (*Bombus ashtoni*), a social parasite that invades the nests of other bumble bee species. Ashton's cuckoo bumble bee has not been detected in Minnesota since 1998 and may be extirpated from the state.

Conservation actions for bees include reconstructing prairie habitats, protecting remnant prairie habitats that have never been converted to row-crop agriculture, managing for floral diversity across all habitat types, conserving nesting habitat, and minimizing insecticide use. Reconstructed prairies can support robust bee communities and even some rarer species, though some at-risk species are preferentially found in remnant habitats (Lane et al., 2023). Generalists like bumble bees are attracted to habitats of many types and sizes, including urban gardens.

## Case Study: Minnesota Bumble Bee Atlas

*Photo: Tri-colored bumble bee during a Bumble Bee Atlas Survey, Mags Edwards*

The Minnesota Bumble Bee Atlas is a statewide program in which volunteers gather data to track Minnesota's native bumble bees. Interested Minnesotans participate in trainings on how to identify and survey bees. Participants select an area within the state in which to survey and conduct catch-and-release surveys of bumble bees in areas of abundant wildflowers during the period of June to September. Each bee is well photographed for identification purposes and verified by experts after the photographs are submitted online. Sites are described including all of the flowering plants and the flowers visited by bees are also recorded. In 2024, more than 240 volunteers conducted nearly 200 surveys of approximately 2,400 individual bees. This long-term dataset provides valuable information about the distribution of bumble bee species. The Minnesota Bumble Bee Atlas is run by the University of Minnesota Extension (with the Xerces Society, DNR, and support from USFWS through a competitive State Wildlife Grant). The scientific power of this effort is multiplied because it is part of the Midwest Bumble Bee Atlas, in which other states and the Xerces Society are all using the same protocols to create a seamless dataset across the region.

### Butterflies and Moths

Lepidoptera (moths and butterflies) stand out as the dominant order of herbivores in terrestrial ecosystems, both in terms of species richness and biomass (Grimaldi & Engel, 2005; Marquis, 2022). Despite this importance, most families have received little study in Minnesota historically, with most attention on butterflies (Macy & Sheppard, 1941). Recent intensive surveys – primarily by the Minnesota Biological Survey – are striving to change this. As of this writing, over 2100 species have been documented in Minnesota and more continue to be discovered on a regular basis. A conservative estimate of Minnesota Lepidoptera richness is 2500 species, but 3000 would not be surprising given many species remain undescribed due to taxonomic difficulty and/or lack of survey effort (Kyle Johnson, DNR, pers. comm.). Of the 2100+ known species in the state, the majority are poorly understood in terms of their distributions, habitat preferences, life histories, and conservation concerns. Therefore, the current SGCN list underrepresents Lepidoptera. Despite these challenges, our collective knowledge of habitat specialists and species of conservation concerns has improved drastically over the past two decades and continues to improve at a rapid pace.

Butterfly species richness and abundance have both declined in Minnesota. Eight species of butterflies are now considered extirpated or likely extirpated: Arogos skipper (*Atrytone arogos*), Assiniboia skipper (*Hesperia assiniboia*), Ottoe skipper (*Hesperia ottoe*), Uncas skipper (*Hesperia uncas*), Garita skipperling (*Oarisma garita*), Poweshiek skipperling (*Oarisma poweshiek*), Uhler's arctic (*Oeneis uhleri varuna*), and Karner blue (*Plebejus samuelis*). Likewise, only a single population of Dakota

skippers (*Hesperia dacotae*) remains despite extensive searching of historically occupied sites. Abundance has also declined among even previously common species (Jessica Petersen, DNR, pers.comm.). Similarly, there have been range contractions for species such as the regal fritillary (*Argynnis idalia*) and dusted skipper (*Atrytonopsis hianna*). Once common species like eastern tailed-blues (*Cupido comyntas*) and pearl crescents (*Phyciodes tharos*) are less abundant than in the past. There is a conservation need for butterfly monitoring of common species in Minnesota to document changes in abundance.

*Photo: Dakota skipper, Bob Dunlap*

Prairies, savannas, barrens, and peatlands are particularly rich in habitat specialists and species of conservation concern. Habitat loss and degradation are likely the greatest threats to Lepidoptera overall (as in the case of most invertebrates) but other important issues such as pesticides and climate change likely threaten them as well (Warren et al., 2011). The essential character of prairies, savannas, and barrens depends on periodic disturbances, notably fire and grazing. Providing these disturbances in isolated habitat remnants can have deleterious effects if not implemented carefully. Timing and intensity, both of fire and grazing, are important considerations, and leaving untreated refuges to assure adequate survival for population recovery is essential (Swengel & Swengel, 2007). Studies on how different habitat management regimes affect Lepidoptera are lacking and would be quite helpful in guiding future conservation efforts.

### Beetles

Of the 18 beetles designated as SGCN or SNI, 11 are rare tiger beetles of the genus *Cicindela*. The Laurentian tiger beetle (*Cicindela denikei*), a special concern species in Minnesota and globally vulnerable (G3), is limited to rock outcrops and sandy openings in hardwood forests in the Border Lakes Subsection. The sandy tiger beetle (*C. limbata*) is known from only one location in the state, sand dunes in Polk County, and may be extirpated now from the state. The sandy stream tiger beetle (*C. macra*) is known from several locations along moist, sandy stream shores in southeastern Minnesota. The splendid tiger beetle (*C. splendida*) requires steep clay embankments and is known from several locations in the Blufflands Subsection. The crimson saltflat tiger beetle (*C. fulgida*) is restricted to alkaline shorelines and mudflats in western Minnesota. Very few re-surveys of these species have occurred with any regularity over the past 10 years.

## Other Invertebrates

### Spiders

Despite their abundance and diversity in most ecosystems, spiders are largely understudied as a group. Yet they serve as important predators of other invertebrates and in turn serve as prey for birds and other organisms. Minnesota first listed eight jumping spiders as species of special concern in 1995. The Minnesota County Biological Survey then incorporated jumping spider surveys into their work around the state and did so through 2013. The list of spiders in Minnesota's State Wildlife Action Plan has seen some revision as new data points have been established; the most recent revision takes into consideration recent collection work and citizen-science data from websites such as iNaturalist and BugGuide.

The greatest threat to Minnesota's rare spiders is habitat loss: both quality and connectivity. Thankfully, their conservation can be tied to conservation of other species through habitat preservation efforts that benefit rare birds, butterflies, plant communities, etc. For example, one jumping spider (*Tutelina formicaria*), listed as threatened in Minnesota is only known from protected sand prairies in Anoka County (although also distributed in other states). A couple of other species of special concern are denizens of rare plant communities that in Minnesota are limited to goat prairies of southeastern Minnesota. The updated list has more diversity than in the past with four jumping spiders, an orbweaver, a cobweb spider and a purse-web spider. For some, extensive surveys in appropriate habitat have indicated their rarity. Other species occur on the updated list because of their limited dispersal methods or their medical significance to humans. Spider distributions are poorly understood in Minnesota and additional survey work could reveal their true abundance and improve plans for their conservation.

While some spider collection has occurred historically in Minnesota, most notably by Willis J. Gertsch (1930s), Daniel T. Jennings (1960s), Bruce Cutler (1970-90s), and more recently William J. Ehmann (1996-2015), such collections were often focused on one taxon (Richman & Cutler 1978; Cutler & Jennings 1992; Ehmann 2002, 2011; Ehman & Boyd 1997), limited in their geographic scope (Cutler et al. 1975; Heimer et al. 1984) or both (Jennings & Cutler 1996). As a result, significant gaps remain in the knowledge of not only which species occur in Minnesota, but how they are distributed within the state.

Recent work has been done to improve our understanding of spider distribution in Minnesota by reviewing the taxonomic literature, finding museum records, collecting and identifying spiders throughout the state and monitoring citizen-science websites such as BugGuide and iNaturalist. Nearly 2,000 county records have been documented by photographs taken by Minnesotans in an iNaturalist project established specifically for Minnesota spiders (Chad Heins, Bethany Lutheran College, pers. comm.). The collection housed at Bethany Lutheran College currently has 3,087 catalogued vials representing 34 families collected in 70 of Minnesota's counties. These include several first state records as well as species awaiting formal description, with a formal checklist in preparation (Heins, in prep).

Presently in Minnesota we have confirmed the presence of 543 species of spiders, while there may be as many as 600-800 species (Chad Heins, pers. comm.). We still know very little about spider distributions in Minnesota, let alone North America. In 2024, Chad Heins found three new species for Minnesota's list. The closest literature records for those species were Colorado, eastern Illinois, and Michigan.

*Photo: Sub-female Paradamoetas fontanus, a jumping spider, Chad Heins*

## Snails

Minnesota is home to approximately 80 species of native terrestrial snails and slugs (gastropods). Terrestrial snails can be found in most habitats in Minnesota ranging from semi-aquatic marsh edges to mesic bluffs. Terrestrial snails are grazers of organic material including detritus, rotting wood, and algae; they also serve as food items for other organisms. Despite nearly ubiquitous distributions, there have been no recent concerted statewide surveys for terrestrial gastropods in Minnesota. Several important studies in the northwestern and northeastern portions of Minnesota have documented 60 species (Nekola et al., 1999; Nekola, 2002), however these data are over 20 years old.

The lack of recent, targeted surveys in southern Minnesota are concerning given the presumed endemism within the region. For instance, in southeastern Minnesota the bluff vertigo (*Vertigo meramecensis*) is a rare species classified as threatened in Minnesota. Along with other species of land snails it persisted in unglaciated Pleistocene refuges found on steep, moist, shaded, cool north-facing slopes and cliff faces in the Blufflands Subsection. Bluff vertigo also occurs on algific slopes and moderate cliffs but generally avoids areas with continuous cooling from cold air or water discharge. It is known to occur at only six sites in Minnesota in Olmsted, Winona, and Wabasha counties, not all of which are protected.

Further conservation issues arise with snail taxonomy due to strong roots in morphological species concepts and a high potential for ecophenotypic plasticity. This has led to lingering questions about the taxonomic distinctness and overall distribution of some of the SGCN land snails.

## SGCN and SNI Summary Information

There are 267 terrestrial invertebrate Species in Greatest Need of Conservation (SGCN): 117 bees, 122 butterflies and moths, 11 beetles, 1 cicada, 1 leafhopper, 8 snails, and 7 spiders (see Table 2.12).

There are 434 terrestrial invertebrate Species in Need of Information (SNI): 125 bees, 10 beetles, 257 butterflies and moths, 5 flies, 6 grasshoppers, 1 millipede, 3 springtails, 4 spiders, 15 snails, and 8 true bugs (see Table 2.12). Please note that only bees, butterflies and moths, and spiders are considered to have been well-surveyed in Minnesota, such that the number of species assessed is somewhat close to the number of species likely present in the state. Other groups are much more under-surveyed. For the full list of SGCN and SNI invertebrate species, see Appendix B.

**Table 2.12. Summary of number of species of terrestrial invertebrate SGCN and SNI.**

| Species Group | No. of SGCN | No. of SNI | Total Assessed | No. of SGCN removed from 2015 List | No. of SGCN added to 2015 List | No. of SNI added |
|---|---|---|---|---|---|---|
| Bees (Class Insecta; Order Hymenoptera) | 117 | 125 | 515 | 0 | 112 | 125 |
| Beetles (Class Insecta; Order Coleoptera) | 11 | 10 | 89 | 1 | 3 | 10 |
| Butterflies, Moths (Class Insecta; Order Lepidoptera) | 122 | 257 | 2087 | 6 | 95 | 257 |
| Flies (Class Insecta; Order Diptera) | 0 | 5 | 67 | 0 | 0 | 5 |
| Grasshoppers, Crickets (Class Insecta; Order Orthoptera) | 0 | 6 | 11 | 0 | 0 | 6 |
| Millipedes (Class Diplopoda) | 0 | 1 | 1 | 0 | 0 | 1 |
| Snails, Terrestrial (Class Gastropoda) | 8 | 15 | 81 | 0 | 3 | 15 |
| Spiders (Class Arachnida; Order Araneae) | 7 | 4 | 528 | 6 | 3 | 4 |
| Springtails (Class Collembola) | 0 | 3 | 3 | 0 | 0 | 3 |
| True Bugs, Cicadas, Leafhoppers (Class Insecta; Order Hemiptera) | 2 | 8 | 12 | 2 | 1 | 8 |
| **TOTAL** | **267** | **434** | **3394** | **15** | **217** | **434** |

## Habitat Associations

Terrestrial invertebrate Species in Greatest Conservation Need use a broad range of habitats (see Table 2.13). Some species, especially those with more general habitat requirements, were assigned to multiple habitats. Appendix D provides a comprehensive list of the animal SGCN and into which habitats they associate. Spiders' habitat use was further distinguished into primary or secondary. Primary habitats are those that a species uses most consistently and is most reliant on; if it were gone or degraded, it would have the greatest effect on the species. Secondary habitats are those where a species can be found some of the time, but less frequently than a primary habitat.

Overall, prairies and grassland provide habitat for the greatest number of terrestrial invertebrate SGCN. Savanna, cliff, talus, and rock outcrops and non-forested wetlands also are habitat to many SGCN.

**Table 2.13. Numbers of Terrestrial Invertebrate Species in Greatest Conservation Need and their associations with habitat types (includes only terrestrial species of beetles and snails).**

| Habitat Type | Bees | Beetles | Butterflies | Moths | Snails | Spiders | True Bugs | Total |
|---|---|---|---|---|---|---|---|---|
| Prairie and Other Grasslands | 83 | 4 | 15 | 56 | 2 | 6 | 2 | 168 |
| Savanna | 4 | 6 | 8 | 40 | 0 | 5 | 0 | 63 |
| Upland Conifer Forest and Woodland | 5 | 2 | 5 | 7 | 5 | 0 | 0 | 24 |
| Upland Deciduous Forest and Woodland | 9 | 1 | 0 | 4 | 6 | 2 | 0 | 22 |
| Mesic Hardwood Forest | 8 | 1 | 0 | 0 | 8 | 2 | 0 | 19 |
| Deciduous Wet Forest | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 4 |
| Coniferous Forest Wetland | 0 | 0 | 3 | 12 | 2 | 0 | 0 | 17 |
| Riparian and Floodplain Forest | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 5 |
| Non-forested Wetlands | 20 | 0 | 6 | 14 | 0 | 1 | 0 | 42 |
| Rivers and Streams | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Lakes | 4 | 2 | 0 | 0 | 0 | 1 | 0 | 5 |
| Cliff, Talus, and Rock Outcrops | 15 | 4 | 8 | 14 | 8 | 1 | 0 | 50 |
| Urban and Other Developed Lands | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 6 |

# Primary Stressors for Terrestrial Invertebrates

## Development

Habitat loss and fragmentation is among the most prevalent threats to terrestrial invertebrates currently listed under the federal Endangered Species Act (Shirey et al., 2025). Residential and commercial development is a driver of both habitat reduction and fragmentation. Indeed, the hairy-necked tiger beetle (*Cicindela hirticollis rhodensis*), a state-listed endangered species in Minnesota, is restricted to a very small area along the Lake Superior shoreline. Habitat loss and shoreline development, including breakwalls affecting natural shoreline processes, are ongoing concerns (DNR, 2022). Species of butterflies that are negatively affected by loss of habitat due to development in the Twin Cities Metro include Leonard's skipper (*Hesperia leonardus*) and Olympia marble (*Euchloe olympia*).

*Photo: Olympia marble pair mating, Jessica Petersen*

## Crop Production

Prairie species such as the Dakota skipper, Poweshiek skipperling, and regal fritillary are affected by conversion of native prairie to row crop agriculture. This loss of prairie habitat is both historical (Samson & Knopf, 1994), and ongoing in Minnesota (Lark et al., 2018).

Insecticides used to control crop pests (especially those applied towards the end of the growing season to control soybean aphids) have been correlated with the recent decline of listed grassland specialist butterflies like Poweshiek skipperling and Dakota skipper, even in protected prairies that are adjacent to row crop fields (Runquist et al., 2024).

## Livestock Management

Grazing livestock can potentially have positive effects on terrestrial invertebrates and serve as an ecological replacement for the loss of disturbance from wild ranging ungulates (i.e., bison; reducing duff accumulation and promoting growth of native vegetation). The Poweskiek skipperling, for example, appears to benefit from light, or "conservative" grazing regimes (Knight et al., 2024). However, herds that are too large or left too long in sensitive management units may have a destructive effect on native insect communities and their habitats. The term "conservation grazing" is used broadly and rigorous assessment of responses of target species and their habitats is warranted.

Care must be taken when treating livestock for pests and parasites, as treatments often contain insecticides. Some insecticides persist in the environment weeks after treatment and can harm beneficial insects and contaminate soil and water via the animals' feces.

## Mining and Quarrying

Mining for sand and gravel in Minnesota is common throughout the grassland region of Minnesota and can disturb and destroyed prairies, which could have widespread effects for many insect species, including prairie obligate species such as the Dakota skipper. Mining and quarrying operations can also cause loss of habitat for cave invertebrate species. Some species that specialize on sandy habitats, such as the ghost tiger beetle (*Cicindela lepida*) may be particularly affected by sand and gravel mining and quarrying activity.

## Roads, Trails, and Railroads

Roads can replace and fragment habitat for insects. In places where little native vegetation remains, such as in highly agricultural or developed areas, when managed well, roadsides can facilitate insect dispersal and provide important nectar resources (Ries et al., 2001; Darst et al. 2024). Roadside rights-of-ways can provide native vegetation that provides valuable resources for foraging and reproducing insects, such as monarchs using milkweed (Kasten et al., 2016; Cariveau et al., 2024); indeed, roadsides and other rights-of-way have been proposed as important components of monarch conservation efforts (Thogmartin et al., 2017). When road rights-of-way are planted in non-native plants, there is a missed opportunity to provide native plants on the landscape, which can be used by a wide variety of wildlife, particularly insects (Mitchell et al. 2024). However, roads also present risks, including collision with vehicles, which vary significantly across space and species (Kantola et al., 2019; Keilsohn et al., 2018; McKenna et al., 2001). In addition, roads introduce pollutants from de-icing salts, heavy metals from vehicle wear and tear, and the legacy of leaded gasoline in Minnesota roadside soils and plants (Mitchell et al 2020, Shephard et al. 2022).

Road maintenance activities are necessary for maintaining sight lines for safety. Broadcast herbicide use can diminish nectar resources and have negative non-target effects. Frequent mowing of roadsides removes nectar resources and reduces the ability for monarch butterflies to successfully reproduce on that milkweed (Hopwood et al. 2015), although mowing earlier in the season, may be beneficial in stimulating new growth in milkweed where monarchs prefer to oviposit (Cariveau et al. 2024, Knight et al. 2024).

## Hunting and Collecting Animals

Harvest of monarch butterflies for unregulated captive rearing programs (for educational use or release) is not a recommended action due to the risk of pathogen spread and fitness consequences for wild populations (Pelton, 2018).

## Gathering Plants and Fungi

Illegal harvest of specific host or nectar plant species can negatively affect terrestrial insects that depend on them.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest of mesic hardwood forests can affect fragile spring ephemerals (wildflowers) in the understory with effects on the various bee species that are specialists of spring ephemerals. For example, the spring beauty mining bee (*Andrena erigeniae*) exclusively feeds its brood pollen from spring beauty (*Claytonia sp.*), the trout lily miner bee (*Andrena erythronii*) feeds its brood pollen from trout lily (*Erythronium sp.*), *Andrena polemonii* feeds its brood pollen from Jacob's ladder (*Polemonium*

*sp.*), and *Andrena uvulariae* feeds its brood pollen from bellwort (*Uvularia sp.*). Similarly, many of the bumble bee queens that emerge in the early spring use pollen and nectar from spring ephemerals to begin to build their colonies, including rusty patched bumble bee. Timber harvest in peatlands paints a mixed picture. Recent surveys of Lepidoptera in Minnesota peatlands show a diverse fauna in sparsely or semi- treed peatlands approximately 2-20 years after timber harvest. But latter successional stages have consistently had poor results, and even 70-year+ stands have been strikingly depauperate (lacking in species richness), perhaps due to denser stand structures that block more sunlight relative to their old growth counterparts. Taiga Alpine (*Erebia mancinus*) is a SGCN which has yet to be found in regenerating peatland habitats, even those with similar floral composition. More research over time is needed.

## Fire Management

Prairie dependent insects such as regal fritillary and Dakota skippers have been negatively affected by the alteration of fire regimes that have resulted from decades of fire suppression. Prescribed fire has been found to be beneficial for some wild bees including ground-nesting bees (Brokaw et al., 2023; Galbraith et al., 2019). However, some SGCN insects such as the crossline skipper (*Polites origenes*) and the yellow bumble bee (*Bombus fervidus*) that overwinter as larvae or nest above ground (Scott, 1979; Williams et al., 2014) many be vulnerable to spring fires.

## Invasive Species (Problematic Non-native Species)

Invasive, non-native plant species can negatively affect terrestrial insect species by outcompeting and displacing species-specific host and nectar plants. Additionally, some invasive plant species may become population 'sinks' by triggering oviposition (egg laying) on unsuitable hosts that would not have been present naturally. This has been found to be the case for monarchs ovipositing on swallowworts (Casagrande & Dacey, 2007) and Dakota skippers on invasive cool-season grasses (Nordmeyer et al., 2021).

Some non-native forbs provide nectar, pollen, and can serve as host plants for some insects. For example, Melissa blue (*Plebejus melissa*) a species in need of information, uses crown vetch as a host plant. Native plants that Melissa blue larvae use as a host plant include *Astragalus* and associated peas. Spot spraying crown vetch has perhaps negatively affected Melissa blue. Spotted knapweed provides nectar for several species of insects including Leonard's skipper and Rusty patched bumble bee, at times when no other nectar resources are available.

Some non-native bee species are thought to be contributing to the decline of native species (LeCroy et al., 2020). *Osmia taurus* was collected by the Minnesota Biological Survey at Carley State Park, near the city of Plainview in Wabasha County on May 10, 2023. At the time of the publication of the bees of Minnesota (Portman et al., 2023), there were 11 non-native species of bees documented in Minnesota. Another mason bee, *Osmia cornifrons* was documented in 2025 in the Twin Cities by community members.

## Problematic Native Species

Pickerelweed (*Pontederia cordata*) is a native, aquatic plant that is thought by some to be outcompeting wild rice in northern Minnesota lakes. Some managers are attempting to remove and control pickerelweed on lakes where wild rice is thought to have declined due to increases in abundance of pickerelweed. There are two SGCN bees, the pickerelweed long-horned bee (*Melissodes apicatus*) and the pickerelweed bee (*Dufourea novaeangliae*) that exclusively feed their brood pollen from pickerelweed and would likely suffer if populations of these species occur at or near lakes where pickerelweed is being actively removed.

## Diseases and Pathogens

Bees are affected by a number of pathogens. Pathogens spread from commercially reared bumble bee species may contribute to some of the declines in native bumble bee species (Colla et al., 2006; Szabo et al., 2012).

## Air-borne Pollution

Pesticide drift is a major issue for terrestrial insects in Minnesota. Approximately 25% of pesticides end up drifting to non-target areas, and drift can occur hundreds of miles from where pesticides were released (Albaseer et al., 2025). Prairies in agricultural areas are subject to insecticide exposure from off-site aerial spraying (Goebel et al., 2022). Prairie reconstructions on land formerly used for agriculture may also be exposed to systemic insecticides from treated seed. Systemic insecticides eventually degrade in soil, but this can take up to several years (Goulson, 2013).

Aerially applied insecticides intended to control biting insects (e.g., mosquitos; both nuisance and disease transmitting) can affect non-target species (Runquist et al., 2024). Pesticide use has been identified as one of the leading drivers of insect declines in the upper-Midwest (Van Deynze et al., 2024). Depending on the chemicals used, these can cause direct mortality upon contact/ingestion, or act as growth inhibitors causing other arthropod species to develop to maturity. Reductions of arthropods in grasslands adjacent to crop fields have been associated with soybean aphid insecticide applications up to 5 days after spraying (Goebel et al., 2024).

Biological insecticides (such as Btk, *Bacillus thuringiensis kurstaki*) used to control invasive Lepidoptera such as spongy moth, *Lymantria dispar*, can cause significant declines in native Lepidoptera species (Strazanac et al., 2007).

*Photo: Hairy-necked tiger beetle, Bob Dunlap*

## Light and Noise Pollution

Nearly half of the United States land surface has light-polluted skies (Falchi et al., 2016). Sources of light pollution at night include interior and exterior lights on homes, buildings, billboards, parking lots, and streets as well as lighted sports fields, industrial plants, and airports (DarkSky International, 2025a). Studies also point to the ecological effects created during the daytime by polarized light that reflects off surfaces such as asphalt roads, glass panes, and solar panels (Chock et al., 2021; Horvath et al., 2009). Because most of the nation's large urban areas (with multiple artificial light sources every night), are embedded in the Temperate Deciduous Forest biome, biota occupying temperate forests are the most vulnerable to these effects (Aubrecht et al., 2010).

Effects of light pollution include disrupting the behavior of amphibians whose breeding calls are delivered at night, drawing nocturnal insects to artificial lights that increase their predation risk, and disorienting birds that use environmental cues to guide their nighttime migration (DarkSky International, 2025a; 2025b). In addition, the phenology, growth rates and biomass of plants are affected (Bucher et al., 2023). Bright day and dark night cycles synchronize the internal clocks of plants

and animals, and alterations to these cycles can affect hormone production, reproductive behavior, neural activity, and metabolic functions (Bumgarner & Nelson, 2021).

Noise pollution from aircraft, vehicles, boats, and other human causes is pervasive. Anthropogenic noise was detected in 36% of national parks surveyed (Buxton et al., 2019), and 12% of wilderness areas had anthropogenic noise levels 3 decibels higher than levels predicted to occur naturally (Buxton et al., 2017). Exposure to increasing noise levels can change the spatial distribution and movement patterns of wildlife, cause avoidance of feeding and nesting areas, and interrupt sleeping patterns and communications (Kok et al., 2023). For plants, noise can reduce seedling recruitment (Phillips et al., 2021).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al. 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate sub-chapter in Chapter 6. Implementation.

Changes in temperature associated with climate change can have significant effects on ectothermic (cold-blooded) organisms, like terrestrial insects, whose development and reproduction are closely tied to ambient temperatures. Weather patterns have been shown to influence insect abundance (Muller et al., 2024). Furthermore, climate warming is driving poleward and elevational shifts in many insect species. Cold-adapted specialists may experience population declines, while warm-tolerant species expand their ranges, reshaping community structure (Parmesan, 2006; Robinson et al., 2021). Shifts in annual temperature patterns can also alter the timing and phenology of insect life cycles. In extreme cases, these changes result in mismatches between co-evolved species during critical life history stages or lead to increased voltinism — the number of insect generations per year — which can, paradoxically, cause population declines due to incomplete or poorly timed generations (Altermatt, 2010; Van Dyck et al., 2015).

Climate warming is a great threat to boreal insects near their southern range limit in northern Minnesota. Some peatland butterflies and moths are already showing worrying signs, with recent surveys failing to find them at the southern range extremes. There are also concerns that habitat shifting caused by changes in temperature and hydrology may decrease the amount of suitable habitat available for prairie butterflies and pollinators.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate sub-chapter in Chapter 6. Implementation.

Extreme precipitation fluctuations are likely to stress populations of wetland specialist invertebrates, both directly (mortality) and indirectly (habitat change). Recent surveys (2024-2025) in peatlands following unusual drought and flood cycles yielded unprecedented low numbers for some specialists (e.g. *Boloria freija*, *B. frigga*). It is plausible that such extreme years might cause extirpation of populations, especially at small and/or vulnerable sites. Likewise, for species with extremely small or localized populations, the effects of severe weather conditions can be devastating. Species that historically had larger ranges may have had sufficient population redundancy to endure local extirpation caused by severe weather or other catastrophic events.

*Photo: Regal fritillary on milkweed, Bob Dunlap*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan (Conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions), three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

Examples of conservation actions are grouped below under these three strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions combine multiple strategies, in which case we present it under the one it fits best. Actions such as those focused on monitoring might not always be tied to a specific stressor; these are labeled with "NA" in the stressor column.

*Photo: DNR surveyors for Pawnee skippers, Glacial Lake State Park, Amy Westmark*

## Potential Conservation Actions for Terrestrial Invertebrates

### Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.

| Stressor | Action |
|---|---|
| | Conduct population and habitat sampling for pathogens and pesticides. |
| | Research how native terrestrial invertebrates respond to different management regimes, including prescribed fire and grazing, with a focus on SGCN. |
| NA | Expand survey programs to monitor SGCN species and other under-studied terrestrial invertebrates. |
| NA | Encourage public participation in observational surveys through available platforms like Bumble Bee Watch and iNaturalist, and in-person events like BioBlitzes. |

### Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.

| Stressor | Action |
|---|---|
| | Prevent conversion and fragmentation of remnant habitats by pursuing protection for them, especially prairies. Many prairie-dependent SGCN insects require remnant prairies and to date have not been shown to utilize planted or reconstructed prairies or degraded grasslands. |
| | Improve planted habitats for the various species of SGCN insects that rely on specific plant species to complete their life cycle by including those plants in reconstructions, such as loosestrife (*Lysimachia*) for oil collecting bees (*Macropis*), prairie violets (*Viola pedatifida*) for regal fritillaries (*Argynnis idalia*), milkweeds (*Asclepias sp.)* for monarchs (*Danaus plexippus*). |
| | Partner with private landowners to conserve prairie and provide technical guidance. Incentivize/subsidize grassland habitat. Reconstruct native prairies. Increase crop diversity and promote perennial crops. |
| | Maintain or enhance the integrity of native plant communities by maximizing native plant diversity and reducing invasive plant species whenever possible. |
| | Follow best practices for treatment of livestock with systemic insecticides for pest or parasite control (such as ivermectin, doramectin, or eprinomectin), not to be released on conservation lands for at least 30 days following treatment. If parasite treatment is needed during the grazing period, the best practice is to remove affected animals for treatment and return them to the site after the recommended amount of time (DNR, 2025). |
| | Support and promote use of native blooming plants including host plants such as milkweed in rights-of-way and energy development projects that may benefit monarch butterflies and bumble bees. |

| Stressor | Action |
|---|---|
| | Create pollinator-friendly energy and transportation rights of way following best management practices such as Minnesota Department of Agriculture's Pollinator Best Management Practices for Roadsides and Other Rights-of-Way and resources found among the University of Illinois-Chicago Rights of Way Working Group's compilation of Best Management Practices. Example practices include seeding with native plants, mowing only the width of the area for safety or needed to protect sight lines, mowing only once per growing season, and minimizing broadcast spraying of herbicides. |
| | Identify and protect important areas for SGCN from overuse. For instance, block off important areas of beach from public access when sensitive species are present. |
| | Apply prescribed fire strategically to help manage prairies and other grasslands while also taking into consideration vulnerabilities of rare SGCN. Manage diversity of native vegetative structure and composition across the landscape and over time. Apply fire only to some areas while leaving aside skipped refuge areas to provide for recolonization of burned sites. |
| | Advocate for pesticide drift buffers. Before installing habitat on previously agricultural land treated with herbicides or insecticides, allow the land to rest before planting. A temporary cover crop may be planted during this time. Refer to herbicide rotation restrictions for forage and cover cropping systems for wait times prior to planting. This document can be used as a surrogate for native species wait times. |
| | Implement best practices for wildlife-friendly outdoor lighting, such as turning off lights when they are not needed, using timers or motion detectors, shielding lights pointed downward, and employing lights in the warmer part of the spectrum. For more detailed information, refer to solutions advised by conservation organizations such as DarkSky, the Xerces Society, and National Audubon's Lights Out Program. |
| | Increase seed collection and restoration to head-start new pockets of habitat. Balancing these benefits of local-ecotype seeds, also consider sourcing seeds from areas that are more similar climatically to future site conditions (i.e., assisted migration). |

### Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.

| Stressor | Action |
|---|---|
| NA | Develop and disseminate education materials that promote the value of terrestrial invertebrates, including Minnesota's Pollinators - DNR webpage. |
| NA | Encourage the use of the DNR Pollinator Best Management Practices and Habitat Restoration Guidelines. |
| NA | Encourage public participation in promoting habitat for pollinators including monarchs and bumble bees (see also Chapter 4. Public Engagement). |
| NA | Advise to limit commercial and recreational rearing of at-risk or declining species, particularly the monarch butterfly. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# PLANTS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Western prairie fringed orchid, Welby Smith; Lichens on talus, Cook County, Michael Lee; Goblin fern, *Botrychium mormo*, Nicholas Jensen; Great Lakes Jacob's-ladder, *Polemonium lacustre*, Welby Smith

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# Plants and Lichens

## Overview

This section provides information for Minnesota's plant and lichen species in greatest conservation need (SGCN) and species in need of information (SNI). 2,468 species of native vascular plant species (hereafter, 'plants') were assessed comprehensively for inclusion in this document using the species conservation assessment process described in the beginning of Chapter 2 (S-ranking). Non-vascular plants and lichens (1,087 species) were assessed more opportunistically and included where information was sufficient to suggest their inclusion as SGCN or SNI.

The effects of stressors and actions to take to mitigate those stressors for plant and lichen SGCN are presented in this chapter through example species or species groups. However, it should be noted that many of the stressors for plants are also described in detail within the Habitat Sub-chapters in Chapter 3. Actions to mitigate many threats to plant and lichen SGCN are mediated by habitat and so addressed in the appropriate habitat chapters.

This sub-chapter does not present actions in the same way as was done for animals. Instead, the authors preferred to highlight information needs and several case studies illustrating the application of conservation actions benefiting plant SGCN. Since State Wildlife Grant funds are not intended for direct application to plants or lichens in the same way as they are intended for animals, it also makes sense to stop short of action planning. We believe the inclusion of plants and lichen, however, will be a good resource for ecologists and land managers to learn more about the imperiled and vulnerable plants in our state so that we can all be implementing conservation actions together.

## Plants

Minnesota contains four distinct ecological biomes. This results in Minnesota having a large and variable flora, and a proportionally large number of rare plant species across all habitats found in the state. Statewide surveys for terrestrial vascular plant species have been a priority in Minnesota for over 30 years as part of the Minnesota County Biological Survey, as well as other efforts. Continued surveys, monitoring and research for all vascular and non-vascular plant species and within aquatic systems continue to be a strategic priority for the Minnesota Biological Survey (MBS) Unit with the DNR. Past efforts produced a variety of datasets and information that contributed to the conservation assessments underlying the plant SGCN and SNI lists.

*Photo: Great Lakes Jacob's-ladder, Polemonium lacustre, Welby Smith*

## Lichens

Lichen “species” are actually a species complex consisting of two or more, typically obligate, symbionts (organisms that mutually benefit one another). The dominant partner is a fungus, which creates the main body of the organism. The endosymbiont is either a green alga or a cyanobacteria that lives within the fungal tissue. One fungal species can contain more than one species of endosymbiont. Identification to a single species name is based on the fungal component. Historically, the study of fungi has been included within the broadest definition of the term "botany," thus, they are included with plants here. However, fungi are an entirely distinct form of life at the Kingdom level.

No statewide survey effort for fungi has taken place in Minnesota. However, there is a history of lichenology in Minnesota (e.g., Wetmore, 1978; Brako, 1981), and there are lichen experts currently active in the state (John Thayer and Otto Gockman; Gockman et al., 2020). Two experts assisted with a modified conservation status assessment process for this SWAP revision using the best available data. They are also working with the DNR’s MBS Unit to conduct a statewide survey of lichen species for conservation purposes. The SNI designation will be helpful in guiding that effort.

*Photo: Lichens on talus, Cook County, Michael Lee*

## SGCN and SNI Summary Information

Plant and lichen species were assigned to SGCN or SNI categories following the flowchart illustrated in Appendix A and summarized in the overview to Chapter 2 with one exception. For designation of SNI species, we also used a previously created Watchlist of plant and fungi that recognizes species that may be in greater conservation need, but for which insufficient information is available to inform conservation and protection decisions. In most cases, a species on the Watchlist was designated as SNI, unless it was already designated a SGCN by another factor in the flowchart.

### Plants

Of the 2467 plant species evaluated, 448 plant species were designated as SGCN and 87 designated as SNI (Appendix B). Four SGCN are federally listed. These include the dwarf trout lily (*Erythronium propullans*), Leedy's roseroot (*Rhodiola integrifolia ssp. leedyi*), prairie bush clover (*Lespedeza leptostachya*), and Western prairie fringed orchid (*Platanthera praeclara*). A total of 301 are state listed, and another 73 had been previously recognized on the DNR's Watchlist of plant and fungi species. Almost 70% of plant SGCN are categorized as Critically Imperiled (S1; 131) or Imperiled (S1S2 & S2; 174). Another 27% are Vulnerable (S2S3 & S3; 124). The remaining 19 plant SGCN were recognized as at risk through their Global Conservation Status (G-rank), state listing status, or inclusion on the Watchlist despite being categorized at the state level as Apparently Secure (S3S4 & S4; 9), Possibly Extirpated (SH; 6) or Unrankable (SU; 4). One species of plant, wild rice (*Zizania palustris*), was tribally nominated and included for having cultural significance and being of conservation concern to Indian Tribes in Minnesota.

The 448 plant SGCN represent 95 phylogenetic families. Most plant SGCN are forbs (herbaceous flowering plants) (67.8%; 304). Of those, 27 are floating or submerged aquatic plant species. Graminoids (grasses, sedges, rushes) represent the next largest proportion (22.5%; 101 species) with the majority in the Cyperaceae (59) and Poaceae (35) families. Of the remaining, 39 are trees or shrubs, two are epiphytes, and two are succulents.

### Lichens

There are 151 lichen species designated as SGCN and 130 designated as SNI (Appendix B). Thirty-two lichen SGCN are state listed, and another 67 had been previously recognized on the DNR's Watchlist of plant and fungi species. Almost 90% of lichen SGCN are categorized as Critical Imperiled (S1; 86) or Imperiled (S2; 49). Another 5% are Vulnerable (S3; 8). The remaining eight lichen SGCN were recognized as at risk through their Global Conservation Status (G-rank), state listing status, or by expert opinion despite being categorized at the state level as Apparently Secure (S4; 1), Possibly Extirpated (SH; 6) or Unrankable (SU; 1). Most lichen SNI are Possibly Extirpated or Unrankable but due to insufficient information.

## Habitat Associations

Plant SGCN are geographically distributed across all parts of the state and found in 15 different Ecological Systems (classified by the DNR's native plant community classification system). To associate plants with the 15 habitat types in this Plan, plant SGCN were categorized by the primary Ecological System in which they are found (with a few species categorized in two main Ecological Systems). Ecological Systems were then cross-walked to the habitat types in this Plan. The primary Ecological System was assigned as the most common association via a review of occurrence data (Relevés or Natural Heritage Information System observations), and by expert opinion where those data were insufficient. Plant SGCN are organized in Appendix E by the SWAP habitat chapter that describes the species' primary Ecological System. A summary of the numbers of plant SGCN across the primary habitat types is shown in Table 2.14. Lichens were not evaluated for habitat associations.

**Table 2.14. Numbers of Plant Species in Greatest Conservation Need and their associations with habitat types.**

| Primary Habitat Type (Chapter) | Number of Plant SGCNs |
|---|---|
| Prairie and Other Grasslands | 119 |
| Savanna | 8 |
| Upland Conifer Forest and Woodland | 35 |
| Upland Deciduous Forest and Woodland | 33 |
| Mesic Hardwood Forest | 52 |
| Deciduous Wet Forest | 7 |
| Coniferous Forest Wetland | 21 |
| Riparian and Floodplain Forest | 22 |
| Non-forested Wetlands | 51 |
| Rivers and Streams | 10 |
| Lakes | 36 |
| Cliff, Talus, and Rock Outcrops | 71 |

*Photo: Botanists sampling plants in bluff prairie*

Together, prairie and savanna habitats support the largest proportion of plant SGCN statewide (28%). There are 113 plant SGCN associated with the Upland Prairie (UP) Ecological System (105 in Prairie and Other Grasslands and 8 in Savanna) and fourteen species associated with the Wet Prairie (WP) Ecological System.

Mesic Hardwoods and Upland Conifer Forest and Woodland and Upland Deciduous Forest and Woodland together account for 27% of the plant SGCN. There are 52 plant SGCN with Fire-Dependent Forest (FD) as the primary habitat, which are represented in the Upland Deciduous Forests and Woodlands chapter or the Upland Conifer Forests and Woodlands chapter. Of the 52 total species, 16 were associated with both habitats; 19 were assigned to the Upland Conifer Forest and Woodlands and 17 to the Upland Deciduous Forest and Woodlands. There are also 52 plant SGCN with Mesic Hardwood (MH) as the primary habitat.

Despite being restricted in terms of acreage on the landscape, the Cliff/ Talus and Rock Outcrop ecological types provides primary habitat for 16% of the plant SGCN, with 49 plant SGCN associated with Rock Outcrop (RO) and 22 with Cliff/Talus (CT).

## Information Needs for Plants

Despite decades of surveys documenting native plant species in Minnesota, rare plants and lichens often lack basic information on which to make sound conservation decisions. Thus, there are unmet information needs associated with most actions taken to conserve plant and lichen SGCN. This is especially true for efforts targeting individual species but can affect habitat mediated actions as well, as described in the habitat sub-chapters.

One of the most basic information needs relates to uncertainty regarding species or variety distinctions. This can lead to uncertainty related to the appropriate unit of conservation, for example an inability to distinguish a rare species or variety from a closely related common one. For example, there are 14 SGCN and 7 SNI in the genus *Rubus* in Minnesota. While the SGCN species are well defined as units of conservation, there is general uncertainty in species identification for many members of the genus. The uncertainty has many causes, from lack of basic phylogenetic research needed to distinguish genetic units, all the way to a lack of botanical knowledge, experience, and tools for in-field identification of known, well-defined species. A variety of taxonomic research and applications are needed to address gaps in this type of information. The Biodiversity Atlas, through the Bell Museum, is an excellent source of this type of botanical information when available.

There is also a widespread lack of information on rare plant species' population genetics. These data are needed to understand elements such as whether a population is experiencing in-breeding, or to identify past reductions in dispersal and genetic diversity due to threats like habitat fragmentation or loss of pollination. This sort of information is crucial to conversation actions involving population relocations, augmentations or re-introductions of rare species. For example, Leedy's rose root is stressed by a genetic bottleneck, and so population augmentation via 'headstarting' or re-introductions are being considered. Another example where relocating populations should be considered is Western prairie fringed orchid. Moving individuals to locations less vulnerable to displacement during road and trail development may help preserve genetic diversity in this species. Rare plant rescue efforts led by the Anoka Sand Plains Partnership are being conducted for a handful of other species in Minnesota. Because re-introductions, relocations or other population augmentations carry genetic risks as well as the potential for genetic benefits, these efforts should be informed by a good understanding of a species' population genetic structure and history. They also require dedicated resources for monitoring the long-term success and effects of these actions.

Another frequent gap in information about rare plants is comprehensive assessments of species' distributions. Distribution is a key biological measure of rarity used to inform a species conservation status or need for legal protection. In Minnesota, there are several taxonomic groups that, in large part, lack the basic survey data needed to fully document species' distributions. Particularly under surveyed taxa are non-vascular plants (algae and mosses), lichens and most other types of fungi. These groups need comprehensive, taxa-wide survey efforts to:

- Improve the total list of species that occur within Minnesota,
- Document species' distributions sufficient to identify rare versus common species, and
- Gather information to improve species' conservation status assessments.

The DNR's Minnesota Biological Survey began a conservation effort focused lichen species survey in 2024 to meet those objectives. Survey efforts target habitats known to contain high lichen species diversity, an abundance of rare, SGCN, or SNI lichen species, or habitats that have a unique conservation concern related to lichen SGCN.

Even when a rare plant species' distribution has been relatively well documented, further ecological data are often needed for conversation planning. Detailed population assessments, including population size, viability and geographic extent inform decisions such as sustainable foraging limits and avoiding negative effects during management or other activities in their habitats. Because these population attributes change over time, those data need to be regularly updated. To address this need, the Minnesota PlantWatch program was launched in 2023. See the Case Study section for more information on Minnesota PlantWatch.

Regular population assessments to update status, while valuable in many ways, are typically not sufficient to quantify trends in population viability. Detailed demographic monitoring is the best way to predict future trends. These studies can be done to determine viability alone or designed to assess the effect of disturbance or management actions on population viability. Trend information is one component of conservation status assessments and is useful in many aspects of conservation planning. See the Case Studies section for an example of long-term demographic monitoring for Western prairie fringed orchid.

Like monitoring a rare species population, monitoring a rare species' habitat is crucial to documenting and predicting trends in habitat attributes. Many aspects of rare plant conservation are mediated by elements of the habitat, such as habitat size, connectedness, quality, or disturbance history. For an example of long-term SGCN habitat monitoring, see the Case Study: Ecological Monitoring Network in the Chapter 5: Monitoring or visit the Ecological Monitoring Network website.

*Photo: DNR staff conducting ecological monitoring*

## Case Study: Minnesota PlantWatch Population Assessments

Rare plants are a strong indicator of overall ecological health and areas with a higher diversity of native plants can support more birds, insects, and other wildlife species. Healthy ecological communities are more resilient to threats such as climate change, invasive species, and disease. Minnesota is home to more than 1,700 vascular plant species, of which over 300 are listed as Endangered, Threatened or of Special Concern. For many of these rare plants, data on their distribution, population status, threats and potential management needs are incomplete. Current information will inform the best methods for protecting and managing these unique species.

Established in 2023, MN PlantWatch is a community science initiative that conducts detailed population assessments for rare plants in their natural habitats. Volunteers are trained to conduct surveys for rare plants in their natural habitats and collect data on population size, phenology (time of the year for biological phenomena) and extent. They also provide information on the rare species' habitat type, the quality of the site and the presence of threats. These data are used to keep the State's Natural Heritage Information System up to date and are provided to landowners and administrators to support on the ground conservation efforts.

MN PlantWatch volunteers also collect seed for conservation seed banking at the University of Minnesota's Landscape Arboretum's Rare Plant Seed Bank. Seed banking is done to help preserve the genetic diversity of a species across its range, provide material for re-introductions or augmentations, and allow for research opportunities to better understand the species.

In its first two years, MN PlantWatch engaged 69 volunteers, logged over 2,500 volunteer hours, completed 141 surveys, within which 63 populations of rare plant species were re-located and assessed, and collected seed from 33 populations.

This program is a collaboration between the University of Minnesota Landscape Arboretum Plant Conservation Program and the DNR's Minnesota Biological Survey, with additional support from The Bell Museum of Natural History, The Minnesota Native Plant Society, and The Minnesota Master Naturalist Program. As of 2025, the program is funded by the Minnesota Environment and Natural Resources Trust Fund (ENTRF) as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

## Primary Stressors for Plants

Stressors are factors that pose direct or indirect challenges to vulnerable plant and wildlife species. Habitat loss and degradation are generally considered the primary threat for most SGCN, and some stressors reduce the quality of those habitats. Other stressors may operate more directly on the SGCN, such as disease and pathogens. In some cases, stressors may operate both directly and indirectly. For example, roads, trails, and railroads can directly harm SGCN through vehicular strikes, or operate indirectly through habitat fragmentation and reduced landscape connectivity. The stressor list below is adapted from an internationally recognized threats classification developed by the International Union for the Conservation of Nature (Salafsky et al. 2024). For more information, see the "Stressors" section of Chapter 1. Species in Greatest Conservation Need.

It is important to note that some factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this species group is included below.

The effects of loss or alteration of natural ecological dynamics through fire suppression, dams in streams and rivers, and loss of wild-ranging ungulates to plant and lichen SGCN are variable, wide-spread, and habitat specific. Please see discussions of these in appropriate habitat sub-chapters within Chapter 3.

## Development

The development of land for housing and other urban land uses encroaches on or destroys habitat for many plant SGCN. Development pressure varies across the state and by habitat or substrate type and so actions will be addressed in habitat chapters. One area in the state under high development pressure is the Anoka Sandplains. Development in this area makes it more difficult to achieve prehistoric fire frequencies, reducing the quality of habitat for fire-dependent plants. Also, development can fragment and isolate populations of SGCN whose state-wide population core resides mostly in this area, such as bristle-berry (*Rubus stipulatus*).

## Crop Production

The conversion of natural habitat to rowcrop agriculture, livestock operations and similar uses encroaches on, degrades or destroys habitat for many plant and lichen SGCN. For example, one of the rarest plant species in Minnesota, ball cactus (*Coryphantha vivipara*), historically occurred in thin-soiled prairies which were largely converted to agriculture; most of its potential habitat in Minnesota has been lost. Agricultural pressures vary across the state and by habitat, although they are especially impactful in grasslands. Actions will be addressed in habitat chapters.

## Mining and Quarrying

Mining and quarrying affect plant and lichen SGCN primarily through direct, often complete, loss of habitat. Habitats with extensive exposed bedrock are most at risk, thus actions to this threat will be addressed in Cliff, Talus, and Rock Outcrop chapter. The ball cactus, for instance, occurs in crevices on granite outcrops, and while its habitat has been lost extensively due to agriculture, its remaining populations could be affected by granite quarrying. Generally, avoidance is key to conserving SGCN potentially threatened by mining and quarrying.

Another example of a plant SGCN threatened by mining and quarrying is wolf's spikerush (*Eleocharis wolfii*). The known habitats of this species in Minnesota are associated with level outcrops of bedrock in the southern part of the state (Minnesota River Prairie and Inner Coteau subsections). Specifically, it resides in the margins of shallow rainwater pools that form in depressions on the bedrock or in thin sediments over the bedrock within a prairie or savanna setting.

Wild rice (*Zizania palustris*) could be affected by mining and quarrying development near shallow lakes.

Many lichen SGCN are also vulnerable to effects from mining and quarrying operations given their high diversity in rock-dominated habitats. For example, Bloody Beard Lichen (*Usnea mutabilis*) is a Minnesota State Threatened species that occurs primarily on sandstone outcrops near cool rivers associated with a variety of other lichen and moss species. It has been documented living on wood in other parts of its global range. We know very little about why it is restricted to outcrops in Minnesota.

## Roads, Trails, and Railroads

SGCN species that can persist in marginal habitats are particularly at risk from maintenance of roads, trails and railroads. Lance-leafed violet (*Viola lanceolata*) is a prime example of a species that is frequently found persisting in this type of altered or fragmented habitat. It is a pioneer species that does not compete well with larger, later successional species. It requires some disturbance to its habitat to be successful. In some cases, anthropogenic (human) disturbance that removes competing vegetation and releases the seed bank can be beneficial to the species. But these activities can also degrade or destroy the habitat beyond what lance-leaf violet can tolerate.

As detailed in the Information Needs section, Western prairie fringed orchid is another example of a species highly vulnerable to road and trail development.

## Gathering Plants and Fungi

Species threatened by gathering pressure in Minnesota include ball cactus, many species of orchids for horticultural purposes, and American ginseng (*Panax quinquefolius*) for its medicinal value.

American ginseng is a perennial herb native to hardwood forests in eastern North America. The roots are commercially harvested, with interstate and international trade regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and harvest further regulated in Minnesota under Minnesota Rules, Chapter 6282. It is listed as a Species of Special Concern in Minnesota. Early harvest was unsustainable across the Eastern United States, resulting in wild ginseng being quite uncommon in Minnesota today. Under the CITES treaty, the export of wild ginseng root can only be allowed if a state can demonstrate that continued export will not cause ginseng populations within that state to decline any further. At this time, Minnesota is considered in compliance. However, populations are currently so depleted and fragmented that adequate recovery is unlikely without further restrictions on harvest. The DNR hosts a webpage to help collectors assure the future of wild ginseng in Minnesota.

As the example of American ginseng illustrates, protecting plant species at risk from gathering requires a multifaceted approach. First, species-specific research and monitoring are needed to determine the level and methods for sustainable harvest. Then outreach and education on those sustainable harvesting practices will need to be ongoing. Designating species with the appropriate legal protection to stop gathering when sustainable harvesting cannot be achieved is critical. Lastly, the threat of gathering cannot be mitigated without adequate resources toward the enforcement of either a species' legal protection status or sustainable harvest regulations.

## Timber Harvest

Timber harvest is a forest management tool that can affect plant habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest can have a variety of effects on plant and lichen SGCN. Effects can be direct, such as removal of their microhabitat, or indirect, such as changes to the forest dynamics or structure. Specifics about this stressor and actions to mitigate those effects are addressed in appropriate habitat sub-chapters.

## Recreation

Recreational activities can have a variety of effects on plant and lichen SGCN, including fragmentation by trails, soil compaction by trampling, and degradation through introductions or spread of invasive species. These are often habitat specific and will be addressed in appropriate habitat chapters.

## Fire Management

Fire suppression has caused habitat degradation for some SGCN in fire-dependent habitat types. For example, many prairie plant SGCN of the great plains have their most eastern populations in Western Minnesota's dry prairies. In the past, many short statured plants like cross-leaved milkwort (*Polygala cruciata*) or prairie shooting star (*Dodecatheon meadia*) were maintained by fire and grazing in prairie systems, which would have created light openings for these plants. Other species, like Kinnickinnick Dewberry (*Rubus multifer*) or kitten-tails (*Synthris bullii*), occur in the transitional communities between prairies and forests that were also maintained in greater abundance by past fire and grazing regimes.

Applying prescribed fire can be an effective way to bring disturbance to fire-dependent plant communities but also presents a risk to the rare plants present - careful planning regarding refugia (sheltered areas) and timing is required.

## Invasive Species (Problematic Non-native Species)

The effects of invasive species on plant and lichen SGCN cannot be overstated. Here also, effects can be direct, species-to-species competition for space or resources, or indirect, such as degradation due to the release of allelopathic chemicals (inhibit the growth of other plants) into a SGCN's habitat. Negative effects are variable, widespread, and habitat specific. They will be addressed in appropriate habitat chapters.

## Problematic Native Species

Native wild rice is at risk of genetic modification due to the introduction of cultivars for commercial harvest into wild lakes, or due to the close proximity of commercial rice fields to natural wild rice beds. There are also no requirements to use wild type seed for wild rice restorations.

## Diseases and Pathogens

The threat of disease and pathogens cannot be overstated, as they have the capacity to cause large-scale, rapid declines to even seemingly secure species. For example, butternut (*Juglans cinerea*) was once common throughout the Eastern United States, including Minnesota. A lethal fungal disease, butternut canker (*Ophiognomonia clavigignenti-juglandacearum*), reached Minnesota in the 1970s, and as of today, nearly all butternut trees in the state are dead or dying. Active research into treatment options and the potential for population augmentations using naturally occurring resistant genotypes is on-going.

Diseases and pathogens can also have indirect effects on plant and lichen SGCN. *Caloplaca parvula* is a Minnesota State Endangered lichen species endemic to the Great Lakes region. It has been documented in two counties in Northeast Minnesota and is found almost exclusively on black ash trees. This species is at risk of being lost from the state as Emerald Ash Borer continues to spread throughout Minnesota, effectively destroying this species' habitat.

## Air-borne Pollution

Plant and lichen SGCN are most affected by water-borne and air-borne pollutants. For example, many lichen species are sensitive to air pollution. Salted Shell Lichen (*Coccocarpia palmicola*) is a Minnesota State Threatened species only documented in two counties in Minnesota. This species is thought to be particularly sensitive to air pollution, believed to be the cause of its decline throughout the Midwest.

## Water-borne Pollution

Wild rice, like many aquatic plant SGCN, can be affected by polluted runoff into lakes and rivers. Water-borne pollutants can be introduced from a variety of sources, for example from mining and quarrying and industrial effluent, and will be addressed in the appropriate habitat chapters. Broadly, increased resources for monitoring and sampling of water quality are needed to detect and correct polluting activities that threaten aquatic SGCN habitat. These data will also aid in planning, helping to, for example, prevent problematic practices in watersheds containing natural wild rice lakes.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (MPCA & MDOC, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate sub-chapter in Chapter 6. Implementation.

Minnesota supports disjunct populations of several species that are more commonly found elsewhere, often in arctic or alpine regions. These populations may possess unique genetic or ecological traits that enable them to persist in atypical habitats; however, they also tend to be small and geographically restricted, making them more vulnerable to decline. A notable concentration of such species occurs in Rock Outcrop and Lake Shore habitats along Lake Superior, where the lake's climate-modifying influence creates localized conditions resembling those of colder, high-elevation environments. Examples include butterwort (*Pinguicula vulgaris*), northern paintbrush (*Castilleja septentrionalis*), small false asphodel (*Tofieldia pusilla*), alpine bistort (*Bistorta vivipara*), and alpine bilberry (*Vaccinium uliginosum*). These specialized habitats and the rare species they support are increasingly threatened by rising temperatures associated with climate change.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which

can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding and landslide risk on steep slopes. The state-endangered Eastern hemlock (*Tsuga canadensis*) faces significant threats in Minnesota. The largest known population occurs on steep slopes within a landscape highly susceptible to landslides. Groundwater seepage has likely supported the persistence of this population, but a major rain event in June 2012 triggered slope failures throughout the area. Water flowing through sand layers confined between clay layers appears to have raised artesian pressure to a level that caused multiple landslides. As a result, four of the 17 mature hemlocks (24%) and numerous seedlings were washed away. While seedling numbers have since rebounded, most are located near the edges of landslides, leaving them vulnerable to future extreme rain events. Efforts are underway to propagate trees from local genetic stock to support population augmentation. More broadly, strategies that reduce the "flashiness" of streamflow (rapid rise in water levels) during heavy rainfall, such as stream restoration or the installation of water control structures, can help mitigate these risks and support long-term population stability.

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate sub-chapter in Chapter 6. Implementation.

*Photo: Goblin fern, Botrychium mormo, Nicholas Jensen*

## Priority Species Conservation Strategies

To implement the SGCN Goal of this Plan (Conserve rare, declining, and vulnerable wildlife and plant SGCN through targeted actions), three strategies were identified:

**Strategy 1. Survey, monitor and research to document the distribution and trends of SGCN, assess the threats they experience, and evaluate conservation actions that support resilient populations.**

**Strategy 2. Collaborate to deliver conservation actions that support resilient populations of SGCN and their habitats in partnership with agencies, Tribes, non-governmental organizations, private landowners, and others.**

**Strategy 3. Develop and share informational material to guide conservation actions for SGCN wildlife, such as species accounts, threat assessments, recovery plans, relevant regulations, avoidance measures, and beneficial habitat management strategies.**

## Potential Conservation Actions for Plants

Please see the earlier section on Information Needs for Plants; no additional conservation actions for plants and lichens were specified in this section. Many actions targeted toward habitat conservation also address plant SGCN needs. In addition, the DNR Rare Species Guide provides basic conservation actions specific to many plant and lichen SGCN species. Further development of species-specific conservation actions for plant SGCN will occur as needed, with the Rare Species Guide as the main avenue for dissemination.

## Case Study: Western Prairie Fringed Orchid

The western prairie fringed orchid is found throughout the prairie region of Minnesota. Despite this wide geographic distribution, we revisit and complete a flowering census of approximately 80% of the state's populations each season. This effort is only possible because of a collaborative effort between the DNR, The Nature Conservancy, The U.S. Fish and Wildlife Service and the National Park Service. This collaborative partnership also means that information about the species' life history and management needs are shared across the entities responsible for the conservation of this rare prairie orchid.

Capturing data on plant emergence of an herbaceous species in a grassland can be challenging. The first step requires locating plants during the growing season in the preceding season. These areas are then marked and visited in early spring. We attempted to find and measure the heights of these individuals to gauge when they emerged. After several years of data collection and anticipating the appropriate timing, we were able to identify a window of typical emergence using a growing degree day model. This understanding was critical to guide managers with the information necessary to minimize affecting this imperiled species while still carrying out needed fire management on the land, as a poorly timed fire could be fatal (Biederman et al., 2018). Additionally, by following the phenological development of individual plants, we discovered that the first plants to emerge are those that would flower in July. These plants also tend to grow more quickly, making them even more susceptible to damage and mortality with a fire too late into the growing season.

*Photo: Western prairie fringed orchid, Welby Smith*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## HABITAT

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: prescribed burn, Amy Westmark; Restoration project in Lost River enhances fish passage and aquatic habitat connectivity, Nicholas Kludt

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# Chapter 3: Habitats

## Overview

This Chapter explains the second goal of the Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for Species in Greatest Conservation Need (SGCN). This chapter emphasizes the importance of habitat for SGCN and outlines five strategies to guide habitat conservation. We explain the context of how habitats were depicted across the Plan versions and our approach to creating an updated habitat spatial layer. A set of 15 detailed habitat sub-chapters, one for each habitat, follows.

## Significance

Habitat conservation is arguably the most central pillar in recovering vulnerable wildlife. Habitat loss and degradation are repeatedly cited as the top reason for wildlife population declines. In the 2015 SWAP, 70% of the SGCN were classified as being affected by habitat-related stressors as a predominant factor (DNR, 2015). This also led the 2015 SWAP to be organized with the 'habitat approach' as the primary strategy for the Plan, a priority that is still relevant today. This makes habitat, and its conservation, the 'heart' of the Plan.

## Historical Loss

Habitats are lost from an accumulation of past and present land use changes such as conversions to development or agriculture.

Many of the natural ecosystems in our state have sustained great losses. A compelling source of information regarding historic changes in Minnesota's habitats come from a comparison of present day landcover to mapped native vegetation present during the Public Land Survey (1847 to 1907) (Marschner, 1974). A whole series of maps illustrate dramatic changes, especially in southern and central Minnesota (Marschner, 1974; Wovcha et al., 1995). In the St. Croix River Valley and Anoka Sandplain, for example, less than 90,000 acres, (6% of the total area) remained in native habitat types when the survey of these two regions was completed in 1990 (Wovcha et al., 1995; Figure 3.1). In the 35 years since that survey, additional changes have likely occurred as well. Land use change in Minnesota can also be visually depicted through historical aerial photography (see Minnesota Historical Aerial Photographs Online).

For example, the historic loss of prairie throughout North America is well-recognized; indeed, tallgrass prairies are classified as critically endangered (the highest level of imperilment short of collapse), according to a recent publication by the International Union for the Conservation of Nature (IUCN) (Comer et al., 2022 2024). The prevalence of native, remnant prairies in Minnesota has dramatically declined from once covering over a third of the state (about 18 million acres; Marschner, 1974) to about 250,000 acres today, or about 1–2 percent of the historical area (DNR, 2018).

## Ongoing Stress

Remaining natural lands are pressured by ongoing economic demands as well as effects such as pollution, invasive species, and changes in climate. These stressors are described carefully and methodically through the use of a threats lexicon (Salafsky et al., 2024). A structured lexicon better specifies the proximate causes of current-day ecological degradation and enables the targeting of conservation actions to ameliorate these threats. We call these "stressors" in this Plan and outline them in relation to SGCN and habitats (see stressor section of Chapter 2. Species in Greatest Conservation Need). It should be noted that some identified stressors might also be applied for conservation purposes, such as in 'fire management.'

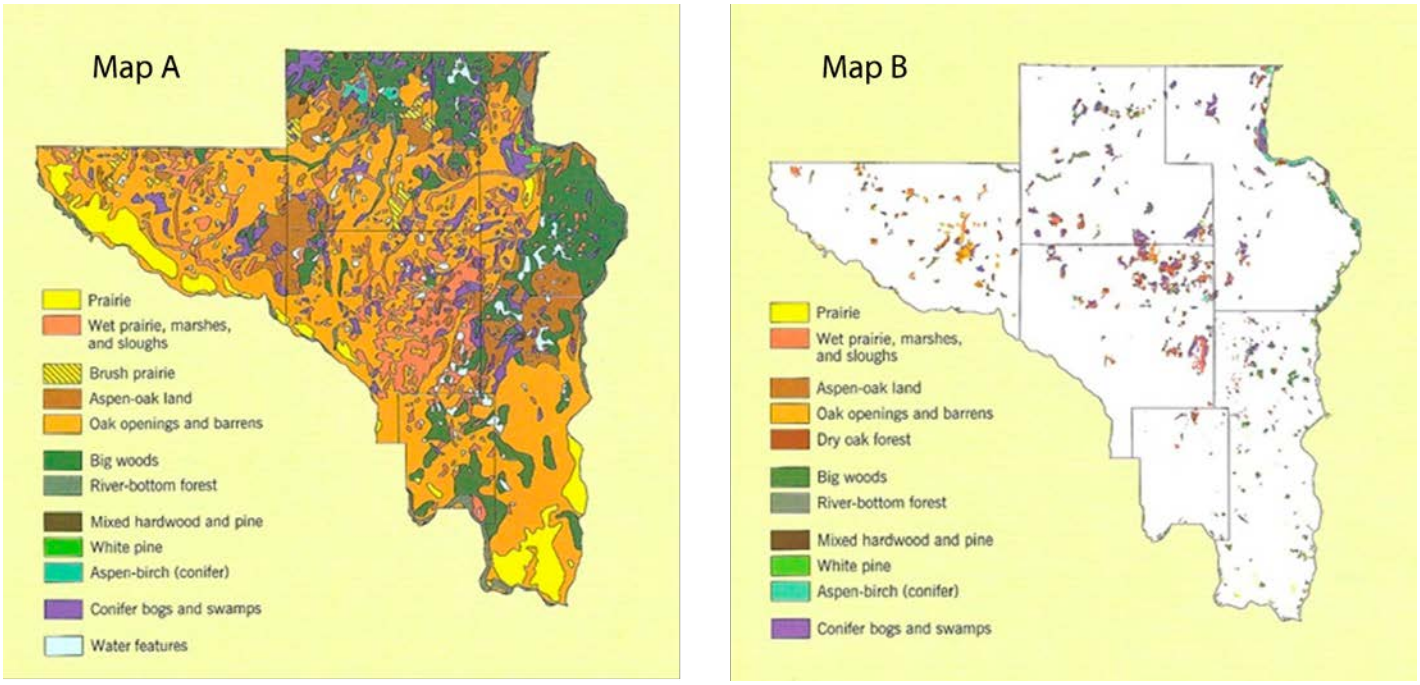


Figure 3.1. A comparison of landcover in the St. Croix – Anoka Sandplain region from the mid 1800's to 1990 (Wovcha et al., 1995). Map A depicts pre-settlement vegetation types and was compiled by FJ Marschner in 1929-30 (Marschner, 1974) using notes from the General Land Office surveys of the mid-1800's in constructing this map. Map B depicts the remaining native vegetation, as recorded by the Minnesota County Biological Survey between 1987 and 1990.

We take care to explain these nuances in the context of each habitat type. Climate change is pervasive throughout all habitat types and interacts with the other stressors. We discuss changes in temperature, precipitation, and hydrology (movement and distribution of water) within the stressors section for each habitat sub-chapter. Further background information and strategies for climate-smart management are presented in the Climate Adaptation section of Chapter 6. Implementation.

## Habitat Conservation

In this chapter we outline five strategies to implement the Habitat Goal of the SWAP (see below). Habitat conservation that is meaningful at a landscape scale requires partnerships between land managers and collaborations across land ownership boundaries. Here is a current breakdown of Minnesota land uses according to the Minnesota state land portfolio

- 5.6 million acres (11%) are state-owned, DNR managed lands
- 3.8 million acres (7%) are federally owned lands
- 2.8 million acres (6%) are state-owned, county-administered tax-forfeited lands
- 0.7 million acres (2%) are tribal owned lands
- 0.3 million acres (1%) are county owned lands
- 25.4 million acres (45%) are in agricultural use (USDA, 2024)

42 million acres (75%) privately owned (Private landowner information)

## Building on the two Prior Plans

### 2005-2015 Tomorrow's Habitat for the Wild and Rare

Minnesota's original State Wildlife Action Plan, Tomorrow's Habitat for the Wild and Rare, identified significant loss and degradation of habitat as the principal management challenge for achieving its goal to stabilize and increase SGCN populations (DNR, 2005). The principal strategy for addressing this management challenge was the need to identify key SGCN habitats and focus management efforts on them. Habitat descriptions were subsequently provided for 16 key habitats in profiles of all 25 ecological subsections in Minnesota (Ecological Classification System). Each subsection profile included a matrix of SGCN use for all habitats that occurred in the subsection along with an assessment of which habitats were the most important to the greatest number of SGCN. Conservation actions to maintain and enhance the key habitats in each subsection were delineated.

### Minnesota's Wildlife Action Plan 2015-2025

Minnesota's Wildlife Action Plan 2015-2025 identified a three-pronged approach to ensuring the long-term health and viability of Minnesota's wildlife, the first and most comprehensive being the habitat approach (DNR 2015). This Plan also presented a Wildlife Action Network to represent high-quality habitats for terrestrial and aquatic SGCN as well as movement corridors among them. To prioritize the implementation of on-the-ground conservation work with our partners, sites within the Wildlife Action Network were assigned priority rankings using five metrics including SGCN population viability and SGCN richness. These rankings were used in combination with a set of Conservation Focus Areas where resources, such as partners and/or funding, were available to address conservation needs through on the ground habitat restoration and management.

## SWAP Habitat Goal

**Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN**

## Habitat Strategies

1. **Protect,** buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.
2. **Restore**, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience
3. **Collaborate** with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas
4. **Monitor** SGCN**,** native plant communities, habitats, and ecosystems for changes through time including responses to stressors, natural disturbances, conservation actions, and climatic conditions.
5. **Connect** to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

## Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

This strategy articulates the need to protect remaining areas of quality habitat, such as remnant prairie, old growth forest, or lakes of biological significance. In addition, areas around those core areas also need safeguarding to provide SGCN access to all habitat needs throughout their annual cycle and allow for range shifts in response to potential environmental or climate related changes, thus creating a more ecologically resilient landscape. The Conservation Action Network (CAN) is a mapped resource representing important areas to the SWAP, including core areas of high biodiversity (high numbers of SGCN), highest quality habitats, and buffers and corridors to further protect and connect them. The CAN is intended to guide and prioritize conservation actions given limited resources (see Conservation Action Network section in Chapter 6: Implementation).

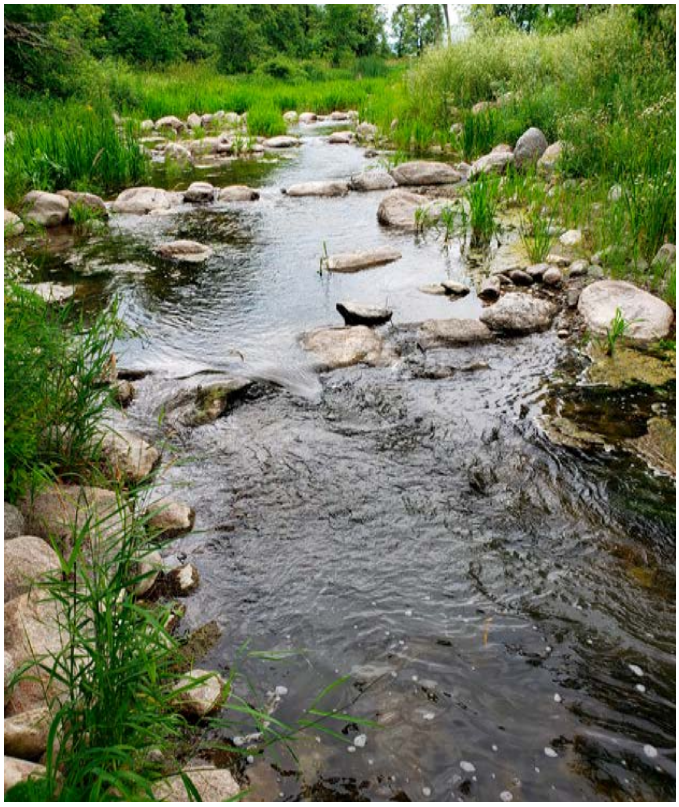

*Photo: Restoration project in Lost River enhances fish passage and aquatic habitat connectivity, Nicholas Kludt*

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

This strategy emphasizes the need to actively manage lands, often layered upon protected lands, but also can be implemented anywhere, by any land manager or private landowner who seeks to improve the ecological function of their property. Restoration projects can be dramatic, such as a prairie reconstruction where a crop field is planted and tended into prairie over time, or they can be more subtle, such as by the dedicated application of conservation practices like prescribed fire or conservation grazing. Enhancement is done by augmenting plant communities that are already present, such as by re-seeding, planting seedlings, or removing invasive species. Maintenance management is critical for many habitats, particularly those dependent on disturbance, such as fire-dependent forests, woodlands, savanna, and prairie. Invasive species management can also be an ongoing maintenance need vitally important to the function of many of our habitats, both terrestrial and aquatic.

*Photo: prescribed burn, Amy Westmark*

### Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas

This strategy calls attention to our need to work together, in broad partnerships, for ecosystem change. As detailed in the stressor sections of the various habitat sub-chapters, the extent to which our environments are affected by human activities, both past and present, require special attention to protecting, restoring, enhancing, and maintaining the habitats we have left, and optimizing their conditions to support species in need. The implementation of habitat conservation practices with a full set of partners, including private landowners, protected area managers, working land managers, and Tribes, enables us to collectively address the scale of stressors on the landscape.

This Plan relies on actions undertaken every year by numerous entities throughout the state. The role of the DNR is to facilitate partnerships with a broad array of entities so that we are working in concert. Collective actions when coordinated across entities such as municipalities, soil and watershed conservation districts, private landowners, Tribes, other state agencies, national agencies, educational institutions, and non-profit organizations will have the most impact. Most of work we do is in partnerships.

The Conservation Action Network can be used in a planning context to focus attention on core areas of high biodiversity, the highest quality habitats, and buffers and corridors protect and connect them. You can find more about the CAN in the Conservation Action Network section of Chapter 6. Implementation.

Conservation Opportunity Areas (COAs) are places where on-the-ground conservation actions are concentrated to benefit SGCN and their habitats. COAs build on the Conservation Action Network. The COAs are prioritized areas delineated specifically for partnerships to focus efforts together on habitat conservation projects designed to benefit SGCN. For more information, please see the Conservation Opportunity Areas section in Chapter 6. Implementation.

It should be noted that collaboration as an approach truly applies to all actions in the Plan, as all conservation actions would benefit by broader implementation by a greater number of entities in more locations.

*Photo: Biologists and Producers on Field Tour at Hole in the Mountain Wildlife Management Area, T.J. Boettcher*

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions

This strategy highlights the importance of scientific information to inform our conservation actions. We need baseline information about our natural communities to learn about changes that may be happening in the systems such as in response to changing climatic factors. Well-designed monitoring projects provide insights about the effects of conservation actions as distinguished from natural changes that are happening in the system. Layered on this we need a sound understanding of whether the conservation actions create persistent change (effectiveness monitoring) and whether SGCN are responding positively to those changes as desired (response monitoring). Greater research into the threats that cause ecosystem change can also help to direct conservation efforts. Also refer to Chapter 5: Monitoring and Research for a comprehensive assessment of monitoring and research needs and approaches.

*Photo: monitoring native plant community*

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

The SWAP puts science into action. However, sometimes there is a deficit in knowing what to do to help particular SGCN on their road to recovery. And, as much as we know about managing healthy ecosystems, we are still learning more each year about practices that are most effective and how in turn these conservation practices may help SGCN. Indeed, there is still a great unfulfilled demand for information to guide conservation efforts by habitat managers and landowners throughout the state.

In some cases, research or investigations are needed to develop the management guidelines, avoidance measures, or habitat best management practices. More studies about the effectiveness of our conservation practices, in learning whether or how species are reacting to our management actions, are essential (see Chapter 5: Monitoring and Research).

In other cases, there may be good knowledge of conservation actions coming out of the research community or become known through applied conservation practice that requires translation into easily applied materials and resources. There is a huge opportunity to investigate, collate, and write up habitat management guidance for more SGCN.

Sometimes existing and emerging resources just need better communications to put them into the hands of more practitioners. Examples include the Landowner Guides to Woodlands, Native Plant Classification guides, and climate adaptation resources. Workshops, field trips, and engaging webinars may work well for engaging managers, with one-pagers and webpages to provide the materials. Sometimes it is a matter of spreading the word, such as when new research or threats assessments or

*Photo: Sharing information about managing habitat for pollinators at Whitewater State Park, Alison Cariveau*

best management practices become available. This is a parallel strategy to Strategy 3 in Chapter 2: Species in Greatest Conservation Need and overlaps also with some of the strategies and actions in Chapter 4: Public Engagement.

## Conservation Actions

Strategies are implemented by conservation actions, which are described in the habitat sub-chapters. These potential conservation actions are grouped under the five strategies and are related to stressors they address with icons (see also Stressors and Actions section in Chapter 2. Species in Greatest Conservation Need). Some actions are widely employed as best practices while others may be more novel.

## Habitat Definition

The term 'habitat' can be used in several ways and warrants clarification (Krausman and Morrison 2016; Hall et al. 1997). Specifically, habitat may be defined as, "the resources and conditions present in an area that produce occupancy, which may include survival and reproduction, by a given organism" (Krausman and Morrison 2016). In contrast to this definition that is organism-specific, 'habitat type,' can be defined to mean, "type of vegetation association in an area or to the potential for vegetation to reach a specified climate stage" (Krausman and Morrison 2016 based on Daubenmire 1968).

In this Plan, we use the term 'habitat' broadly, like the 'habitat types' defined above. We take this approach because with over 1,000 Species in Greatest Conservation Need, it is not practical to discuss the specific habitat requirements of each species. Indeed, by adding plants as SGCN, we emphasize the importance of biodiversity and a broad conservation approach. And, when we manage natural communities for values such as ecosystem health or function, including the support of biodiversity, we are also providing habitat for animals that live in that community.

To analyze conservation needs and actions for the different types of habitat types present in our state, we created a set of 15 habitat types (see list below and Figure 3.2). For most terrestrial types we used ecological systems to group native plant communities into habitat types such as 'prairies and other grasslands.' For aquatic systems we followed hydrological classifications to define types such as 'rivers and streams.' Other habitats were inherently more specific, such as 'caves' and 'cliffs, talus, and rock outcrops.' In another case, we created a grouping based on non-natural landcover types, classified as 'urban and other developed lands.'

These groupings are only meant for organizational purposes and do not replace the specificity of native plant community descriptions. In addition, the full array of specific habitat requirements, particular conditions, or micro-habitats needed by particular SGCN are not easily depicted at a statewide scale or in these sub-chapters. Rather, we provide a list of animal SGCN that use the habitat in Appendix D and a list of plant SGCN that use the habitat in Appendix E and briefly highlight a subset to illustrate use of the habitats in the sub-chapters. For more detailed information about species' habitat requirements, we recommend referencing the DNR's webpages for Animals, Plants, and the Rare Species Guide or other external resources cited in the SGCN species group sub-chapters in Chapter 2. Species in Greatest Conservation Need.

## Primary Habitat Types

1. Prairie and Other Grasslands
2. Savanna
3. Upland Conifer Forest and Woodlands
4. Upland Deciduous Forests and Woodlands
5. Mesic Hardwood Forest
6. Deciduous Wet Forest
7. Coniferous Forest Wetland
8. Riparian and Floodplain Forest
9. Non-forested Wetlands
10. Rivers and Streams
11. Lakes
12. Vernal Pools
13. Cliff, Talus, and Rock Outcrop
14. Caves
15. Urban and Other Developed Lands

## Habitat Map Methods

### Overview

For the 2025-2035 SWAP we recognized the need for an updated habitat map of Minnesota that was accurate at a site-level scale and provided full coverage of the state. There was also a need to provide accurate representation of anthropogenically (human) modified habitats such as agriculture, and developed areas as SGCN are sometimes found in these locations. There are examples of layers that cover the entire state including the Crop Data Layer and Midwest Terrestrial Habitat layer. These layers are remotely sensed and often lose accuracy as map resolution is increased. Because they cover such broad areas, it is infeasible to ground-truth every cover-type. Other layers, such as the Native Plant Communities, National Wetland Inventory, and Lake Morphology layers are more accurate but lack comprehensive coverage. Due to these inherent strengths and weaknesses, it became apparent that the best course of action was to combine several layers into one, leveraging the accuracy from some and the coverage of others. Thus, the SWAP Habitat Map (Figure 3.2) was created by combining six different GIS layers. These layers consisted of the DNR Native Plant Communities (NPC), Stream Routes with Strahler Stream Order, Shallow Lakes Identified by DNR Wildlife, Lake Basin Morphology, National Wetland Inventory for Minnesota (NWI), and Midwest Terrestrial Habitat System (MWTHS) layers

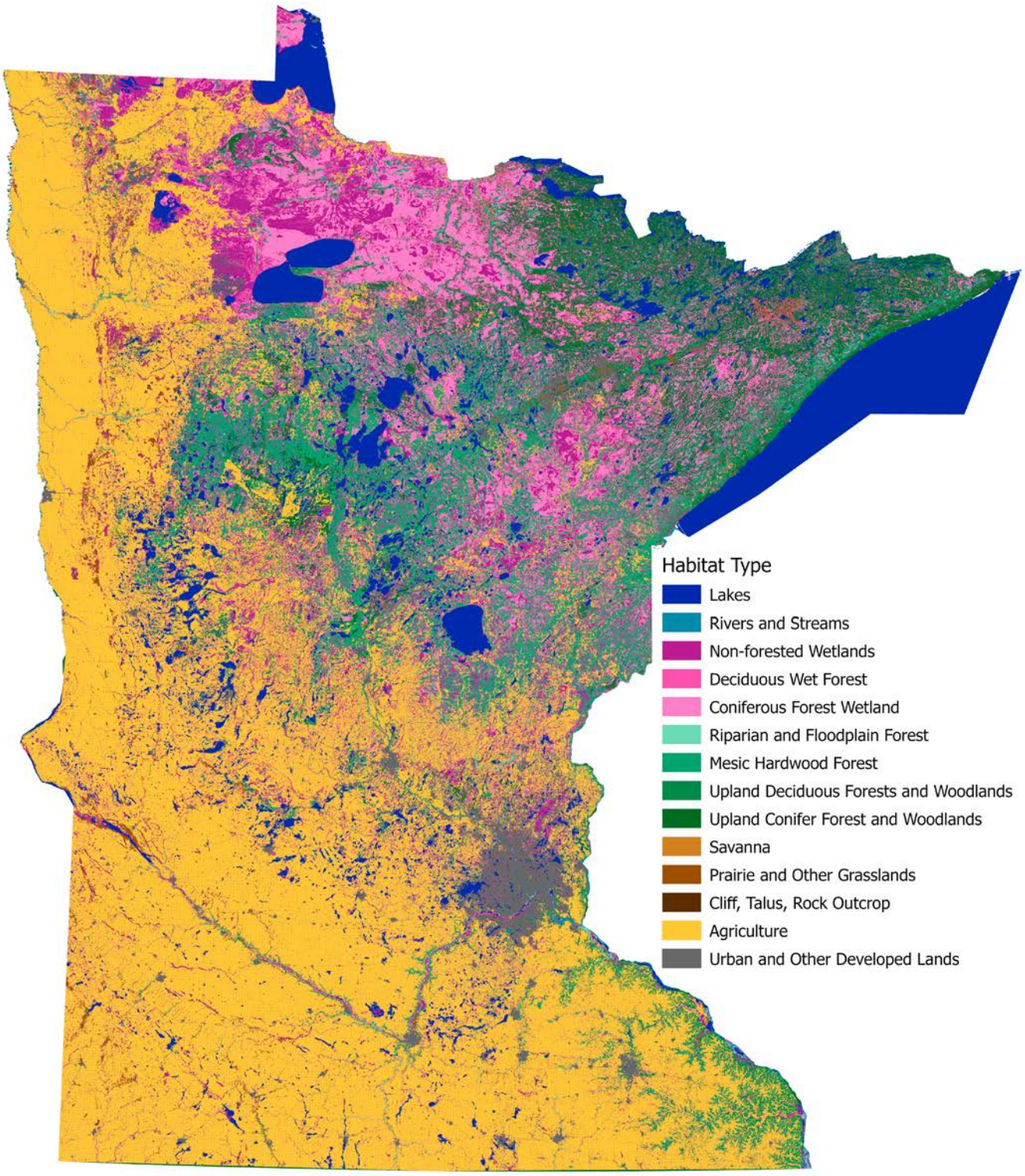


Figure 3.2. Map depicting Minnesota's 2025-2035 Wildlife Action Plan Habitat Layer, depicting each of the primary habitat types described by sub-chapters, except for caves which are not depicted here. Also, Agriculture is not one of the SWAP Habitats but is included in this map as a prominent landcover type.

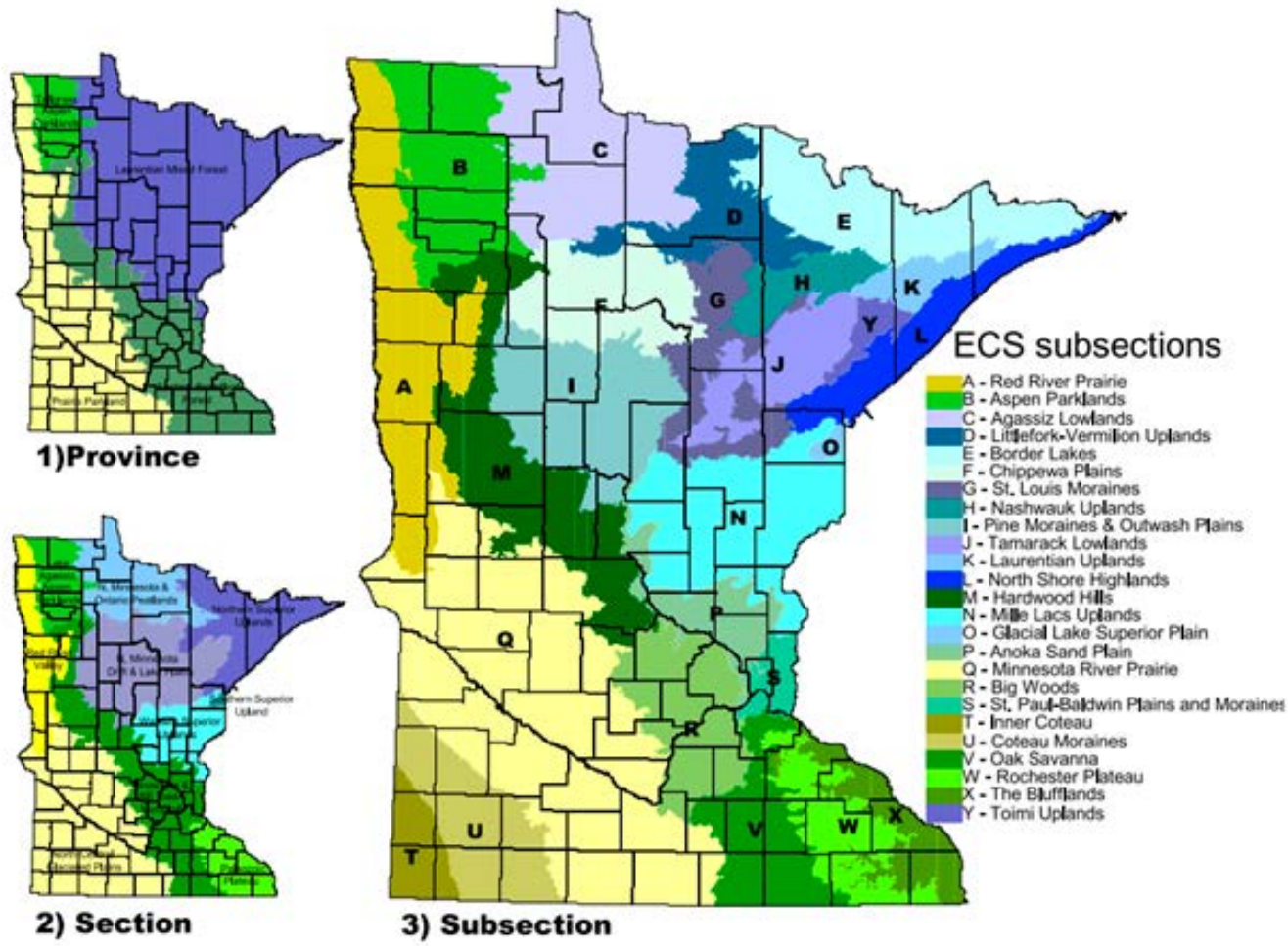


Figure 3.3. Minnesota Ecological Provinces, Sections, and Subsections.

**Table 3.1 Minnesota's Native Plant Community Classification Hierarchy.**

| Classification Level | Dominant Factors | Example |
|---|---|---|
| System Group | Vegetation structure & hydrology | Upland Forest & Woodland Systems |
| Ecological System | Ecological Processes | Fire-Dependent Forest/ Woodland |
| Floristic Region | Climate & paleohistory | Central |
| NPC Class | Local environmental conditions | Central Dry Pine Woodland |
| NPC Type | Canopy dominants, substrate, or finer environmental conditions | Jack Pine-(Yarrow) Woodland |
| NPC Subtype | Finer distinctions in canopy dominants, substrate, or environmental conditions | Ericaceous Shrub |

## Component Descriptions

### Minnesota Ecological Classification System

We use Minnesota's Ecological Classification System (ECS) to describe the geography of where habitats occur. This system was developed by the Minnesota Department of Natural Resources and the U.S. Forest Service for ecological mapping and landscape classification. This hierarchical ecological land classification system is used to identify, describe, and map areas of land with uniform ecological features. The ECS system uses associations of biotic and environmental factors, including climate, geology, topography, soils, hydrology, and vegetation. There are eight levels of ECS units in the United States. Map units for six of these levels occur in Minnesota: Provinces, Sections, Subsections, Land Type Associations, Land Types, and Land Type Phases.

Within the SWAP we reference the 4 Provinces, 13 Sections, and 25 Subsections in Minnesota (see Figure 3.3). Provinces are units of land defined using major climate zones, native vegetation, and biomes such as prairies, deciduous forests, or boreal forests. There are four Provinces in Minnesota. Sections are units within Provinces that are defined by origin of glacial deposits, regional elevation, distribution of plants, and regional climate. Minnesota has 10 sections. Subsections are units within the Sections that are defined using glacial deposition processes, surface bedrock formations, local climate, topographic relief and the distribution of plants, especially trees. Minnesota has 25 subsections.

### Native Plant Communities

The DNR's Native Plant Community Classification hierarchy (Table 3.1) further divides plant communities into systems, classes, and types. The DNR's classification is intended to provide a framework and common language for improving our ability to manage vegetation, survey natural areas for biodiversity conservation, identify research needs, and promote study and appreciation of native vegetation in Minnesota. Three levels of this classification system can be found in the final habitat layer: System Groups, Native Plant Community Classes, and Native Plant Community Types. System Groups**,** the highest level, were created to allow development of manageable field keys for lower levels of the classification. System groups were formed by combining lower levels of the classification along major physiognomic and hydrologic splits in vegetation. The system level most closely matches the Habitat Chapters within the SWAP, and the Classes and Types are then further used to describe the habitats where SGCN are found. Native Plant Community Classes are units of vegetation that generally have uniform soil texture, soil moisture, soil nutrients, topography, and disturbance regimes. For wooded vegetation, native plant community classes were developed by emphasizing understory vegetation more than canopy trees, under the hypothesis that in much of Minnesota understory plants are often more strongly tied to local habitat conditions (such as levels of nutrients and moisture) than are canopy trees. Native Plant Community Types are defined by dominant canopy trees, variation in substrate, or fine-scale differences in environmental factors such as moisture or nutrients. Type distinctions were also made to describe geographic patterns within a class.

The DNR Native Plant Communities layer was desirable for a few reasons: 1) The NPC hierarchy is a system widely used across the state by both internal and external partners, and 2) the geographic extent of NPC's are highly accurate because many of them have been identified and mapped on site. Due to these strengths, it was ranked as the highest importance for the final layer; however, it does have a few caveats: 1) It only covers around 10% of the total land area of the state, 2) it only includes terrestrial or emergent wetland plant communities, and 3) it does not classify human-modified plant communities or land cover.

### Streams with Strahler Stream Order

To incorporate rivers and streams into the habitat layer, components from two layers were combined into one. The attributes associated with the Stream Routes with Strahler Stream Order layer were desirable because streams and rivers could be categorized into different sizes. This layer also included the Kittle number designated by the DNR Fisheries Stream Survey database meaning future attributes could be added based on this unique identifier. While this layer had the desirable attributes, it could not be used alone due to it being a line feature which meant it did not capture the spatial extent of the rivers and streams. For this reason, another layer was needed that represented the shape and size of rivers and streams as closely as possible. The NWI layer meets this need as its polygons outline the shapes of rivers and streams but lacked attributes that classified them into different sizes. To merge the two layers into one, all polygons categorized as "Riverine Systems" in the Circ39 Class attribute of the NWI layer were selected and exported as their own layer. Then a 500-foot buffer was added around the Stream Route layer and then clipped using the exported Riverine layer. In this way, a new feature class was created that followed the shape of the riverine polygons from the NWI layer while maintaining the attributes of the Stream Routes. Finally, a new attribute field was created to categorize the stream order sizes. Streams with stream orders from 1-4 were classified as "small," 4-6 as "medium-large," and 7-8 as "large."

### Shallow Lakes

For shallow lakes, the Shallow Lakes Identified by DNR Wildlife layer was used. The layer was developed to help natural resource managers identify these bodies of water for habitat restoration and enhancement. To qualify as a shallow lake, the body of water must be 50 acres or greater in size and have a maximum depth of 15 feet or less. Some lakes have an "undefined" depth and may be deeper than 15 feet but were still included.

### Lake Basin Morphology

To capture deeper lakes, the Lake Basin Morphology layer was used. This layer describes the physical form and morphology of lakes in Minnesota. Like the Shallow Lakes layer, it contains an attribute called "DOWLKNUM" which is a unique identifier for each lake in Minnesota. This number enables the sharing of data and attributes from different layers that also have the "DOWLKNUM" attribute field. Any lakes that were not captured by the Shallow Lakes or Lake Basin Morphology layer were captured by the National Wetland Inventory Layer.

### National Wetland Inventory

The NWI Layer was used to capture any lakes, rivers, or wetlands in Minnesota not mapped by the previous layers. Administered by the United States Fish and Wildlife Service, the National Wetland Inventory data provides detailed information on abundance, characteristics, and distribution of American wetland and deepwater habitats, as well as changes in these habitats through time. This information is provided through two resources: the Wetland Geospatial Dataset and Wetlands Status and Trends report. Within the NWI layer, several attribute fields were used to crosswalk wetland types with habitats: the Cowardin codes, the Simplified Plant Community Classification (SPCC), and the Circular 39 fields (similar but slightly different than the SPCC; see Table 3.2). The relationship between these two classification systems is an approximation. Riverine types (R2ABH, R2EM2F, R2EM2H, R2UBF, R2UBH, R2USA, R2USC, R3UBH, R4SBA, R4SBC) were related to the Rivers habitat. For more detail, please refer to the Minnesota Wetland Inventory: User Guide and Summary Statistics (Kloiber et al. 2019).

### Midwest Terrestrial Habitat System

The Midwest Association of Fish and Wildlife Agencies (MAFWA) passed a resolution to endorse the Midwest Landscape Initiative (MLI) to help meet the need for landscape-level conservation planning in the Midwest.

MLI created a regional terrestrial habitat system that provided common descriptions for natural habitats within the Midwest, thus providing a common naming convention that could be used to help coordinate conservation planning across state lines. The data used to create this map was initially modelled from the LANDFIRE Consortium using artificial intelligence and remote sensing. NatureServe then assigned the natural systems to their appropriate National Vegetation Classification (NVC). The Midwest Terrestrial Habitat System 2025 Update (MWTHS) incorporates three levels of classification; groups, macrogroups, and divisions. It also crosswalks the NVC groups with each state's unique heritage vegetation classes. This layer is a large component of the SWAP Habitat layer because it fills many of the spatial gaps left by the previous layers.

**Table 3.2. Table cross-walking National Wetland Inventory (NWI) types to Plan habitat sub-chapters, the simplified plant community classification (SPCC) and Cowardin codes (based on table in Kloiber et al. 2019).**

| Chapter | SPCC | Cowardin code |
|---|---|---|
| Conifer Forest Wetland | Coniferous Bog | PFO2Dq, PFO4Dq |
| Conifer Forest Wetland | Coniferous Wetland | PFO2D, PFO4D |
| Non-forested Wetland | Deep Marsh | PEM2G, L2EM2G, L2EM2H, PEM2H, R2EM2G, R2EM2H |
| Deciduous Wet Forest | Hardwood Wetland | PFO1A, PFO1C, PFO1D |
| Lakes | Non-Vegetated Aquatic Community | L1UBH, L2RSC, L2USA, L2USC, PUSA, PUSC, R2UBF, R2UBG, R2UBH, R2USA, R2USC, R3UBG, R4SBA, R4SBC, L2UBF, L2UBG, L2UBH, PUBF, PUBG, PUBH |
| Non-forested Wetland | Open Bog | PEM1Dq, PSS1Dq, PSS2Dq, PSS3Dq, PSS4Dq |
| Non-forested Wetland | Seasonally Flooded/Saturated Emergent Wetland | PEM1A, PEM1D |
| Non-forested Wetland | Shallow Marsh | L2EM2F, PEM1C, PEM1F, PEM2F, R2EM2F |
| Non-forested Wetland | Shallow Open Water Community | L1ABH, L2ABF, L2ABG, L2ABH, PABH, R2ABG, R2ABH, PABF, PABG |
| Non-forested Wetland | Shrub Wetland | PSS1A, PSS1C, PSS1D, PSS1F, PSS2D, PSS3D, PSS4D |
| Deciduous Wet Forest | Artificially Flooded Hardwood Wetland | PFO1K |
| Lakes | Artificially Flooded Non-Vegetated Aquatic Community | L1UBK, PUSK, L2UBK, PUBK |
| Non-forested Wetland | Artificially Flooded Shallow Marsh | PEM1K |
| Non-forested Wetland | Artificially Flooded Shallow Open Water Community | L2ABK, PABK |
| Non-forested Wetland | Artificially Flooded Deep Marsh | L2EM2K, PEM2K |
| Non-forested Wetland | Artificially Flooded Shrub Wetland | PSS1K, PSS3K |

## Habitat Map Compilation

To merge the individual component layers, the Union tool was utilized in ArcGIS Pro. However, before the individual component layers could be combined, each layer needed to be prepared. For the Union to work, all layers needed to be vectors. Fortunately, the MWTHS was the only layer that needed to be converted from a raster to a vector. The next step was to reduce the amount of attribute fields in each layer keeping only those relevant to habitats. Taking this step reduced the overall data size of the final layer which increased processing speeds. An additional field was created for each layer prior to the Union that assigned each instance in the attribute table to one of the SWAP habitat chapters.

Once all the layers were prepared, they were merged via the Union tool and ranked based on their importance to the final layer. Ranking the layers ensured that the more accurate ones were visible when they overlapped with other layers. Once the final layer was created, another attribute field, called SWAP Habitats was created. Then, the associated SWAP Habitat chapters for each polygon were calculated for this field based on the SWAP Habitat Chapters from the component layers. This ranked Union is conceptualized in Figure 3.4.

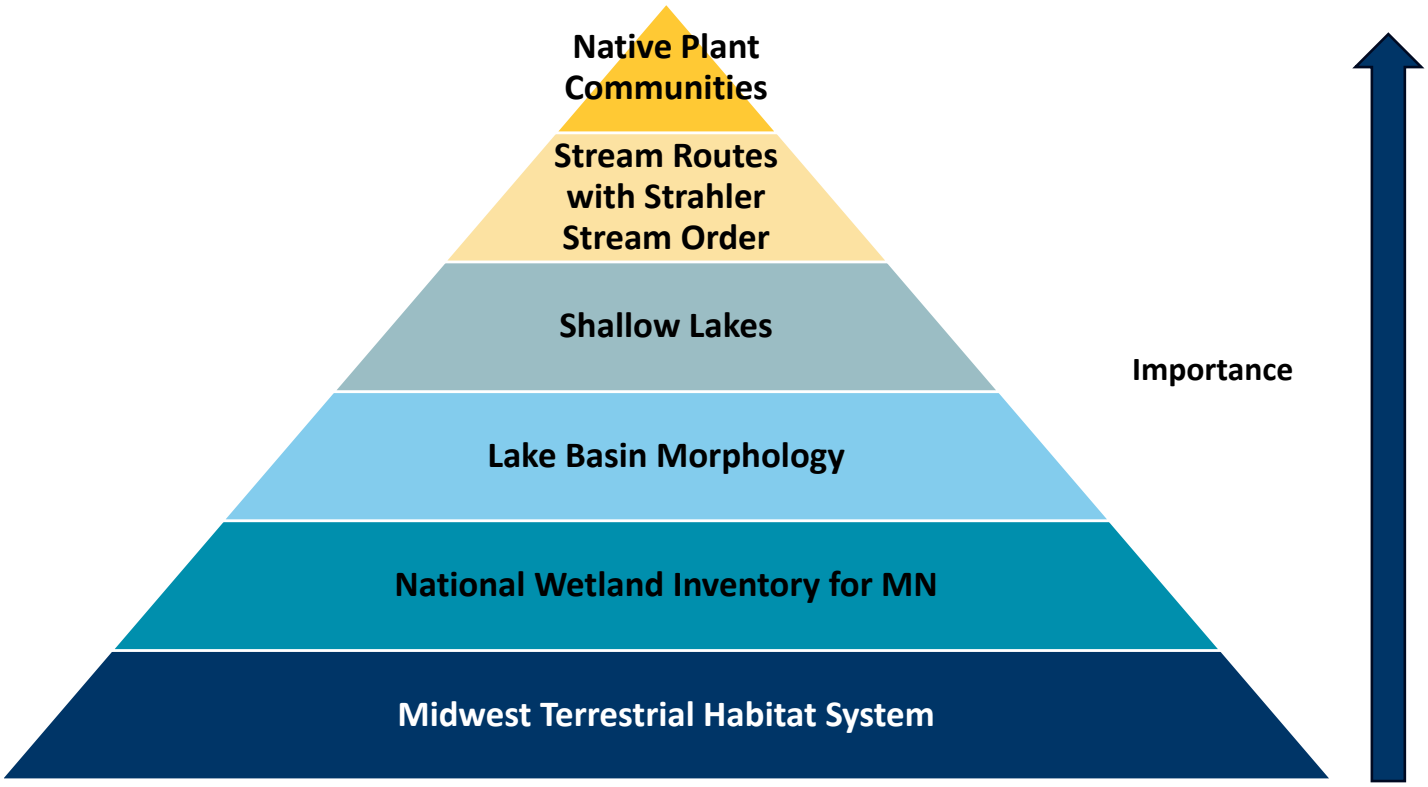


Figure 3.4. Conceptualization of the ranking of the individual component layers that make up the final habitat layer.

## Habitat Sub-chapters

Habitat sub-chapters will follow for each of the 15 habitat types, with the following sections.

### General Description

Here we describe general characteristics of the habitat type and any major sub-types. We reference the Minnesota Ecological Systems and Native Plant Community Classes and any other sources used to compile the habitat type in the habitat layer.

### Conservation Context

This section briefly summarizes information about past and present extent and condition of habitat type.

### Species in Greatest Conservation Need

We give a summary of the number of SGCN species that are associated with this habitat type and descriptions of representative SGCN from various species groups.

### Primary Stressors in this Habitat

The primary stressors that may negatively affect the habitat are described. Each stressor is depicted by an 'icon' to help the reader connect content from stressors to actions.

### Priority Habitat Conservation Strategies

The five conservation strategies for the Habitat Goal are shared in each habitat sub-chapter.

### Conservation Actions

Conservation actions are listed under the most pertinent strategy that they implement and tagged with icons to signify the stressor(s) they address. Frequently a conservation action can address more than one stressor. In those cases, the conservation action is identified by multiple stressor icons. Some actions are widely in practice while others may be more novel.

### Case Studies

Throughout the sub-chapters we highlight case studies and key partnerships and provide links to important resources pertinent to the habitat. Case studies feature examples of conservation projects that effectively address one or more of the stressors. These give a brief summary of the project as well as links to read additional information. The case studies and key partnerships described are not an exhaustive list, but rather a set of examples to help readers engage in conservation actions.

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## PRAIRIE AND OTHER GRASSLANDS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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This document contains maps that are available in alternative formats to individuals with disabilities by calling (651) 259-5149 or emailing the SWAP Coordinator at alison.cariveau@state.mn.us.

Cover Photos: Reconstructed prairie, Lisa Gelvin-Innvaer; Bluff prairie, Mound Prairie Scientific and Natural Area

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# Prairie and Other Grasslands

## Habitat Description

Prairie ecosystems are dominated by native graminoids (grasses and grasslike plants) with a species-rich component of forbs (flowering plants other than grasses or sedges). Prairie native plant communities are often found on mollisols, soils with a dark colored surface horizon high in organic matter. These fertile, base-rich mineral soils span a soil moisture spectrum from dry sand-gravel prairies on coarse droughty soils, to wet prairies on poorly drained sites with a variety of soil textures. Prairies are primarily distributed in the western and southern parts of the state in the Prairie Parkland Province, and in the southernmost portions of the Anoka Sandplain Subsection in the Eastern Broadleaf Forest Province.

Ecological processes including fire and grazing have shaped prairie and other grasslands of Minnesota. Frequent fire helps to reduce invasion by trees and shrubs. In tallgrass prairie, average fire intervals were thought to be 10 years or less (Zouhar, 2021). Fire is critical for maintaining the dominance of herbaceous species by preventing trees and shrubs from becoming large enough to survive fire. The burning process also removes litter and stimulates grass production. Grazing by bison (*Bos bison*) and elk (*Cervus canadensis*) was a vital ecological process on pre-European settlement prairies. Grasses, which grow from lateral meristems at the base of the plant, are well adapted to the process of grazing, because it generally removes only the upper portion of the plant. Grazing by large ungulates also facilitated forb diversity and abundance on native prairies by suppressing grasses from dominating the plant community.

Grassland types cover a wide spectrum, ranging from prairie remnants to many types of restored and working grasslands. The following are reference descriptions of Minnesota's prairies and grasslands (for more information visit the DNR's Minnesota Prairie website).

*Photo: Prairie, Hole in the Mountain Wildlife Management Area, Megan Benage*

### Native (Remnant) Prairie

Native prairie, or remnant prairie, refers to grasslands dominated by native prairie vegetation, typically occurring where the sod has never been broken. These grass-dominated communities host a large diversity of forbs (wildflowers) and wildlife. Prairies are often further classified by soil moisture, species composition, and geography.

### Dry Prairies

Dry prairies can vary widely in species composition based on soils and topography but are usually dominated by grasses such as big bluestem (*Andropogon gerardii*), prairie dropseed (*Sporobolus heterolepis*), and little bluestem (*Schizachyrium scoparium*). The most common forbs are in the sunflower or pea families (Asteraceae and Fabaceae). Woody species are limited to dwarf shrubs such as leadplant (*Amorpha canescens*) and prairie rose (*Rosa arkansana*). This plant community is likely to be found in areas featuring conditions that preclude plants needing mesic or wet conditions. These range from wind-blown sand dunes to sandy riverine outwash, to excessively drained gravelly ridges or slopes. Most sites containing dry prairie experience frequent and severe growing-season moisture deficits due to soil type and/or topography.

## Mesic Prairies

Mesic prairies are frequently dominated by tallgrass species such as big bluestem and yellow prairie grass (*Sorghastrum nutans*), with prairie dropseed often a codominant or subdominant component. Forb cover is variable by soil type, again with plants in the sunflower or pea families frequently present. Prairie rose and leadplant are the most common woody species, occasionally with patches of wolfberry (*Symphoricarpos occidentalis*). Various other native shrubs are typically not abundant. Mesic prairies cover a wide gradient of soil types and topography, with much species overlap between dry prairies and wet prairies. Changes between mesic prairie and other prairie types are often subtle, with hydrological and topographical features differentiating the cover types.

## Wet Prairies

Wet prairies typically feature big bluestem and prairie cordgrass (*Spartina pectinata*) as major species and a variety of sedges (*Carex spp.*). Wet prairies include numerous forbs, dwarf shrubs (such as prairie rose), and true shrubs like red-osier dogwood (*Cornus sericea*) and willows (*Salix spp.*). Wet prairies are typically found in shallow depressional areas within the larger prairie landscape, most often on poorly drained loam soils. Wet prairies can also occasionally be found on loamy sands in areas with a shallow water table.

## Bluff Prairies

Bluff prairies, or sometimes referred to as 'goat prairies', are characteristic on dry, steep south and west facing slopes on the bluffs in the Driftless region of southeastern Minnesota. Species composition is similar to dry prairies, consisting of species tolerant of lower quality rocky soils. These include big bluestem, little bluestem, sideoats grama (*Bouteloua curtipendula*), hairy grama (*Boutleloua hirsuta*), leadplant, hoary puccoon (*Lithospermum canescens*), pasqueflower (*Pulsatilla patens*), and prairie smoke (*Geum triflorum*). Bluff (goat) prairies require regular disturbance, and reduced frequency of fire and grazing on these prairies has led to the encroachment of red cedar (*Juniperus virginiana*) and other native and non-native woody species including prickly ash (*Zanthoxylum americanum*) and multiflora rose (*Rosa multiflora*).

*Photo: Bluff prairie, Mound Prairie Scientific and Natural Area*

## Brush Prairies

In brush-prairies, herbaceous prairie plants are still a major component of the vegetation, but the woody components are more prevalent than in other prairie types. Brush prairies are characterized by an abundance of taller shrubs, oak "grubs" and sprouts, and quaking aspen (*Populus tremuloides*) suckers. In the absence of fire, both savannas and brush-prairies rapidly succeed to woodland; brush-prairie moves to woodland faster than does savanna. Today, most brush-prairies occur in the Tallgrass Aspen Parklands Province in northwestern Minnesota.

## Reconstructed and Restored Prairies

These grasslands result from efforts to re-build prairies by planting native prairie seeds or plants (plugs) back into areas previously converted to another land use, typically agricultural fields. Prairie reconstructions seek to support biologically diverse native plants and wildlife (including Species in Greatest Conservation Need (SGCN). This restores ecological function and increases resistance to invasion by non-native plants, while being cost-effective to manage. In recent years, much attention has been given to data collection and monitoring of reconstructed and restored prairies to compare restoration efforts against remnant prairies (see the Prairie Reconstruction Initiative).

Reconstructed prairies are often more species-rich than conservation plantings, though less so than remnant prairies. It is challenging to produce seed for many native species found in remnant prairies, often limiting the number of species available to practitioners for prairie reconstructions. Though modern conservation plantings generally feature native grassland species, they are often tailored to programmatic goals. In contrast, prairie reconstructions are usually focused on reconstructing overall ecosystem function. Consequently, prairie reconstructions will often include more grass and forb diversity than conservation plantings and are typically planted at a 1:1 grass-forb ratio.

*Photo: Reconstructed prairie, Lisa Gelvin-Innvaer*

## Conservation Plantings

Conservation plantings are generally created through conservation programs, such as the Conservation Reserve Program (CRP) administered by Farm Service Agency through the United States Department of Agriculture, funded by the federal Farm Bill. Other similar programs include the Reinvest in Minnesota (RIM) program administered by the Minnesota Board of Water and Soil Resources, and numerous other programs administered by a variety of state/federal agencies and non-governmental organizations. Grasslands planted through conservation programs vary widely in their composition. Each program typically has unique specifications for seed mix requirements that lead to variations in habitat quality. For instance, a seed mix meant to control soil erosion might consist of 90% grasses, while a mix meant to attract pollinators might contain 75% wildflowers (forbs). Many conservation plantings completed in the 1980s and 1990s contained non-native species such as smooth brome (*Bromus inermis*), alfalfa (*Medicago sativa*), and bird's-foot trefoil (*Lotus corniculatus*). Unfortunately, these competitive

species are known increasers (grazing-tolerant or unpalatable plants) and can invade native prairie. Despite being a source of non-native species, these older plantings do still provide marginal habitat for many grassland wildlife species and can contribute to habitat complexes alongside higher quality remnant and reconstructed prairies. Nearly all new conservation plantings focus on native species in seed mixes.

## Other Grasslands

Other grasslands include old agricultural fields, hayfields, pastures, and roadsides, along with open space and park grasslands in developed areas. They provide various benefits, but do not have the full biodiversity and function of native prairies. Termed "surrogate grasslands" in prior Minnesota SWAPs, they could also be termed 'developed grasslands,' described in the 2005 Plan as "grasslands that have developed as a result of human activities since settlement." These sites occur in areas that once supported prairie or forest communities and are found statewide but less commonly in the northeast. Developed grasslands are typically dominated by non-native, cool-season grasses, such as smooth brome (*Bromus inermis*), quackgrass (*Agropyron repens*), redtop (*Agrostis gigantea*), timothy (*Phleum pratense*), and Kentucky bluegrass (*Poa pratensis*). Reed canary grass (*Phalaris arundinacea*), is an increasing species that can dominate and exclude other species on wetter sites. The forb component of surrogate grasslands is also dominated by invasive species, such as yellow sweet clover (*Melilotus officinalis*), white sweet clover (*M. alba*), alfalfa (*Medicago sativa*), dandelions (*Taraxacum spp.*), bird's-foot trefoil (*Lotus corniculatus*), and canada thistle (*Cirsium arvense*). Native forbs may also occur in these grasslands, especially goldenrods, milkweeds, and asters. Left unmanaged, these grasslands are often encroached on by native and invasive trees and shrubs. Encroachment by non-native species such as Siberian elm (*Ulmus pumila*) and Russian olive (*Elaeagnus angustifolia*), and by natives such as green ash (*Fraxinus pennsylvanica*), cottonwood (*Populus deltoides*), and sumacs (*Rhus spp.*), can convert grasslands to woodlands or shrublands, reducing or eliminating their habitat value for many grassland species.

## Savanna

This type of habitat hosts few trees in a grassland matrix; please see the Savanna Sub-chapter.

# Habitat Map

To depict Prairie and Other Grassland habitat (see Figure 3.5), we compiled spatial data from several sources: the DNR's Native Plant Communities and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3. Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological Systems

### Upland Prairie (UP)

UPn12 Northern Dry Prairie (PDF)

UPn23 Northern Mesic Prairie (PDF)

UPs13 Southern Dry Prairie (PDF)

UPs23 Southern Mesic Prairie (PDF)

### Wetland Prairie (WP)

WPn53 Northern Wet Prairie (PDF)

WPs54 Southern Wet Prairie (PDF)

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Northern Tallgrass Prairie, Eastern North American Ruderal Meadow and Shrubland, and Northern Great Plains Ruderal Exotic Grassland and Shrubland.

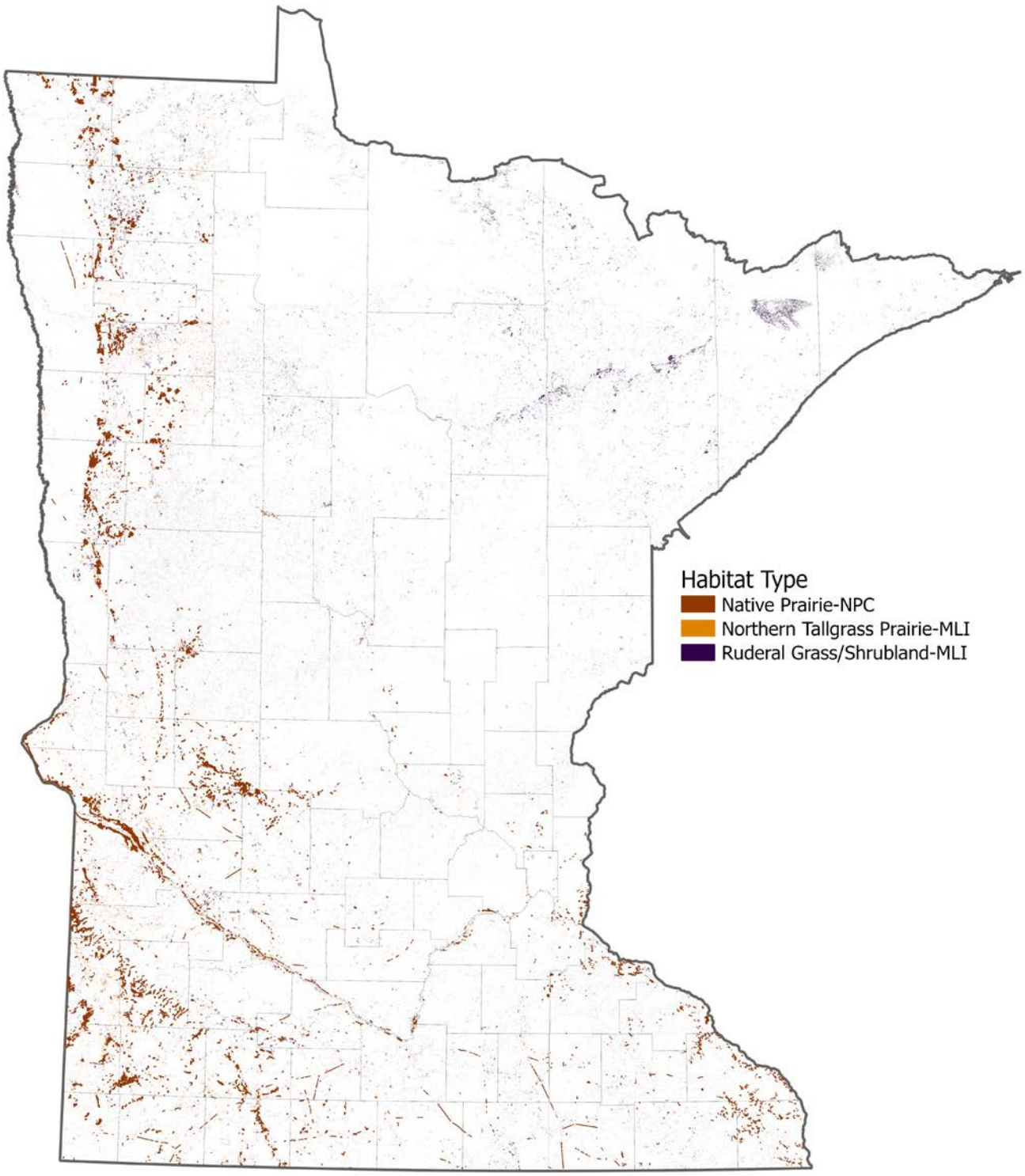



Figure 3.5. A map depicting Prairie and Other Grassland habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological Systems of Upland Prairie and Wetland Prairie as well as three types from the Midwest Terrestrial Habitat System.

## Conservation Overview

Temperate prairie is a globally rare habitat. Tallgrass Prairies are Critically Endangered (the highest level of imperilment short of collapse), according to the International Union for the Conservation of Nature (IUCN) Red List of Ecosystems. The list evaluates the extent, degradation, and biotic processes of ecosystems globally (Comer et al., 2022).

The prevalence of native, remnant prairies in Minnesota has dramatically declined from once covering over a third of the state (about 18 million acres; Marschner, 1974) to about 250,000 acres today, or about 1–2 percent of the historical area. This is largely due to land conversion (DNR, 2018). Conversion of remnant prairies continues, with over 200 acres lost per year on average, and 4,248 acres documented as converted since 1987 (MBS, 2017). Thus, remaining remnant prairie is of the highest priority for protection and restoration.

To guide prairie conservation efforts, Minnesota DNR developed a 25-year Minnesota Prairie Conservation Plan that lays out core areas, connective corridors, and establishes local landscape teams. Many of the largest remaining tracts of remnant prairie are managed for conservation purposes. These remaining tracts provide a space for public engagement with the prairie community including its Species in Greatest Conservation Need. They are also essential for growing our understanding of the prairie community through research and adaptive management. To complement these large areas, ongoing protection for smaller prairies across the landscape is offered to private landowners through the DNR's Minnesota Native Prairie Bank.

The scarcity of remnant prairie underscores the importance of restored prairie and other grasslands in providing vital ecosystem functions including habitat for wildlife and plant SGCN. Restoring, enhancing, and managing other grasslands complements the function of the prairie at an ecosystem level by providing connectivity for animals to move, buffering sensitive communities like wetlands and streams, and enhancing watershed, soil health, and water quality. Focusing grassland habitat restoration around building larger complexes of both remnant prairie and other grasslands will be crucial for restoring and maintaining ecosystem health into the future.

As an example, according to the DNR's long-term Sustaining Prairie in a Changing Environment (SPICE) study (see the Case Study in Chapter 5: Monitoring), declining trends of grassland birds appear to be similar in protected, relatively high-quality remnant prairies as they are regionally. Indeed, most SPICE grassland bird species' population trends mirror the negative statewide trends from prairie region Minnesota transects of the North American Breeding Bird Survey (BBS) data, roadside surveys that cross different habitats of various quality and protection status, (see Table 2.5 in the Birds Sub-chapter). Of the 11 prairie obligate bird species (9 of which are SGCN) for which data were sufficient to determine trends, seven were found to have declining trends that were generally similar in magnitude in both SPICE and BBS. This suggests that mechanisms other than local-scale habitat protection are needed to address the declining trends in grassland bird populations. Protection or management focused on reserves, while important, is not enough. For grassland birds at least, conservation efforts should be expanded into the surrounding landscape. Similar effects may be found for other wildlife, such as prairie-obligate insects, some of which have declined dramatically in the past 20 years.

Prairies and other grasslands have also been affected by a change in disturbance regimes including a loss of fire and grazing. Ecosystem productivity and species diversity decline when litter and thatch are not periodically removed by fire, grazing, or haying (Anderson, 1990, Knapp et al., 2009). Minnesota remnant prairies have been shown to significantly decline in native species richness in the absence of fire (Larson et al., 2020). Grasses have a positive feedback relationship with fire, which creates

strong barriers to tree and shrub establishment (Ratajzcak et al., 2014). Before European settlement fires were frequent, estimated to occur every 1-5 years (Hartman and Steel, 2015). Frequent fire with return intervals of less than 10 years is critical for the occurrence of upland prairies in Minnesota (Upland Prairie System Summary). It is widely recommended that prescribed fire be implemented every 3-5 years to increase native plant diversity and decrease encroachment by woody plant species.

Historically, native ungulates like bison (*Bison bison*), elk (*Cervus canadensis*), and white-tailed deer (*Odocoileus virginianus*) were widely abundant and were a significant influence on prairie composition and diversity (Knapp et al., 1999). Following European settlement, all three species were effectively extirpated from the prairie ecosystem, to be replaced by cattle, sheep, and goats (Hartman and Steele, 2015). Concurrently, fire suppression began in earnest, and many grasslands were intensively grazed and even overgrazed. The absence of fire coupled with intensive, sustained grazing represented a large shock to the ecological dynamics of the prairie ecosystem.

Subsequently, changes to policy and scale in the agricultural economy resulted in many small, family farms being consolidated into larger commodity operations from the 1960s–2000s. This led to widespread reductions in livestock grazing in many areas, many of which have not been grazed since (Hartman and Steele, 2015). The sudden removal of all grazing pressure following decades of intensive grazing represents another shock to the ecology of the prairie ecosystems.

In locations where fire and grazing have both been removed, remaining prairies are at risk of conversion to woody plant communities (Hartman and Steele, 2015). As such, many remnant prairies have been degraded to some degree resulting from the removal of any disturbance regime.

In the bluff prairies of the driftless region of Southeastern Minnesota, native grazers including bison, elk, and white-tailed deer (*Odocoileus virginianus*) were present before European settlement and likely contributed to disturbance to an unknown degree (Hartman and Steele, 2015). As elk, bison, and most white-tailed deer were extirpated, intermittent grazing was taken over by domesticated livestock including sheep, cattle, and goats (Hartman and Steele, 2015).

*Photo: prescribed burn, Hole in the Mountain Wildlife Management Area, Lisa Gelvin-Innvaer*

Grazing by livestock increased from the early to mid-1900's and likely became very intensive during the droughts of the 1930's as farmers struggled to find enough forage (Hartman and Steele, 2015). These habitats likely became overgrazed and became subject to varying degrees of erosion, but varying and diverse grazing systems helped to maintain the overall structure of these habitats (Hartman and Steele, 2015). From the 1960's to present, farm practices changed including the reduction of diversity of livestock and grazing of bluff prairies and associated savannas altogether.

Today, Minnesota's prairie region is dominated by cropland, though hayfields, developed areas, riparian areas, streams, rivers, wetlands, and lakes are also present. Working lands, most of which are privately owned, such as ranches, farms, and lands used for energy production, are essential for both the state's economy and natural resource stewardship. These lands produce food, fiber, fuel, and other goods, while also offering the opportunity for animal and plant conservation when managed sustainably. Multi-faceted approaches including diverse financial incentives, technical guidance, and effective landowner engagement can lead to the application of more conservation practices to benefit SGCN and their key habitats. Private landowners can benefit economically and ecologically by engaging in sustainable practices that are compatible with their management objectives, and such practices also provide additional "stackable benefits" such as carbon sequestration, soil health, and water quality.

## Climate Profile

This section on the anticipated effects of climate change on Prairies and Other Grasslands is built from two main information sources, both sponsored by the Midwest Climate Adaptation Science Center. The first is derived from a set of reports completed for various habitat types in support of State Wildlife Action Plans, similar to what is presented for other habitat types in this Plan. The second is a supplemental exploration of climate exposure and the literature specifically in relation to the plants Minnesota grasslands, as conducted by the University of Wisconsin-Madison for this report.

The anticipated effects of climate change on Prairies and Other Grasslands were profiled in the report "Effects of Climate Change on Midwestern Ecosystems: Central and Eastern North American Grassland and Shrubland" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025a). The most impactful changes in climate for this system include more frequent droughts and shifts in seasonality — earlier springs and longer growing seasons.

Drought is an important factor that shapes grasslands, including species composition, ecosystem function, and ecosystem boundaries (i.e., the extent of grassland vs shrubland or woodland). Increased evapotranspiration demands driven by higher temperatures, measured as increased vapor pressure deficit, will likely cause drier soil conditions and intensify drought conditions (Ratcliffe et al., 2025a; Figure 3.6).

Anticipated ongoing seasonal shifts including earlier spring conditions, more frost-free days, and longer growing seasons (see Table 3.4). These shifts can affect plant and animal phenology, community productivity, and ecological function (Ratcliffe et al., 2025a). Earlier spring warming can shift flowering dates for blooming plants with recent evidence of some species now flowering 8–16 days earlier (Geissler and others, 2023; Memmott and others, 2007; Prevéy and others, 2020 in Ratcliffe et al. 2025a). Expanded growing seasons can enhance productivity, but spring fluctuations in temperature (e.g., early thaw and late frosts) are challenging for species lacking frost tolerance.

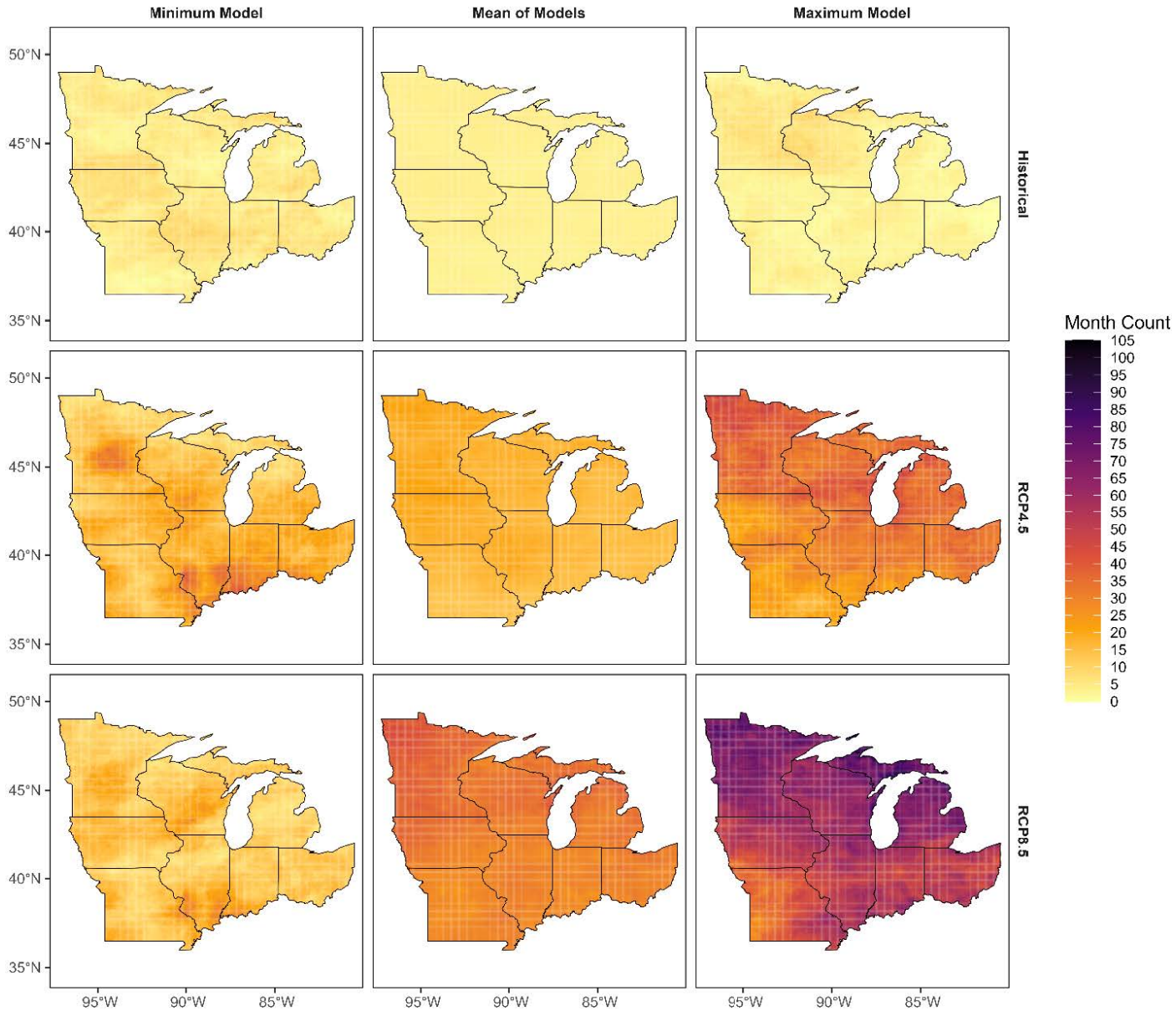



Figure 3.6. Reproduced with permission from Ratcliffe et al. 2025a. Projected changes in 30-year extreme drought incidence in the Midwest region. Projections use gridded Standardized Precipitation-Evapotranspiration Index (SPEI) values obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme drought incidence is defined as the number of months within a 30-year period with an SPEI value of ≤ -2, corresponding to the driest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show mean historical (1971–2000, top row) and projected (2070–2099) 30-year extreme drought incidence (months) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected 30-year extreme drought incidence under RCP 8.5 are presented in addition to the mean of all models (middle column).

**Table 3.4. Projected changes in growing season length in the Northern Plains ecoregion. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show mean historical (1971–2000) and projected growing season length (consecutive days with minimum temperatures above freezing) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected growing season length under RCP 8.5 are presented in addition to the mean of all models. Modified from Ratcliffe et al. 2025a.**

| Model Type | Historical (1971-2000) | RCP 4.5 Midcentury (2040-2069) | RCP 8.5 Midcentury (2040-2069) | RCP 4.5 Late Century (2070-2099) | RCP 8.5 Late Century (2070-2099) |
|---|---|---|---|---|---|
| Minimum model | 147.6 | 154.8 (5%) | 160.6 (9%) | 146.8 (-1%) | 160.1 (8%) |
| Mean of models | 149.2 | 168.9 (13%) | 178.3 (20%) | 165.7 (11%) | 187.0 (25%) |
| Maximum model | 150.6 | 196.5 (30%) | 207.9 (38%) | 192.0 (27%) | 217.8 (45%) |

**Key Climate Change Effects** (from Ratcliffe et al., 2025a; please reference to find source citations):

- **Habitat structure:** Drought will reduce soil moisture, plant productivity and cover, and potentially intensify erosion and nutrient loss impairing soil health. High temperatures combined with drought can cause physiological stress in plants ultimately suppressing growth and reproduction and increasing mortality, which may be more detrimental to plants with less robust and shallow root systems.
- **Community composition:** Changing mean annual temperature and precipitation patterns may favor expansion of prairie in the aspen parkland region of northwestern Minnesota by favoring drought-tolerant species such as little bluestem (*Schizachyrium scoparium*) or gramas (*Bouteloua* spp.) while reducing the dominance of aspen. However, droughts may increase the encroachment of other woody species that are more deep-rooted shrubs, particularly in the absence of fire. Earlier spring conditions may favor early-growing and phenotypically plastic species and challenge less flexible plant species, potentially creating phenological mismatches and detrimental effects on species such as pollinators.
- **Invasive species:** Climate change is predicted to favor species with ruderal traits, such as rapid growth, and high fecundity, and those with high plasticity and an ability to exploit warmer conditions, variable precipitation, and readily recover from drought stress. Warmer spring conditions may give advantage to cool season invasive grasses such as smooth brome (*Bromus inermus*) and Kentucky bluegrass (*Poa pratensis*), enabling them to better compete against later-emerging native grasses.
- **Herbivory:** If white-tailed deer populations expand under warmer and more droughty future climate conditions, this could contribute to declines in native forb diversity via reduced plant defenses and extended foraging window.

- **Microbial and fungal communities:** Drought may negatively affect soil function through reductions in microbial biomass and, in particular the function of arbuscular mycorrhizal fungi, which supports drought tolerance in plants.

A second project through the Midwest Climate Adaptation Science Center and University of Wisconsin assessed the climatic factors of importance to grasslands and how changes in those factors under future climate projections may affect the health and composition of grasslands in Minnesota. The project created maps of climate exposure (Figure 3.7), of the primary factors that influence grassland plant communities using climate projections from the Minnesota CliMAT (Climate Mapping and Analysis Tool). In addition, it included a systematic literature review to assess how climatic stressors affect grassland and wetland habitats within Minnesota, based on empirical statistical tests extracted from research papers from the upper Midwest and Great Plains (Barfknecht et al., in prep.).

**Climate exposure**

Plant community layers were based on the Midwest Terrestrial Habitat System (MWTHS) layer that uses attributes based on the National and International Vegetation Classification (NVC and IVC, respectively) designations for all natural landcover types, and LANDFIRE classifications for all non-natural landcover types. Central Tallgrass Prairie (CTP) communities are largely within the western, central, and southeastern portion of the state, but are mainly concentrated in the southern portions of the state in the Eastern Broadleaf Forest Province (Rollins, 2009; Tracey et al., 2024; Fig. 3.7). In comparison, Northern Tallgrass Prairie (NTP) communities largely reside within the entire western, central, and southwestern portions of the state, including the Tallgrass Aspen Parklands, Prairie Parkland Provinces, and are scattered in the southwestern portions of the Laurentian Mixed Forest Province. CTP communities are characterized by deeper and richer soils compared to NTP communities.

Climate projections within CTP communities show uniform increases in drought whereas projected changes in precipitation and temperature are more geographically complex (Figure 3.7; Liess et al., 2022 & 2023). Across the southeastern portion of the state, regions that support CTP communities are predicted to experience higher drought and growing season temperature and lower spring and growing season precipitation. The greatest warming trends are expected to occur in the western regions of CTP. In comparison, NTP communities are expected to exhibit higher drought in the southwestern portion of the state with decreased spring and growing season precipitation and increased growing season temperature in the northwest.

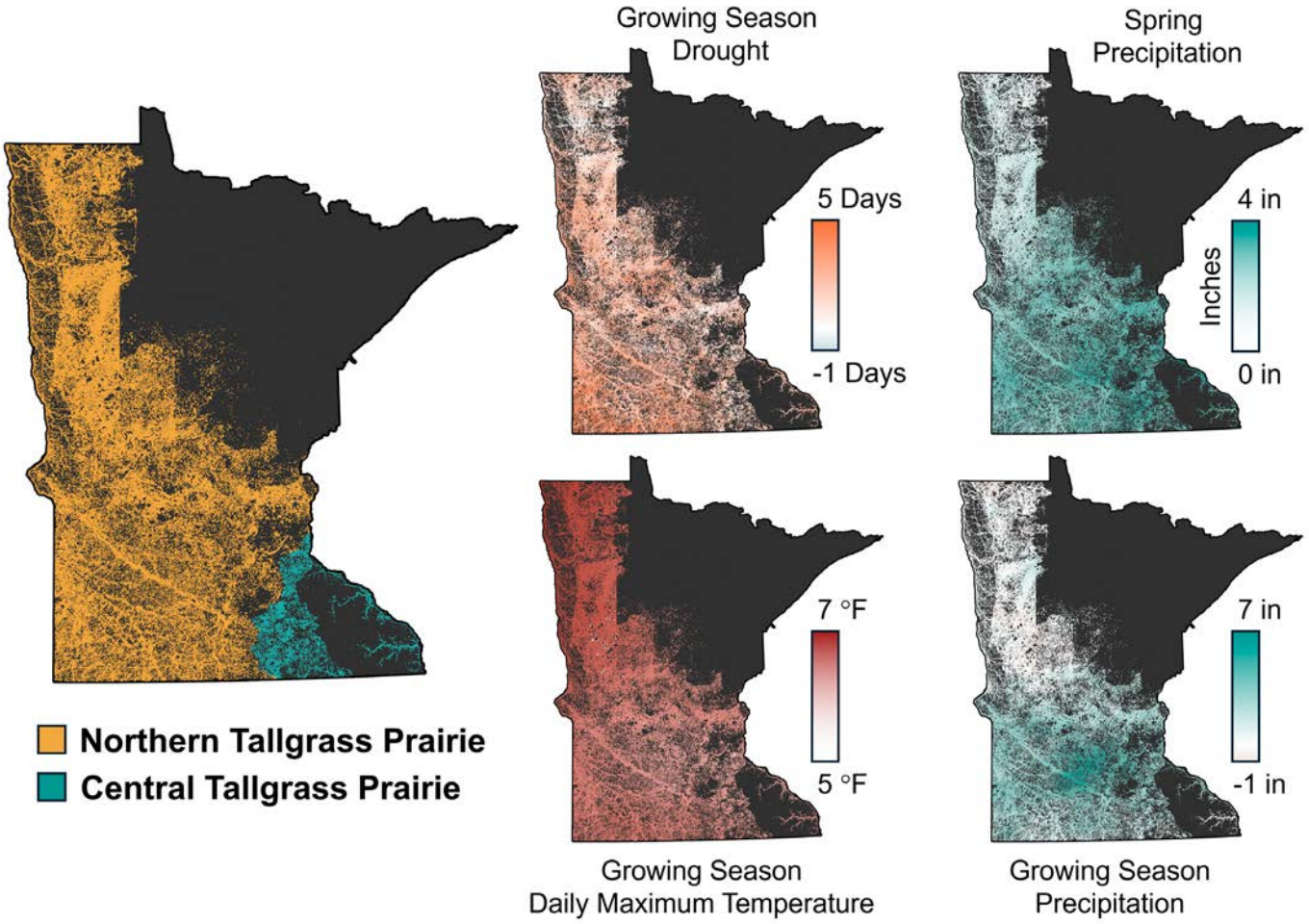



Figure 3.7. This figure depicts projected Climatic changes in Minnesota prairies. The left map depicts the extent of Northern Tallgrass Prairie and Central Tallgrass Prairie communities; as these are illustrated by points to highlight geographic range, they do not accurately portray the area of these communities. The right four panels depict the differences in future projected climate variables based on an ensemble of five climate models for the late century period (2060-2079) compared to historical simulations (1995-2014) under the SSP-585 (high emissions) scenario (Minnesota CliMAT).The factors depicted are growing season drought (maximum consecutive days with less than 0.01 in. of precipitation), growing season maximum temperatures (°F), and spring and growing season precipitation (in.).

**Climate literature review**

The systematic literature review identified 42 studies focused on grassland systems with 912 total statistical tests (Table 3.5). Studies were reviewed to assess statistical results for plant-climate relationships and summarized using a vote counting approach to determine directionality and consensus of each relationship. Across all studies, positive results were assigned a "+1", insignificant results were assigned a "0", and negative results were assigned a "-1". Results for each plant-climate relationship were summarized across all studies and then averaged.

Based on these findings, drought appears to reduce overall grassland plant diversity, functional traits (such stem density and total number of stems), and plant productivity (Table 3.4), but with varying responses based on species and populations due to local adaptability (specifically based on big bluestem; Galliart et al., 2019).

**Table 3.5. Plant-climate relationship tests (912 tests) from 42 grassland research papers based on the vote counting approach. Columns represent the respective number of tests for each plant-climate relationship category (Tests), number of studies (Studies), and the number of significantly positive (POS), insignificant (NULL), and significant negative (NEG) tests. The overall directionality of these tests (SUM) and the average vote counting (VC Mean) represent the consensus response.**

| Plant-climate relationship | Tests | Studies | POS | NULL | NEG | SUM | VC Mean |
|---|---|---|---|---|---|---|---|
| Diversity and drought | 116 | 6 | 3 | 86 | 26 | -23 | -0.207 |
| Diversity and precipitation | 189 | 18 | 66 | 107 | 16 | 50 | 0.265 |
| Diversity and temperature | 63 | 7 | 6 | 41 | 16 | -10 | -0.159 |
| Functional trait and drought | 48 | 5 | 5 | 31 | 12 | -7 | -0.146 |
| Functional trait and precipitation | 49 | 5 | 16 | 26 | 7 | 9 | 0.184 |
| Functional trait and temperature | 43 | 2 | 6 | 36 | 2 | 1 | 0.116 |
| Population and drought | 15 | 1 | 7 | 7 | 1 | 6 | 0.400 |
| Population and precipitation | 192 | 8 | 38 | 131 | 4 | 34 | 0.078 |
| Population and temperature | 4 | 2 | 2 | 2 | 0 | 2 | 0.500 |
| Productivity and drought | 90 | 7 | 11 | 56 | 23 | -12 | -0.133 |
| Productivity and precipitation | 67 | 10 | 35 | 27 | 5 | 30 | 0.448 |
| Productivity and temperature | 36 | 2 | 8 | 27 | 1 | 7 | 0.194 |

In experimental studies of precipitation, Koerner et al. (2014) and Koerner and Collins (2014) observed lower species richness, evenness, diversity, stem density, stem number, and aboveground net primary productivity in rainfall amendment (lower precipitation) treatments established in tallgrass prairie plots at Konza Prairie, Kansas compared to ambient control (higher precipitation) treatments, representing a large-scale pattern across multiple grasslands. Similarly, Serafini et al. (2019) observed lower plant species richness and diversity and both total and relative productivity under lower precipitation ("rainout") treatments in grasslands in southeastern Ontario compared to control treatments. At Cedar Creek Natural History Area, in Minnesota, Tilman and Haddi (1992) and Tilman (1996) observed that severe drought and low precipitation conditions reduce plant diversity and productivity, often driven by the loss of foundational and rare species. Although less pronounced, there was some evidence for warmer temperatures to be positively associated with productivity and functional traits, while negatively associated with plant diversity.

In summary, an increased incidence of drought would be expected to negatively affect many grassland plant species and hinder overall grassland plant diversity, while increased precipitation will promote plant diversity, functional traits, and productivity. Higher temperatures may increase productivity but reduce plant diversity.

## Species in Greatest Conservation Need

Prairies and Other Grasslands provide habitat for 222 animal and 119 plant SGCN as primary or secondary habitat (see Table 3.6) Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. Primary habitats are those that species rely on and use most consistently. Loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with only one or a few. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants).

Prairie and other grasslands support significantly more SGCN than any other habitat. This is likely due in part to their significant reduction over the past 150 years. The 54 vertebrate SGCN represents 33% of all vertebrate SGCN; the 119 plants represent 27% of all plant SGCN; and the 168 terrestrial invertebrates represent nearly 64% of all terrestrial invertebrates. Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

In addition to implications for individual SGCN animals, some species perform keystone roles for prairie ecosystem function. For example, the digging behavior of American badgers (*Taxidea taxus*), northern pocket gophers (*Thomomys talpoides*), and Richardson's ground squirrels (*Spermophilus richardsonii*) create patches of bare soil and nesting sites for insects such as some wild bees and tiger beetles. Other mammals, birds, and reptiles may use their burrows for shelter and to hunt prey. Soil disturbance, burrowing, seed eating and dispersal, and micro-grazing by rodents all create unique micro-habitats which help to support prairie diversity. Lastly, many SGCN are important parts of the prairie food web as predators, prey, or herbivores.

**Table 3.6. Numbers of species of SGCN associated with Prairie and Other Grasslands habitat as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 1 | 0 | 1 |
| Birds | 22 | 7 | 29 |
| Mammals | 12 | 1 | 13 |
| Reptiles | 11 | 0 | 11 |
| Bees | - | - | 83 |
| Beetles (terrestrial) | - | - | 4 |
| Butterflies | - | - | 15 |
| Moths | - | - | 56 |
| Snails (terrestrial) | 0 | 2 | 2 |
| Spiders | 4 | 2 | 6 |
| True Bugs | - | - | 2 |
| Plants | 119 | - | 119 |
| **Total** | **169** | **12** | **341** |

## Amphibians

The great plains toad (*Anaxyrus cognatus*) is the only amphibian SGCN that is primarily associated with open grassland habitats. Remnant tallgrass prairie, wet meadows, and even agricultural fields provide summer forage and overwintering habitat. Shallow wetlands provide breeding habitat; even small depressions in agricultural fields that accumulate small pools of water following heavy rainstorms may be used for breeding. The toads spend much of their time in underground burrows throughout the rest of the year and may estivate (become dormant with reduced activity and metabolism) during hot and dry periods.

## Birds

Grassland birds are declining at greater rates than any other habitat guild, with an overall 53% decline since 1970 (Rosenberg et al., 2019). The great imperilment of grassland birds is likely indicative of the status of other wildlife and plants that use prairie. Birds are very detectable and common subjects of monitoring and are widely viewed as indicators of ecosystem health and function. A growing body of work focused on other species, such as butterflies, suggests threats and population declines extend beyond birds (Edwards et al., 2025).

The decline of grassland habitat, and subsequently grassland bird populations is not unique to Minnesota. Indeed, scientists have been sounding the alarm for decades regarding steep population-level declines in grassland bird species (Brennan and Kuvlesky, 2005; Rosenberg et al., 2019; Bernath-Plaisted et al., 2023). These declines are likely the result of landscape-scale conversion of grassland habitat to cropland as well as the disruption of historic fire and grazing regimes (Knopf, 1994; Samson et al., 2004; Augustine et al., 2019; Bernath-Plaisted et al., 2023). With ~80% of the remaining grasslands in the United States being privately owned and managed (Bernath-Plaisted et al., 2023), future trends for grassland bird populations may be largely dependent upon private land conservation efforts.

*Photo: Greater prairie-chicken, Bob Dunlap*

Ultimately, these continent-wide population declines in grassland bird species underscore the critical need to protect remaining intact grasslands, while subsequently investing heavily in prairie restoration and reconstruction efforts, both on public and privately owned land.

Three bird SGCN, Sprague's pipit (*Anthus spragueii*), chestnut-collared longspur (*Calcarius ornatus*), and Baird's sparrow (*Centronyx bairdii*), are native prairie specialists that were common in portions of western Minnesota prior to settlement by people of European descent, but are now extremely rare. Pipits and longspurs prefer dry prairie sites with short and mid-height grasses. Typically, natural disturbance such as fire or grazing are necessary to provide suitable grassland structure for these species. Baird's sparrows are largely restricted to native prairie with structural diversity maintained by natural disturbance, occupying areas with taller grasses than the previous two species. However, they have been found to use non-native grasslands in other parts of their breeding range (Green et al., 2020).

All other grassland bird SGCN may be found in both native and non-native (surrogate) grasslands if suitable microhabitat features are present. Species found in mesic grasslands with taller grasses include sedge wrens (*Cistothorus stellaris*), LeConte's (*Ammospiza leconteii*) and Henslow's sparrows (*Centronyx henslowii*), bobolinks (*Dolichonyx oryzivorus*), and eastern meadowlarks (*Sturnella magna*). Grasslands with a short grass component, often maintained by grazing or fire, are preferred by upland sandpipers (*Bartramia longicauda*), western kingbirds (*Tyrannus verticalis*), and grasshopper sparrows (*Ammodramus savavvarum*). Sharp-tailed grouse (*Tympanuchus phasianellus*), lark sparrows (*Chondestes grammacus*), and field sparrows (*Spizella pusilla*) occupy grasslands with scattered low shrubs or small trees.

## Mammals

Prairies and other grasslands are the primary habitat for the largest number of SGCN mammals (12). The extensive loss and degradation of this habitat across western and southern Minnesota is likely responsible for the declining populations and vulnerability of so many species. Historically, one of most visible, abundant and iconic inhabitants of Minnesota's grasslands were elk (*Cervus canadensis*). Reintroduced in the 1930s, the free roaming population now consists of only 200-250 animals in northwestern Minnesota. Most of the SGCNs are small to mid-sized mammals that are limited to grassland habitats. These prairie-specialist mammals include but are not limited to the white-tailed jack rabbit (*Lepus townsendii*), American badger, prairie vole (*Microtus ochrogaster*), Northern grasshopper mouse (*Onychomys leucogaster*), plains pocket mouse (Perognathus flavescens), and Richardson's ground squirrel; each can also be found in savanna habitats.

The important ecological roles that small and mid-sized mammals play in grassland systems were summarized by Ayodele (2025) (see the DNR Prairie Wildlife webpage). They include nutrient cycling, soil disturbance, grazing, dispersal of seeds and mycorrhizal fungi,

*Photo: Plains pocket mouse, Abby Benson*

and serving as both predators and prey for other animals. SGCN mammals can be vital to populations of SGCN from other groups. For example, Richardson's ground squirrels are widely cited as being strongly associated with the population health of key SGCN predators such as the burrowing owl (*Athene cunicularia*) and Swainson's hawk (*Buteo swainsoni*) (Houston and Bechard, 1984; Conway, 2018). White-tailed jackrabbit's selective grazing activities play an important role in the distribution of grassland plants while their burrows can act as seed pits or refuges (Schlater et al., 2021). Both these SGCN species have experienced population declines. White-tailed jackrabbit populations, for example have significantly declined over the past century, primarily due to eradication efforts (e.g., hunting and poisoning) aimed at reducing crop damage in the early 1900s (Brown et al., 2018) and the loss of the species' preferred habitats, including grasslands, pastures, hayfields, and small grains. Today, the species' population is only a fraction of what it was throughout its range compared to the previous century (Brown et al., 2020), and it is rarely seen in Minnesota (DNR ARS 2024). Despite this decline in the species' population, it is not well researched (Schlater et al., 2021).

Other grasslands such as pastures also provide habitat for several SGCN. Most of these species are adapted to prairie but some find appropriate habitat features in these

grasslands, particularly those who are seeking sparser or shorter vegetation structure. For instance, plains pocket mice require sparse grassland vegetation. Prairie voles prefer relatively dry upland prairies and pastures with a high diversity of forbs. Richardson's ground squirrels are usually found in short grass prairie or pasture where they can see over the vegetation. Some SGCN will use surrogate grasslands that contain certain soil textures for burrowing, such as plains pocket mice using exposed, sandy soils.

## Reptiles

Eleven of the thirteen reptile species that have been designated SGCN use prairies and other grasslands as one of their primary habitats. Other related open habitats commonly used by these species that depend on the sun for thermoregulation include savannas and cliffs, talus, and rock outcrops. Included are seven snake species, two lizards (six-lined racerunner [*Aspidoscelis sexlineatus*] and common five-lined skink [*Plestiodon fasciatus*]), and two turtles (Blanding's turtle [*Emydoidea blandingii*] and wood turtle [*Glyptemys insculpta*]). Among the seven snake SGCN, the plains hog-nosed snake (*Heterodon nasicus*) is limited almost entirely to prairies, open grasslands, and savannas. This habitat specialist prefers well-drained, loose loamy or sandy soils, sparsely vegetated habitats and frequently uses the burrows of pocket gophers. Gophersnakes (*Pituophis catenifer*) also are closely tied with all open habitats including prairies, savannas, and old fields; sites with sandy soils are especially important (Moriarty & Hall, 2014).

## Insects

It has long been known that fragmentation and destruction of grassland reduces insect species diversity and abundance (Collinge, 2000). Several prairie specialists have already been extirpated in Minnesota, including these butterflies: the arogos skipper (*Atrytone arogos*), Poweshiek skipperling (*Oarisma poweshiek*), Ottoe skipper (*Hesperia ottoe*), Assiniboia skipper (*Hesperia assiniboia*), Garita skipperling (*Oarisma garita*), and Uhler's arctic (*Oeneis uhleri varuna*). Many insect SGCN are prairie specialists. These insect SGCN often require habitat features provided by native or perhaps restored prairie that are not found in other grassland habitats, such as a specific host plant or microhabitat structure limited to prairie. Insects that require a specific host plant as larvae to complete their life cycle include the regal fritillary (*Speyeria idalia*) and prairie violet (*Viola pedatifida*), and bird's foot violet (*Viola pedata*); red-tailed leafhopper (*Aflexia rubranura*) and prairie dropseed; and the phlox moth (*Schinia indiana*) whose host plant is prairie phlox (*Phlox pilosa*), typically found in remnant native prairie.

In addition, some butterflies may require a particular microhabitat structure. For example, several skippers, including the Dakota skipper (*Hesperia dacotae*), require bunchgrasses characteristic of the prairie habitat as opposed to sod-forming grasses, which often characterize other grasslands. All butterflies require flowering forbs as nectar sources on which adults feed.

Though actions that benefit prairie plant communities generally benefit prairie dwelling insects as well, it is important to note that any given management action may negatively affect some insect species and positively affect others depending on location, method, and time of year. Insects may winter above or below ground as eggs, larvae, pupae, or adults. Many species are capable of flight in adult stage for only a short time and are immobile or less mobile the rest of the year. Therefore, the seasons during which insects are vulnerable to above-ground disturbance (e.g., fire, mowing, haying, grazing) or below-ground disturbances such as digging or disking differ by species. As emphasized by Leone et al. (2022), prairie management should be conceptualized as a mosaic of practices and conditions across prairie landscapes and through time, rather than a "one size fits all" approach.

## Plants

Prairie systems support many endangered, threatened, and special concern plants with a wide range of ecological retirements. Plants such as Sullivant's milkweed (*Asclepias sullivantii*) or small white lady slipper (*Cyperpedium candidum*) require the varying hydrology of wet prairies associated with intact wetlands. Species of inland dunes like sea-side three-awn (*Aristida tuberculosa*), blue toadflax (*Nuttlanthus canadensis*), and goat's rue (*Tephrosia virginiana*) colonize sparsely vegetated areas of wind-deposited fine sand. In the Southeast, prairies support many species on the edge of their ranges such as Indian plantains (*Arnoglossum* spp.) and wild quinine (*Parthenium integrifolium*).

*Photo: Western prairie fringed orchid, Blue Mounds State Park*

In the Western prairies, many species of the great plains have their most eastern populations in Minnesota's dry prairies. In the past, many short statured plants like cross-leaved milkwort (*Polygala cruciata*) or prairie shooting star (*Dodecatheon meadia*) were advantaged by fire and grazing in prairie systems which would have created openings for these plants. Other species, like kinnickinnick dewberry (*Rubus multifer*), or kitten-tails (*Synthris bullii*) occur in the transitional communities between prairies and forests that were maintained in greater abundance by past fire and grazing.

Due to these microhabitat requirements, most rare SGCN plant species appear to be restricted to remnant prairies. Restoration plantings of the surrounding landscape may benefit remnant species by increasing connectivity for pollinators and buffering communities containing plant SGCN from invasive species and edge effects. These include: earleaf false foxglove (*Agalinis auriculata*), roundstem false foxglove (*Agalinis gattingeri*), winter bentgrass (*Agrostis hyemalis*), clasping milkweed (*Asclepias amplexicaulis*), prairie milkweed (*Asclepias hirtella*), narrow leaved milkweed (*Asclepias stenophylla*), Sullivant's milkweed (*Asclepias sullivantii*), slender milkvetch (*Astragalus flexuosus var. Flexuosus*), Missouri milkvetch (*Astragalus missouriensis var. Missouriensis*), spike oat (*Avenula hookeri*), plains wild indigo (*Baptisia leucophaea*), prairie moonwort (*Botrychium campestre*), frenchman's bluff moonwort (*Botrychium gallicomontanum*), plains reedgrass (*Calamagrostis montanensis*), hooker's sedge (*Carex hookerana*), blunt sedge (*Carex obtusata*), Hill's thistle (*Cirsium pumilum* var. *Hillii*), white prairie clover (*Dalea candida* var. *Oligophylla*), and blanketflower (*Gaillardia aristata*).

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, intensive agriculture, subsistence, livelihoods, and recreation. Habitat loss or alteration remains the primary threat to most, if not all SGCN. In this section we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Pressure from urban and exurban development encroaches on grasslands, with particular pressure on sand barrens and sand prairies near large urban areas. Development accounts for 25% of documented prairie acres lost between 1987 and 2015 (MBS, 2017). In addition, the conversion of prairie habitat to development often alters hydrology, affecting adjacent prairie patches.

According to the Minnesota State Demographic Center, our state's population is projected to grow from 5.78 million in 2024 to 6.11 million in 2075. The addition of 330,000 people over the next 50 years will add to current development pressure and will likely threaten conversion of some remaining grasslands. Specifically, MNDOT estimates that 70% of population growth over the next 20 years will be focused on the seven-county metro area, putting substantial pressure on remaining dry prairie habitats in this region.

### Crop Production

Conversion of native prairie to agricultural use has drastically reduced the prevalence of native prairie in the last 150 years, and in some economic markets remains an ongoing threat. Conversion to row crops remains the largest land use conversion of documented remnant prairies in Minnesota, accounting for 62% of acres lost between 1987 and 2015 (MBS, 2017).

Agricultural practices can alter hydrology in prairie systems, by increasing runoff from heavy rain events and introducing sediment and chemical residue into streams and wetlands. Draining of fields with pattern drain tiling alters the water table depth and may increase flash flooding during heavy rain events (see also Water Management and Use).

Abundant and widespread fertilizer use has long been a feature of Minnesota's agricultural system. However, high usage of nitrogen may degrade Minnesota's remaining prairie communities. High rates of nitrogen application can change the bacterial composition and nitrogen availability of the soil and is not restricted to the area of application (McLeod et al., 2016). This additional nitrogen can promote and facilitate the spread of invasive species (Morghan and Seastedt, 1999; McLeod et al., 2016), with reed canary grass (Rickey and Anderson, 2004) and smooth brome (Clark, 2008) being notable issues in Minnesota.

Pesticide use from agricultural practices have been identified as a leading factor in the declines of grassland dependent species (Mineau et al., 2005; Gibbs et al.,

2009; Gibbons et al., 2015; Forister et al., 2016; Sánchez-Bayo and Wyckhuys, 2019). Neonicotinoids (systemic insecticides often applied as seed coats to corn, soybeans, and other crops) have become one of the most widely applied classes of insecticides and have been widely posited as a primary driver of insect declines and potentially other wildlife (Mason et al., 2013; Goulson, 2013; Gibbons et al., 2015; Pecenka and Lundgren, 2015; Gilburn et al., 2015; Forister et al., 2016; Basley and Goulson, 2018; Olaya-Arenas and Kaplan, 2019; Li et al., 2020; Roy and Chen, 2023). Insecticides applied via aerial spraying include broad-spectrum insecticides such as organophosphates (especially chlorpyrifos) and pyrethroids. Often targeting soybean aphid and other crop pests, these can be easily transported into non-target prairie preserves from neighboring and even distant crop fields (Foreman et al., 2000; Mackay et al., 2014). Two of these, chlorpyrifos (organophosphate) and bifenthrin (pyrethroid), have been frequently documented far within prairies designated as Critical Habitat for listed butterflies including Dakota skipper, and whose applications are at least correlated with their declines (Runquist et al., 2024).

Mechanical harvest through haying can be a very effective method to enhance grassland stands by removing weeds, stimulating root development in grasses, and reducing the duff layer to allow native grass species to increase in density. However, haying can have negative effects on ground nesting birds and other wildlife species through nest destruction and habitat loss. Haying should be planned during times that will minimize effects on ground-nesting birds. The nesting season is generally considered to be between April 15th and August 1st. As a result, haying should be conducted in August or September. To avoid significant effects on wildlife, it is recommended that no more than fifty percent of a field be hayed in any given year to maintain adequate cover for wildlife habitat. Flushing bars and mowing patterns that drive wildlife to the outer edges of the field should also be used.

## Livestock Management

Livestock operation management can either benefit or degrade a grassland ecosystem and directly influences the plants and wildlife that utilize the associated habitat. Properly managed grazing can stimulate plant diversity and create diverse vegetative structure across the landscape. Overgrazing, if left unchecked, can reduce diversity in vegetative cover and structure, and have severe negative effects on biodiversity, ecosystem function, soil health, and forage production.

Over the last 30 years, advances in range science, grazing management practices, technology, and increased education and outreach efforts within the agricultural community have allowed livestock producers to manage their herds to meet economic goals while preserving healthy grasslands for future generations. However, overgrazing is still widespread in Minnesota and is exacerbated by increasing drought patterns. Overgrazing favors plants that are grazing increasers (species tolerant to intensive grazing), which eventually take over and are often undesirable, non-native, or even invasive. Under heavy continuous grazing, plant diversity can decrease by reducing or eliminating plant species intolerant to intensive grazing such as big bluestem (*Andropogon gerardii*), porcupine grass (*Hesperostipa spartea*), little bluestem (*Schizachyrium scoparium*), yellow prairie grass (*Sorghastrum nutans*), prairie dropseed (*Sporobolus heterolepis*), prairie onion (*Allium stellatum*), leadplant (*Amorpha canescens*), prairie clovers (*Dalea spp.*), narrow-leaved purple coneflower (*Echinacea angustifolia*), stiff sunflower (*Helianthus pauciflorus*), and blazing stars (*Liatris spp.*).

Low diversity grasslands also limit native species of pollinators that have evolved alongside native plants. In addition, overgrazing reduces grass and forb heights and can increase bare ground on many sites. Along with increasing the risk of erosion, these conditions are generally not as favorable for

species adapted to the tallgrass prairie such as bobolinks and Henslow's sparrow, which prefer mid-height to tall vegetation with 1-3 years of thatch.

Care must be taken when treating livestock for pests and parasites, as treatments often contain insecticides. Some insecticides persist in the environment weeks after treatment and can harm beneficial insects and contaminate soil and water via the animals' feces.

## Mining and Quarrying

Sand and gravel mining in particular affects dry prairies, especially sand prairies, by converting habitat in order to extract the sub-surface aggregate material. Mining accounted for 12% of conversions of documented remnant prairie from 1987 to 2015 (MBS 2017), and conversions from prairie to mining appear to be increasing over time.

The construction of roads, trails, and railroads requires aggregate material. In areas with remnant dry prairie, the substrate beneath the dry prairie is often targeted for extraction to build these lines of infrastructure. It is impossible to repair these dry prairies once they have been mined for aggregate.

Dry prairies in closer proximity to highly developed areas and/or major roadways are at serious risk for sand and gravel mining. Developers and road authorities typically try to source aggregate material near the project site to reduce costs, putting prairies near emerging projects at high risk. As developmental pressures increase, the risk of these prairies being lost will increase substantially.

## Wind and Solar Energy Infrastructure

According to Our Minnesota Climate "The amount of energy our state produces from renewable resources like solar power and wind has risen 60% over the past decade. Today, renewable energy accounts for 28% of Minnesota's electricity generation, with 52% of our energy coming from carbon-free sources like renewables, nuclear, and hydropower." These successes in renewable energy production, while critical to reducing climate-warming greenhouse gas emissions, can be complex in the context of wildlife and habitat effects. Both wind and solar development can indirectly affect SGCN due to loss and fragmentation of grassland habitat. In addition, some SGCN, such as the greater prairie chicken, have shown avoidance behaviors toward wind developments (Winder et al., 2014; LeBeau et al., 2017). Wind turbines are associated with direct effects on birds and bats. particularly during migration, with wind turbine collisions documented as a high source of mortality for both groups. Loss and his colleagues (2013b) estimated between 140,000 and 328,000 birds are killed annually at wind turbines across the contiguous United States; mortality increased with the height of the turbine hub. Foliage and tree-roosting bats, such as hoary bats and eastern red bats, also are frequently found dead below wind turbines (Arnett et al. 2008). Although variable in timing, most mortality occurs during late summer and fall, corresponding with migration and mating seasons. Estimates place the loss at approximately 888,000 bats per year (Smallwood 2013). To date, lighting and noise appear to not influence the level of mortality.

Similarly, land-use effects in and around solar arrays and wind turbines can negatively affect native plant communities (predominantly prairie) and rare features. Taking lessons from traditional power infrastructure and development, we can be mindful to wildlife considerations in the siting and design of immerging alternative energy resources.

## Roads, Trails, and Railroads

Railroads, roads, and trails, while essential, fragment grassland habitats. They can also alter hydrology, increase sedimentation and runoff, and act as a vector for the introduction of invasive species. The associated effects from initial construction as well as routine maintenance and infrastructure installation can have detrimental effects on

habitat within the right of way for the life of the road, trail or railroad.

## Utility Corridors

Utility corridors intersect prairie and other grasslands throughout the state and can include pipelines, telephone lines, and power lines. These lines can be aerial or below ground. Regardless of type, utility corridors can fragment habitat based on their size, purpose, and the upkeep that is required to maintain them.

The initial construction of the associated utility infrastructure as well as the long-term maintenance of that infrastructure can have lasting effects on native plant communities and the SGCN associated with them. Increased funding for rural broadband, conversion of aboveground powerlines to belowground, and development of new utilities (solar, wind, etc.) continue to pressure grassland habitats.

These corridors and the increased travel from vehicles and equipment that they require act as vectors for invasive plant species. The required vegetative management practices often include herbicide applications, removal of woody vegetation, and/or mowing. This increased disturbance increases the likelihood of establishing invasive plant species within the corridors and then spreading to adjacent lands.

## Hunting and Collecting Animals

Small mammals can be affected by deliberate trapping or shooting. For example, while Northern pocket gophers are rare, the Plains pocket gopher is very abundant and is unprotected, meaning that hunting and trapping is not limited. Several other SGCN, Richardson's ground squirrels and Franklin's ground squirrels and American badgers are still to this day considered pests. The burrowing nature of these species is concerning to some agricultural producers and may result in increased control measures.

## Gathering Plants and Fungi

In Minnesota state parks, recreation areas, waysides, forests, and Aquatic and Wildlife Management Areas, gathering of fruits and mushrooms for personal consumption is allowed (see Harvesting Plants and Harvesting on State Forest Lands). However, it is illegal to dig up or damage plants on any state lands (Minnesota Statute 6100.0900). Harvesting can cause numerous effects, which can negatively affect natural resources and other visitors' experiences, such as: disturbing soils and trampling other plants, which can lead to invasive species taking hold; removing food sources otherwise available for wildlife; reducing the natural reproduction of some species; and preventing other people from having the same experience.

A threat to Minnesota grasslands is the overcollection of seed and, in some cases, illegal collection of plants, for use in native plant sales. The rarest species, with the smallest amount of seed produced, and those with the highest market value, are the most vulnerable from overcollection. One of the most popular plants for collection is narrow-leaved coneflower (*Echinacea angustifolia*).

Another type of plant harvesting is for the use of medicinal, herbal, or food purposes. Species that are most vulnerable to overharvesting include species with edible tubers such as prairie turnip (*Pediomelum esculentum*) and wild/prairie onion (*Allium stellatum*). Natural areas close to large population centers are most vulnerable to over harvesting.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest in the Tallgrass aspen parkland region may alter patch dynamics between aspen and prairie stands by increasing root suckering and clonality of aspen.

## Recreation

Recreational overuse can threaten sensitive grassland plants and grassland communities. Foot traffic in popular hiking areas may degrade plant communities and rare plants could be trampled if visitors do not stay on established trails. Foot traffic also introduces the risk of spreading invasive species.

## Fire Management

Fire is a necessary and natural feature of Minnesota's native grasslands. Fire-adapted ecosystems, which includes all of Minnesota's grassland habitats, have evolved to thrive with fire disturbance. Sediment cores from the Northern Great Plains indicate that grasslands, drought, and fire have been a key feature of this landscape for much of the past 10,000 years (Nelson and Hu, 2008; Grimm et al., 2011). If litter or thatch are not periodically removed by fire, grazing, or haying, ecosystem productivity and species diversity decline (Anderson, 1990; Knapp et al., 2009).

In the modern era, landscape conversion and development has led to most remaining grasslands of all types being highly fragmented, scattered, and (in most cases) small in size. Though fire is necessary to maintain grassland habitat, the current nature of small, isolated grasslands means that, without careful planning, SGCN populations could be critically reduced and even extirpated by fire.

Lack of fire is a stressor for many prairie plant communities, including dry and mesic tallgrass prairie, bluff prairies, brush-prairies, and savannas. Fire suppression leads to woody species encroachment, such as eastern red cedar (*Juniperus virginiana*) and/or Siberian elm (*Ulmus pumila*); for additional information, see Problematic Native Species and Invasive Species, respectively. If left unchecked, these woody species can result in wholescale ecosystem conversion (DeSantis et al., 2011).

## Invasive Species (Problematic Non-native Species)

Invasive plant species can have negative effects on native plant communities in prairie and grassland ecosystems. While both native and non-native plant species can become overdominant and be problematic in prairies and grasslands, non-native invasive plant species are of particular concern. Non-native plants did not evolve within the ecosystem that they now inhabit and were likely imported for their ability to establish easily and spread quickly. As a result, they are able to outcompete native plant species for available resources while decreasing biodiversity and degrading already limited habitat for SGCN.

A prevalent example of this is smooth brome (*Bromus inermis*). Smooth brome is a perennial cool season grass native to Europe and Asia. It has become quite dominant in prairies across much of the state. In remnant prairies, smooth brome has been shown to reduce native plant richness (Jones et al., 2023; Otfinowski et al., 2007), reduce native cover (Fink and Wilson, 2011), and alter soil dynamics (Vinton, 2006; Bell et al., 2023). Like many non-native cool season grasses, smooth brome is difficult to manage once it is established. Work is ongoing to develop effective management strategies to reduce smooth brome in grassland habitats. Anecdotal evidence to date suggests that late fall (post-hard frost) herbicide applications and late spring burns can help to suppress smooth brome and allow native prairie species room to compete. Treatments will likely need to be repeated through time. Careful consideration should be exercised in using these techniques, particularly on remnant prairies. While already affecting many remnant prairies, smooth brome is predicted to become more problematic in prairie ecosystems under increased nitrogen deposition (Clark, 2008), increased atmospheric carbon dioxide concentrations, and increased spring rainfall (Prevey, 2014; Printz and Hendrickson, 2015). Understanding effective management practices for reducing

smooth brome in tallgrass remnant prairies is increasingly important. Likewise, Kentucky bluegrass (*Poa pratensis*) is another invasive cool-season grass that causes degradation similar to smooth brome (Gannon, 2024).

From 1960 to present, invasive woody species including common buckthorn (*Rhamnus cathartica*) and bush honeysuckle (*Lonicera spp.*) have proliferated and continued to invade natural areas including bluff prairies and adjacent savanna (Hartman and Steele, 2015). Invasive forb species such as sweetclover (*Melilotus officinalis*) are also common invasive species in these habitat types (Hartman and Steele, 2015). As buckthorn and honeysuckles continue to spread, all prairie habitat types are now being affected by these woody invaders. These species are an impending challenge for prairie land managers, particularly in areas that are difficult to burn.

## Problematic Native Species

Native plant species can possess characteristics associated with invasive species (non-native problematic species), such as encroaching into prairie habitat. These plant species are often referred to as pioneer or volunteer species. These characteristics can make them problematic under certain conditions. This is especially true in the absence of disturbance such as fire, thinning, or grazing. Historically disturbance was a limiting factor for many of these problematic native species. Frequent disturbance through fire limited the spread of these species by killing them before maturity and reproductive age.

An example of this is eastern red cedar (*Juniperus virginiana*). Its seeds are readily consumed and transported by birds and small mammals. Young red cedar trees will not tolerate fire and are killed. In the absence of fire this native tree species can encroach into prairie and grassland ecosystems and grow to maturity. Once established, mature cedar trees develop an extensive fibrous root system that can extend laterally up to 20 ft from the root crown. Mature trees are able to take advantage of moisture and nutrients in the soil profile and eventually shade out many if not all of the native prairie vegetation at the ground level. This prevents grasses and forbs from growing, thus eliminating the fine fuels needed to carry fire and kill the trees. This self-reinforcing feedback loop allows cedar to continue to spread once firmly established. In prairie and grassland ecosystems these eastern red cedar groves eliminate native perennial grasses and forbs, fragment habitat, provide hunting perches for raptors that prey on ground nesting birds, and generally degrade the biodiversity in the area they inhabit.

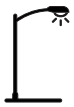
Another increasing species is reed canary grass, previously classified as an invasive species but more recently thought to be native in at least some of Minnesota based upon research at the University of Minnesota (Reed Canary Grass). Reed canary grass is particularly damaging in wet prairies. The thick sod layer and dense growth can rapidly outcompete desirable native species, and it is common to see former wet prairies transition to a near monoculture of reed canary grass in areas where this species is present. To date, land managers have been unable to find an effective management strategy to reduce or eliminate reed canary grass.

## Air-borne Pollution

Experiments under controlled greenhouse conditions have shown that increased levels of atmospheric carbon dioxide may favor the competitiveness of woody plants and cool season invasives by stimulating photosynthesis and growth. It may also reduce mild to moderate abiotic stress in woody plants if root growth and nutrients are not limited.

Nitrogen levels in the atmosphere are driven by natural processes as well as transportation and agricultural sources, primarily fertilizer (Burke et al., 2002; Wall and Pearson, 2013). A study indicates that increased atmospheric deposition of nitrogen reduced plant species numbers by 17% by increasing soil acidity and increasing above ground production of certain

plants that reduces light availability to other plant species. This can lead to competitive exclusion. This suggests that chronic but low-level nitrogen deposition may have a greater effect on diversity than previously thought (Clark & Tilman, 2008).



## Light and Noise Pollution

Nearly half of the United States land surface has light-polluted skies (Falchi et al. 2016). Sources of light pollution at night include interior and exterior lights on homes, buildings, billboards, parking lots, and streets as well as lighted sports fields, industrial plants, and airports (DarkSky International 2025a). Studies also point to the ecological effects created during the daytime by polarized light that reflects off surfaces such as asphalt roads, glass panes, and solar panels (Chock et al. 2020; Horvath et al. 2009).

Effects of light pollution include disrupting the behavior of amphibians whose breeding calls are delivered at night, drawing nocturnal insects to artificial lights that increase their predation risk, and disorienting birds that use environmental cues to guide their nighttime migration (DarkSky International 2025a, 2025b). In addition, the phenology, growth rates and biomass of plants are affected (Bucher et al. 2023). Bright day and dark night cycles synchronize the internal clocks of plants and animals, and alterations to these cycles can affect hormone production, reproductive behavior, neural activity, and metabolic functions (Bumgarner & Nelson, 2021).

Noise pollution from aircraft, vehicles, boats, and other human causes is pervasive. Anthropogenic noise was detected in 36% of national parks surveyed (Buxton et al. 2019), and 12% of wilderness areas had anthropogenic noise levels 3 decibels higher than levels predicted to occur naturally (Buxton et al. 2017). Exposure to increasing noise levels can change the spatial distribution and movement patterns of wildlife, cause avoidance of feeding and nesting areas, and interrupt sleeping patterns and communications (Kok et al. 2021). For plants, noise can reduce seedling recruitment (Phillips et al. 2021).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). According to the Minnesota Pollution Control Agency and the Minnesota Department of Commerce these changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years. Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025b).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (in; Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 in. or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; Runkle, J., et al (2022)). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota).

*Photo: Restoration planting at Glendalough State Park*

By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 in., depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation section in Chapter 6: Implementation.

## Case Study: Regenerative Grazing and Audubon Conservation Ranching

Audubon Conservation Ranching (ACR) is the flagship grassland habitat program of the National Audubon Society. With most remaining grasslands privately owned and operated as working lands, partnering with landowners is the most effective conservation collaboration to impact habitat and bird populations on a landscape scale. North America's grassland bird populations have experienced a steep decline of more than 53% over the last 50 years. By partnering with regenerative-minded farmers and ranchers through the ACR Program, Audubon is working to stabilize and grow those populations across the continent by building resilient lands that support wildlife, ecosystem services, people, and agriculture. Promoting regenerative grazing practices such as rotational grazing, reduced chemical use, cover crops, and native plant establishment, can lead to improved forage quality, drought resiliency, soil stability, carbon sequestration, animal health, and water quality. These key ecological benefits lend to long-term sustainability and improved bottom lines of each individual farm and ranch. To be certified in the ACR program, landowners must meet habitat management, environmental sustainability, and animal welfare standards. Once qualified by a third-party audit, producers then use the Audubon Certified Bird-Friendly seal for packaging and promotion of beef or bison products, which recognizes lands managed for birds and biodiversity. Consumers can then support conservation when they select products from these certified bird-friendly lands.

*Photo: Conservation grazing in prairie, Lisa Gelvin-Innvaer*

Lonetree Ranch, spanning 9.000 acres in Wyoming and Utah, produces organic, grass-fed cattle and is an excellent example of ACR certified bird-friendly land. The Taylor family manages their sage dominated acres for forage and habitat for species such as the greater sage grouse, mule deer, pronghorn, elk, and moose. Their priority is to increase the biodiversity of their vegetative community to establish resiliency and ensure consistent forage for their cattle and wildlife. Lonetree Ranch partnered with Audubon and the Wyoming Department of Conservation to rejuvenate sagebrush habitat. When sagebrush goes too long without disturbance, such as fire, drought, or grazing, it grows so densely that other plants can't survive in the understory. Project partners performed sagebrush mowing to open the canopy, increasing forb presence and diversity, while also encouraging younger sagebrush to establish. In addition, Audubon replaced barbed wire fences with wildlife friendly alternatives to provide safe migration corridors for mule deer and pronghorn.

In Minnesota, Audubon began certifying farms through the ACR program in 2024. With funding from the National Fish and Wildlife Foundation, the Minnesota Environment and Natural Resources Trust Fund, and a USDA NRCS Conservation Innovation Grant, Audubon is dedicated to providing technical and financial assistance to participating ACR producers in addition to monitoring the effects of the applied regenerative practices on birds, vegetation, and soil health.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan (Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN), five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN habitat management practices to benefit SGCN.**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Prairie and Other Grasslands

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Protect remaining remnant prairie from conversion to other land uses. |
| | To protect prairie remnants from pressure for mining resources, increase funding for acquisitions and payments through programs such as the Minnesota Native Prairie Bank. |

| Stressor | Action |
|---|---|
| | Prevent further fragmentation of grassland habitat. Support diverse financial incentives to help landowners avoid conversion of grasslands into row crops where remnant prairie and/or SGCN occur. Implement landowner outreach and engagement activities. Prioritize access for landowners to a variety of programs for implementation of land protection options such as conservation easements. Support conservation programs that provide economic benefits for set aside and conservation programs and assist in public outreach. Improve access to USDA Farm Bill and other wildlife resources for landowners. |
| | Control or prevent the invasion of grasslands by trees and shrubs with mowing and cutting woody vegetation, prescribed fire, grazing, and careful use of herbicides with consideration for SGCN. |
| | Control spread of invasive species on native-dominated sites. Ensure equipment is cleaned prior to moving mowers, haying equipment, and seed harvesters among sites to prevent spreading invasive species. |
| | Livestock treated with systemic insecticides for pest or parasite control (such as ivermectin, doramectin, or eprinomectin) should not be released on conservation lands for at least 30 days following treatment. If parasite treatment is needed during the grazing period, the best practice is to remove affected animals for treatment and return them to the site after the recommended amount of time. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Promote and participate in prairie reconstruction and restoration to expand the amount of prairie and provide a diversity of native plants to sustain biodiversity and provide ecosystem benefits including healthy soil, carbon storage, improved hydrology, watershed health, and cleaner water. Projects that restore more natural hydrology, such as breaking up drain tile, can also benefit streams and downstream habitats. Planning projects to be resilient under anticipated changes in climate regimes will be the most successful (see also climate section in Chapter 6: Implementation). |
| | To protect nesting SGCN birds in hayfields and mowed grasslands, consider adopting these bird-friendly measures: use flushing bars, lengthen cutting rotations, and avoid early-season (May-June) mowing and haying. |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land-based activities like biking, hiking, and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. Consider maintaining buffers around and minimizing disturbance to bluff prairies when designing and maintaining trails. |

| Stressor | Action |
|---|---|
| | Avoid soil compaction in areas occupied by mammal and reptile SGCN. |
| | Incentivize conservation grazing practices that benefit grassland SGCN habitat. Increase landowner knowledge of the methods and benefits of various regenerative grazing practices and provide diverse funding opportunities to transition to sustainable grazing and incentivize better habitat management on private lands. Promote the use of rotational grazing, adaptive grazing, and other regenerative practices to build higher quality habitat in addition to boosting cattle production. Support practices to improve soil health (structure, water retention, etc.), prevent erosion, and lower inputs (reseeding, fertilizer, etc.). Specific practices will depend on the targeted SGCN, site conditions, landscape context, and other objectives. See for instance Minnesota Grazing Lands Conservation Association for more information and training opportunities as well as the Case Study on regenerative grazing and the Audubon Conservation Ranching program below. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Increase incentives and planning, and potentially ordinances, to include higher density housing, such as multi-dwelling housing, and create zones of no net growth in areas where grasslands are pressured by urban and exurban development. Awareness, education, economic incentives, community support, and working with local governments can all be part of this effort. |
| | Support more regular and well-planned fires in the prairie. Support the formation of Prescribed Burn Associations. Maintain and encourage the collaboration of agencies and nonprofits to meet prescribed fire objectives on a larger landscape scale. Ensure that burn plans incorporate best practices for SGCN; for example, noting the timing of butterfly and moth larval emergence and use of burn units, rotations, and fire exclusion areas to avoid negatively affecting butterfly and moth populations when they are vulnerable to fire. Creating permanent non-fire refuges within fire-managed sites can benefit Lepidopteran populations (Kwilosz and Knutson, 1999; Swengel and Swengel, 2007). Likewise, other factors like timing, time of day, frequency, ambient temperature, fire intensity, fire direction, buffers around hibernacula, and refuges are considerations for SGCN reptiles and amphibians. |
| | Increase incentives to develop solar in and on developed areas (e.g, atop buildings and parking lots) rather than in undeveloped lands. Site wind and solar developments on low-use croplands and prohibit development in areas with prairie remnants. Consult with parties earlier in planning processes, including with counties. Explore options with wind energy companies to modify wind easements that are only intended to preclude development that would block wind to allow opportunities for acquisition and easements for conservation. |

| Stressor | Action |
|---|---|
| | Implement best practices for minimizing light and noise pollution, especially near grassland preserves. Consider wildlife-friendly lighting solutions as recommended by conservation organizations such as DarkSky and National Audubon Society's Lights Out Program. Best practices include using outdoor lighting only where and when it is actually needed, use of motion detectors and/or automatic timers so lights only turn on when they are most needed, placing light covers or shields so that light only shines down to the ground, and keeping landscape lighting low to the ground, and away from white or reflective surfaces. If lighting is necessary, swap out lights for less bright and warmer (yellow or red) bulbs, or cover existing bulbs with a filter that does the same. Consider closing your curtains at night to keep your light indoors (Xerces Society Firefly Friendly Lighting). |

### Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Implement rigorous effectiveness monitoring or research to assess SGCN responses to management practices to help inform evidence-based adaptive management. |

### Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Develop more evidence-based guidance for conservation grazing that is based on effectiveness monitoring and research, including not only vegetative targets but also responses by Species in Greatest Conservation Need. |
| | Research, better understand, and share information about the potential to use climate-smart regenerative agricultural practices to improve soil health, prevent soil erosion, build carbon storage, and reduce the carbon footprint of agricultural production to benefit SGCN. |
| | Share information about the Northern pocket gopher and encourage counties to eliminate bounties on ground squirrels and gophers in their range. |
| | Promote the coexistence of burrowing SGCN and livestock grazing. Emphasize the benefits of diverse grassland communities, discourage activities related to varmint hunting and pest control. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# SAVANNA

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Oak savanna restoration at Myre-Big Island State Park, Emily Peters; St. Croix Savanna Scientific and Natural Area, David Minor

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# Savanna

## Habitat Description

Savannas typically have scattered trees, sometimes clumps of trees, above a layer of prairie grasses and forbs. Bur oak (*Quercus macrocarpa*) is the most common and widespread tree, but Northern pin oak (*Quercus ellipsoidalis*) and, in the extreme southeastern part of the state, black oak (*Quercus velutina*) are also typical. Small, open-grown, often gnarled bur oaks are the most distinctive savanna tree species. Jack pine (*Pinus banksiana*) is the predominant savanna tree species on deep sand substrates in the northern half of the state.

Savannas in Minnesota are classified as part of the Upland Prairie Ecological System (see also the Prairie and Other Grasslands sub-chapter). Savannas typically occur where fire frequency or intensity is somewhat lower than in prairie landscapes, yet higher than in forested areas. At such sites, more fire-tolerant shrubs and trees can persist, forming brush-prairie and savanna communities.

## Habitat Map

To depict savanna habitat (see Figure 3.7), we compiled spatial data from several sources: DNR's Native Plant Communities and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

*Photo: St. Croix Savanna Scientific and Natural Area, David Minor*

## Associated Native Plant Community Classes by Ecological Systems

**Upland Prairie (UP)**

UPn13 Northern Dry Savanna (PDF)

UPn24 Northern Mesic Savanna (PDF)

UPs14 Southern Dry Savanna (PDF)

UPs24 Southern Mesic Savanna (PDF)

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included this group: Midwest Woodland and Savanna.

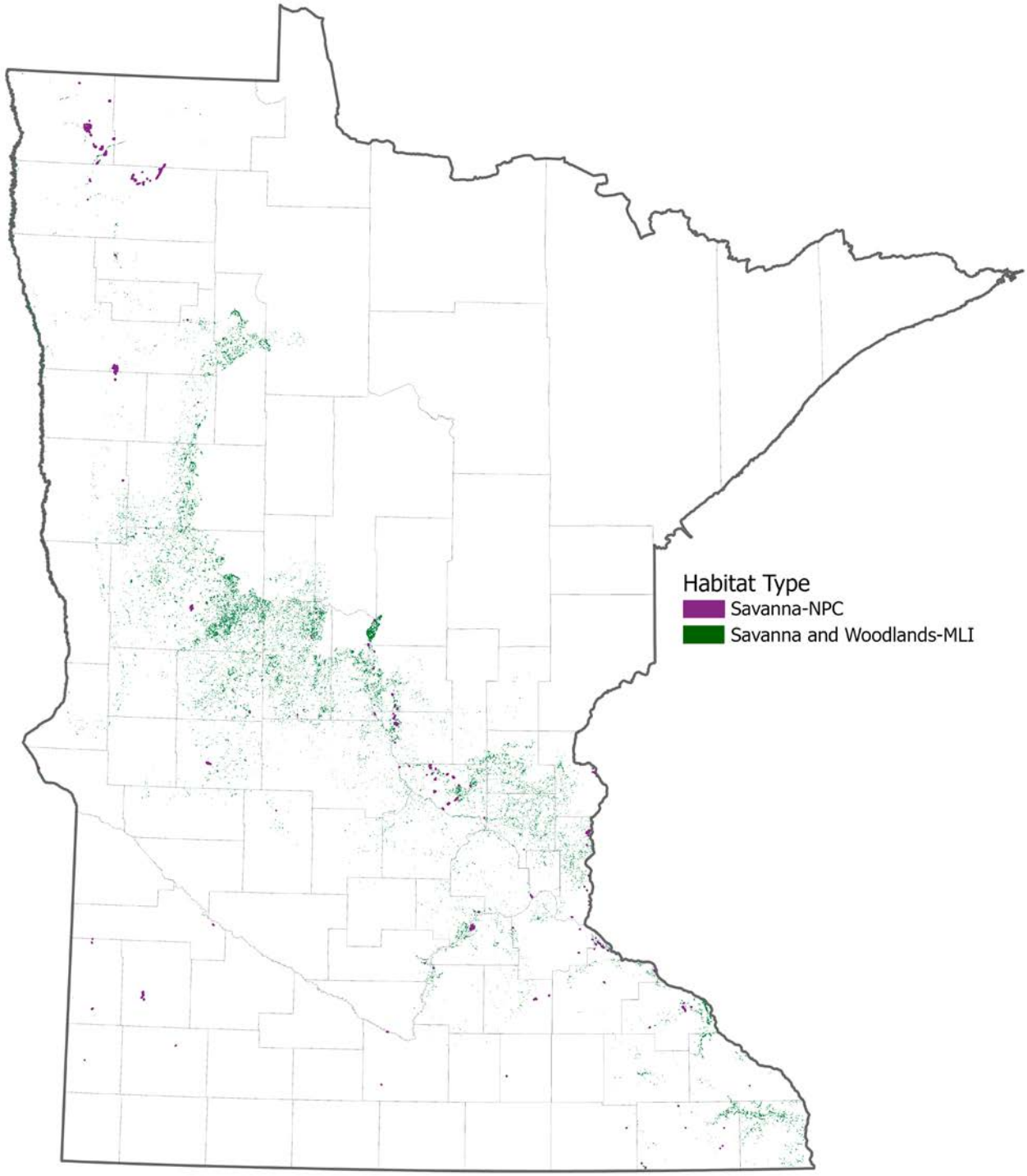


Figure 3.7. A map depicting Savanna habitat in Minnesota, including four savanna DNR Native Plant Community Classes in the Ecological Systems of Upland Prairie as well as Midwest Woodland and Savanna from the Midwest Terrestrial Habitat System.

## Conservation Overview

Oak savanna is one of Minnesota's rarest wildlife habitats. Prior to European settlement, oak savanna was one of the more common ecosystems in Minnesota, covering roughly 10 percent of the state. Fire suppression, agriculture, and urban growth have reduced the extent of oak savanna coverage to approximately 0.02% of its former range in the Midwestern United States (DNR). Statewide, it is estimated that approximately 9,800 to 11,100 acres of the State's original extent of Oak Savanna (all subtypes) remains. Dry Barrens Oak Savanna in Minnesota is even rarer, with acreage totaling less than 5400 acres. Owing to its' rarity, Dry barrens oak savanna is considered Critically Imperiled to Imperiled (S1S2) at the State level and Imperiled at a global level (G2). The savanna is a transitional ecosystem between the tallgrass prairie and woodland environments, so it is an important habitat for both woodland and prairie wildlife (see also the Prairie and Other Grasslands sub-chapter for relevant information on stressors and actions). Before European settlement, native grazers, including bison (*Bison bison*), elk (*Cervus canadensis*) and white-tailed deer (*Odocoileus virginianus*) contributed to the disturbance and maintenance of oak savanna habitats (Hartman and Steele, 2015). As elk and bison were extirpated and white-tailed deer populations significantly reduced, intermittent grazing was taken over by domesticated livestock including sheep, cattle, and goats (Hartman and Steele, 2015).

## Climate Profile

The anticipated effects of climate change on savanna ecosystems were profiled in the report "Effects of Climate Change on Midwestern Ecosystems: Central Interior Oak Forest, Woodland and Savanna" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025). This Climate Profile section is derived from that report, focused on Central Midwest Oak Openings National Vegetation Classification habitat type (please see the report for source citations). These structurally open, fire-maintained habitats typically occur on well-drained soil and represent an ecotone between grassland and woodland. Historically, this habitat type was aided by indigenous fire practices, and frequent, low intensity fires maintained open canopies, restricted woody encroachment, and stimulated warm season prairie grasses and forbs (Ratcliffe et al. 2025).

In addition to exposure to a projected increase in annual temperature of 5.8 degrees F under a moderate emissions scenario for late century (2070-2099), the most impactful changes in climate for this habitat are increasing droughts and commensurate changes in fire behavior and frequency (Ratcliffe et al. 2025). Vapor deficit, which takes into account temperature and water use by evapotranspiration, is projected to increase on average by 33% or 72% over historical levels in the late century, under moderate or high emissions, respectively. This increases the probability of conditions for extreme fire danger (based on low fuel moisture), which could be favorable to this habitat type, unless the fires are too extreme, destroying the canopy and damaging the soil (Ratcliffe et al. 2025).

**Key Climate Change Effects** (from Ratcliffe et al. 2025; please reference for the source citations):

- **Habitat structure** can be altered by drought that reduces herbaceous cover, soil microbial activity and decomposition, which can lead to reduced nutrient availability and

increased erosion, particularly on sandy soils. High-intensity fire would also exacerbate these effects on soil structure and erosion.

- **Community composition** may shift toward more xeric species such as drought-tolerant warm-season grasses although extreme drought or drought with an absence of fire may favor shrubs and encroaching trees. Drought conditions will likely be more favorable for oaks over maples and birches, although extreme drought may inhibit oak recruitment and cause canopy failure.
- **Invasive species** with broad tolerances and rapid recovery strategies can be favored by drought, such as brome (*Bromus*) species. Fire can be effective in suppressing some invasive shrubs, but is not thought to be effective in suppressing some, such as invasive honeysuckles (*Lonicera* spp.), common buckthorn (*Rhamnus cathartica*), and autumn olive (*Elaeagnus umbellata*) that are persistent in the seed bank and recover readily after fire.
- **Pests and pathogens** may become more prevalent as trees are stressed by drought, such as oaks becoming more susceptible to oak borer species. Rising temperatures may increase outbreaks in some pathogens such as moths and bark beetles. Root rots may be diminished by drought or may flourish under fluctuating moisture regimes.
- **Herbivory** could be expected to increase if warming winters support higher populations of white-tailed deer. Increased browsing pressure could inhibit the reproduction of oaks and reduce forb diversity. In addition, drought can inhibit plants investments in chemical defenses.

## Species in Greatest Conservation Need

Savannas provide habitat for 100 animal and 8 plant SGCN as primary or secondary habitat (see Table 3.7).

**Table 3.7. Numbers of SGCN associated with Savanna as either primary or secondary habitat.**

| Species Groups | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Birds | 3 | 4 | 7 |
| Mammals | 5 | 13 | 18 |
| Reptiles | 12 | 0 | 12 |
| Bees | - | - | 4 |
| Beetles (terrestrial) | - | - | 6 |
| Butterflies | - | - | 8 |
| Moths | - | - | 40 |
| Spiders | - | - | 5 |
| Plants | 8 | - | 8 |
| **Total** | **28** | **17** | **108** |

Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. For plants, only a single primary habitat was identified per species. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants). Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

## Birds

Native savanna that meets native plant community criteria (native prairie with scattered native trees or shrubs) is now rare in Minnesota because of conversion to other land uses or through succession to oak woodland due to fire suppression. Most SGCN birds that historically occurred in savanna also make use of non-native surrogate habitats with savanna-like structure. Native savanna often has a range of woody cover, and bird SGCN will vary along this gradient. Open areas dominated by grassland, with scattered shrub or small trees, may support typical grassland birds, while larger patches of trees can provide suitable habitat for woodland or forest species.

Red-headed woodpeckers (*Melanerpes erythrocephalus*) are dependent on large dead trees and snags without bark. Typically, suitable dead trees are adjacent to open areas. Eastern whip-poor-wills (*Antrostomus vociferus*) nest in savanna with a semi-open tree canopy, sand or gravel soils, and an open ground layer. Loggerhead shrikes (*Lanius ludovicianus*) require areas of shorter grass adjacent to scattered trees for perches and nesting. Shrikes are now found more often in savanna-like habitat, often along roadsides or fencelines.

Savannas that are predominantly grassland, with only widely-scattered small trees or shrubs, are preferred by field sparrows (*Spizella pusilla*), lark sparrows (*Chondestes grammacus*), and Eastern meadowlarks (*Sturnella magna*), and may be suitable for other grassland bird SGCN (see Prairie/Grassland sub-chapter). Bell's vireos (*Vireo bellii*) breed in dense, shrubby thickets, primarily in southeastern Minnesota.

Suitable shrub thickets may occur within upland savanna, prairie, shrub swamps, or along forest or wetland edges. However, Bell's vireos are restricted to shrub patches within or at the edges of open landscapes, rather than under a forest canopy.

*Photo: Red-headed woodpecker, Earl Bye*

## Mammals

The open landscape of savannas provides primary habitat for five SGCN mammals. Considered a sentinel or keystone species of grasslands and savannas, the American badger has a significant impact on the surrounding landscape. Residing in underground burrows, and digging through loose, loamy or sandy soils for prey, its excavations provide numerous benefits including aerating the soil, creating shelters for other animals, and improving

nutrient cycling. Three other mammals are closely associated with savanna habitats, including the least weasel (*Mustela nivalis*), the plains pocket mouse (*Perognathus flavescens*), and the plains spotted skunk (*Spilogale interrupta*); prairies and other grasslands are primary habitats for each of these species as well. Despite intensive surveys for the spotted skunk in the 1990s, only 4 animals were found resulting in the species listing as a state threatened.

## Reptiles

Savannas are especially important habitats for reptiles; 12 of the 13 reptile SGCN use these open habitats of oaks and jack pine. Common five-lined skinks (*Plestiodon fasciatus*), six-lined racerunners (*Aspidoscelis sexlineatus*), Eastern hog-nosed snakes (*Heterodon platirhinos*), milk snakes (*Lampropeltis triangulum*), and lined snakes (*Tropidoclonion lineatum*) are most common in and around woodland edge habitats and savannas. Five-lined skinks use rock fissures and cracks in bedrock outcrops as hibernacula, but the suitability of this habitat is threatened by the encroachment of Eastern red cedar (*Juniperus virginiana*). Several of these reptiles (six-lined racerunners, north American racers (Coluber constrictor), and lined snakes) prefer more open areas. Other species (common five-lined skinks, eastern hog-nosed snakes, and milk snakes) prefer edges, using openings as basking areas. Key habitat features for these species include down woody debris (for cover, nesting sites, and basking sites) and burrows or crevices as overwintering sites. An iconic species of these open habitats is the gophersnake (*Pituophis catenifer*), which typically favor the loose, sandy soils of savannas which also support a rich abundance of burrowing small mammals for food (Moriarty and Hall, 2014).

*Photo: Gophersnake, Leslie Parris*

## Plants

Savanna communities with their herbaceous prairie ground layer support many of the same endangered, threatened, and special concern plant species found in respective open prairie habitats (see Prairie and Other Grasslands sub-chapter), such as spike oat (*Avenula hookeri*), plains reedgrass (*Calamagrostis montanensis*), blunt sedge (*Carex obtusata*), and others. Dry barrens communities, with sand soils and arid conditions also host a number of annual and perennial species adapted to, and dependent on these conditions. Annuals such as seaside three-awn (*Aristida tuberculosa*), annual skeletonweed (*Shinnersoseris rostrata*), and purple sandgrass (*Triplasis purpurea*) require shifting sands and this habitat can be threatened by encroaching vegetation (often native) that stabilizes the sands. Some rare perennial species are also primarily found in barrens and dune communities in Minnesota, including Indian ricegrass (*Achnatherum hymenoides*), winter bentgrass (*Agrostis hyemalis*), slender hairgrass (*Deschampsia flexuosa*), beach heather (*Hudsonia tomentosa*), narrow-leaved pinweed (*Lechea tenuifolia*), and Drummond's campion (*Silene drummondii*). Some of the rare species found in savanna barrens are at the edge of their ranges in Minnesota, and in the state only savanna barrens satisfy their habitat requirements. Indian ricegrass, for example, is a western species of dry plains that only finds suitable habitat at a few barrens locations in Minnesota.

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the Stressors Section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

A large extent of savanna and upland shrublands have been affected by development for housing and agricultural use, particularly as these habitats ranged across parts of the state with the highest density of human development.

### Crop Production

Conversion of savanna habitat to agriculture in conjunction with other forms of human development is a historical and potential future concern.

### Tree Plantations

Pine plantations are present in some areas formerly occupied by savanna habitat. Care should be taken to avoid pressure on this sensitive habitat from tree planting campaigns, including for carbon sequestration.

### Livestock Management

As elk and bison were extirpated and white-tailed deer populations significantly reduced, grazing by livestock including sheep, cattle, and goats increased from the early to mid 1900s and likely became very intensive during the droughts of the 1930's as farmers struggled to find enough forage (Hartman and Steele, 2015). Some savanna habitats likely became overgrazed and became subject to varying degrees of erosion.

### Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others.

### Fire Management

Historically the open environment of oak savanna was maintained largely by fire. Savannas occurred in physical proximity to prairies, but where features such as streams, lakes, and steep topography impeded the spread of those fires. Savannas form where fire occurs frequently enough to prevent trees and shrubs from dominating and shading out sun-loving herbaceous plants, but where frequency and severity are low enough to allow fire-tolerant trees to become established and sometimes reach maturity. All savannas are highly sensitive to fire suppression, quickly succeeding to woodland and eventually to forest in the absence of fire. In the absence of fire, woodland species and invasive shrubs gradually fill the savanna, closing the canopy and shading the prairie grasses and forbs.

## Invasive Species (Problematic Non-native Species)

Invasive woody species include common buckthorn (*Rhamnus cathartica*), bush honeysuckle (*Lonicera* sp.), and multiflora rose (*Rosa multiflora*). Forbs such as sweetclover (*Melilotus officinalis*) and grasses such as kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) are also common invasive species in this habitat type.

## Diseases and Pathogens

Bur oak blight is a native fungal disease that affects some bur oaks causing leaves to brown and die. Over time, bur oak blight may weaken the tree, promoting infestation by two lined chestnut borer or Armillaria root disease. Wetter springs may increase the prevalence and severity of this disease as fungal spores spread from the diseased leaves by rainwater, exacerbated by earlier spring rainstorms brought on by Minnesota's changing climate. Oaks in open upland areas are more at risk, and the disease is most problematic for stressed bur oak; healthy bur oaks can tolerate bur oak blight for a decade or more.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (MPCA 2025)).

Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al. 2025).

Looking ahead, this warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic

patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al. 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation section in Chapter 6: Implementation.

*Photo: Uncas Dunes Scientific and Natural Area, Kelly Randall*

# Case Study: Restoration of Oak Savannas in Southern Minnesota

Prior to European settlement, oak savannas covered roughly 10% of Minnesota's land base, however, today less than 0.1% of the original oak savannas remain. Primary threats contributing to the loss or degradation of oak savannas include the exclusion of fire, agricultural and residential development and the establishment of invasive species including both common buckthorn and honeysuckles. The Oak Savanna Subsection alone, which covers portions of Fillmore, Goodhue, Rice, Dakota, Mower, Freeborn, Steele and Waseca Counties, is home to at least 93 species of greatest conservation need (SGCN).

Myre-Big Island State Park, which is located in Freeborn County, had a number of potential candidate sites for oak savanna restoration. In 2022, staff from the DNR Division of Parks and Trails Resource Management Program selected three sites, which encompassed over 75 acres. The sites retained some structural characteristics of oak savannas. These included the presence of widely-spaced, open-grown bur oaks. Intensive grazing throughout the first half of the 20th century, the cessation of fire, and the encroachment of woody invasives and more mesic native hardwood species had resulted in a closed overstory, and the loss of the native grasses and forbs that once dominated the ground layer.

To date, through a combination of selective tree and brush removal, forestry mowing, targeted prescribed grazing/browsing, prescribed burning and inter-seeding, both structural and functional characteristics of the oak savanna are returning to these sites. Similar projects are occurring across Southern Minnesota on both public and private lands, including those administered by the DNR Division of Wildlife. With the goal of creating more connectivity between remnant and restored sites across the landscape, the hope is to improve habitat for a variety of species, including red-headed woodpeckers, Blandings turtles and a variety of migratory songbirds. Work for this project could not have been accomplished without assistance from the Conservation Corps of Minnesota and Iowa and financial support from the Clean Water Land and Legacy Amendment. For more information on the Oak Savanna Subsection see Oak Savanna Subsection ECS.

*Photo: Oak savanna restoration at Myre-Big Island State Park, Emily Peters*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan (Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN), five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience.**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN.**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Savannas

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Due to their rarity on the landscape, priority should be given to protecting savannas from development. |
| | Encourage the application of habitat conservation funds towards the protection, restoration, and enhancement of savanna and woodlands, which are highly imperiled but because they are less extensive might not have the emphasis that prairies and forests do in some funding programs. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience .

| Stressor | Action |
|---|---|
| | To address fire suppression, seek to restore fire to overgrown savannas and brush-prairies, by increasing fire frequency on public lands (and potentially on private lands) and conducting prescribed fires. To address limited agency budgets and lack of capacity and trained personnel, support inter-agency groups working to restore fire and cost-shared 'strike-teams' that send fire crews across lands held by multiple land management entities. Coordinate and collaborate with indigenous people and Tribes restoring fire. |
| | To effectively restore sites degraded by invasive species, such as Kentucky bluegrass, smooth brome, buckthorn, honeysuckle, and multiflora rose, a combination of several conservation actions will most likely be needed (Hartman and Steele, 2015). Monitor the understory and edges of your savanna for these invasive species and take fast action to control them through prescribed fire, hand or mechanical removal, or selective/spot herbicide treatment, all of which can help the system to be as healthy and resilient as possible. The goal for conservation actions should be to reintroduce disturbance regimes that would have naturally kept woody species in check. This may include prescribed fire or grazing. However, persistent or particularly dense stands of non-native woody species may require a combination of mechanical and chemical treatments to effectively re-establish these natural disturbance regimes. Even as natural disturbance regimes are re-established, ongoing monitoring may be needed to spot treat non-desirable species. See also the Woodlands of Minnesota Landowner Handbook: Oak Savanna. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Enhance education for natural resource professionals on how to identify savanna remnants and appropriate management scenarios for mitigating the threat of inappropriate tree planting within savanna habitat. |
| | Reintroduction of elk and bison to these natural systems may be difficult due to societal reasons, but the reintroduction of domestic livestock may be more manageable and with conservation grazing practices, could help to mimic the natural grazing patterns of their native counterparts. |
| | Encourage managers of savannas, including in urban and suburban parks, to maintain dead trees and trees with dead branches to provide habitat for insects and cavity nesting birds |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Monitor the effects of fire suppression and prescribed fire. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Distribute and encourage the use of the following technical resources for managing high quality oak savannas: 1) the High Value Conservation Forests for Dry Barrens Oak Savanna, part of Forest Certification, which outlines, based on the condition of the site, best practices for prescribed fire, forestry, grazing, and restoration; and 2) the Woodlands of Minnesota Landowner Handbook – Oak Savanna which is more directed at private landowners. |
| | Increased spring and early summer rain can increase the prevalence of burr oak blight. As stressed trees are more susceptible to burr oak blight, sometimes only some trees in an area will become affected and can be removed or treated (see this handout for more information). However, if an area has a lot of burr oak blight, possibly consider other strains or types of trees may be better adapted to the changing climatic conditions (additional resources on forests and climate change can be found here.) |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# UPLAND CONIFER FOREST AND WOODLAND

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Upland Conifer Forest and Woodland (Fire-dependent)

## Habitat Description

Upland coniferous forests occur primarily on mesic to dry sites with coarse sandy or gravelly soils or with thin soils over bedrock in the Laurentian Mixed Forest Province, also as small patches in the Driftless Region in the Eastern Broadleaf Forest Province in the southeastern part of the state. Dominated by pines (*Pinus spp.*), spruce (*Picea spp.*), balsam fir (*Abies balsamea*), or eastern white cedar (*Thuja occidentalis*), these fire-dependent forests also can contain hardwoods such as quaking aspen (*Populus tremuloides)*, paper birch (*Betula papyrifera)*, oaks (*Quercus spp.*), and red maple (*Acer rubrum*) (see also the Upland Deciduous Forest and Woodland sub-chapter). Historically, fire was the major source of tree mortality; in a modern context, timber harvests are influential in determining forest ages and patch sizes.

*Photo: Upland conifer forest, Hubbard County, Eric Ogdahl*

Fire has shaped this forest type, and the dominant trees of this forest, like most plants characteristic of fire-dependent communities, are adapted to survive repeated surface fires or to regenerate successfully following stand-replacing fire. Many plants have seeds or vegetative structures designed to survive fire or are opportunists that can take advantage of short periods when nutrients are relatively abundant and light levels are high. Fires vary greatly in intensity from crown fires, which kill most of the canopy trees, to moderate surface fires, which kill few canopy trees. Fire exerts a strong influence on the pattern of plant reproduction by exposing mineral soil seedbeds, triggering seed dispersal, and increasing the amount of light reaching the forest floor; it also played a significant role in nutrient cycling and nutrient availability.

The frequency of wildfires in this habitat historically varied from an average of every 20 years to every 100 years across forest types in the fire-dependent system, with the northern forest generally experiencing longer intervals than those of the central floristic region (Laurentian Mixed Forest Fire-Dependent Forest/Woodland System Summary). Some of the northern forests are estimated to have had stand-replacing fires every 170 to 220 years with surface fires about 210 to 260 years with a combined rotation period for all fires of 100 to 115 years. In contrast, central region forests are estimated to have experienced stand-replacing fires every 110 to 130 years and surface fires about every 30 years, with a combined frequency of fire every 22 to 25 years.

Wind was and continues to be another important natural disturbance, as evidenced by the 1999 windstorm that caused extensive damage over nearly 500,000 acres in the Superior National Forest in northern Minnesota, as well as countless acres in Ontario and elsewhere across northern Minnesota (Parke & Larson, 1999). Winds averaged 60 mph and were clocked as high as 80 to 100 mph; and it was estimated that anywhere form approximately 25 million trees on the Superior National Forest and 48 million region-wide were blown down. In addition to the forest, many homes and businesses were affected.

Plants in this forest type must also survive frequent drought and potentially long periods between disturbance events when nutrients are tied up in plant material and light levels decrease beneath increasingly dense tree

canopies. Evergreen or over-wintering leaves are particularly characteristic; these adaptations enable plants to conserve scarce nutrients in response to low nutrient levels and the thickened outer membranes help to reduce water loss or even herbivory. In general, the species in fire dependent communities have lower nutrient and water requirements and higher light requirements. See also the DNR's Trees and Forests website for an overview of forests in Minnesota.

There are several types of old growth forest that may occur within the Upland Conifer Forest and Woodland habitat type. Old growth red and white pine forests were formerly common but are now rare due to their high demand for building material from 1850 to 1920. Red and white pine forests are considered old growth if the trees are at least 120 years old or have a tree diameter greater than 20 inches. The oldest trees can be 400 years old with a diameter of 3 feet or more (Characteristics of Old Growth). Upland white cedar forests are most common on Lake Superior's north shore; to be considered old growth, these forests are at least 120 years old or have an average tree diameter greater than 10 inches. However, white cedar can be found commonly more than 400 years old. Because their wood is dense, white cedar trees may not be large. White spruce trees do not live as long as other trees, so white spruce forests of northern Minnesota are considered old growth at 90 years old, and the oldest trees are 150 years old (Characteristics of Old Growth).

## Habitat Map

To depict Upland Conifer Forest and Woodland habitat (see Figure 3.8), we compiled spatial data from several sources: DNR's Native Plant Communities and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological System

In the Fire-dependent Forest system, some Native Plant Community Classes split up into different Types, with some in this Conifer Forest and Woodland sub-chapter with others in the Upland Deciduous Forest and Woodland sub-chapter. Types are idented and indicated with a letter following the number in the alphanumeric code.

### Fire-dependent Forest

FDc12-Central Poor Dry Pine Woodland

FDc23-Central Dry Pine Woodland

FDc24-Central Rich Dry Pine Woodland

FDc25-Central Dry Oak-Aspen (Pine) Woodland

FDc25a Jack Pine-Oak Woodland

FDc34-Central Dry-Mesic Pine-Hardwood Forest

FDc34a Red Pine-White Pine Forest

FDn12-Northern Dry-Sand Pine Woodland

FDn22-Northern Dry-Bedrock Pine (Oak) Woodland

FDn22a-Jack Pine Woodland (bedrock);
FDn22b-Red Pine-White Pine Woodland (Northeastern Bedrock)
FDn22d-Red Pine-White Pine Woodland (Eastcentral Bedrock))

FDn32-Northern Poor Dry-Mesic Mixed Woodland

FDn33-Northern Dry-Mesic Mixed Woodland

FDn33a Red Pine-White Pine Woodland
FDn33c Black Spruce Woodland

FDn43-Northern Mesic Mixed Forest

FDn43a-White Pine-Red Pine Forest
FDn43c-Upland White Cedar Forest

FDs27-Southern Dry-Mesic Pine-Oak Woodland

FDs27b White Pine-Oak Woodland (Sand)

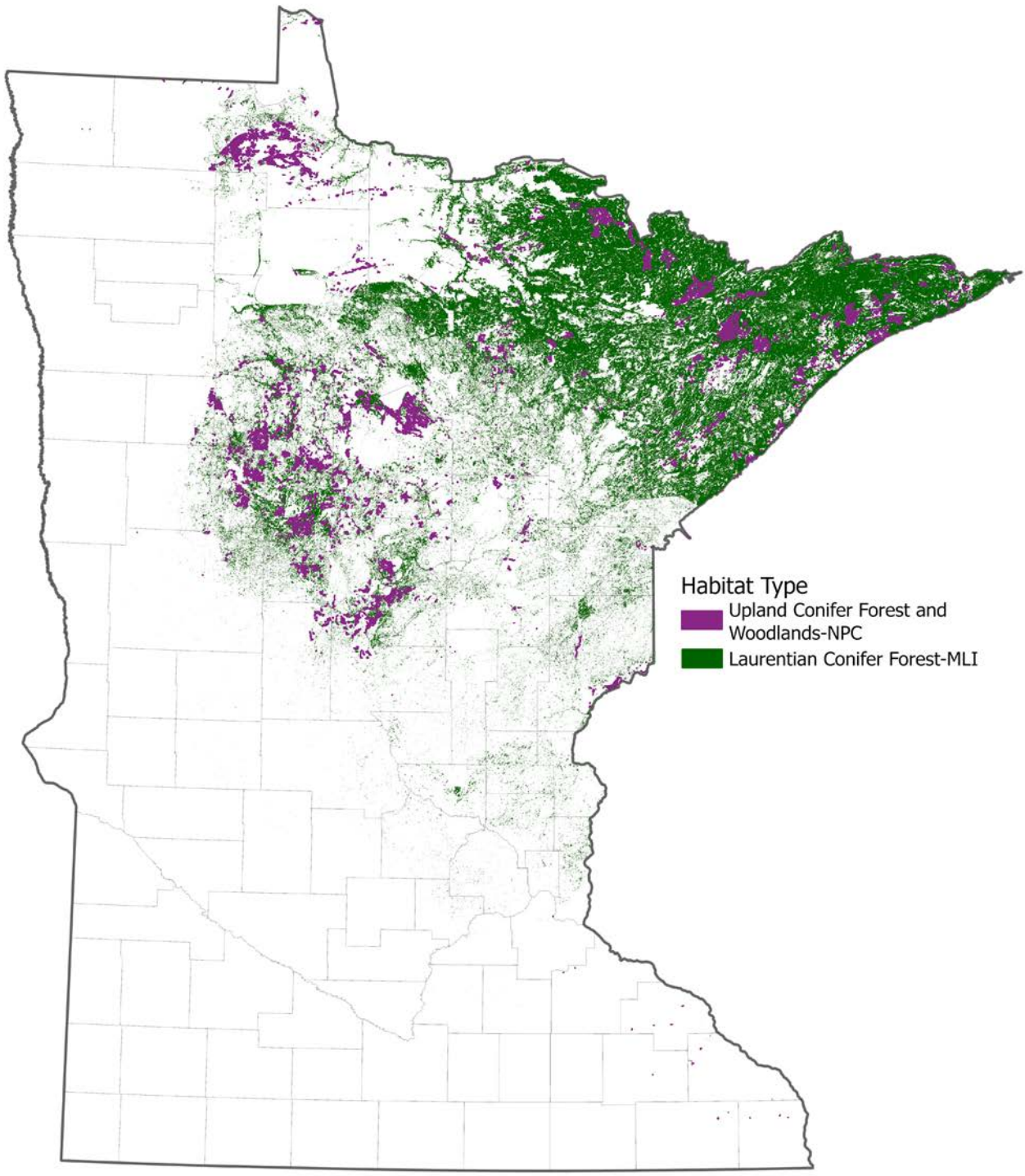



Figure 3.8. A map depicting Upland Conifer Forest and Woodland habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological Systems of Fire-dependent Forest/Woodland as well as four types from the Midwest Terrestrial Habitat System (see narrative). One caveat about the mapped NPC's is that they are based on where upland conifer forest could grow and currently may be in an early growth stage dominated by aspen for timber production.

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Laurentian Pine – Oak Forest and Woodland, Laurentian Pine Barrens, Laurentian Subboreal Dry Pine – Black Spruce Woodland, and Laurentian Subboreal Mesic Balsam Fir – Spruce – Hardwood Forest.

## Conservation Overview

Today, fire has been essentially replaced with timber harvest as a means of forest disturbance, resulting in a different distribution of forest patch sizes, ages, and composition. Moreover, conversion of upland conifer forests to other uses (such as agriculture, development and transportation corridors) has fragmented this habitat across the Laurentian Mixed Forest Province. The remaining forests in this region often lack the ecological complexity of pre-European settlement forests because of many factors (such as, grazing, invasive plants and animals, edge effects, changes in native animal populations, and consumptive uses), whose relative importance varies in different regions of the state. Even in the largely forested areas of northern Minnesota, rural sprawl has greatly reduced the extent of large, contiguous forest areas; most forest areas are within 25 kilometers (15.5 miles) of small housing settlements (Radeloff et al., 2005).

Historically, wildfire played an important role at both the site and landscape level in these forests, but due to land use changes and fire suppression, wildfire is not common today. Following a crown fire, a variety of biological legacies, or features of the predisturbance ecosystem that persist after disturbance (Perry & Amaranthus, 1997), remain in the young regenerating forest. These biological legacies, which include standing dead trees, large trees that escaped the fire, down logs, and small patches of unburned vegetation, provide important habitat features for SGCN. At the landscape level, wildfires create a shifting mosaic of native plant communities with a variety of ages and structural characteristics that provide habitats for SGCN.

Throughout the Laurentian Mixed Forest Province, the extent of upland conifer forest has been reduced by two-thirds since settlement by people of European descent and most have been replaced by aspen-dominated forests (Friedman & Reich, 2005). Fire has been replaced by timber harvest as the major stand-replacing disturbance. The legacy of early logging practices resulted in a decrease in the amount of old forests compared to pre-settlement age-class distributions; however, recent trends since 2008 show small increases in older forests (Hillard et al., 2022). Management to reduce spruce budworm outbreaks (harvesting balsam fir at young ages) may reduce populations of the warblers that eat spruce budworms. Even in the Boundary Waters Canoe Area Wilderness, the huge blowdown of 1999 is resulting in the conversion of pine forests to forests dominated by other tree species.

Old growth forests are recognized in Minnesota for their ecological, scientific, educational, aesthetic, and spiritual significance, including biological features that have developed over centuries (see DNR's Old Growth Forests). In addition to the presence of taller, older trees, these forests include relatively complex stand structure with more snags (dead standing trees), fallen logs and woody debris, all of which contribute to providing nesting, foraging, and denning sites for wildlife including more than 40 species of birds and mammals. The DNR manages a network of old growth forest sites on state lands (estimated at 44,000-acres in 2025) with the goal of maintaining "a viable network of high-quality old growth forest sites along with relatively undisturbed, natural-origin younger forests that will be managed to promote old growth characteristics in the future (i.e., future old growth)" (Old Growth Forests). In general, stands of old growth forest are protected from harvest, road-building, and other similar disturbances, unless for ecological benefit. Site-level management decisions in old growth forests typically mimic natural processes to promote regeneration and maintain and restore ecosystem integrity, and use the least intensive methods available,

such as hand tools rather than mechanical equipment (Managing Old Growth Forests).

Climate changes can indirectly affect all of Minnesota's forest communities by interacting with invasive species, insect pests and diseases, fires, and deer herbivory (Galatowitsch et al., 2009; Handler et al., 2014). Droughts will lead to an increased risk for wildfires. Minnesota's conifer forests are particularly vulnerable to the effects of climate change, with broadleaf temperate trees able to outcompete coniferous boreal tree species, in addition to the other negative effects warming can have on these forests (Frelich et al., 2021).

## Case Study: Forestry for Minnesota Birds

This case study features Forestry for Minnesota Birds (FMNB), a program that applies the best available science from avian ecology and sustainable forest management to provide strategies for creating bird habitat in contemporary forests. By collaborating with land managers, landowners, and forest stewards, FMNB aims to improve bird habitat and support bird populations through sustainable forest management practices. Recognizing that bird presence and abundance reflect overall forest health, the program promotes practices that benefit both habitat requirements of diverse bird species and human needs, such as timber production, hunting, and recreation. This effort was led by the Forest Stewards Guild, the American Bird Conservancy, and the University of Minnesota's Natural Resources Research Institute, in partnership with key federal, state, county, academic, non-profit, and forest industry partners and support provided by the Upper Mississippi Great Lakes Joint Venture using Great Lakes Restoration Initiative. While this case study is an excerpt focused on upland conifer habitat, the full guide highlights species specific recommendations for forestry management actions across a variety of forest types.

The FMNB selected 18 focal bird species to profile, including 5 SGCN, featuring several species as indicators of high-quality habitat in various forest types at various successional stages (i.e., developmental stages of a forest over time). The FMNB highlights habitat features of importance to various birds and suggests a variety of silvicultural "tweaks" for land managers to consider when interested in supporting bird habitat. A few examples include retaining mature, seed-bearing conifers to ensure a seed source for regeneration or using prescribed fire, when possible, to replicate natural disturbance. Each forester or land manager is encouraged to tailor these tweaks based on specific site characteristics, surrounding landscape, and landowner goals before including these recommendations for their forest management plans.

*Photo: Evening grosbeak, Bob Dunlap*

Upland coniferous forests provide critical feeding, roosting, and perching habitat for a variety of breeding and migrating birds. SGCN associated with upland coniferous forest as a primary habitat include Cape May warbler, Swainson's thrush, evening grosbeak, olive-sided flycatcher and Eastern whip-poor-will. Profiled in the FMNB are the Blackburnian warbler, magnolia warbler, and pine warbler. Upland coniferous forest types also support a variety of mammal SGCN including the little brown bat, snowshoe hare, moose, gray wolf, and the Canada lynx.

Upland coniferous forests could experience significant community changes due to a variety of climate-related factors. Drought and changes to the water table are predicted to increase stress, making trees more susceptible to pressure from native and invasive pests. Mortality from these pests and drought conditions could increase the frequency of stand-replacing fires. Many of the tree species in this forest type are predicted to decrease, and a few may increase as climate change progresses. Species predicted to decline include balsam fir, black spruce, jack pine, northern white cedar, tamarack (significantly with mortality caused by Eastern larch beetle), and white spruce. Species that may increase include red and white pine.

## Species in Greatest Conservation Need

Upland conifer forests and woodlands provide habitat for 66 animal and 35 plant SGCN as primary or secondary habitat (see Table 3.8). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. For plants, only a single primary habitat was identified per species.

Animals with more general habitat requirements are associated with multiple habitats, while specialists are associated with fewer. Plants were only associated with their most primary habitat. Detailed tables associating each of the SGCN with each of the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D for animals and Appendix E for plants. Examples of some of the SGCN and their significance are described below; state-listed species are linked to their account in the Rare Species Guide.

**Table 3.8. Numbers of species of SGCN associated with the Upland Conifer Forest and Woodland as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 0 | 3 | 3 |
| Birds | 7 | 9 | 16 |
| Mammals | 1 | 18 | 19 |
| Reptiles | 3 | 1 | 4 |
| Terrestrial Invertebrates | - | - | - |
| Bees | - | - | 5 |
| Beetles (terrestrial) | - | - | 2 |
| Butterflies | - | - | 5 |
| Moths | - | - | 7 |
| Snails (terrestrial) | 1 | 4 | 5 |
| Plants | 35 | - | 35 |
| **Total** | **47** | **35** | **101** |

## Amphibians

Three salamander SGCN – spotted salamander (*Ambystoma maculatum*), four-toed salamander (*Hemidactylium scutatum*), and Eastern newt (*Notophthalmus viridescens*) – are strongly associated with mature forest habitats. They primarily occupy deciduous forests but will also use mixed deciduous-conifer forest types. While typically not associated with drier, well drained upland coniferous forests, these SGCN salamanders may be found in the more mesic, nutrient rich fire-dependent communities with rolling terrain. Availability of abundant leaf litter and high canopy closure is vital to the survival of these salamanders. Even more critical is access to vernal pools, or other fishless seasonal ponds, which are used in the spring to breed. Eggs are laid in or near the water, and larvae remain in the pools until metamorphosis occurs. Four-toed salamanders specifically lay their eggs in moss hummocks next to wetlands. Four-toed salamanders occur most frequently in mature upland forests on glacial moraine landscapes with frequent isolated wetlands that include an alder margin and moss hummocks adjacent to pockets of open water. Two salamanders that are not SGCN are also prevalent in this habitat (Eastern red-backed salamander (*Plethodon cinereus*) and blue-spotted salamander (*Ambystoma laterale*)), further emphasizing the importance of Upland Conifer Forests to these amphibians for all activities outside of the breeding season.

## Birds

Many SGCN birds of upland forests are adapted to the wide range of habitat conditions and landscape patterns created by natural disturbance regimes such as fire. Black-backed (*Picoides arcticus)* and American three-toed woodpeckers (*Picoides dorsalis*) are most frequently found in recently burned upland coniferous forests, where they feed on wood-boring beetles. Prior to fire suppression, new patches of burned forest occurred near older burn areas within a decade or less, providing a steady supply of dead trees for woodpeckers. Black-backed and three-toed woodpeckers will also utilize unburned forest where suitable dead trees are available. Wildfires also created a mosaic of new patches of dense young forests of jack pine and spruce, ideal habitat for spruce grouse (*Canachites canadensis*), which feed primarily on needles of these species. The fire regimes in upland coniferous forests allowed the development of extensive old growth forests with habitat features such as large snags, down trees with root wads, stumps, very large trees, and small openings in the canopy, which provide optimal habitat for winter wrens. Older stands of white spruce and balsam fir provide optimal habitat for bay-breasted warblers (*Setophaga castanea*) and Cape May warblers (*Setophaga tigrina*), which feed on spruce budworms and increase during periodic outbreaks of budworm in older spruce and fir. Black-throated blue warblers (*Setophaga caerulescens*) require mature closed-canopy forests, often on steep slopes, with a well-developed understory and dense shrub layer. In fire-dependent upland forests, black-throated blue warblers require forest communities on the mesic side of the spectrum (almost exclusively found in northern mesic mixed forest – FDn43). Occupied forest stands typically have a mix of coniferous and deciduous trees but may occur in conifer-dominated forests if other structural characteristics (mature trees, dense shrub layer, etc.) are present. Upland conifer forest is a preferred habitat of American goshawks (*Astur atricapillus*) for nesting and foraging. Goshawks prefer forests with a relatively open flight path between the canopy and subcanopy. Because they have home ranges that extend over several native plant communities, the landscape mosaic is particularly important. The Eastern whip-poor-will (*Antrostomus vociferus*) may reach its highest population density in the state in pine-dominated (particularly jack pine or young red pine (*Pinus resinosa*)) woodlands and forests in north-central Minnesota. Key habitat components are dry sand or gravel soils and an open ground layer lacking dense saplings or shrubs.

## Mammals

Among the 19 mammal SGCN that utilize Upland Conifer Forests and Woodlands, only one is a habitat specialist. The rock vole (*Microtus chrotorrhinus*) may be found in a variety of habitats but in Minnesota is largely restricted to northern conifer and hardwood forests where the understory includes boulder fields, moss-covered rocks, talus, and downed logs and a nearby water source. In addition to Upland Conifer Forests, Upland Deciduous Forests and Cliffs, Talus and Rock Outcrops have all been identified as primary habitats. Included among the other 18 SGCN that can be found in Upland Conifer Forests are all 7 bat SGCN and top predators such as the Canada lynx (*Lynx canadensis*) and gray wolf (*Canis lupus*).

*Photo" Canada lynx, Anya Auerbach*

## Reptiles

Upland Conifer Forests and Woodlands are designated primary habitat for three reptile species and secondary habitat for one. The wood turtle (*Glyptemys insculpta*) is Minnesota's most terrestrial turtle, found in small or medium-sized rivers running through both conifer and deciduous uplands, often found in adjacent riparian habitat basking, foraging, and laying their eggs. A telemetry study in northern Minnesota found that wood turtles wander up to 525m from the river to forage during their post-nesting period, and they have a preference for pine forest.

The Eastern hog-nosed snake (*Heterodon platirhinos*) utilizes a variety of upland habitats but demonstrates a preference for open fields, field/forest edges, and sandy pine stands. Such conditions can be found in many habitats including Upland Conifer Forests and Woodlands. Common five-lined skink (*Plestiodon fasciatus*) use Upland Conifer Forests and Woodlands in the Upper Minnesota River Valley as part of a landscape mosaic of many habitat types. While primarily associated with large non-forested wetland complexes, Blanding's turtles will also utilize Upland Conifer Forests and Woodlands during terrestrial movements in the spring and summer related to breeding, foraging, and nesting, as well as hatchling movements in the fall.

## Plants

The 35 SGCN plants primarily associated with the upland conifer forest represent approximately 8% of all SGCN plants identified for the 2025-2035 SWAP (447).

Among the plant SGCN found in upland conifer forests, Slender Hair Grass, (*Deschampsia flexuosa*) is a particularly enigmatic plant often found near the shoreline of Lake Superior in association with pine forests. Little is known about this species biology, ecology or management needs. It emphasizes the importance of information gathering, such as management effectiveness monitoring, for the long-term conservation of plant SGCN.

Eastern hemlock (*Tsuga canadensis*) is a slow-growing, long-lived, and late successional conifer with a range occurring from New England to the Great Lakes and extending down the Appalachian Mountains (Godman & Lancaster, 1990). While capable of living to over 500 years old, few seedlings reach maturity, with fewer than half of these seeds being fertile (Godman & Lancaster, 1990), and germination is dependent on specific substrate requirements; mineral soils or rotting logs can provide the moisture requirements for seedlings (Harmon et al., 1986; Olson et al., 1959; Rooney & Waller, 1998), hence mature

hemlock trees facilitate seedling regeneration (Holmes, 2009; Tyrrell & Crow, 1994). Historic reports show hemlock in north central and northeastern Minnesota, but logging and fire (Lawson, 1942) and the early animal hide tanning industry (Stearns, 1997) have shrunk Minnesota's population down to an estimated 40-50 wild trees in small stands around Duluth (DNR Rare Species Guide). Minnesota's largest population of hemlock grows on steep slopes that are prone to landslides (Mooers and Wattrus, 2005). Groundwater seepage has likely contributed to this population's persistence, but recent large rain events have caused slope failures, washing away mature trees and seedlings (Perry, 2024). Minnesota's stands are failing to regenerate naturally, given the challenges of reduced seed source and facilitation of mature trees to establish seedlings. Enacted protections around endangered species support a hands-off approach, making research into artificial regeneration methods more difficult (Ellingson, 2017). Increasing populations of hemlock in Minnesota will likely require reintroduction or assisted migration (Pollack, 2024).

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Residential, commercial, and industrial development can all directly alter forest ecosystems by removing, degrading, or fragmenting forest cover and habitat. Fragmentation of forests is a growing concern, and occurs when a large contiguous forest land mass is divided into smaller tracts through sale and subdivision, road construction, or clearing of forests for agriculture, housing, or other commercial developments. This often creates smaller forest pockets, which are interspersed with non-forest land activities. Fragmentation can inhibit the natural migration of many plant and animal species, increase the risk of wildfires at the wildland urban interface, restrict public recreational access, reduce the habitat value and ecological complexity of forest lands, and contribute to the spread of invasive species. Because of their natural beauty, diversity, recreation opportunities, and abundant natural resources, forested landscapes are appealing places to live; even in the largely forested areas of northern Minnesota, rural development has greatly reduced the extent of large, contiguous forest areas; most forest areas are within 25 kilometers (15.5 miles) of small housing settlements (Radeloff et al., 2005). Forested lands adjacent to lakes and rivers are especially attractive sites for development.

### Crop Production

Forests and woodlands, especially in the southern portions of the

Laurentian Mixed Forest Province, where Upland Coniferous forests are most common, are susceptible to conversion for agricultural use. Although large-scale row crops are not common, small farmsteads with cattle and hayfields are scattered throughout the landscape.

## Tree Plantations

Tree plantations include intensively managed tree farms and historic red pine plantations. Red pine plantations have been planted in the past on sites where red pine and jack pine forests and woodlands occurred naturally. These plantations were designed to maximize stand-level growth of red pine, and do not typically resemble the more biodiverse, naturally occurring woodlands where red pine often occurred with white and jack pine and several other less abundant species. In general, monoculture plantations have lower value for wildlife and biodiversity than natural forests (Hua et al., 2022)

## Livestock Management

Minnesota currently has over 650,000 acres of mesic, upland deciduous, and riparian forests on farms that are grazed by livestock (Zamora et al., 2017; Garrett et al., 2004). Concerns around soil and water quality can arise when forests are grazed. Historically, grazing by livestock in forested landscapes likely became very intensive during the droughts of the 1930s as farmers struggled to find enough forage (Hartman and Steele, 2015). These habitats likely became overgrazed and subject to varying degrees of erosion, while the forest vegetation was subject to trampling, grazing, fraying, and bark stripping all of which can affect regeneration. (Hartman and Steele, 2015).

## Mining and Quarrying

Forests, when they co-occur with mineral or sand and gravel deposits, are at risk of degradation due to the direct and indirect effects of mining activities such as soil compaction, introduction of invasive species, human disturbance, waste discharge and pollution, forest fragmentation, and in some cases, permanent forest loss (Sonter et al., 2018). Mining projects can trigger additional land use changes with the establishment of associated infrastructure such as improved road access. Renewed interest in mining copper, nickel, cobalt and precious metals in northern Minnesota has heightened public concern about the potential effects in the northern forest region. Managing the potential for mining effects on high conservation value forests can be more challenging when those forests are co-located on some types of lands such as school trust lands, where Minnesota law directs that lands be managed “for maximum long-term economic return…consistent with…sound natural resource conservation and management principles” (see Minnesota Statute section (Minn. Stat. sec.) 127A.31). The DNR’s duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)). In these situations, the DNR may consider the use of potential mitigation strategies to minimize effects or to identify other lands for permanent protection.

## Roads, Trails, and Railroads

Roads, trails, and railroads can create fragmentation and edge effects in large tracts of forest. Increase in the number of roads and trails increases human disturbance and the potential for introduction of invasive species further into the forest. Repeated use and soil compaction associated with roads and trails also can modify the vegetation within the area of use. Temporary winter logging trails may become rutted while materials used to stabilize the trails for heavy vehicles may remain in place, leaving behind wood planks and wood chips, although Minnesota’s forest management guidelines are designed to avoid or promptly address these effects. Trails that provide winter access to upland deciduous stands can disturb forest wildlife, especially species that begin nesting in late winter, such as many forest raptors.

## Utility Corridors

Utility corridors can cause fragmentation and habitat degradation, such as by introducing invasive plants into forests and woodlands, as well as direct disturbance and oftentimes permanent deforestation and habitat loss incurred during their installation.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Even-aged harvests followed by natural or artificial regeneration are typical in upland conifer forests. Depending on management application, timber harvest may mimic stand-replacing fires and natural insect outbreaks that historically occurred in these forests. Timber harvest in this fire-dependent conifer forest can increase the amount of young forest on the landscape, change age-class distributions, change species and structural diversity in stands, convert forest types (i.e., jack pine to red pine) and affect habitat connectivity.

Silvicultural thinning in conifer plantations dominated by red pine is a practice that can improve stand value and forest health by removing diseased or insect-damaged trees. A variety of thinning practices are available, and new approaches such as variable density thinning, which promotes structural diversity in a stand, are still being researched to understand in what cases it is suitable and an appropriate tool to reach desired goals (Palik & Kastendick, 2023).

Timber harvest is used to address forest health concerns, such as dwarf mistletoe in black spruce, and Diplodia (*Diplodia sapinea*), a fungus that infects red pine, especially young red pines (see also the Diseases and Pathogens stressor).

At times, the status of some forests, located on school trust lands for example, can make it difficult to protect SGCNs and sensitive areas on these lands, because Minnesota law directs that school trust lands be managed "for maximum long-term economic return… consistent with…sound natural resource conservation and management principles" (see Minn. Stat. sec. 127A.31). The DNR's duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)).

## Recreation

In addition to the effects that may be caused by recreational trails (discussed above), recreational activities themselves can spread invasive species. Seeds of invasive plants such as common tansy (*Tanacetum vulgare*) can become embedded in the wheels of vehicles or the shoes of individuals and eventually become established along compacted trails where conditions for their growth may be more favorable. Earthworm egg cases, which are problematic for moonwort (*Botrychium*) species, can also be spread in mud. Increased use of roads and trails also increases human disturbance in the forest.

## Fire Management

A history of altered fire intervals, fire-suppression, and exclusion of cultural burning practices has resulted in an accumulation of fuels. In some areas the historical understory vegetation was more open to allow for ease of hunting and to encourage berry producing shrubs such as blueberries. Fire suppression for extended periods of time favors shade-tolerant species such as red maple and oaks. Over time this leads to mesophication of the plant community and results in declining diversity of plant and animal species (Hanberry et al., 2012; Nowacki & Abrams, 2008). Prescribed fire is infrequently applied.

*Photo: Badoura Jack Pine Woodland Scientific and Natural Area, Kelly Randall*

## Invasive Species (Problematic Non-native Species)

Invasive species are an ongoing stressor in Minnesota's forest and woodland systems. Invasive plant species, such as buckthorn (*Rhamnus cathartica*) and non-native bush honeysuckles (*Lonicera* spp.) often outcompete native plant species for light, space, and water and repress understory plant species leading to modified habitats unsuitable for SGCN. Dense canopies formed by invasive shrubs also inhibit the regeneration of native tree species due to the increase in shade.

Invasive animals, primarily invertebrates, cause profound ecological changes in forests (Frelich et al. 2019). Eurasian earthworms upend the traditional soil profile (Hale et al. 2005; Fahey et al. 2013), remove the accumulated layers of organic leaf litter (Holdsworth et al. 2008, 2012), and alter the community of soil mycorrhizal fungi (Paudel et al. 2016). These changes cascade through the ecosystem, including ground layer vegetation (Hale et al. 2006; Holdsworth et al. 2007), leaf litter fauna (McCay and Scull 2019), salamanders (Maerz et al. 2009; Ziemba et al. 2016), and likely other vertebrates.

The spongy moth (*Lymantria dispar*) is an invasive forest pest that feeds on more than 300 species of deciduous trees and shrubs, including aspen, oak, and birch. Repeated removal of leaves, or defoliation, stresses trees and can leave them vulnerable to disease or other pest infestations that can kill trees. Once it becomes established in a location, the spongy moth has cycles of large population outbreaks every eight to 12 years, leading to widespread defoliation and nuisance from caterpillars.

European pine sawfly (*Neodiprion sertifer*) primarily feeds on two and three-needle pines but can also infest five-needle pines when populations are high or when they are growing adjacent to their preferred host type.

## Problematic Native Species

Overbrowsing by deer can severely limit natural tree regeneration (Matonis et al., 2011; De Jager et al., 2013), especially for preferred species, such as white pine and oak. Elevated deer populations also reduce populations of palatable ground layer plants, including orchids (Knapp and Wiegand, 2014), members of the lily family (Balgooyen and Waller, 1995; Augustine and Frelich 1998; Fletcher et al., 2001), and rare species (McGraw and Furedi, 2005). Decades of cumulative effects have resulted in profound changes to the composition of native plant communities (Wiegmann and Waller, 2006; Frerker et al., 2014; Nuttle et al., 2014; Flagel et al., 2016; Anderson et al. 2017; Sabo et al. 2017). The effects of deer browsing often interact with those of invasive earthworms (Fisichelli et al., 2013; Davalos et al., 2014).

Eastern spruce budworm is a native caterpillar and is the most destructive pest of spruce-fir forests in eastern North America. Outbreaks

may be related to factors such as annual weather variation and climate change. Spruce budworm outbreaks attract a variety of predator specialists including the bay-breasted (*Setophaga castanea*), Cape May (*Setophaga tigrina*), and Tennessee warblers (*Leiothlypis peregrina*).

## Diseases and Pathogens

Diseases and pathogens are ongoing and future stressors in forest and woodland systems. Diplodia (*Diplodia sapinea*) is a fungus that causes dead branches and branch tips (shoot blight), decreased growth, top-kill, and sometimes death in jack pine and red pine. It is not known if the pathogen is native to Minnesota, but it has been present since the 1970s. It is most detrimental to seedlings and saplings growing in the shade. Diplodia is widespread throughout Minnesota in a latent form. Addressing Diplodia concerns should incorporate management objectives, desired species composition, and acceptable level of shoot blight severity (Haugen & Ostry, 2013). Another similar fungal pathogen is *Sirococcus conigenus*. In one study, sapling pines developing near previously infected older pines were at greater risk for becoming infected and dying from these two fungal pathogens (Haugen & Ostry, 2013); thus, standard practice is to remove all mature pines from most harvests where pines are the target replacement trees. The fungus is assumed present even if it is not observed.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, heightened disease and pathogen risks, winter burn, and deer herbivory (Galatowitsch et al., 2009; Handler et al., 2014).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). Minnesota's conifer forests are particularly vulnerable to the effects of climate change, with broadleaf temperate trees able to outcompete coniferous boreal tree species, in addition to the other negative effects warming can have on these forests (Frelich et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022:

Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). More frequent droughts will lead to an increased risk for wildfires. Restoration efforts can be disrupted by droughts, which are becoming more frequent with changing climatic conditions, causing seedling mortality and shifts in community composition if there are multiple seasons with insufficient rain. Prolonged droughts also can stress trees, increasing susceptibility to disease, pests, or pathogens. For more information and resources for climate-adapted management strategies, see the Climate Adaptation section in Chapter 6: Implementation.

*Photo: Lost 40 Scientific and Natural Area, Kelly Randall*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan (Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN), five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience.**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.**

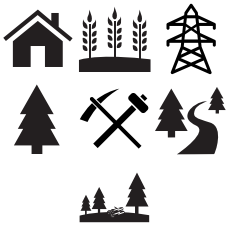
**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN.**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Upland Conifer Forests and Woodlands

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
|  | Identify priority areas for protected area designations to facilitate long-term conservation outcomes and protect against conversion of forest to different land uses. Use the Conservation Action Network or other sources of information to highlight high biodiversity areas or those providing connectivity between protected areas that are likely to provide disproportionately high conservation value. |

| Stressor | Action |
|---|---|
| | Consider projected effects on high value conservation forests, old growth forests, and Important Bird Areas when making decisions and policy that may affect upland coniferous forests (e.g., mining and quarrying, planning for new development of energy sources and any associated new road or trail construction). High conservation value forests can be vulnerable to degradation by mining activities. Exploration of conservation solutions must align with existing Minnesota statutes and policy guidance, such as in the case of School Trust Lands that must be managed "for maximum long-term economic return…consistent with…sound natural resource conservation and management principles" (see Minn. Stat. sec. 127A.31). The DNR's duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)). |
| | Engage in forest planning to collaborate and share interdisciplinary knowledge, supporting conservation of SGCN habitat and addressing values of biodiversity, rare features, structural and compositional plant diversity and wildlife needs. Maintain, adapt, or develop policies and procedures guiding habitat management that are based on the best available science. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Encourage the use of existing corridors for new trails, roads, and utility corridor development to minimize the construction of new roads and trails that would increase forest fragmentation. |
| | Limit the use and operation of heavy equipment when road or site conditions are vulnerable to damage following best management practices. For instance, depending on the site characteristics, conducting timber harvests during frozen ground conditions can reduce soil compaction and rutting effects. Increases in winter temperatures are reducing the duration of the winter season. |
| | Support forest management approaches that are informed by ecological processes, increase structural and compositional complexity and diversity, and assist in resilience towards future stressors (e.g., climate change, disease outbreaks, invasive species) in forests (refer to Native Plant Classification silviculture strategies for forest management). Promote forest management for a diversity of forest growth stages across the landscape to promote vegetation characteristics that maintain habitat for a wide range of plant and animal species, promote resiliency to insect and disease outbreaks, and mitigate the adverse effects of climate change. Ensure older forest and old forest qualities are retained on the landscape in amounts and areas that provide critical habitat to SGCN animals and plants; encourage management that sustains mature and old growth forests in forest planning efforts. Maintain or enhance habitat connectivity between forest patches to allow wildlife movement. Explore a range of silvicultural methods to regenerate jack pine in central Minnesota where the nutrient poor soils initially slow the growth of young seedlings. |

| Stressor | Action |
|---|---|
| | Apply knowledge of SGCN habitat use into forest planning efforts to help balance habitat for SGCN and other values according to management requirements and objectives. Consider natural area designations and other ways to enhance and preserve mature stands. Consider the ecological values of various forest ages and how they relate to SGCN habitat when determining desired future conditions and planning sustainable management to advance those conditions. |
| | Retain old and dead standing trees (snags) in forests when practical as habitat for wildlife, including cavity-nesting birds. |
| | To adapt to a warming climate, consider strategies for maintaining conifers in the Laurentian Mixed Forest Province, focusing on species, such as white pine and jack pine, that are predicted to be well-adapted to a warming climate. Collaborate with various partners to select sites in northern Minnesota ('conifer strongholds') where replanting would be most successful. |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. |
| | Explore opportunities to increase fire frequency on public lands, implement forest management practices that use fire, let some wildfires burn when safe to do so, and apply prescribed fire. Support forest centered burn crews. Cooperate with forest managers to prepare forests for prescribed burning and to prevent catastrophic fire. |
| | Enact measures to ensure that conifer seedlings prone to overbrowsing by deer are adequately protected when deemed necessary. Bud capping, fencing, and slash walls are ways to mitigate potential effects from deer browse. |
| | Implement control strategies for invasive species, such as buckthorn, and ensure sufficient timeframe for follow-up management that extends for many years. Support funding for these activities and consider expanding restoration resources to make sure they can be applied to woodland systems, which are sometimes in between funding opportunities aimed at prairies or forests. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Support local governments in measures that minimize fragmentation and encroachment into high quality forests and woodlands such as protecting high quality areas, zoning that guides housing developments, lot sizes that support local forests, and land use planning and development guidance. |
| | Encourage sustainable forest management through planning when and where timber harvest can be used as an effective tool to address a range of values and priorities, including forest health and productivity, critical ecological functions, and habitat restoration from historical disturbance events. Incorporate considerations of forest compositional and structural diversity at meaningful scales, historic size and return intervals of disturbance regimes, biodiversity, rare features, wildlife needs, and diversity of native plant community growth stages. Ensure that a balance of forest habitat conditions (e.g. younger and older forest, small and large patch sizes) are available for plant and animal species across the landscape over time. |
| | Collaborate across forest ownerships and managers to implement sustainable forestry at the site and landscape level to create habitat conditions important to SGCN, such as creating larger forest patches and reducing forest fragmentation. Support forest management approaches that are informed by ecological processes, increase structural and compositional complexity and diversity, and assist in resilience towards future stressors (e.g., climate change, disease outbreaks, invasive species). Promote forest management strategies that mimic landscape disturbance patterns, maintain or enhance connectivity among forest patches to enable wildlife movement, and retain biological legacies (at site level) such as large trees with cavities. Consult Native Plant Community Classification silvicultural strategies for forest stand prescriptions. |
| | Incorporate climate adaptation into forestry planning, including climate-adapted silviculture. Extending the duration of grants and contracts for restoration projects could help to allow conservation practitioners to plant when conditions are more favorable, considering droughts are likely to become more frequent. Reference resources from the Northern Institute of Applied Science, such as their adaptation workbook, or the Tree Species Projections for Ecological Sections in Minnesota from the Climate Change Response Network. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Monitor the responses of SGCN to various types of forest management at the site-level and landscape-scale. Conduct research and model anticipated changes with different forest management scenarios for effects on wildlife habitat. Develop models of habitat configurations for various SGCN and consider how current harvest forecasts and conversion rates (i.e., one forest type to another; natural origin habitat to plantation) relate to those models in terms of sustainability for maintaining habitat for SGCNs. Support the collection of accurate and reliable forest stand inventory data for planning. |
| | Communicate and research alternative management techniques (i.e., variable density thinning, natural seeding), reference to natural disturbance intervals, natural regeneration methods, and to increase habitat quality for SGCN. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Promote and consider further development of tax incentives that enable landowners and farmers to gain value for maintaining conservation values on their properties. Provide increased levels of incentive payments for woodland owners to help protect woodlands and forests from further reduction due to development pressure. Support and promote education and technical assistance to maintain or restore forest habitat. |
| | Managing for an increased diversity of dominant species in a site can assist in resilience toward future disease outbreaks, reduce susceptibility to some pathogens, and discourage invasive species. To assist in the management of woodlands and forests that are resilient to pathogens and invasive species may require additional funding. Also consider pairing management of non-native invasives with other incentivized management activities and prioritizing comingled activities to create efficiencies. |

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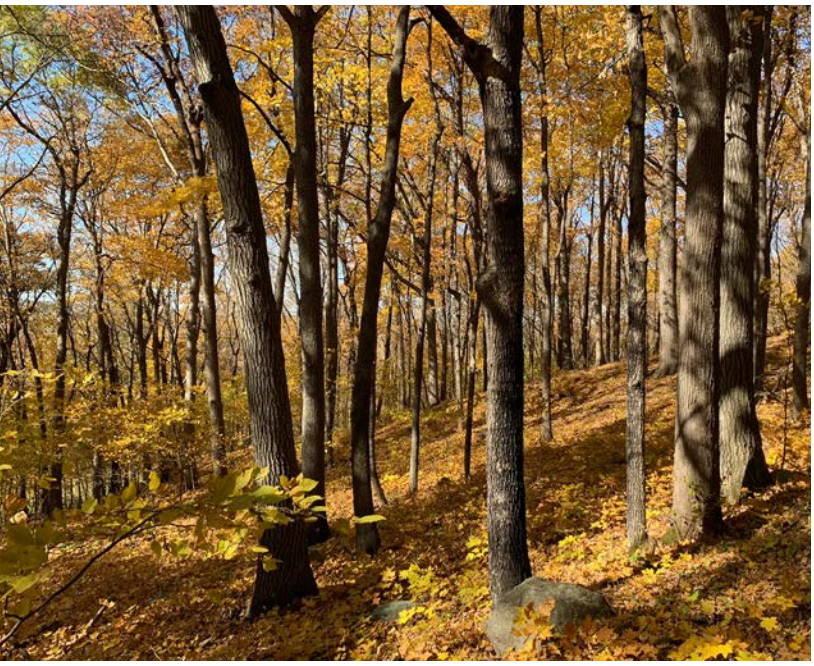
# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# UPLAND DECIDUOUS FOREST AND WOODLAND



DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Upland Deciduous Forest and Woodland

## Habitat Description

Upland deciduous forests, in the fire-dependent ecological system, are found throughout the Laurentian Mixed Forest and Eastern Broadleaf Forest provinces, and much less commonly in the Prairie Parkland and Tallgrass Aspen Parklands provinces. Fire-dependent forests can include aspens (*Populas spp.*), oaks (*Quercus spp.*), birches (*Betula spp.*), pines (*Pinus spp.*), spruce (*Picea spp.*), and balsam fir (*Abies balsamea*). Please see the Upland Conifer Forest sub-chapter for information on conifer-dominated forests. Soils, landforms, and disturbances, primarily fire, drive the distribution, patch size, ages, and composition of upland forests. See also the DNR's Trees and Forests website for an overview of forests in Minnesota.

Because the forest canopy blocks most of the sunlight before it reaches the understory, most understory plants have evolved some degree of shade tolerance. The amount of light reaching the understory also has a strong effect on the structural complexity of the forest. As these forests age, they become structurally more complex as canopy trees die, producing gaps in the canopy that allow growth of less shade-tolerant shrubs and trees. Standing large dead trees become more frequent, eventually becoming large down logs, which add to the structural diversity of older forests. Fire-dependent forests tend to have a more open canopy than Mesic Hardwood forests and a denser layer of shrubs such as hazelnuts (*Corylus spp.*), dogwoods (*Cornus spp.*), and mountain maple (*Acer spicatum*).

Fire-dependent upland deciduous forests include forests with a blend of dominance by tree species including oaks, aspen, and maples. Although there is a continuum, we can break the narrative to focus on oak-dominant and aspen-dominant.

*Photo: Aspen and bur oak, Two Rivers Aspen Parklands Scientific and Natural Area, Eric Ogdahl*

## Oak-dominant forests and woodlands

Upland hardwood oak forest habitats occur on xeric (dry) to relatively mesic (moist) forest sites throughout the Eastern Broadleaf Forest Province. This habitat is found in portions of the western half of the Laurentian Mixed Forest Province but is uncommon in the northeast. On drier sites, northern pin oak (*Quercus ellipsoidalis*), bur oak (*Q. macrocarpa*), white oak (*Q. alba*), and, in the southeast, black oak (*Q. velutina*) are important canopy species. Associated canopy trees include black cherry (*Prunus serotina*), paper birch (*Betula papyrifera*), aspens, and shagbark hickory (*Carya ovata*). These forests occur on nutrient-poor, well-drained sandy soils on outwash plains, river terraces, and beach ridges, and in the past were strongly influenced by fire. The canopy of modern dry oak forests is relatively open, allowing for a dense shrub layer, typically dominated by American hazel (*Corylus americana*). Many of the drier oak forests contain open-grown trees indicative of a more open woodland or savanna prior to fire suppression.

Oak forest is considered old growth forest if the trees are at least 120 years old or have an average tree diameter between 10-15 inches. The oldest trees in an old growth

oak forest are often 150– 200 years old or older with diameters of 20 inches in the north and 30 inches in central and southern Minnesota. These forests are typically dominated by red or white oak, with aspen, paper birch, black cherry in the north or black oak, bur oak, bitternut hickory, and pignut hickory in the southern part of the state (Characteristics of Old Growth).

## Aspen-dominated Forest and Woodlands

Fire-dependent upland hardwood forest (aspen) is characterized by a canopy dominated by quaking aspen (*Populus tremuloides*), big-toothed aspen (*P. grandidentata*), paper birch, or a mixture of these species. These shade-intolerant tree species are the dominant trees in the early stages of a wide variety of native plant communities in fire-dependent and mesic hardwood forest systems. Thus, aspen forest is a cover type that may eventually develop into many other native plant communities. In the absence of disturbance, such as fire or timber harvest, aspen acres may decline across the landscape as they succeed to longer-lived species.

Aspen forests typically have a nearly complete canopy of aspen or birch, but the canopy is not as dense as that of sugar maple. As a result of higher light levels penetrating the canopy, these forests usually have a well-developed shrub layer dominated by hazelnuts (*Corylus* spp.) or dogwoods (*Cornus* spp.). The coverage and diversity of the herbaceous plant layer are highly variable depending on site conditions and stand history.

As aspen forests age, they typically increase in structural diversity. Historically, most aspen stands in northern Minnesota had a conifer component, which increased as the stand aged. Today, most aspen stands have little or no conifer understory, due to past management and slash fires. Still, many older aspen stands are relatively structurally diverse, with large trees, snags, down logs, and an understory containing more shade-tolerant hardwoods or conifers that will become the canopy dominants in the absence of stand-replacing disturbance. See also the Mesic Hardwoods Chapter.

## Habitat Map

To depict Upland Deciduous Forest and Woodland habitat (see Figure 3.9), we compiled spatial data from several sources: DNR's Native Plant Communities and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological System

In the Fire-dependent Forest system, some Native Plant Community Classes split up into different Types, with some in this Conifer Forest and Woodland sub-chapter with others in the Upland Deciduous Forest and Woodland sub-chapter. Types are idented and indicated with a letter following the number in the alphanumeric code.

### Fire-dependent Forest

FDc25-Central Dry Oak-Aspen (Pine) Woodland
- FDc25b Oak – Aspen Woodland

FDc34-Central Dry-Mesic Pine-Hardwood Forest
- FDc24b Oak – Aspen Forest

FDn22-Northern Dry-Bedrock Pine (Oak) Woodland
- FDn22c Pin Oak Woodland (Bedrock)

FDn33-Northern Dry-Mesic Mixed Woodland
- FDn33b Aspen – Birch Woodland

FDn43-Northern Mesic Mixed Forest
- FDn43b Aspen – Birch Forest

FDs27-Southern Dry-Mesic Pine-Oak Woodland

FDs27c Black Oak – White Oak Woodland (Sand)

FDs36-Southern Dry-Mesic Oak-Aspen Forest

FDs37-Southern Dry-Mesic Oak (Maple) Woodland

FDs38-Southern Dry-Mesic Oak-Hickory Woodland

FDw24-Northwestern Dry-Mesic Oak Woodland

FDw34-Northwestern Mesic Aspen-Oak Woodland

FDw44-Northwestern Wet-Mesic Aspen Woodland

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Midwest Oak-Hickory Forest, Eastern North American Native Ruderal Forest, and Northern Tallgrass Oak-Aspen Woodland.

*Photo: Avon Hills Forest Scientific and Natural Area, Kelly Randall*

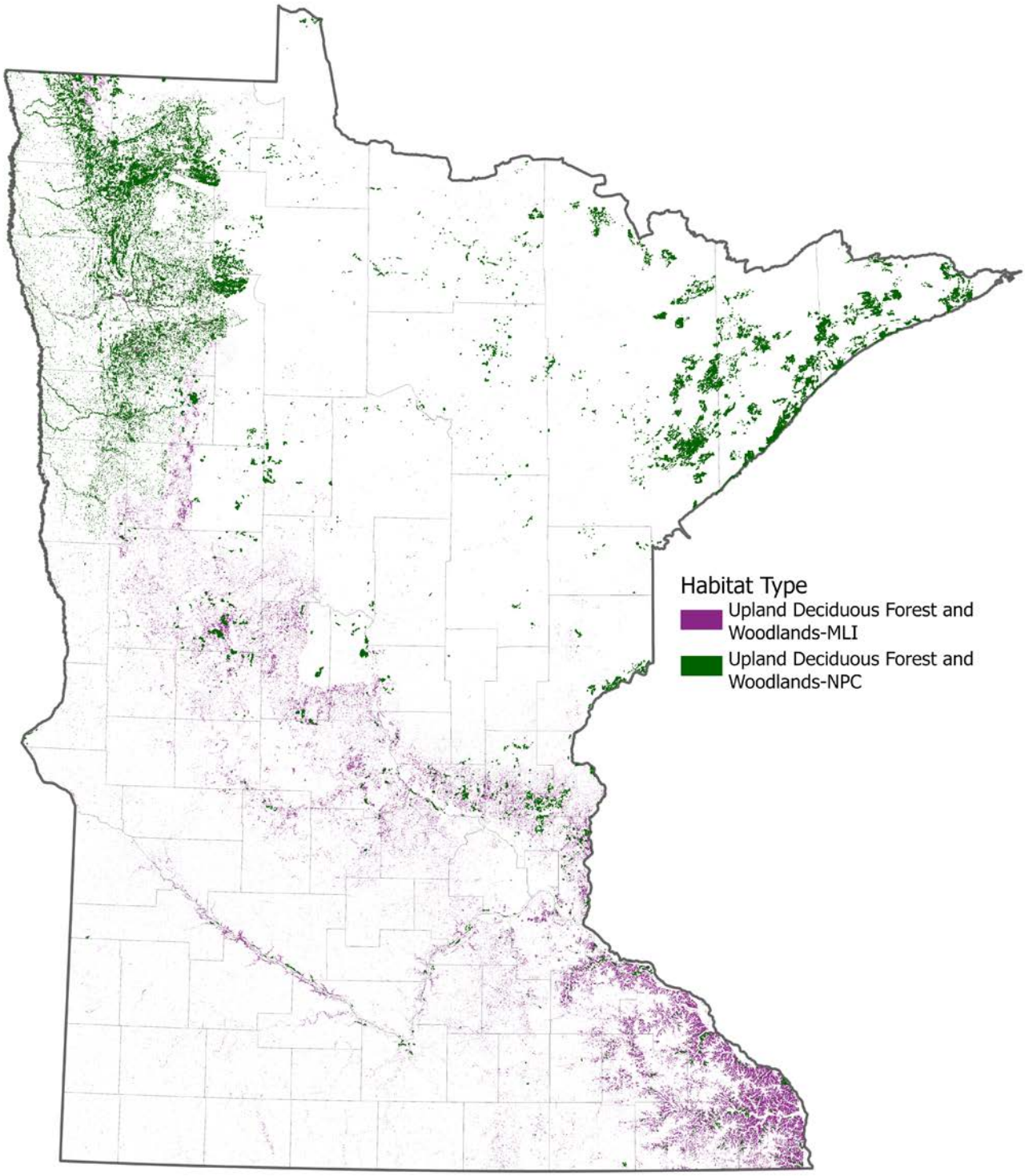


Figure 3.9. A map depicting Upland Deciduous Forest and Woodland habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological Systems of Fire-dependent Forest/Woodland as well as three types from the Midwest Terrestrial Habitat System (see narrative).

## Conservation Overview

Historically, wildfire played an important role at both the site and landscape level in these forests, but due to land use changes and fire suppression, wildfire is less common today. With the decline of fire frequency post Euro-American settlement, most upland deciduous forests remain on sandy, gravelly, or otherwise droughty sites where succession to closed-canopy mesic hardwood forest communities has been slowed by harsh growing conditions. In the past, fires in the deciduous woodlands could kill stands of trees and other aboveground vegetation under the right climate, fuel, and topographic settings. However, even intense fires in these deciduous woodlands did not generate the kinds of conflagrations possible in closed-canopy coniferous forests. By comparison, fires in upland deciduous woodlands were more regenerative than destructive. Following a crown fire, a variety of biological legacies, or features of the pre-disturbance ecosystem that persist after disturbance, remain in the young regenerating forest (Perry and Amaranthus 1997). These include standing dead trees, large trees that escaped the fire, downed logs, small patches of unburned vegetation, and surviving propagules and organisms (such as buried seeds, surviving roots, mycorrhizal fungi and other soil microbes and invertebrates). Such features are important ecologically and can provide habitat for SGCN. At the landscape level, wildfires create a shifting mosaic of native plant communities with a variety of ages and structural characteristics that provide habitats for SGCN.

Plants that occur in this community have seeds or vegetative structures that can survive fire and are good at colonizing burned sites. Many plants are opportunists that can take advantage of the short periods following fire when nutrients are relatively abundant and light levels are high. Such plants must also survive frequent drought and potentially long periods between fires when light levels decrease beneath increasingly dense shrub and tree canopies. The most evident characteristic of plants in this community is their ability to sprout prolifically. The trees, shrubs, and many of the herbs can store considerable amounts of carbohydrates below ground in roots, rhizomes, or other specialized organs and then sprout vigorously after aerial stems are destroyed by fire. These plants seem to be particularly plastic in allocating resources to underground or aboveground tissues, depending on the effect of fire on their overall vigor.

With fire less frequent in these forest stands, forest management activities including timber harvests are now the most prevalent form of disturbance. Sustainable forest management includes planning when and where timber harvest can be used as an effective tool to address a range of values and priorities, including forest health and productivity, critical ecological functions, and habitat restoration from historical disturbance events. During timber harvest planning, it's important to consider forest compositional and structural diversity at meaningful scales and pursue efforts to replicate natural disturbance regimes that define these plant communities. Planning efforts must strive to ensure that a balance of forest habitat conditions (e.g. younger and older forest, small and large patch sizes) are available for plant and animal species across the landscape over time. The multiple uses of forests can limit the ability to provide these habitat parameters, such as in the case of school trust lands, which by Minnesota law must be managed "for maximum long-term economic return…consistent with…sound natural resource conservation and management principles" (see Minn. Stat. sec. 127A.31). The DNR's duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)).

Conversion to other uses such as agriculture, urban development, and transportation corridors has fragmented forests across the state. This is most evident in southeastern and central Minnesota where few large patches of upland forest remain. The remaining forests

in these regions typically lack the ecological complexity of pre-European settlement forests due to several factors such as, grazing, invasive plants and animals, edge effects, changes in native animal populations, and consumptive uses. Even in the largely forested areas of northern Minnesota, rural sprawl has greatly reduced the extent of large, contiguous forest areas; most forest areas are within 25 kilometers (15.5 miles) of small housing settlements (Radeloff et al., 2005).

## Aspen-dominated Forest

Today, aspen forest is the most abundant forest habitat in Minnesota and much more widespread than it was prior to settlement by people of European descent. An analysis of General Land Office bearing tree records from the late 1800s and Forest Inventory and Analysis plots from the 1990s shows that in the Laurentian Mixed Forest Province, aspen forest communities have increased nearly tenfold (Friedman and Reich 2005). However, it is thought that aspen forests are structurally less diverse than they were historically, and on average younger than that of pre-European settlement aspen forests. Currently, about 60% of the aspen age class distribution is 1-40 years old, and about 18.5% of the cover type is over 60 years old statewide (U.S. Department of Agriculture, Forest Service, FIA Program, 2025). The location of older aspen stands shift across the landscape over time as old stands are harvested or succeed to other tree species, and young-mature aspen stands that aren't harvested age. Older, more structurally diverse aspen forests have high value to some SGCN, such as American goshawk (*Astur atricapillus*). The configuration of that habitat on the landscape (e.g. tract size, proximity to other forest types) also relates to its suitability and significance as habitat for SGCN.

## Oak-dominated Forest and Woodlands

Historically, fires in the oak habitat were more regenerative than destructive. The typical cycle involved top-killing of plants and vegetative recovery by resprouting. Fires enhanced plant reproduction by exposing mineral soil, triggering seed dispersal, breaking seed dormancy, and increasing light and heat conditions on the ground. In the absence of fire, relatively mesic or fire-sensitive species such as bitternut hickory (*Carya cordiformis*), basswood (*Tilia americana*), and red maple (*Acer rubrum*) are increasing in abundance in this habitat. Without fire, there is little natural oak regeneration in most dry oak stands.

Some oak forest stands have been colonized by invasive species such as buckthorn (*Rhamnus cathartica*) and non-native bush honeysuckles (*Lonicera* spp.). Like other forest habitats, most oak forest habitats in the Eastern Broadleaf Forest Province and southern and western portions of the Laurentian Mixed Forest Province have been fragmented by agriculture and development.

Old growth forests are recognized in Minnesota for their ecological, scientific, educational, aesthetic, and spiritual significance, including biological features that have developed over centuries (see DNR's Old Growth Forests). In addition to the presence of taller, older trees, these forests include relatively complex stand structure with more snags (dead standing trees), fallen logs and woody debris, all of which contribute to providing nesting, foraging, and denning sites for wildlife including more than 40 species of birds and mammals. The DNR manages network of old growth forest sites on state lands (estimated at 44,000-acres across all types in 2025) with the goal of maintaining "a viable network of high-quality old growth forest sites along with relatively undisturbed, natural-origin younger forests that will be managed to promote old growth characteristics in the future (i.e., future old growth)" (Old Growth Forests). In general, stands of old growth forest are protected from harvest, road-building, and other similar

disturbances, unless for ecological benefit. Site-level management decisions in old growth forests typically mimic natural processes to promote regeneration and maintain and restore ecosystem integrity, and use the least intensive methods available, such as hand tools rather than mechanical equipment (Managing Old Growth Forests).

## Climate Profile

The anticipated effects of a changing climate on upland deciduous ecosystems were profiled in the report "Effects of Climate Change on Midwestern Ecosystems: Central Interior Oak Forest, Woodland and Savanna" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025). This Climate Profile section is derived from that report for the North Central Oak-Hickory Forest and Woodland National Vegetation Classification habitat type (and please see the report for source citations). This habitat type typically occupies well-drained soils ranging from more xeric to mesic and characterized by a drought and fire tolerant canopy. Periodic low to moderate frequency surface fires maintained somewhat open conditions. Fire suppression has created conditions for fire intolerant woody species to increase and shade out more fire adapted and shade intolerant understory species. This can lead to "mesophication" where a more closed canopy favors more mesic plants and can contribute to a loss of biodiversity and structural heterogeneity. Non-native invasive species are also prominent stressors in this system.

Climate projections include projected increases in annual temperatures of 6.2 – 10.7 degrees F by the end of century (2070-2099), depending on emissions levels (Table 26 in Ratcliffe et al., 2025). Precipitation levels are on average projected to increase modestly 1.7 to 2.9 inches by the end of century depending on emissions (Table 27 in Ratcliffe et al., 2025), with an expectation that rainfall is more variable, with more extreme events and drier summers.

The most prominent climate factors for upland deciduous forests are drought and fire. Summer vapor pressure deficit, which incorporates temperature and water use via evapotranspiration, are projected to increase 36-72% over historical levels by end of century, depending on emission levels (Table 28 in Ratcliffe et al., 2025). These higher rates of water loss can exacerbate drought conditions and increase fire risk. Annual extreme fire danger (based on days with very low fuel moisture) is projected to increase 65%-81% over historical levels by end of century, depending on emission levels (Table 29 in Ratcliffe et al., 2025).

**Key Climate Change Effects** (from Ratcliffe et al. 2025; please reference for the source citations):

**Habitat structure** can be altered by drought that increases soil drying and reduces herbaceous cover, soil microbial activity and decomposition, which can lead to reduced nutrient availability and increased erosion particularly on sandy soils. A greater incidence of high-intensity fires would exacerbate degradation of soil structure and erosion.

- **Community composition** may shift toward more xeric species such as drought-tolerant warm-season grasses although extreme drought or drought with an absence of fire may favor shrubs and encroaching trees. Drought conditions will likely be more favorable for oaks over maples and birches, although extreme drought could inhibit oak recruitment and survival.
- **Invasive species** with broad tolerances and rapid recovery strategies can be favored by drought, such as brome (*Bromus*) species. Fire can be effective in suppressing some invasive shrubs, but is less effective in suppressing some such as invasive honeysuckles (*Lonicera* spp.), common buckthorn (*Rhamnus cathartica*), and autumn olive (*Elaeagnus umbellata*) that are persistent in the

seed bank and recover readily after fire, particularly on more mesic sites.

- **Pests and pathogens** may become more prevalent as trees are stressed by drought, such as oaks becoming more susceptible to oak borer species. Rising temperatures may increase outbreaks in some pathogens such as moths and bark beetles. Root rots may be diminished by drought or may flourish under fluctuating moisture regimes.
- **Herbivory** could be expected to increase if warming winters support higher populations of white-tailed deer. Increased browsing pressure could inhibit the reproduction of oaks and reduce forb diversity. In addition, drought can inhibit plants investments in chemical defenses.

## Species in Greatest Conservation Need

Upland deciduous forests and woodlands provide primary or secondary habitat for 68 animal and 33 plant SGCN (see Table 3.9). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. For plants, only a single primary habitat was identified per species.

**Table 3.9. Numbers of Species in Greatest Conservation Need associated with the Upland Deciduous Forest and Woodlands as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 3 | 0 | 3 |
| Birds | 4 | 8 | 12 |
| Mammals | 2 | 19 | 21 |
| Reptiles | 9 | 1 | 10 |
| Bees | - | - | 9 |
| Beetles (terrestrial) | - | - | 1 |
| Moths | - | - | 4 |
| Snails (terrestrial) | 3 | 3 | 6 |
| Spiders | 1 | 1 | 2 |
| Plants | 33 | - | 33 |
| **Total** | **55** | **32** | **101** |

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants).

Of the 130 terrestrial vertebrate SGCN identified in the 2025-2035 SWAP, 35% (46) occur in upland deciduous forests and woodlands. A large proportion (69%) of the 31 mammal SGCN occur in this habitat. Like other fire-dependent habitats, plants found in the upland deciduous forests only represent 7% of the 447 that are designated as SGCN. Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

## Amphibians

Three salamander SGCN – spotted salamander (Ambystoma maculatum), four-toed salamander (*Hemidactylium scutatum*), and Eastern newt (*Notophthalmus viridescens*) – are strongly associated with mature forest habitats. They primarily occupy deciduous forests but will also use mixed deciduous-conifer forest types. Access to wetlands, such as vernal pools, are critical for these species, which use them in the spring to breed. Eggs are laid in or near the water, and larvae remain in the pools until metamorphosis occurs. Four-toed salamanders specifically lay their eggs in moss hummocks next to wetlands. Eggs are laid in or near the water, and larvae remain in the pools until metamorphosis occurs. Four-toed salamanders specifically lay their eggs in moss hummocks next to wetlands. Four-toed salamanders occur most frequently in mature upland forests on glacial moraine landscapes with frequent isolated wetlands that include an alder margin and moss hummocks adjacent to pockets of open water.

## Birds

SGCN birds more typical of Mesic Hardwood Forest can also occupy dry-mesic fire-dependent forests in certain landscape settings (e.g., when part of a larger forested site where forest types co-occur, depending on slope, aspect, and soils). For example, dry-mesic oak forests often occur on south- or west-facing slopes, forming an important component of forested stream valleys important to Acadian flycatchers (*Empidonax virescens*), cerulean warblers (*Setophaga cerulea*), and Louisiana waterthrushes (*Parkesia motacilla*). Such forests must have the same structural components important to these species as Mesic Upland Forest (i.e., mature trees, closed-canopy, structurally diverse understory/subcanopy, etc.).

Similarly, SGCN found in savanna (e.g., eastern whip-poor-will (*Antrostomus vociferus*), red-headed woodpecker (*Melanerpes erythrocephalus*) or dry conifer woodlands also occur in semi-open deciduous woodlands that have the necessary habitat components. Dry sand or gravel soils and an open ground layer are important to whip-poor-wills, while red-headed woodpeckers require dead trees and snags without bark (see Savanna sub-chapter).

Young (early successional) upland deciduous forest, including edges, is an important component of golden-winged warbler (*Vermivora chrysoptera*) habitat. However, a mosaic of seral (intermediate) stages is important, including mature forest. Suitable early successional habitat may occur in several forest types – not just Upland Deciduous. Aspen and birch are frequent dominants, although other tree species can be suitable for golden-winged warblers. Early successional habitat may occur in monocultures following disturbance (e.g., fire, windthrow, silvicultural activities), in naturally fragmented mosaics (e.g., upland forest interspersed with wetland openings, shrub swamps, lowland conifers, lake or river shores) as well as along road or utility corridors through forested landscapes.

## Mammals

Upland Deciduous Forests and Woodlands support a very similar mammalian SGCN fauna as Upland Conifer Forests. Once again, all 7 bat SGCN are reported in Upland Deciduous Forests but it is considered primary habitat for just one, the Tri-colored bat (*Perimyotis subflavus*). This cave-hibernating species commonly roosts during the spring, summer and fall among the leaves of live or recently dead hardwood trees. As noted by the USFWS, tri-colored bats have been devasted by the effects of white-nose syndrome, causing an estimated decline of more than 90% in the species' hibernating colonies across North America. One other species that is more likely to be seen in Upland Deciduous Forests is the plains spotted skunk (*Spilogale interrupta*). This species is also found in a range of other habitats, especially open or brushy edge habitats.

## Reptiles

Eastern hog-nosed snakes (*Heterodon platirhinos*) are most common in and around woodland edge habitats. Key habitat features for these species include down woody debris (for cover, nesting sites, and basking sites) and burrows or crevices as overwintering sites. Eight other reptile SGCN's also utilize Upland Deciduous Forests and Woodlands as primary habitat including six snakes: North American racer (*Coluber constrictor*), timber rattlesnake (*Crotalus horridus*), Eastern hog-nosed snake (*Heterodon platirhinos*), smooth greensnake (*Opheodrys vernalis*), Western ratsnake (*Pantherophis obsoletus*), and gophersnake (*Pituophis catenifer*). All of these species can be found in a wide variety of habitats. The North American racer, common five-lined skink (*Plestiodon fasciatus*) and timber rattlesnake use deciduous forests and woodlands for foraging and temperature regulation, if they are close to rock outcrops and cliffs that are important for basking, overwintering and denning. While primarily associated with large non-forested wetland complexes, Blanding's turtles will also utilize Upland Deciduous Forests and Woodlands during terrestrial movements in the spring and summer related to breeding, foraging, and nesting, as well as hatchling movements in the fall.

*Photo: Western ratsnake, Jeff LeClere*

## Plants

Fire dependent upland forests and woodlands are habitat to a number of unique and rare plant species that help make up the complexity of these native plant communities (see Appendix E). For example, black huckleberry, (*Gaylussacia baccata*), is a rare, fire adapted species with a limited range in Minnesota. Much of its habitat is fragmented and lacks the fire needed to maintain its habitat. Without fire, fire-sensitive and more shade tolerant species can invade black huckleberry's habitat. Prescribed fires are needed to approximate natural wildfires and allow black huckleberry to persist.

## Case Study: The American Goshawk and Upland Deciduous Forest

The American goshawk (previously known as the Northern goshawk) was listed in Minnesota as a species of special concern in 2013. Since 2003, a partnership including federal, state, academic and tribal entities have monitored American goshawk territories in northern Minnesota collecting data on occupancy, nest success and number of young produced. The results of this long-term effort have highlighted some continuing challenges and concerning details about the American goshawk population trend in Minnesota. Over the past 20 years, the average territory occupancy rate is 71%, nest success is 70%, and the productivity rate averages 1.5 fledglings annually. These Minnesota averages are on the low end or lower than national average. In addition, through DNA analysis of feathers under nest sites, the DNR has been able to identify 107 individuals and has confirmed a high level of site fidelity (i.e., females using the same nest territory year after year), which is an important factor when it comes to habitat considerations. Goshawks commonly nest in upland deciduous forest, with 71% of nests occurring in large aspen trees. Stand age and structure appear to be the most important features within habitat, with 81% of nest occurring in stands that are 60+ years old and the average aspen stand age being 69 years old. While American goshawk is not necessarily an old growth dependent species, it does require large tracts of mature and older forest (Crozier, MOU Presentation 2022).

*Photo: American goshawk, Michael Furtman*

Throughout the many years of goshawk monitoring, it has become clear that determining population trends is difficult given this species' relatively low abundance over a broad range (Bruggeman et al. 2011). The DNR and the University of Minnesota recently completed some habitat modeling analyses for goshawks to assess which habitats were correlated with successful goshawk breeding areas. Overall, nest attempts and success were positively related to the amount of mature aspen and birch forests in the territory (230 meter radius area surrounding nests) and negatively related to the amount of young aspen/ birch forest, mature lowland conifer forest, and total area of harvest (Bruggeman, 2022). Based on these habitat association models; one strategy has been to look at the rate of habitat change over time as a proxy to the goshawks population trend in Minnesota. A conservative assessment of change for all land management types shows a 6% decline in older aspen/birch between 2003-2015 (Crozier, 2022). However, some challenges with this approach remain, such as a lack of information about the quality of habitat or goshawk use of private lands. Habitat changes over time were also assessed in the long-term monitoring project and showed the average of 26% loss of preferred habitat within known goshawk territories over a 10-year period. This highlights that occupied goshawk territories may be at higher risk to habitat change than the trends detected on a statewide scale across all management types.

The American goshawk remains a species of conservation concern, and its apparent declining population trend will be watched closely in the coming years. Minnesota has a long-standing tradition of integrated, landscape-scale forest management which may benefit the species. This kind of management is coordinated across ownership boundaries and strives to maintain a diverse landscape for all forest-dependent species (MNBBA).

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the Stressors section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Residential, commercial, and industrial development can all directly alter forest ecosystems by removing, degrading, or fragmenting forest cover and habitat. Fragmentation of forests is a growing concern, and occurs when a large, contiguous forest land mass is divided into smaller tracts through sale and subdivision, road construction, or clearing of forests for agriculture, housing, or other commercial developments. This often creates smaller forest pockets, which are interspersed with non-forest land activities. Fragmentation can inhibit the natural migration of many plant and animal species, increase the risk of wildfires at the wildland urban interface, restrict public recreational access, reduce the habitat value and ecological complexity of forest lands, and contribute to the spread of invasive species. Because of their natural beauty, diversity, recreation opportunities, and abundant natural resources, forested landscapes are appealing places to live; even in the largely forested areas of northern Minnesota, rural development has greatly reduced the extent of large, contiguous forest areas; most forest areas are within 25 kilometers (15.5 miles) of small housing settlements (Radeloff et al., 2005). Forested lands adjacent to lakes and rivers are especially attractive sites for development.

Development can also indirectly affect forests, through modification of ecosystem hydrology, introduction of non-native species, altered disturbance regimes, reduced connectivity to other habitats, increased abundances of competitors and predators, altered microhabitat conditions, increased direct human disturbance, and avoidance by wildlife that evolved to use large areas of habitat embedded in a landscape dominated by native ecosystems.

### Crop Production

Historically, many of the upland deciduous and mesic hardwood forests were converted to cropland, leaving a patchwork of widely scattered wood lots, averaging 40 to 80 acres in size, across central and southeastern Minnesota. The conversion of forests to agricultural use is ongoing in some locations.

### Livestock Management

Minnesota currently has over 650,000 acres of mesic, upland deciduous, and riparian forests on farms that are grazed by livestock (Zamora et al., 2017, Garrett et al., 2004). Properly managed grazing can stimulate plant diversity and create diverse vegetative structure across the landscape. Overgrazing, if left unchecked, can reduce diversity in vegetative cover and structure, and have severe negative effects on biodiversity, ecosystem function, soil health, and forage production.

Historically, grazing by livestock in forested landscapes likely became very intensive during the droughts of the 1930s as farmers struggled to find enough forage (Hartman & Steele, 2015). These habitats likely became overgrazed and became subject to varying degrees of erosion, while the forest vegetation was subject to trampling, grazing, fraying, and bark stripping all of which can affect regeneration. (Hartman and Steele, 2015). From the 1960's to present, grazing practices have changed. This includes reductions in the types of livestock raised by agricultural producers to primarily cattle, as well as the elimination of grazing on many bluff prairies and associated savannas altogether. This reduction in grazing has led to an increase of woody vegetative cover and the reduction of bluff prairie and savanna habitats. Best management practices associated with silvopasture, or the practice of intentionally combining management of trees, forage, and grazing as one integrated practice, has the potential to contribute to the restoration of Oak-dominant forests and woodland habitats.

## Mining and Quarrying

Forests, when they co-occur with mineral, oil, or gas deposits, are at risk of degradation due to the direct and indirect effects of mining activities such as permanent forest loss, soil compaction, introduction of invasive species, human disturbance, waste discharge and pollution, and forest fragmentation (Sonter et al., 2018). Mining projects can trigger additional, cascading land use change with the establishment of associated infrastructure such as improved road access.

## Roads, Trails, and Railroads

Roads, trails, and railroads can create fragmentation and edge effects in large tracts of forest. Increase in the number of roads and trails increases human disturbance and the potential for introduction of invasive species further into the forest. Repeated use and soil compaction associated with roads and trails also can modify the vegetation within the area of use. Temporary winter logging trails may become rutted while materials used to stabilize the trails for heavy vehicles may remain in place, leaving behind wood planks and wood chips, although Minnesota's forest management guidelines are designed to avoid or promptly address these effects. Trails that provide winter access to upland deciduous stands can disturb forest wildlife, especially species that begin nesting in late winter, such as many forest raptors.

## Utility Corridors

Utility corridors transect forested habitats throughout the state. These corridors can contain a variety of utility infrastructure. This includes pipelines, telephone lines, and power lines. These lines can be aerial, above ground, or below ground. Regardless of type, utility corridors can fragment habitat based on their size, purpose, and the upkeep required to maintain them.

The initial construction of the associated utility infrastructure as well as the long-term maintenance of that infrastructure can have lasting effects on native plant communities and the SGCN associated with them. Increased funding for rural broadband, conversion of aboveground powerlines to belowground, and development of new utilities (solar, wind, etc.) continue to threaten forested habitats.

These corridors and the increased travel from vehicles and equipment that they require act as vectors for invasive plant species. The required vegetative management practices often include herbicide applications, removal of woody vegetation, and/or mowing. This increased disturbance increases the likelihood of establishing invasive plant species within the corridors and then spreading to adjacent lands.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions,

including inaction, typically have positive effects for some species and negative effects for others. Even-aged harvests (e.g. clear or seed-tree cuts) are mostly used in fire-dependent forests and are similar to stand replacing fires of historical disturbance regimes. Methods to enhance biological legacies at local and landscape scales in even-aged harvests need more study and application.

Oak forests become more susceptible to disease with age and can spread disease from old oaks to seedlings; these forests are commonly managed with full even-aged harvests. Even-aged management may create forests that differ from forests experiencing more natural disturbance which may in turn impact habitat conditions for SGCN. Many wildlife species benefit from managing for within-stand species and structural diversity in large habitat patch sizes to provide habitat for area-sensitive species and to minimize habitat fragmentation effects. Long term impacts of oak harvest, incorporating regeneration dynamics, forest health, and landscape-scale age class distributions should be considered. The multiple uses of forests can limit the ability to provide these habitat parameters, such as in the case of school trust lands, which by Minnesota law must be managed "for maximum long-term economic return…consistent with… sound natural resource conservation and management principles" (see Minn. Stat. sec. 127A.31). DNR's duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)).

## Recreation

In addition to the effects that may be caused by recreational trails (discussed above), recreational activities themselves can spread invasive species. Seeds of invasive plants such as common tansy (*Tanacetum vulgare*) and garlic mustard (*Alliaria petiolata*) can become embedded in the wheels of vehicles or the shoes of individuals and eventually become established along compacted trails where conditions for their growth may be more favorable. Earthworm egg cases, which are problematic for moonwort (*Botrychium*) species, can also be spread in mud. Increased use of roads and trails also increases human disturbance in the forest.

## Fire Management

A history of fire suppression, insufficient fire frequency, and the exclusion of cultural burning practices contributes to the ongoing homogenization of composition and structure in upland, fire-dependent forest habitats (Hanberry et al., 2012). In the absence of fire, open forests can transition into closed forest ecosystems, leading to decreased structural diversity and a decline in the diversity of associated plant and animal species. Woody densification also creates a positive feedback loop of mesophication, where cool, damp, and shaded conditions increase ecosystem moisture and further reduce flammability (Nowacki and Abrams, 2008). Oaks, in particular, have declined dramatically and have been outcompeted by fire-sensitive and shade-tolerant canopy trees (e.g., elms, boxelder, maples, American basswood, and ashes). Today, in the absence of fire, even-aged timber harvests (e.g., clear or seed-tree cuts) are frequently used in fire-dependent forests. Oak regeneration following timber harvest can be challenging. Poor oak seedling recruitment (especially if a poor acorn crop preceded the harvest), competition with other tree species, and deer browsing can all reduce successful regeneration (Jacobson et al. 2019).

## Invasive Species (Problematic Non-native Species)

Invasive plant species, such as buckthorn (*Rhamnus cathartica*) and non-native bush honeysuckles (*Lonicera* spp.) often outcompete native plant species for light, space, and water and repress understory plant species leading to modified habitats unsuitable for SGCN. Dense canopies formed by invasive shrubs also

inhibit the regeneration of native tree species due to the increase in shade. While a concern statewide, upland deciduous forests in central and southern Minnesota are currently most affected by these invasive shrubs.

Invasive animals, primarily invertebrates, cause profound ecological changes in forests (Frelich et al., 2019). First, Eurasian earthworms upend the traditional soil profile (Hale et al., 2005; Fahey et al., 2013), remove the accumulated layers of organic leaf litter (Holdsworth et al., 2008, 2012), and alter the community of soil mycorrhizal fungi (Paudel et al., 2016). These changes cascade through the ecosystem, including ground layer vegetation (Hale et al., 2006, Holdsworth et al. 2007), leaf litter fauna (McCay and Scull, 2019), salamanders (Maerz et al., 2009, Ziemba et al., 2016), and likely other vertebrates.

Second, the spongy moth (*Lymantria dispar*) is an invasive forest pest that feeds on more than 300 species of deciduous trees and shrubs, including aspen, oak, and birch. Repeated removal of leaves, or defoliation, stresses trees and can leave them vulnerable to disease or other pest infestations that can kill trees. Once it becomes established in a location, the spongy moth has cycles of large population outbreaks every eight to 12 years, leading to widespread defoliation and nuisance from caterpillars.

Other invasive insects defoliate trees but typically do not cause significant mortality. Elm zigzag sawfly (*Aproceros leucopoda*) is an invasive defoliator of elm trees that was reported in Minnesota in July 2024 for the first time.

## Problematic Native Species

Overbrowsing by deer can severely limit natural tree regeneration (Matonis et al., 2011; De Jager et al, 2013), especially for preferred species, such as oak. Elevated deer populations also reduce populations of palatable ground layer plants, including orchids (Knapp and Wiegand, 2014), members of the lily family (Balgooyen and Waller 1995; Augustine and Frelich, 1998; Fletcher et al., 2001), and rare species (McGraw and Furedi, 2005). Decades of cumulative effects have resulted in profound changes to the composition of native plant communities (Wiegmann and Waller, 2006; Frerker et al., 2014; Nuttle et al., 2014; Flagel et al., 2016; Anderson et al., 2017; Sabo et al., 2017). The effects of deer browsing often interact with those of invasive earthworms (Fisichelli et al., 2013; Davalos et al. 2014).

## Diseases and Pathogens

Oaks are susceptible to several types of disease and pathogens, such as oak wilt (caused by the invasive fungus *Bretziella fagacearum*), sudden oak death (caused by the water mold *Phytophthora ramorum)*, and bur oak blight (caused by a native fungal pathogen, *Tubakia iowensis*). Individual trees tend to be more susceptible when under stress, which may interact then with other threats, such as if future climatic conditions bring more frequent late summer droughts. Older oak trees are more susceptible to interacting stressors including drought, heavy seasonal precipitation, insects, and diseases. Wetter springs may increase the prevalence and severity of fungal diseases as spores spread from the diseased leaves by rainwater, exacerbated by earlier spring rainstorms brought on by Minnesota's changing climate.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a

reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Warming can indirectly affect all of Minnesota's forest communities by altering the effect of invasive species, insect pests and diseases, winter burn, drought, and deer herbivory (Galatowitsch et al., 2009; Handler et al., 2014).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation section in Chapter 6: Implementation.

Restoration activities could also be disrupted by causing seedling mortality and shifts in community composition if there are multiple seasons with insufficient rain. Short funding windows for restoration efforts exacerbate the problem by inducing restoration plantings even in dry periods. Prolonged drought has stressed trees in the south east making some particulalry susceptible to native pests and pathogens. Changes in precipitation interact with the age class distribution of tree species such as oak, in which old trees are more susceptible to stress from drought, heavy seasonal precipitation, in turn making trees vulnerable to insects and and diseases.

Heavy rain events have been increasing in frequency and severity in Minnesota in recent decades. Forests on steep slopes, common in the state's southeastern counties, are vulnerable to landslides during these events.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan (Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN), five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience.**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN.**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Upland Deciduous Forests and Woodlands

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Consider projected effects on areas of biological significance such as high value conservation forests, old growth forests, and Important Bird Areas when making decisions and policy that are expected to affect upland deciduous forests (e.g., mining and quarrying, planning for new development of energy sources and any associated new road or trail construction). |
| | Engage in forest planning to collaborate and share interdisciplinary knowledge, supporting conservation of SGCN habitat and addressing values of biodiversity, rare features, structural and compositional plant diversity and wildlife needs. Maintain, adapt, or develop policies and procedures guiding habitat management that are based on the best available science. On state lands, all actions must align with existing Minnesota statutes and policy guidance, such as in the case of School Trust Lands that must be managed “for maximum long-term economic return…consistent with…sound natural resource conservation and management principles” (Minn. Stat. sec. 127A.31). |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Explore the potential use of silviopasture management regimes (the practice of intentionally combining management of trees, forage, and grazing as one integrated practice) to help restore some upland deciduous forests that do not spring ephemerals or other sensitive SGCN species (UMN Extension: Silvopasture: Establishment and Management Principles for Minnesota 2013) |
| | Attempt to minimize forest fragmentation when planning the location of new roads and trails. |
| | Encourage the use of existing corridors for new trails, roads, and utility corridor development to minimize the construction of new roads and trails that would increase forest fragmentation. |
| | Apply knowledge of SGCN habitat use into landscape forest planning efforts, to help balance habitat for SGCN and other values according to management requirements and objectives. Consider natural area designations and other ways to enhance and preserve key mature stands. Conduct research and model anticipated changes with different forest management scenarios for effects on wildlife habitat. Consider the ecological values of various forest ages and how they relate to SGCN habitat when determining desired future conditions and planning sustainable management to advance those conditions. |
| | Limit the use and operation of heavy equipment when road or site conditions are vulnerable to damage per best management practices. For instance, depending on the site characteristics, conducting timber harvests during frozen ground conditions can reduce soil compaction and rutting effects. |
| | Provide information on important habitat types, landscape configurations, and conditions most beneficial for SGCN. Support forest management that reflects ecological disturbance goals and SGCN habitat needs such as stable amounts of older forest. Communicate and document the benefits of alternative management techniques (i.e., variable density thinning, natural seeding), reference to natural disturbance intervals, natural regeneration methods, and to increase habitat quality for SGCN. |
| | Retain old and dead standing trees (snags) in forests when practical as habitat for wildlife, including cavity-nesting birds. |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. |
| | Implement control strategies for invasive species, such as buckthorn, and ensure sufficient timeframe for follow-up management that extends for many years. Support funding for these activities, and consider expanding restoration resources to make sure they can be applied to woodland systems, which are sometimes in between funding opportunities aimed at prairies or forests. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Support local governments in measures that minimize fragmentation and encroachment into high quality forests and woodlands such as protecting high quality areas, zoning that guides housing developments, lot sizes that support local forests, and land use planning and development guidance. |
| | Collaborate across forest ownerships and managers to implement sustainable forestry at the site and landscape level to create habitat conditions important to SGCN, such as unfragmented older mesic hardwood forests to create larger forest patches and reduce forest fragmentation. Support forest management approaches that are informed by ecological processes, increase structural and compositional complexity and diversity, and assist in resilience towards future stressors (e.g., climate change, disease outbreaks, invasive species). Promote forest management strategies that mimic landscape disturbance patterns (for example, retaining large blocks of mature habitat and creating more small forest openings as gaps or strips), maintain or enhance connectivity among forest patches to enable wildlife movement, and retain biological legacies (at site level) such as large trees with cavities. Consult Native Plant Community Classification silvicultural strategies for forest stand prescriptions. Enrolling forests in forest sustainability certification programs, such as by Forest Stewardship Council and Sustainable Forestry Initiative, also may help in implementing sustainable forestry. |
| | Manage for a diversity of forest growth stages across the landscape to promote vegetation characteristics that maintain habitat for a wide range of plant and animal species, promote resiliency to insect and disease outbreaks, and mitigate the adverse effects of climate change. Ensure mature, older forest and old forest qualities are retained on the landscape in amounts and areas that provide critical habitat to SGCN animals and plants; encourage management that sustains mature and old growth forests in forest planning efforts. Apply management practices to create young, early successional forest on the landscape to provide vegetation characteristics and edge habitat between young and mature forest that support plant and animal species. |
| | Droughts are becoming more frequent and can challenge the success of restoration plantings; extending the duration of grants and contracts for restoration projects could help to allow conservation practitioners to plant when conditions are more favorable. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Monitor the responses of SGCN to various types of forest management at the site-level and landscape-scale. Collaborate with MFRC site-level guideline monitoring and NPC silvicultural case studies to incorporate SGCN monitoring (Silviculture Case Studies). Develop models of habitat configurations for various SGCN and consider how current harvest forecasts and conversion rates (i.e., one forest type to another; natural origin habitat to plantation) relate to those models in terms of sustainability for maintaining habitat for SGCNs. |
| | Collaboratively explore techniques to promote forest regeneration for oak, with an emphasis on forests of high conservation value. |
| | Support the collection of accurate and reliable biological and forest inventory data to inform management practices and monitor forest dynamics |
| | Explore opportunities to burn upland deciduous forest stands with a significant oak component to investigate and then monitor the results for oaks as well as other vegetative components of the forest stands. Include other considerations to improve outcomes such as a good acorn crop year prior to the burn and management to stem the growth of competing species. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Promote and consider further development of tax incentives that enable landowners, homeowners, and farmers to gain value for maintaining conservation values on their properties. Provide increased levels of incentive payments for woodland owners to help protect woodlands and forests from further reduction due to development pressure. |
| | Managing for an increased diversity of dominant species, and age classes when appropriate, in a site may assist in resilience toward future disease outbreaks, susceptibility to some pathogens, and invasive species. For instance, oak forests with a higher diversity of additional species can be more resilient to oak wilt's overall effect. For more information, see DNR Oak Wilt Management and DNR Oak Decline. |
| | Seek additional funds to assist with the management of woodlands and forests to increase their resilience to pathogens and invasive species. Also consider pairing invasives management with other incentivized management activities to create efficiencies. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# MESIC HARDWOOD FOREST

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Mesic Hardwood Forest

## Habitat Description

Mesic (moist) hardwood forest habitat can be found across the state. It is present throughout portions of the Laurentian Mixed Forest Province where it occurs on level to rolling landscapes with fine-textured soils that retain water, and in the Eastern Broadleaf Forest Province where rugged terrain, water bodies such as lakes and rivers, and moist soil provide protection from wildfires. It can be found to a much lesser extent in the Prairie Parkland and Tallgrass Aspen Parklands Province, where it is primarily limited to well-drained soils found in the rolling till plains. Regardless of their location, the common features are uplands with soils that retain water and settings where wildfires are infrequent. A continuous, often dense, canopy of deciduous trees, typically including sugar maple (*Acer saccharum*), American basswood (*Tilia americana*), Northern red oak (*Quercus rubra*), quaking aspen (*Populus tremuloides*) and bigtooth aspen (*Populus grandidentata*), is also characteristic of this habitat and varies across native plant community classes. Other canopy trees include American elm (*Ulmus americana*), red elm (*Ulmus rubra*), black ash (*Fraxinus nigra*), green ash (*Fraxinus pennsylvanica*), bitternut hickory (*Carya cordiformis*), and hackberry (*Celtis occidentalis*).

Because the forest canopy blocks most of the sunlight before it reaches herbaceous plants and seedlings on the forest floor, most understory plants have evolved some degree of shade tolerance. Some species, known as spring ephemerals, have adapted to the low light conditions by developing and flowering before the canopy has fully leafed out. Mature mesic forest stands commonly have several nearly closed layers of woody plants, including a well-defined forest canopy, subcanopy, and shrub layer. These layers combine to produce largely continuous cover. As these forests age, they become structurally more complex as canopy trees die, producing gaps in the canopy

*Photo: Little Elk State Wildlife Management Area, Rachel Kranz*

that allow the growth of less shade-tolerant shrubs and trees. Standing large dead trees become more frequent, eventually becoming large, downed logs, which add to the structural diversity of older forests.

Natural disturbance in this habitat is characterized by the death of individual trees, which occurs at a rather constant rate in older forests. Stand-regenerating disturbances such as wildfires and catastrophic windthrow were rare historically in this mesic habitat, having average frequencies of once every 360 to more than 1,000 years. Disturbances that resulted in the partial loss of canopy trees, such as light surface fires and moderate windthrow, were far more frequent. Historically, surface fire was more important in the north, and wind was more important in central and southern Minnesota.

Typical sites are buffered from seasonal drought by fine-textured soils with impermeable soil horizons capable of retaining rainfall or snowmelt below the surface. Usually, these soils are well drained and are waterlogged or saturated only after spring snowmelt or heavy, prolonged rains. Essential nutrients, especially nitrogen, are mineralized from decaying organic matter at relatively high rates and quickly become available again for uptake

by plants during the spring and early summer months. As a result, nutrients and organic matter accumulate at the soil surface in leaf litter and humus.

Mesic Hardwood Forest in some locations contain vernal pools, small, ephemeral wetlands that occur within Minnesota's forests and provide habitat to an array of SGCN; see the Vernal Pool sub-chapter.

Mesic hardwood forests have diverse characteristics that vary considerably depending on site conditions and location. In addition to the sugar maple-basswood-northern red oak forests of the Big Woods region, the blend of dominant trees can vary considerably in abundance, ranging from drier, more fire-dependent aspen-dominated habitats to more mesic sites dominated by oaks. Aspen dominated forests and oak forests are briefly described below.

Old growth forest can be found in maple-basswood forests in southern Minnesota and northern hardwood forests in northern Minnesota. These old growth forest appear dense with layers of vegetation, and they perpetuate themselves over many centuries if they are not disturbed by severe storms or cutting. Seedlings and saplings tolerate living for years in deep shade until a gap opens in the canopy. Old growth forests are at least 120 years old, with the oldest trees being 300–400 years old. Tree diameters are typically 10-15 inches, but trees can grow to diameters of 20 inches in the north and 26 inches in the south (Characteristics of Old Growth).

## Aspen-dominant Forest

Mesic aspen forest is characterized by a canopy dominated by quaking aspen, big-toothed aspen, paper birch (*Betula papyrifera*), or a mixture of these species. These shade-intolerant tree species are the dominant trees in the early stages of a wide variety of native plant communities in fire-dependent and mesic hardwood forest systems across a range of dry to mesic soils. Thus, aspen forest is a cover type that may eventually develop into many other native plant communities. In the absence of disturbance, such as fire or timber harvest, aspen acres may decline across the landscape as they succeed to longer-lived species.

Aspen forests typically have a nearly complete canopy of aspen or birch, but the canopy is not as dense as that of sugar maple. As a result of higher light levels penetrating the canopy, these forests usually have a well-developed shrub layer dominated by hazelnuts (*Corylus* spp.) or dogwoods (*Cornus* spp.). The coverage and diversity of the herbaceous plant layer are highly variable depending on site conditions and stand history.

## Oak-dominant Forest

Oak forest habitat on more mesic sites is dominated by Northern red oak, white oak (*Quercus alba*), and bur oak (*Quercus macrocarpa*). Tall, straight, single-stemmed trees and a less dense shrub layer characterize the oak habitat on these sites.

See also the Upland Deciduous Forests and Woodlands (Fire-dependent) sub-chapter and DNR's Trees and Forests website for an overview of forests in Minnesota.

# Habitat Map

To depict Mesic Hardwood Forest habitat (see Figure 3.10), we compiled spatial data from several sources: DNR's Native Plant Communities and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological Systems

### Mesic Hardwood Forest (MH)

MHc26 Central Dry-Mesic Oak-Aspen Forest (PDF)

MHc38 Central Mesic Cold-Slope Hardwood-Conifer Forest (PDF)

MHc36 Central Mesic Hardwood Forest (Eastern) (PDF)

MHc37 Central Mesic Hardwood Forest (Western) (PDF)

MHc47 Central Wet-Mesic Hardwood Forest (PDF)

MHn45 Northern Mesic Hardwood (Cedar) Forest (PDF)

MHn35 Northern Mesic Hardwood Forest (PDF)

MHn47 Northern Rich Mesic Hardwood Forest (PDF)

MHn44 Northern Wet-Mesic Boreal Hardwood-Conifer Forest (PDF)

MHn46 Northern Wet-Mesic Hardwood Forest (PDF)

MHs37 Southern Dry-Mesic Oak Forest (PDF)

MHs38 Southern Mesic Oak-Basswood Forest (PDF)

MHs39 Southern Mesic Maple-Basswood Forest (PDF)

MHs49 Southern Wet-Mesic Hardwood Forest (PDF)

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Laurentian Hardwood Forest, North-Central Beech-Maple-Basswood Forest, and Laurentian Hemlock-White Pine-Hardwood Forest.

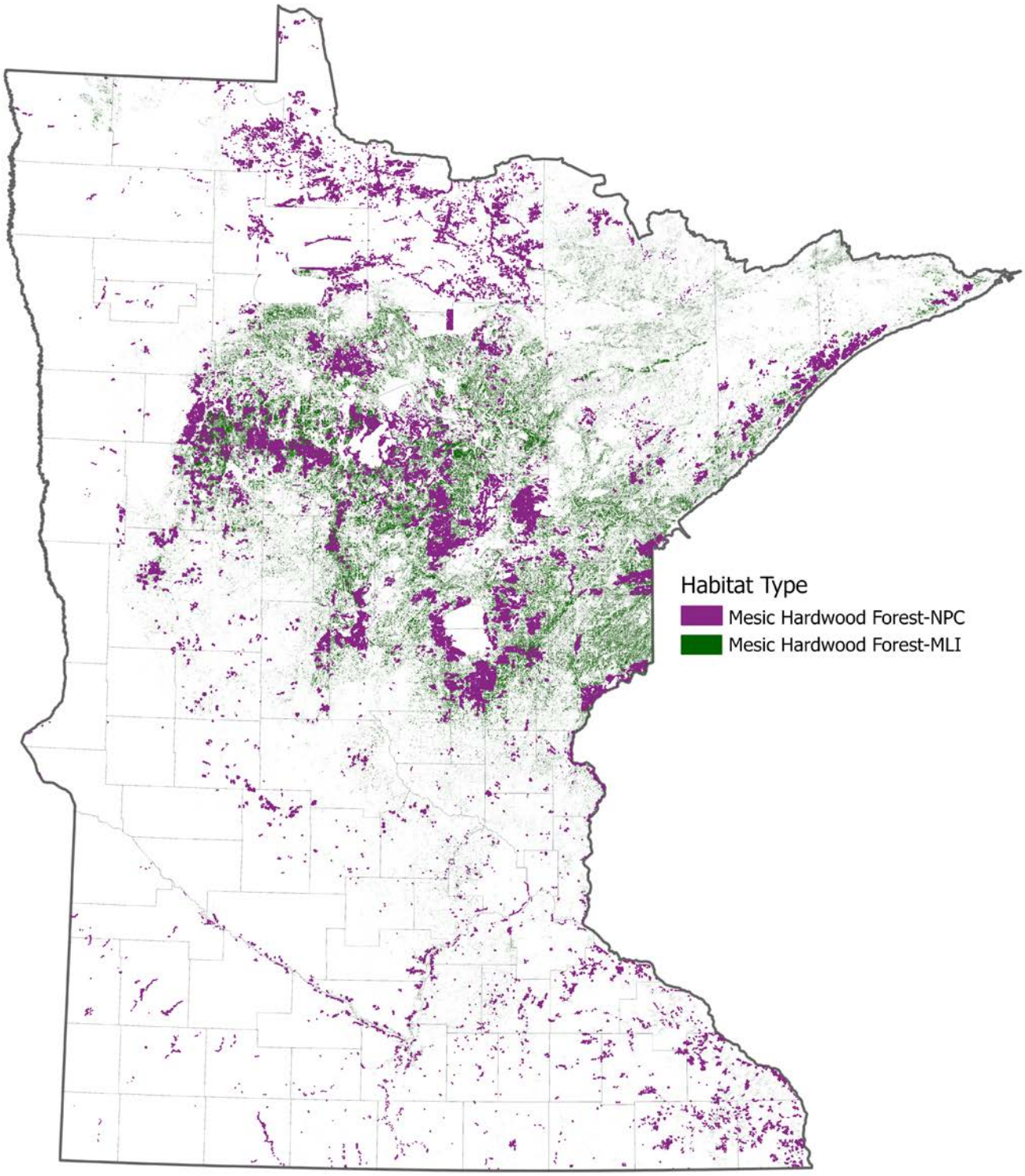


Figure 3.10. A map depicting Mesic Hardwood Forest habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological Systems of Mesic Hardwood Forest as well as three types from the Midwest Terrestrial Habitat System as previously described in the narrative.

## Conservation Overview

The extent of upland deciduous hardwood forests has been greatly reduced in southern and west-central Minnesota since settlement by people of European descent. The extensive mesic hardwood forests of the Big Woods Subsection have been reduced by a factor of more than 100. However, in the northern parts of the Laurentian Mixed Forest Province, the extent of maple-basswood forests has increased because of fire suppression. Like other forest habitats, most maple-basswood habitats in the Eastern Broadleaf Forest Province and southern and western portions of the Laurentian Mixed Forest Province have been fragmented by agriculture and development. In many locations, the remaining forests typically lack the ecological complexity of pre-European settlement forests because of several factors (for example, grazing, invasive plants and animals, edge effects, changes in native animal populations, and consumptive uses).

Forest planning is critical to ensure that a balance of forest habitat conditions (e.g., younger and older forest, small and large patch sizes) are available for plant and animal species across the landscape and can support conservation goals. For instance, aspen and birch are short-lived tree species and naturally transition towards other forest types (e.g., maple, basswood, oak) in the absence of significant disturbance. Given that some species require younger forest habitat or mature habitat of shorter-lived tree species, it can be important to maintain those conditions through the application of management tools like timber harvest and prescribed fire. Conversely, other plant and animal species require habitats characterized by a non-stand replacing or smaller-scale disturbance, including larger blocks of older forest and mature forests of later successional tree species. For these forest species, large-scale, whole canopy removal may negatively affect local habitat conditions in the short-term.

Old growth forests are recognized in Minnesota for their ecological, scientific, educational, aesthetic, and spiritual significance, including biological features that have developed over centuries (see DNR's Old Growth Forests). In addition to the presence of taller, older trees, these forests include relatively complex stand structure with more snags (dead standing trees), fallen logs and woody debris, all of which contribute to providing nesting, foraging, and denning sites for wildlife including more than 40 species of birds and mammals. The DNR manages network of old growth forest sites on state lands (estimated at 44,000-acres across all types in 2025) with the goal of maintaining "a viable network of high-quality old growth forest sites along with relatively undisturbed, natural-origin younger forests that will be managed to promote old growth characteristics in the future (i.e., future old growth)" (Old Growth Forests). In general, stands of old growth forest are protected from harvest, road-building, and other similar disturbances, unless for ecological benefit. Site-level management decisions in old growth forests typically mimic natural processes to promote regeneration and maintain and restore ecosystem integrity, and use the least intensive methods available, such as hand tools rather than mechanical equipment (Managing Old Growth Forests).

## Aspen-dominated Forest

As aspen forests age, they typically increase in structural diversity. Historically, most aspen stands in northern Minnesota had a conifer component, which increased as the stand aged. Today, most aspen stands have little or no conifer understory, due to past management and slash fires. Still, many older aspen stands are relatively structurally diverse, with large trees, snags, down logs, and an understory containing more shade-tolerant hardwoods or conifers that will become the canopy dominants in the absence of stand-replacing disturbance.

Today, aspen forest is the most abundant forest habitat in Minnesota and much more widespread than it was prior to settlement by people of European descent. An analysis of General Land Office bearing tree records from the late 1800s and Forest Inventory and Analysis plots from the 1990s shows that in the Laurentian Mixed Forest Province, aspen forest communities have increased nearly tenfold (Friedman & Reich, 2005). However, it is thought that aspen forests are structurally and compositionally less diverse than they were historically (Friedman & Reich, 2005; Handler et al., 2014), and on average younger than that of pre-European settlement aspen forests. Currently, about 60% of the aspen age class distribution is 1-40 years old, and about 18.5% of the cover type is over 60 years old statewide (U.S. Department of Agriculture, Forest Service, FIA Program, 2025). The location of older aspen stands shift across the landscape over time as old stands are harvested or succeed to other tree species, and young-mature aspen stands that aren't harvested age.

Older, more structurally diverse aspen forests have high value to some SGCN, such as American Goshawk, and the configuration of that habitat on the landscape (e.g. tract size, proximity to other forest types) also relates to its suitability and significance as habitat for SGCN.

## Oak-dominated Forest

Mesic Hardwood oak forests had fewer severe fires prior to settlement by people of European descent than did dry oak forests, and more mesic, fire-sensitive trees such as basswood, green ash, bitternut hickory, and big-toothed aspen are usually present with the oaks. Nevertheless, those fires that did occur were responsible for the establishment and maintenance of oaks on these sites. Without fire or appropriate forest management to replace fire, most mesic oak forests will succeed to maple-basswood forests.

Some oak forest stands have been colonized by invasive species such as buckthorn (*Rhamnus cathartica*) and non-native bush honeysuckles (*Lonicera* spp.). Like other forest habitats, most oak forest habitats in the Eastern Broadleaf Forest Province and southern and western portions of the Laurentian Mixed Forest Province have been fragmented by agriculture and development.

*Photo: Mesic hardwood forest, Houston County, Eric Ogdahl*

## Climate Profile for Mesic Hardwood Forest

**Placeholder:** The anticipated effects of climate change on ecosystems were profiled in the series of reports “Effects of Climate Change on Midwestern Ecosystems” published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025). Additional content in addition to what is shared below, from the Laurentian-Acadian Northern Hardwood-Conifer Forest publication, which will be added, if appropriate, to this chapter upon its availability in Fall 2025.

The anticipated effects of climate change on Mesic Forests were profiled in the report “Effects of Climate Change on Midwestern Ecosystems: Appalachian-Interior-Northeast Mesic Forest” published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025). Please note that this entire Climate Profile is derived from that source. The most impactful changes in climate for this system include more frequent droughts and

milder winters. Mesic forests have generally been experiencing moister conditions (mesophication) as well as fire suppression over the past century, favoring shade-loving moisture-dependent species. While precipitation is expected to increase overall, particularly during the springtime, the increase in late summer drought may shift conditions to be more favorable for more drought-tolerant and fire-adapted species.

Dryer and hotter summers mean droughts are expected to increase in both frequency and severity, primarily affecting soil moisture and increasing tree mortality, overall leading to changes in species composition. Wildfire risk will also be heightened in these dryer conditions. In the Driftless Region (southeast), drought conditions are expected to increase by over 800%.

Warmer winters will also have effects as reduced snowpack leads to changes in habitat availability and growing season. Warmer winters will promote the migration of invasive species better suited for warmer climates. Pests and pathogens may also do more damage under future climate scenarios as winter kills will be less impactful.

Key Climate Change Effects:

- **Habitat Structure:** Climate-induced erosion from flooding and drier soils will negatively affect the slopes and hillsides where hardwood mesic forests are commonly found. Drought and warmer winters will also affect other soil metrics such as pH and nutrient availability, further affecting habitat structure.
- **Community Composition:** This habitat type is adapted to primarily wet conditions, which makes it particularly susceptible to the warmer, dryer conditions climate change may bring. Regions like the Driftless Area may see these effects sooner and more concentrated compared to Northern Regions like the Erie Drift Plains, which is aided by the lake-effect. Throughout the state, drought resistant species like *Quercus* (oaks) will become better adapted and more common, while species adapted to wetter conditions may decline. Wildfire will also become more common during the warm and dry summers, supporting fire-adapted species. Lastly, warmer winters may mean less snowpack and increased freeze-thaw cycles, leading to plant mortality and changes in species composition.
- **Invasive Species:** Climate change conditions will favor invasive species, especially fire-dependent and drought-adapted species. Wildfire will present opportunity for more shade-intolerant and fire-dependent invasive species to colonize this habitat. Warmer winters will allow invasive species from warmer regions to begin to colonize colder regions.
- **Pests and Pathogens:** Pest populations are expected to increase with climate change. Drought will make hosts more susceptible to pests, while warmer winters are expected to kill less pests than they had in the past and allow for their northward expansion. Pest mortality may increase in some cases, for example during more frequent and intense heatwaves.
- **Herbivory:** Mild winters will increase white-tailed deer (*Odocoileus virginianus)* populations as food becomes more available and winter mortality decreases. This may lead to a transition to more browse-resistant species, which in some cases suppresses climate-resilient species.

## Climate Spotlight: Cerulean Warbler

This profile is excerpted from "Effects of Climate Change on Midwestern Ecosystems: Appalachian-Interior-Northeast Mesic Forest" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al. 2025).

The cerulean warbler (*Setophaga cerulea*) is a small, Nearctic-Neotropical migratory songbird considered to be a Bird of Conservation Concern (Buehler and others, 2020; U.S. Fish and Wildlife Service, 2021). Like many long-distance migratory birds, cerulean warblers demonstrate a limited capacity to advance migratory arrival in response to advancing spring conditions and may be vulnerable to phenological asynchrony (i.e., peak nesting and insect availability) (Connare and Islam, 2022). This is of special concern given cerulean warblers' heavy reliance on Lepidoptera (Auer and others, 2016) and the vulnerability of insects to climate change (Edwards and others, 2025). The species is associated with mature, deciduous forests with canopy gaps (Buehler and others, 2020). In the breeding range, they demonstrate preference for white oak (*Quercus alba*) and bitternut hickory (*Carya cordiformis*), avoiding northern red oak (*Quercus rubra*) and red maple (*Acer rubrum*) (Buehler and others, 2020), potentially reflecting higher lepidopteran abundance in forests dominated by these tree types (Connare and Islam, 2022). Novel interspecific interactions are also of concern. For example, as the northern parula (*Setophaga americana*) breeding range expands northward, hybridization with cerulean warbler may become more common (Trimbath and others, 2019).

In the overwintering range, cerulean warblers may be found in old growth forests, shade coffee plantations, and low-mid elevation forests of the Andes (Buehler and others, 2020). The U.S. Gulf Coast and Mississippi Valley provide important stopover habitat to meet migratory demands of trans-Gulf crossings (Raybuck and others, 2022). Climate change threatens suitable habitats across the nonbreeding range. In the Andes, studies predict a moderate contraction (19–43%) in suitable range, driven by climate change, and an upslope elevational shift (Brodie et al. 2024). Both climate-driven flood hazard and human alterations to the Mississippi River system threaten the viability of bottomland hardwood forests (Munoz and others, 2018). Targeted forest management and restoration may be viable strategies to offset declines in the species, provided it increases stand structural diversity, creates small canopy openings, and promotes preferential tree species (e.g., white oak) (Kellner and others, 2016; Nareff and others, 2019).

*Photo: Cerulean warbler, Adobe Stock*

## Species in Greatest Conservation Need

Mesic Hardwoods provide primary or secondary habitat for 52 animal SGCN and 52 plant SGCN (see Table 3.10). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants).

**Table 3.10. Numbers of Species in Greatest Conservation Need associated with Mesic Hardwood Forest as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 3 | 0 | 3 |
| Birds | 6 | 2 | 8 |
| Mammals | 2 | 14 | 16 |
| Reptiles | 5 | 1 | 6 |
| Bees | - | - | 8 |
| Beetles (terrestrial) | - | - | 1 |
| Snails (terrestrial) | 4 | 4 | 8 |
| Spiders | 2 | 0 | 2 |
| Plants | 52 | - | 52 |
| **Total** | **74** | **21** | **104** |

Of the 130 terrestrial vertebrate SGCN identified in the 2025-2035 SWAP, 24% (34) occur in mesic hardwoods. Half of the mammal 31 SGCN species are associated with this habitat. The 52 plant SGCN found in mesic hardwoods represent 12% of the 448 SGCN. Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

## Amphibians

Three salamander SGCN – spotted salamander (*Ambystoma maculatum*), four-toed salamander (*Hemidactylium scutatum*), and eastern newt (*Notophthalmus viridescens*) – are strongly associated with vernal pools (see Vernal Pool sub-chapter) and the mature forest habitats surrounding them. Temporary forested wetlands are critical for these species, which need them in the spring to breed. Eggs are laid in or near the water, and larvae remain in the pools until metamorphosis occurs.
Four-toed salamanders specifically lay their eggs in moss hummocks next to wetlands. Four-toed salamanders occur most frequently in mature upland forests on glacial moraine landscapes with frequent isolated wetlands that include an alder margin and moss hummocks adjacent to open water. After the breeding season or larval metamorphosis within the vernal pools, all three of these salamanders occupy the understory of closed canopy mesic hardwood forests under abundant leaf litter and decaying woody debris. Eastern newts present a unique exception to this - after several years as an eft (terrestrial juvenile stage), eastern newts return to vernal pools, or other aquatic features, and undergo an additional metamorphosis to become primarily aquatic adults.

*Photo: Eastern newt, terrestrial juvenile stage, Julia Geschke*

## Birds

Acadian flycatchers (*Empidonax virescens*), black-throated blue warblers (*Setophaga caerulescens*), cerulean warblers (*Setophaga cerulea*), hooded warblers (*Setophaga citrina*), Louisiana waterthrushes (*Parkesia motacilla*), American goshawks (*Astur atricapillus*), and red-shouldered hawks (*Buteo lineatus*) generally require large areas of contiguous mature to old growth hardwood forest. Acadian flycatchers favor relatively undisturbed forests and experience high rates of brood parasitism and nest depredation in fragmented landscapes. They have habitat requirements very similar to Louisiana waterthrushes but are less dependent on swiftly flowing streams. Where permanent streams are not present, Acadian flycatchers are still usually associated with steep-sided ravines. Cerulean warblers need large, tall trees with horizontal heterogeneity in the canopy, and hooded warblers need mature forests with significant treefall gaps that provide shrubby undergrowth for nesting. Mesic forest dominated by older aspen is a preferred habitat for nesting and foraging for American goshawks in northern Minnesota.

Louisiana waterthrushes are dependent on small swiftly flowing streams bordered by mature closed-canopy deciduous forests, typically in steep-sided valleys. Mesic hardwoods are the most important forest type for louisiana waterthrush through most of their Minnesota range (e.g., Blufflands ECS subsection), although floodplain forests gain importance farther north (e.g., Mille Lacs Uplands ECS subsection). A key characteristic of suitable Louisiana waterthrush habitat is high quality forest in both the valley bottom and on both adjoining slopes. Several mesic hardwood native plant community classes provide suitable habitat, although Southern Wet-mesic Hardwood Forest on the valley bottom is particularly important (DNR Minnesota Biological Survey unpublished data). Although the minimum width of forest corridors necessary for Louisiana waterthrushes is unknown, occupied forested stream valleys in Minnesota were a minimum of 300 meters wide.

Largely restricted to northeastern Minnesota, black-throated blue warblers require mature closed-canopy forests, often on steep slopes, with a well-developed understory and dense shrub layer. In Mesic Hardwood forests, black-throated blue warblers are often found in mixed deciduous-coniferous stands. However, suitable forest structure is more important than the exact species composition of canopy trees.

## Mammals

The mammalian SGCN fauna is quite similar across all upland forest habitats, including Upland Conifer Forests (19 mammal SGCN), Upland Deciduous Forests (21 mammal SGCN) and Mesic Hardwoods (16 mammal SGCN). Missing in the Mesic Hardwoods are several species more closely associated with boreal habitats including moose (*Alces alces*), snowshoe hare (*Lepus americanus*), Canada lynx (*Lynx canadensis*), rock vole (*Microtus chrotorrhinus*), and Eastern heather vole (*Phenacomys ungava*). For some species with home ranges that extend over several native plant communities, such as gray wolves (*Canis lupus*), the landscape mosaic can be as or more important than the individual habitats.

Woodland voles (*Microtus pinetorum*) are the one species not found in fire-dependent upland forests. They require moist, light soil or humus in forests to construct burrows and sub-surface runways. Grazing by cattle, which compacts the soil, and the presence of invasive non-native earthworms, which destroy the humus, may make forests within its limited range in southeastern Minnesota unsuitable for this species. They are also found in Deciduous Wet Forest and Riparian and Floodplain Forests. Currently their distribution is limited to extreme southeastern Minnesota. Mesic Hardwoods also provide primary habitat to the cave-hibernating Tri-colored bats (*Perimyotis subflavus*). Live or recently dead leaves of hardwood trees provide their roosting habitat during the spring, summer, and fall months. As noted by the USFWS, the species population has declined more than 90% in recent years due to the effects of white-nose syndrome. As a result, the species has been proposed for federal listing as a Threatened species.

## Reptiles

The reptilian SGCN fauna found in Mesic Hardwoods is similar to that found in Upland Deciduous Forest and Woodlands but includes only six species compared to the 10 found in Upland Deciduous Forests; none are unique to the Mesic Hardwoods. Included are one lizard (Common Five-lined Skink, *Plestiodon fasciatus*), two turtles (Wood Turtle, *Glyptemys insculpta*; Blanding's turtle, *Emydoidea blandingii*), and three snakes (North American racer (*Coluber constrictor*); timber rattlesnake (*Crotalus horridus*); and Western ratsnake (*Pantherophis obsoletus*)). With the exception of the wood turtle, the remaining SGCN depend on unique microhabitat features that are found in the Mesic Hardwoods of southeastern Minnesota. These include rocky outcrops, forested rocky bluffs, bluff prairies, and rock crevices that are common in the Mississippi River blufflands, as well as granite outcrops, that are common along portions of the Minnesota River valley. These features provide multiple basking sites for thermoregulation and dens for overwintering, two of the SGCN most essential habitat requirements. Limited to the southeastern corner of the state, the Western ratsnake spends considerable time in trees (6 to 12 meters above ground) and may take cover in tree cavities (Moriarty and Hall, 2014). While primarily associated with large non-forested wetland complexes, Blanding's turtles will also utilize Mesic Hardwood Forest during terrestrial movements in the spring and summer related to breeding, foraging, and nesting, as well as hatchling movements in the fall.

## Plants

The relative lack of stand-replacing disturbance events and rich growing conditions of mesic hardwood forests supports a diverse assemblage of plant species. Among them are some of the smallest plants in Minnesota- a group of tiny ferns known as moonworts and grapeferns (*Botrychium* and *Sceptridium*). Some of the rarest of these <4" tall ferns, including goblin fern (*Botrychium mormo*), narrow triangle moonwort (*Botrychium angustisegmentum*), and blunt-lobed grapefern (*Sceptridium oneidense*), inhabit the shaded groundlayer of mature maple-basswood forests. Changes to local habitat conditions, either from canopy opening/removal or leaf litter consumption by non-native earthworms, threaten the ability of these unique and often cryptic plants to persist in an area. Given their small stature, moonwort spore dispersal distances are quite limited, making local conservation efforts critical.

American ginseng (*Panax quinquefolium*) is a perennial herb native to hardwood forests in eastern North America. Wild ginseng became quite rare in Minnesota due to the widespread clearing of mesic hardwood forests for agriculture and development, and unsustainable ginseng harvest levels. The roots are commercially harvested, with interstate and international trade regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and harvest further regulated in Minnesota under Minnesota Rules, Chapter 6282. Under the CITES treaty, the export of wild ginseng root can only be allowed if a state can demonstrate that continued export will not cause ginseng populations within that state to decline any further. Currently, Minnesota is considered in compliance. However, populations are currently so depleted and fragmented that adequate recovery is unlikely without further restrictions on harvest. The DNR hosts a webpage to help collectors assure the future of wild ginseng in Minnesota.

Butternut (*Juglans cinerea*) was once common throughout the Eastern United States, including Minnesota. A lethal fungal disease, butternut canker (*Ophiognomonia clavigignenti-juglandacearum*), reached Minnesota in the 1970's, and as of today, nearly all butternut trees in the state are dead or dying. Active research into treatment options and the potential for augmentations using naturally occurring resistant genotypes is on-going.

## Case Study: Mesic Hardwood Community Conservation Initiative and Botrychium Working Group

While the extent of mesic hardwood forest has been increasing over the past several decades on lands of the Leech Lake Band of Ojibwe (LLBO) Reservation and Chippewa National Forest, the quality of these communities appears to be in decline. Evidence of decline is found in loss of biodiversity and declines in keystone species such as sugar maple and the goblin fern (*Botryichium mormo*) (Zlonis & Henderson, 2018). Much of this decline is attributed to the introduction and spread of non-native invasive earthworms, although there are other factors impacting this ecosystem as well. The goblin fern, listed as endangered by LLBO, threatened by Minnesota, and as a sensitive species by the USFS Chippewa Forest, is the focus of a new Botrychium Working Group. The group seeks to bring about conservation actions to benefit this species that is so highly dependent on a healthy mesic hardwood forest. The recommendations of the group also are intended to benefit many additional vulnerable species, enhance biodiversity, and improve ecosystem function. Initial members of the working group include Lake Band of Ojibwe, U.S. Forest Service Chippewa National Forest, DNR, and the University of Minnesota Landscape Arboretum. For more information, you can contact the Plants Department within the LLBO Division of Resource Management.

*Photo: Goblin fern, Nicholas Jensen*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the Stressors section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Residential, commercial, and industrial development can all directly alter forest ecosystems by removing, degrading, or fragmenting forest cover and habitat. Fragmentation of forests is a growing concern, and occurs when a large, contiguous forest land mass is divided into smaller tracts through sale and subdivision, road construction, or clearing of forests for agriculture, housing, or other commercial developments. This often creates smaller forest pockets, which are interspersed with non-forest land uses. Fragmentation can inhibit the natural migration of many plant and animal species, increase the risk of wildfires at the wildland urban interface, restrict public recreational access, reduce the habitat value and ecological complexity

of forest lands, and contribute to the spread of invasive species. Because of their natural beauty, diversity, recreation opportunities, and abundant natural resources, forested landscapes are appealing places to live; even in the largely forested areas of northern Minnesota, rural development has greatly reduced the extent of large, contiguous forest areas; most forest areas are within 25 kilometers (15.5 miles) of small housing settlements (Radeloff et al., 2005). Forested lands adjacent to lakes and rivers are especially attractive sites for development.

## Crop Production

Historically, many of the mesic hardwood forests were converted to cropland, leaving a patchwork of widely scattered wood lots, averaging 40 to 80 acres in size, across central and southeastern Minnesota. The conversion of forests to agricultural use is ongoing in some locations.

## Livestock Management

Minnesota currently has over 650,000 acres of mesic, upland deciduous, and riparian forests on farms that are grazed by livestock (Zamora et al., 2017; Garrett et al., 2004); heavy grazing could impair soil health and water quality.

## Mining and Quarrying

Forests, when they co-occur with mineral or sand and gravel deposits, are at risk of degradation due to the direct and indirect effects of mining activities such as permanent forest loss, soil compaction, introduction of invasive species, human disturbance, waste discharge and pollution, and forest fragmentation (Sonter et al., 2018). Mining projects can trigger additional, cascading land use change with the establishment of associated infrastructure such as improved road access. Managing the potential for mining effects on high conservation value forests can be more challenging when those forests are co-located on some types of lands such as school trust lands, where Minnesota law directs that lands be managed "for maximum long-term economic return…consistent with…sound natural resource conservation and management principles" (see Minn. Stat. sec. 127A.31). The DNR's duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)). In these situations, the DNR may consider the use of potential mitigation strategies to minimize effects or to identify other lands for permanent protection.

## Roads, Trails, and Railroads

Roads, trails, and railroads can create fragmentation and edge effects in large tracts of forest. Increase in the number of roads and trails increases human disturbance and the potential for introduction of invasive species further into the forest. Repeated use and soil compaction associated with roads and trails also can modify the vegetation within the area of use (Zenner et al., 2008). Temporary winter logging trails may become rutted while materials used to stabilize the trails for heavy vehicles may remain in place, leaving behind wood planks and wood chips, although Minnesota's forest management guidelines are designed to avoid or promptly address these effects. Trails that provide winter access to upland deciduous stands can disturb forest wildlife, especially species that begin nesting in late winter, such as many forest raptors.

## Utility Corridors

Utility corridors transect forests and woodlands throughout the state. These corridors can contain a variety of utility infrastructure. This includes pipelines, telephone lines, and power lines. These lines can be aerial, above ground, or below ground. Regardless of type, utility corridors can fragment habitat based on their size, purpose, and the upkeep that is required to maintain them.

The initial construction of the associated utility infrastructure as well as the long-term maintenance of that infrastructure can have lasting effects on native plant communities and the SGCN associated with them as well as the direct disturbance and oftentimes permanent deforestation and habitat loss incurred during their installation.

These corridors and the increased travel from vehicles and equipment that they require act as vectors for invasive plant species. The required vegetative management practices often include herbicide applications, removal of woody vegetation, and/or mowing. This increased disturbance increases the likelihood of establishing invasive plant species within the corridors and then spreading to adjacent lands.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. As forest composition and structure vary across mesic hardwood native plant communities and local conditions, so do the silvicultural practices typically used during the management of these sites. More moist and rich forest conditions support longer-lived, shade tolerant tree species that are often harvested with uneven-aged approaches (e.g., gap or patch cuts, thinning) in comparison to drier and more nutrient poor sites with shorter-lived, shade intolerant tree species where even-aged harvests (e.g. clearcut or shelterwood harvest) are more prevalent. While each of these silvicultural strategies can incorporate elements of natural disturbance regimes (e.g., a gap harvest approximates a small wind throw event, a clearcut approximates a major blowdown), the resulting habitat quality may vary depending on the management intensity and design. For instance, lower overstory retention leads to a loss of structural complexity in post-harvest stands. Additionally, the scale and rate of harvest activities in mesic hardwood forests shapes landscape-scale age class distributions and the amount of forest habitats in suitable condition and configuration for a range of plant and animal species.

Oak forests become more susceptible to disease with age and can spread disease from old oaks to seedlings; these forests are commonly managed with full even-aged harvests. Even-aged management may create forests that differ from forests experiencing more natural disturbance which may in turn impact habitat conditions for SGCN. Long term impacts of oak harvest, incorporating regeneration dynamics, forest health, and landscape-scale age class distributions should be considered to provide habitat for area-sensitive species and to minimize habitat fragmentation effects. The multiple uses of forests can limit the scope of providing those habitat parameters, such as on school trust lands, because they must be managed "for maximum long-term economic return… consistent with…sound natural resource conservation and management principles" (see Minn. Stat. sec. 127A.31). The DNR's duties to manage for maximum long-term revenue are not discretionary and take precedence in the event of conflicting management objectives (see Minn. Stat. sec. 84.027 subd. 18(a-b)).

## Recreation

In addition to the effects that may be caused by recreational trails (discussed above), recreational activities themselves can spread invasive species. Seeds of invasive plants such as common tansy (*Tanacetum vulgare*) and garlic mustard (*Alliaria petiolata*) can become embedded in the wheels of vehicles or the shoes of individuals and eventually become established along compacted trails where conditions for their growth may be more favorable. Earthworm egg cases, which are problematic for moonwort (*Botrychium*) species, can also be spread in mud. Increased use of roads and trails also increases human disturbance in the forest.

## Fire Management

Some mesic forests have originated from forests originally dominated by oaks. However, there is an inherent difference in soils and topographic features that promote the establishment of Mesic Hardwood Forest ecosystems. On the landscape they are buffered from seasonal drought by fine-textured soils capable of holding or perching rainfall. Over time, as climates became cooler and wetter, conditions were more favorable for maples, basswood, and other fire-sensitive hardwoods. These conditions were enhanced by the suppression of fire. Now, as temperatures continue to rise and droughts become more frequent, oaks are more likely to thrive in many areas.

## Invasive Species (Problematic Non-native Species)

The arrival of Eurasian earthworms is causing profound ecological changes to previously worm-free mesic hardwood forests (Frelich et al., 2019). They upend the traditional soil profile (Hale et al., 2005; Fahey et al, 2013), remove the accumulated layers of organic leaf litter (Holdsworth et al., 2008, 2012), and alter the community of soil mycorrhizal fungi (Paudel et al., 2016). These changes cascade through the ecosystem, including ground layer vegetation (Hale et al., 2006; Holdsworth et al., 2007), leaf litter fauna (McCay and Scull 2019), salamanders (Maerz et al., 2009; Ziemba et al., 2016), and likely other vertebrates. One rare plant in particular, the goblin fern, is threatened with widespread extirpation due to earthworms (Gundale, 2002; Zlonis and Henderson, 2018). On the other hand, invasive plant species generally benefit from earthworms (Nuzzo et al., 2009; Whitfeld et al., 2014). They can also stress sugar maples, leading to canopy dieback (Bal et al., 2018), and they may slow the climate-induced replacement of boreal tree species by temperate species (Frelich et al., 2012). In addition to the earthworm species such as nightcrawlers (*Lumbricus* species) that have been well-studied in northern Minnesota forests, there is the concern that jumping worm species (*Amynthas* and *Metaphire* species) could arrive in these forests and cause additional effects. Invasive plant species, such as buckthorn and Tartarian honeysuckle often outcompete native plant species and repress understory plant species leading to modified habitats unsuitable for SGCN. While a concern statewide, forests in central and southern Minnesota are currently most affected by these invasive shrubs. Where they co-occur with SGCN plants might be a good place to prioritize control efforts.

The spongy moth (*Lymantria dispar*) is an invasive forest pest that feeds on more than 300 species of deciduous trees and shrubs, including aspen, oak, and birch. Repeated removal of leaves, or defoliation, stresses trees and can leave them vulnerable to disease or other pest infestations that can kill trees. Once it becomes established in a location, the spongy moth has cycles of large population outbreaks every eight to 12 years, leading to widespread defoliation and nuisance from caterpillars.

Other non-native insects defoliate trees but typically do not cause significant mortality. Elm zigzag sawfly (*Aproceros leucopoda*) is a non-native defoliator of elm trees that was reported in Minnesota in July 2024 for the first time.

## Problematic Native Species

Over browsing by deer can severely limit natural tree regeneration (Matonis et al., 2011; De Jager et al., 2013). Elevated deer populations also reduce populations of palatable ground layer plants, including orchids (Knapp and Wiegand, 2014), members of the lily family (Balgooyen and Waller, 1995; Augustine and Frelich, 1998; Fletcher et al., 2001), and rare species (McGraw and Furedi, 2005). Decades of cumulative effects have resulted in profound changes to the composition of native plant communities (Wiegmann and Waller, 2006; Flagel et al., 2016; Frerker et al., 2014; Nuttle et al., 2014; Anderson et al., 2017; Sabo et al., 2017).

## Diseases and Pathogens

Oaks are susceptible to several types of disease and pathogens, such as oak wilt (caused by the non-native fungus *Bretziella fagacearum*), sudden oak death (caused by the water mold *Phytophthora ramorum*), and bur oak blight (caused by a native fungal pathogen, *Tubakia iowensis*). Individual trees tend to be more susceptible when under stress, which may interact then with other threats, such as if future climatic conditions bring more frequent late summer droughts. Older oak trees are more susceptible to interacting stressors including drought, heavy seasonal precipitation, insects, and diseases. Wetter springs may increase the prevalence and severity of fungal diseases as spores spread from the diseased leaves by rainwater, exacerbated by earlier spring rainstorms brought on by Minnesota's changing climate.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

Projections include increased temperatures for the growing season as well as increased winter temperatures (Ratcliffe et al., 2025). Increased wintertime temperatures may bring additional freeze-thaw cycling, put spring buds at risk of being affected by frost, and increase the probability of phenological mismatch between plants and animals reliant on them (such as insects). Climate change will affect different types of trees and forests; for instance, monotype aspen stands are less resilient than mixed species forests, with moderate-high vulnerability to climate change (Handler et al., 2017).

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation section in Chapter 6: Implementation.

If late summer droughts become more frequent under future climate conditions, this could pose a challenge to oak heath, exacerbating the prevalence of disease and pathogens.

Restoration activities could also be disrupted if there are multiple seasons with insufficient rain for a successful seeding or seedling planting. The ability for different seeds to emerge and thrive under altered climatic patterns may also influence community composition post-restoration. As noted above, as temperatures rise and drought events increase, oak is likely to become a more prevalent component of upland deciduous forests. In addition to precipitation and hydrology, extreme weather events (e.g., large wind events, ice storms, heavy snowfall) are expected to increase as temperatures increase, as well as the risk of wildfire (Ratcliffe et al., 2025).

Heavy rain events have been increasing in frequency and severity in Minnesota in recent decades. Forests on steep slopes, especially in southeastern Minnesota, are vulnerable to landslides during these events. An increase in rain events has already affected the mesic hardwood forest at Nerstrand Big Woods State Park in Rice County. Much wetter than it was 100 years ago, the park has experienced tree mortality in approximately 12%, or 200 acres of its property. The trees affected include maples, basswood, and oaks.

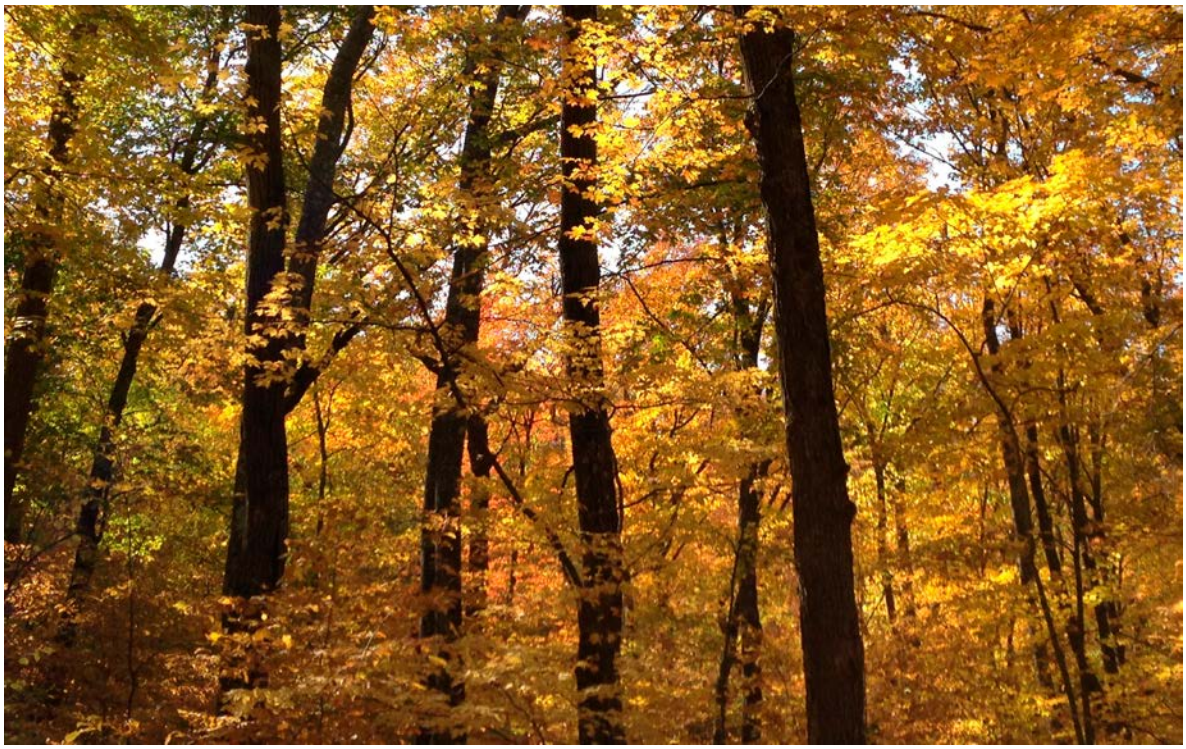

*Photo: Mesic hardwood forest, Mille Lacs Moraine Scientific and Natural Area, Kelly Randall*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan (Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN), five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience.**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN.**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Mesic Hardwood Forest

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Identify priority areas for protected area designations to facilitate long-term conservation outcomes and protection against conversion of forest to different land uses. Use the Conservation Action Network or other sources of information to highlight high biodiversity areas or those providing connectivity between other protected areas that are likely to provide disproportionately high conservation value. |
| | Apply knowledge of SGCN habitat use into forest planning efforts to help balance habitat for SGCN and other values according to management requirements and objectives. Consider natural area designations and other ways to enhance and preserve key mature stands. |

| Stressor | Action |
|---|---|
| | Engage in forest planning to collaborate and share interdisciplinary knowledge, supporting conservation of SGCN habitat and addressing values of biodiversity, rare features, structural and compositional plant diversity and wildlife needs. Maintain, adapt, or develop policies and procedures guiding habitat management that are based on the best available science. On state lands, all actions must align with existing Minnesota statutes and policy guidance, such as in the case of School Trust Lands that must be managed "for maximum long-term economic return…consistent with…sound natural resource conservation and management principles" (Minn. Stat. sec. 127A.31). |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Explore the potential use of silvopasture management regimes (the practice of intentionally combining management of trees, forage, and grazing as one integrated practice) to help restore some upland deciduous forests that do not have spring ephemerals or other sensitive SGCN species (UMN Extension: Silvopasture: Establishment and Management Principles for Minnesota 2013). |
| | Consider projected effects on high value conservation forests, old growth forests, and Important Bird Areas when making decisions and policy that are projected to affect upland deciduous forests (e.g., mining and quarrying, planning for new development of energy sources, and any associated new road or trail construction). |
| | Encourage the use of existing corridors for new trails, roads, and utility corridor development to minimize the construction of new roads and trails that would increase forest fragmentation. |
| | Limit the use and operation of heavy equipment when road or site conditions are vulnerable to damage per best management practices. For instance, depending on the site characteristics, conducting timber harvests during frozen ground conditions can reduce soil compaction and rutting effects. Avoid rutting and damage to peat soils when harvesting spruce tops. |
| | Consider the ecological values of various forest ages and how they relate to SGCN habitat when determining desired future conditions and planning sustainable management to advance those conditions. |
| | Manage for a diversity of forest growth stages across the landscape to promote vegetation characteristics that maintain habitat for a wide range of plant and animal species, promote resiliency to insect and disease outbreaks, and mitigate the adverse effects of climate change. Ensure older forest and old forest qualities are retained on the landscape in amounts and areas that provide critical habitat to SGCN animals and plants; encourage management that sustains mature and old growth forests in forest planning efforts. Also apply management practices to create young, early successional forests on the landscape to provide vegetation characteristics and edge habitat between young and mature forests that support plant and animal species across at least part of their life cycle. |
| | Retain old and dead standing trees (snags) in forests when practical as habitat for wildlife, including cavity-nesting birds, such as detailed in the Minnesota Forest Resource Council's Site-Level Forest Management Guidelines. |

| Stressor | Action |
|---|---|
| | Well-managed and contained fires will need to become a more important forest management tool in the near future to improve the chances of oak regeneration as mesic forests become less resilient and oak becomes more dominant in this changing climate scenario (Frelich et al., 2019). |
| | Manage for an increased diversity of dominant species in a site to assist in resilience toward future disease outbreaks, susceptibility to some pathogens, and invasions by non-native species. Assisting in the management of woodlands and forests that are resilient to pathogens and invasive species may require additional dedicated and certain funding. Also consider pairing invasives management with other incentivized management activities and prioritizing comingled activities to create efficiencies. |
| | Implement control strategies for non-native invasive species and ensure sufficient timeframe for follow-up management that extends for many years. Invasive species require control strategies, prioritization, and ongoing funding to prevent reinvasion or encroachment of additional invasive plants following disturbance from initial treatments. |
| | Incorporate climate change into forestry planning, including climate-adapted silviculture. Implement strategies and approaches for climate-informed forest management. Reference resources from the Northern Institute of Applied Science, such as their adaptation workbook, or the Tree Species Projections for Ecological Sections in Minnesota from the Climate Change Response Network. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Support local governments in measures that minimize fragmentation and encroachment into high quality forests and woodlands such as protecting high quality areas, zoning that guides housing developments, lot sizes that support local forests, and land use planning and development guidance. |
| | Collaborate across forest ownerships and managers to implement sustainable forestry at the site and landscape level to create habitat conditions important to SGCN, such as creating larger forest patches and reducing forest fragmentation. Support forest management approaches that are informed by ecological processes, increase structural and compositional complexity and diversity, and assist in resilience towards future stressors (e.g., climate change, disease outbreaks, invasive species), [such as through engaging in the Minnesota Forest Resource Council's Regional Landscape Committees]. Promote forest management strategies that mimic landscape disturbance patterns, maintain or enhance connectivity among forest patches to enable wildlife movement, and retain biological legacies (at site level) such as large trees with cavities. Consult DNR's Native Plant Community Classification silvicultural strategies for forest stand prescriptions. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Monitor the responses of SGCN to various types of forest management at the site-level and landscape-scale. Collaborate with MFRC site-level guideline monitoring and NPC silvicultural case studies to incorporate SGCN monitoring . Develop models of habitat configurations for various SGCN and consider how current harvest forecasts and conversion rates (i.e., one forest type to another; natural origin habitat to plantation) relate to those models in terms of sustainability for maintaining habitat for SGCNs. |
| | Support research on ways to remove or reduce prevalence and/or effects of earthworms in invaded forests. Examples include the Minnesota Invasive Terrestrial Plants and Pests Center work with invasive jumping worms. |
| | Conduct research and model anticipated changes with different forest management scenarios for effects on wildlife habitat. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Promote and consider further development of tax incentives that enable landowners and farmers to gain value for maintaining conservation values on their properties. Provide increased levels of incentive payments for woodland owners to help protect woodlands and forests from further reduction due to development pressure. |
| | Support and promote education and technical assistance to maintain or restore forest habitat. |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. Prioritize high recreation use areas where invasive species have not yet established. |
| | Provide information on important habitat types, landscape configurations, and conditions most beneficial for SGCN. Support forest management that reflects ecological disturbance goals and SGCN habitat needs, including how specific management techniques (i.e., variable density thinning, natural seeding, planting densities, species composition) may help create beneficial habitat for SGCN. Refer to the Native Plant Community silvicultural strategies for forest stand prescriptions and the Forestry for Minnesota Birds Guidebook. |
| | Research and communicate the benefits of alternative management techniques (i.e., variable density thinning, natural seeding), reference to natural disturbance intervals, natural regeneration methods, and to increase habitat quality for SGCN. |
| | Engage with stakeholders, including Minnesota DNR Division of Fish and Wildlife, to inform goal- setting processes to establish ecologically and socially desirable deer population levels across the state. Encourage bud capping, fencing, and slash walls to mitigate potential effects from deer browse. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# DECIDUOUS WET FOREST

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: DNR Biologist conducting ecological monitoring in deciduous wet forest, Allen Lake Aquatic Management Area, Katie Reisinger; Deciduous wet forest in St. Croix State Park, Grace Lehinger

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# Deciduous Wet Forest

## Habitat Description

Black ash (*Fraxinus nigra*) is the dominant canopy tree in deciduous wet forests statewide; yellow birch (*Betula alleghaniensis*), red maple (*Acer rubrum*), aspens (*Populus spp.*), and balsam poplar (*Populus balsamifera*) are common associates in the Laurentian Mixed Forest Province; and basswood (*Tilia americana*), elms (*Ulmus spp.*), paper birch (*Betula papyrifera*), and yellow birch in the Eastern Broadleaf Forest Province. Wet forests are also found to a lesser extent in the Prairie Parkland and Tallgrass Aspen Parklands Province. Conifer species, especially white cedar (*Thuja occidentalis*) and balsam fir (*Abies balsamea*) are sometimes present in the canopy and understory (and see the Coniferous Wetland Forest sub-chapter). See also the DNR's Trees and Forests website for an overview of forests in Minnesota.

In southeastern Minnesota, this habitat occurs as small patches in areas of groundwater seepage, usually at the base of steep slopes on level river terraces. In such settings, the water table is almost always within reach of plant roots but does not remain above the mineral soil surface for long periods during the growing season. In northern Minnesota, larger basins connected to shallow aquifers create more expansive ash swamps with occasional springs and moving groundwater.

Understories are characterized by patches of shrubs, including speckled alder (*Alnus incana)*, mountain maple (*Acer spicatum*), dogwoods (*Cornus* spp.), gooseberries or currants (*Ribes* spp), and winterberry (*Ilex verticillata*). Mosses and upland forest herbs occur on raised hummocks, down logs, and tip-up mounds, and sedges and wetland forbs occur in wet or mucky hollows. Soils in these wet forests are typically peaty or mucky mineral soils.

Black ash forests are considered old growth when they are at least 120 years old, with some trees being 200 years old or more. Old growth

*Photo: Deciduous wet forest in St. Croix State Park, Grace Lehinger*

black ash trees can grow to be 15-20 inches in diameter, with the size of trees varying with soil moisture and latitude (Characteristics of Old Growth).

## Habitat Map

To depict Deciduous Wet Forest habitat (see Figure 3.11), we compiled spatial data from several sources: DNR's Native Plant Communities, the MN National Wetland Inventory, and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

### Associated Native Plant Community Classes by Ecological Systems

#### Wet Forest (WF)

WFn55 Northern Wet Ash Swamp (PDF)

WFn64 Northern Very Wet Ash Swamp (PDF)

WFw54 Northwestern Wet Aspen Forest (PDF)

WFs57 Southern Wet Ash Swamp (PDF)

WFs55 Southern Wet Aspen Forest (PDF)

### National Wetlands Inventory

From the National Wetland Inventory for Minnesota (NWI) Layer we included the Hardwood Wetland Simplified Plant Community Class type.

### Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included the Eastern North American Ruderal Flooded and Swamp Forest group.

*Photo: Northwestern wet aspen forest, Two Rivers Aspen Parklands Scientific and Natural Area, Kelly Randall*

## Conservation Overview

Deciduous wet forests are found in shallow depressions or in narrow zones along the margins of lakes, wetlands, and peatlands throughout Minnesota. These swamp forests have high plant species diversity. Due to their seasonally saturated conditions, most deciduous wet forest ecosystems have not been largely developed or degraded and are still generally intact. However, threats to these habitats include altered hydrology from a variety of sources (e.g., ditching, utility rights-of-way) and invasive species effects, especially including emerald ash borer (*Agrilus planipennis)* expansion. The emerald ash borer is an invasive insect from Asia (UMN, 2024) that has killed millions of ash trees throughout the eastern half of the U.S. and southeastern Canada.

The expanding presence of emerald ash borer in Minnesota may eventually lead to a significant reduction in black ash as a predominant tree in wet deciduous forests. The loss of ash that is not replaced by trees can lead to a transition from wet forest to a wetland dominated more by shrubs and herbaceous vegetation and result in declines in forest-dependent wildlife species (Grinde et al., 2021).

Old growth forests are recognized in Minnesota for their ecological, scientific, educational, aesthetic, and spiritual significance, including biological features that have developed over centuries (see DNR's Old Growth Forests). In addition to the presence of taller, older trees, these forests include relatively complex stand structure with more snags (dead standing trees), fallen logs and woody debris, all of which contribute to providing nesting, foraging, and denning sites for wildlife including more than 40 species of birds and mammals. The DNR manages network of old growth forest sites on state lands (estimated at 44,000-acres across all types in 2025) with the goal of maintaining "a viable network of high-quality old growth forest sites along with relatively undisturbed, natural-origin younger forests that will be managed to promote old growth characteristics in the future (i.e., future old growth)" (Old Growth Forests). In general, stands of old growth forest are protected from harvest, road-building, and other similar disturbances, unless for ecological benefit. Site-level management decisions in old growth forests typically mimic natural processes to promote regeneration and maintain and restore ecosystem integrity, and use the least intensive methods available, such as hand tools rather than mechanical equipment (Managing Old Growth Forests).

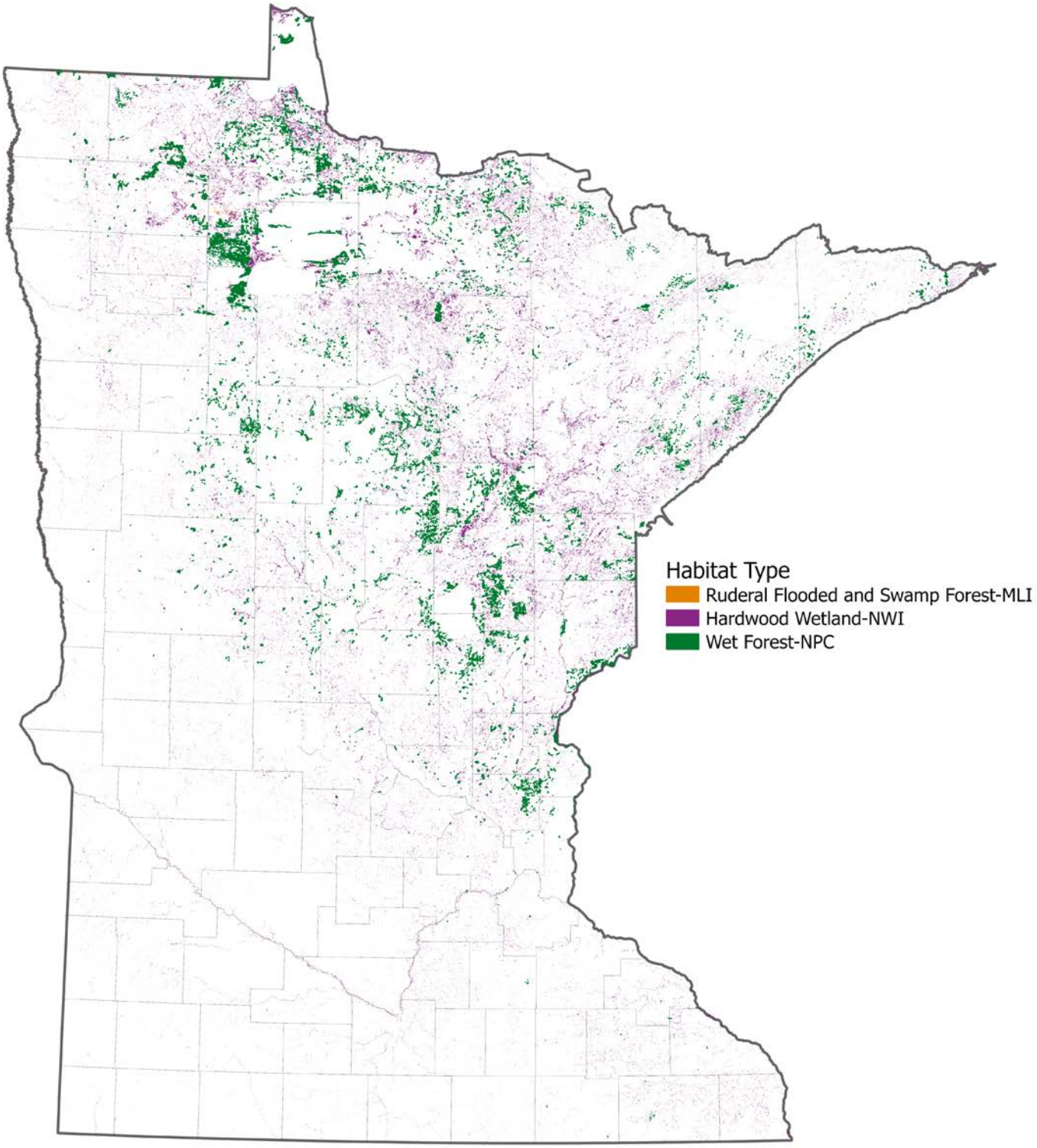


Figure 3.11. A map depicting Deciduous Wet Forest habitat in Minnesota, including DNR Native Plant Community Classes in the Wet Forest Ecological System, Hardwood Wetland Simplified Plant Community Class from the National Wetland Inventory, and Eastern North American Ruderal Flooded and Swamp Forest from the Midwest Terrestrial Habitat System.

## Climate Profile for Deciduous Wet Forest

Climate effects on Deciduous Wet Forest are described in the section on the Laurentian-Acadian Alkaline Swamp in the report "Effects of Climate Change on Midwestern Ecosystems: Temperate Flooded and Swamp Forest" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025). The most impactful changes in climate for this system include increases in spring rainfall of 25% over historical by late century, with more frequent and larger flood events to increase the duration of and level of flooding in these forests. Additionally, higher temperatures combined with less summer precipitation creates vapor pressure deficits (VPD; driven by higher evapotranspiration) projected to be 72% higher by end of century over historical (1971-2000). The most impactful changes in climate for this system include more frequent and larger flood events, also with more frequent late summer drought periods.

A major concern for Deciduous Wet Forests is more frequent and more intense flooding events. More precipitation will mean more sediment deposition as well as habitat changes. This projected increase in flooding will favor pioneer and early successional species, while limiting the growth of more stable species. Further habitat change will occur during more frequent summer droughts, which will affect plant growth and favor drought dependent species. These climate-induced changes may promote the spread of invasive species. Last, pests and pathogen outbreaks may have a greater effect on Deciduous Wet Forests as pest ranges expand, populations increase, and hosts become more susceptible to infection. Large increase in flood frequency and intensity is projected to occur in the spring, as both winter and spring precipitation is projected to increase. Coupled with warmer temperatures leading to an earlier snowmelt, large floods are predicted to continue to greatly affect Deciduous Wet Forests.

This habitat will also be affected by warmer and dryer summers, which will cause soil drying and an overall reduction of habitat in these water-dependent ecosystems.

Key Climate Change Effects:

- **Habitat Structure:** More frequent flood and droughts will alter species composition in this habitat type, especially among wetland adapted species. Windthrow events may become more frequent due to more flooding, less frozen soils, and more pest pressure.
- **Community Composition:** Plant communities will be greatly affected by drier summer and more frequent flooding. Regeneration will become increasingly difficult under these conditions, and better adapted species will begin to dominate these habitats.
- **Invasive Species:** Flooding events create opportunities for invasive species to establish their populations, and as these flooding events become more common, so do the invasive species.
- **Pests and Pathogens:** Climate change will both increase the number of pests and pathogens and will make hosts more susceptible to the pests and pathogens. In some cases, like heatwaves, pests and pathogens may also see declines in population.
- **Herbivory:** Deer populations are expected to grow as climate change brings warmer winters and greater food availability. This increase in deer population will favor browse-tolerant species as well as disrupt tree regeneration.

## Species in Greatest Conservation Need

Deciduous wet forests provide primary or secondary habitat for 28 animal and 7 plant SGCN (see Table 3.11). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. Plant species were only associated with their single most primary habitat. Detailed tables associate each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants).

Of the 130 terrestrial vertebrate SGCN identified in the 2025-2035 SWAP, 18% (24) occur in deciduous wet forests. Of the 31 mammal SGCN, 38% occur in this habitat. The seven plant SGCN found in this wet forest habitat represent less than 2% of all plant SGCN. Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

## Amphibians

Two salamander SGCN – spotted salamander (*Ambystoma maculatum*) and four-toed salamander (*Hemidactylium scutatum*) – are associated with vernal pools (see Vernal Pool sub-chapter) and the mature Deciduous Wet Forests. The forests were identified as secondary habitat for the salamanders who breed in these areas each spring. Eggs are laid in or near the water, and larvae remain in the pools until metamorphosis occurs. Four-toed salamanders specifically lay their eggs in moss hummocks next to wetlands. Four-toed salamanders occur most frequently in mature upland forests on glacial moraine landscapes with frequent isolated wetlands that include an alder margin and moss hummocks adjacent to pockets of open water.

**Table 3.11. Numbers of Species in Greatest Conservation Need associated with the Deciduous Wet Forest as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 0 | 3 | 3 |
| Birds | 0 | 5 | 5 |
| Mammals | 1 | 11 | 12 |
| Reptiles | 3 | 1 | 4 |
| Dragonflies & damselflies | - | - | 1 |
| Moths | - | - | 1 |
| Snails (terrestrial) | 0 | 1 | 1 |
| Spiders | 0 | 2 | 2 |
| Plants | 7 | - | 7 |
| **Total** | **11** | **23** | **36** |

## Birds

Most SGCN birds found in other deciduous forest types may also utilize Wet Forests, but none exclusively. Cerulean warblers (*Setophaga cerulea*), Louisiana waterthrushes (*Parkesia motacilla*), and red-shouldered hawks (*Buteo lineatus*) may be present in Wet Forests, but primarily when part of a mosaic of large tracts of mature Floodplain or Mesic Hardwood forests. In such cases, key habitat features such as flowing streams or seepage channels for Louisiana waterthrushes, or large-diameter trees near wetland openings for red-shouldered hawks, must be present. Red-headed woodpeckers (*Melanerpes erythrocephalus*) may frequent black ash Deciduous Wet Forests when suitable dead trees are present.

## Mammals

Eleven of the twelve mammal SGCN that occur in Deciduous Wet Forest were found in multiple other habitats ranging from upland fire-dependent communities and riparian forests to prairies and other grasslands, savannas, and even urban and other developed lands. These habitat generalists include five bat species: the big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), Eastern red bat (*Lasiurus borealis*), Hoary bat (*Lasiurus cinereus*) and little brown myotis (*Myotis lucifugus*). A cave-hibernating species, the little brown bat has been heavily affected by white-nose syndrome.

*Photo: Woodland vole, Mike Mossman*

The woodland vole (*Microtus pinetorum*) is the only species for which Deciduous Wet Forest has been designated its primary habitat. Other primary habitats for the species include Mesic Hardwoods and Riparian and Floodplain Forests. They prefer loose, well-drained soils and humus layers to construct burrows and sub-surface runways. Grazing by cattle, which compacts the soil, and the presence of invasive non-native earthworms, which destroy the humus, may make forests within its limited range in southeastern Minnesota unsuitable for this species.

## Reptiles

Deciduous Wet Forest provides primary habitat for three reptile SGCN: wood turtle (Glyptemys insculpta), Eastern hog-nosed snake (*Heterodon platirhinos*), and Western ratsnake (Pantherophis obsoletus), and secondary habitat for Blanding's turtle (*Emydoidea blandingii*). Wood turtles use Deciduous Wet Forest as one of 5 forested habitats that can provide primary habitat when including fast-moving rivers and streams. Even though the Eastern hog-nosed snake feeds almost exclusively on amphibians it also is not restricted to wet habitats but occupies forest edges and sites with sandy soils where the ground is conducive to burrowing. The Western ratsnake uses Deciduous Wet Forest along with Upland Deciduous Forest, Mesic Hardwoods, and Savanna in Fillmore and Houston counties where the species resides. Blanding's turtles will also use Deciduous Wet Forest habitat for terrestrial movements in the spring and summer related to breeding, foraging, and nesting, as well as hatchling movements in the fall.

## Plants

The relatively nutrient rich and seasonally saturated soils of deciduous wet forests present a challenging and competitive habitat for plant species. These sites can host some unique and rare plants that occupy specific niches in the ground layer of swamps and seepages. Bog bluegrass (*Poa paludigena*) occurs only

in groundwater-connected forested wetland habitats, where it grows on mossy logs and hummocks above deeper mucky pools under shady black ash canopies. The annual, spring ephemeral forb, false mermaid (*Floerkea proserpinacoides*) grows in localized seepage habitats beneath mature black ash, basswood, and American elm overstories. Both species and their respective wet forest habitats are sensitive to changes in local hydrology as well as effects from non-native invasive species.

## Lichens

Deciduous wet forests are also home to unique lichen species. Lichen "species" are complexes that consists of two or more, typically obligate, symbionts. The dominant partner is a fungus, which creates the main body of the organism. The endosymbiont is either a green alga or a cyanobacteria that lives within the fungal tissue. *Caloplaca parvula* is a Minnesota State Endangered species endemic to the Great Lakes region. It has been documented in two counties in Northeast Minnesota and is found almost exclusively on black ash trees. This species is at risk of being lost from the state as emerald ash borer continues to spread throughout Minnesota.

## Case Study: Habitat connectivity solutions for wood turtles

Wood turtles, which rely on deciduous wet forests and edge habitats found along rivers and streams in eastern Minnesota, are stressed by a variety of a factors including loss of habitat connectivity and flooding from changes in land use and climate. The cumulative result of these threats is a species that is declining across most of its range and is listed as a state threatened species and a candidate for federal listing. Wood turtles need nesting habitat, foraging habitat, and hibernacula sites connected within the river corridor. Roads, trails, bridges, culverts, dams, and fragmented habitats and create obstacles to movement within their full range. When natural nesting sites are degraded or unavailable, female turtles often nest along road shoulders where they are vulnerable to being hit by traffic or poached by collectors.

As part of the State Wildlife Grants Program, a partnership including the Minnesota, Wisconsin and Iowa Departments of Natural Resources, the University of Minnesota and the Conservation Corps set out to address some of the habitat degradation and connectivity issues for Wood Turtles within the region (Minnesota DNR 2020). With roads recognized as one of the primary threats for this species, temporary road barriers were installed in four areas to deter access, and 24 nesting sites were created or restored away from roads to provide alternative, less risky, nesting opportunities. To reduce the effect of increased flooding, all restored or enhanced nesting habitats were located in flood-safe locations.

The successful creation of suitable nesting sites is just the beginning. We are also invested in determining the effectiveness of these conservation actions by monitoring turtle habitat use through field surveys, habitat assessments, radio telemetry, and remote cameras. Through these initial monitoring efforts, a comprehensive monitoring program was established, and a population model was developed to allow us to assess the long-term effectiveness of the conservation actions on the population over time.

While these conservation actions are showing signs of progress, wood turtles and other native turtles continue to suffer from road mortality even where road barriers were erected. New designs for more effective barriers, such as extending them out longer, using more sturdy materials such as half-culverts, or considering passages under bridges are needed. Wood turtles also lose many nests to predators. Nest success increased from 5% to 48% when predators were excluded, (see Case Study: Wood Turtle Nest Success in chapter 2, Reptiles subsection) so protection of nests using electric fences will likely boost recruitment of young turtles in the future.

*Photo: DNR biologist prepares to uniquely mark a wood turtle's shell for a mark-recapture study, part of the DNR's long-term monitoring efforts.*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Roads, Trails, and Railroads

Roads, trails, and railroads can create fragmentation and edge effects. Increase in the number of roads and trails increases human disturbance and the potential for introduction of invasive species into forests. Repeated use and soil compaction associated with roads and trails also can modify the vegetation and hydrology in the area.

### Utility Corridors

Utility corridors transect deciduous wet forests throughout the state. These corridors can contain a variety of utility infrastructure. This includes pipelines, telephone lines, and power lines. These lines can be above ground, or below ground. Regardless of type, utility corridors can cause fragmentation and habitat degradation based on their size, purpose, and the upkeep that is required to maintain them.

The initial construction of the associated utility infrastructure as well as the long-term maintenance of that infrastructure can have lasting effects on native plant communities and the SGCN associated with them. Pipelines have the potential to change the hydrology of deciduous wet forests through impoundment of water and changing of surface and groundwater flow.

These corridors and the increased travel from vehicles and equipment that they require act as vectors for invasive plant species. The required vegetative management practices often include herbicide applications, removal of woody vegetation, and/or mowing. This increased disturbance increases the likelihood of establishing invasive plant species within the corridors and then spreading to adjacent lands.

### Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest activity in deciduous wet forest habitats has generally been limited in scope and intensity due to the constraints of operating on saturated soils that don't reliably freeze in winter. When timber harvesting does occur, uneven aged silvicultural practices are generally applied (e.g., strip or gap harvest, hardwood thinning) and retain greater amounts of canopy trees to maintain evapotranspiration rates and local hydrologic conditions. Pre-salvage timber harvest of ash has increased with the spread of EAB (Holt et al., 2021) and is used as a strategy to retain some timber value before EAB-driven disturbance. Supporting

forest regeneration, including ash regeneration, after timber harvest remains critical (Higgins et al., 2025; Kolka et al., 2018).

## Recreation

Recreation can spread invasive species, inadvertently being moved on people's shoes or gear. Moving wood for campfires can inadvertently move pests such as emerald ash borer in the firewood, so firewood is not to be moved across the state.

## Invasive Species (Problematic Non-native Species)

Invasive species are ongoing stressor in forest and woodland systems. Specifically pertinent to black ash forests, emerald ash borer is an invasive insect from Asia (UMN 2024) that has killed millions of ash trees throughout the eastern half of the U.S. and southeastern Canada. The expanding presence of emerald ash borer in Minnesota may lead, eventually, to a significant reduction in black ash as a predominant tree in wet deciduous forests. Minnesota's deciduous wet forests can contain nearly pure stands of black ash trees, where they help maintain the water table. Black ash trees often form dense stands and have a relatively high rate of evapotranspiration (releasing water vapor from their leaves into the atmosphere) and this draws down the water table. Loss of these trees, such as by emerald ash borer mortality, can cause the wet forest habitat to become more inundated and change over to grass, cattails, and shrubs, threatening the plants and animals that rely on black ash forest habitats.

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al. 2022; Climate Change in Minnesota). Higher growing season temperatures combined with less summer precipitation creates vapor pressure deficits (VPD; driven by higher evapotranspiration) projected to be 72% higher by the end of the century compared to historical levels (1971-2000; Ratcliffe et al., 2025). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th

century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months (as much as 25%), which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation. Also see Climate Profile inset for more information.

*Photo: DNR Biologist conducting ecological monitoring in deciduous wet forest, Allen Lake Aquatic Management Area, Katie Reisinger*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan (Protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN), five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience.**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN.**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Deciduous Wet Forest

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Engage in forest planning to collaborate and share interdisciplinary knowledge, supporting conservation of SGCN habitat and addressing values of biodiversity, rare features, structural and compositional plant diversity and wildlife needs. Maintain, adapt, or develop policies and procedures guiding habitat management that are based on the best available science. On state lands, all actions must align with existing Minnesota statutes and policy guidance, such as in the case of School Trust Lands that must be managed “for maximum long-term economic return…consistent with…sound natural resource conservation and management principles” (Minn. Stat. sec. 127A.31). |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Explore a range of options relative to managing forests with emerald ash borer. When harvesting mature ash trees and promoting other tree species in wet forests, avoid removing all trees in a stand, as the maintenance of some larger trees will maintain site hydrology. Removing groups of ash (0.1 to 0.5 acre in size) is best, and strip clearcuts and strip shelterwoods are methods successful at promoting other species if those other species are present (e.g., red maple and balsam fir) (DNR, 2025). Retain some ash, since they will provide habitat for wildlife when they die. Field studies on the Chippewa National Forest concluded that group selection, individual tree selection, and shelterwood harvest are good options. See also this handbook for private landowners managing ash woodlands (UMN, 2019). Seek opportunities to support the natural retention of ash forests, such as by supporting naturally resistant ash trees and applying biological controls. |
| | For forests depleted by emerald ash borer, encourage more diverse tree species regeneration in an effort to maintain ecosystem functionality into the future. Consider the use of more southern species when establishing new species in black ash stands affected by emerald ash borer, such as swamp white oak and hackberry (Palik et al., 2021). |
| | Buy local and burn local - be careful not to move firewood across the state (DNR, 2025b), because that can inadvertently move invasive pest species such as emerald ash borer that can be in the firewood. Follow best practices and buy firewood adjacent to where it will be burned. |
| | Managing for forests that are resilient to pathogens and invasive species may require additional dedicated and stable funding. Implementing control strategies for invasive species, such as buckthorn, requires a sufficient timeframe for follow-up management that extends for many years. Support funding for these activities and consider expanding restoration resources to make sure they can be applied to woodland systems, which are sometimes in between funding opportunities aimed at prairies or forests. |
| | Manage for an increased diversity of dominant species to assist in establishing resiliency toward future disease outbreaks, susceptibility to some pathogens, and invasions by invasive species. In response to emerald ash borer dieback, promote a diversity of trees. Increasing forest diversity while maintaining water regulation and groundwater conditions suitable for forest growth are key strategies. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Encourage collaboration among all stakeholders and across ownerships to promote effective management for the health and resilience of forests and their ability to provide ecological, wildlife habitat, and other values. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | In places where people recreate, conduct outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. At trailheads for motorized and non-motorized recreation, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# CONIFEROUS FOREST WETLAND

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Coniferous Forest Wetland

## Habitat Description

The Coniferous Forest Wetland habitat type includes wet cedar forests; forested rich peatlands (relatively nutrient rich often due to groundwater inputs); and conifer swamps and forested bogs, which are more acidic, associated with nutrient-poor substrates and a lack of connection to groundwater flow. This habitat type may be considered both as a forest type and a wetland type. Coniferous forest wetlands are found throughout the Laurentian Mixed Forest Province (Forested Rich Peatlands and Acid Peatlands), with concentrations of large peatlands in the Agassiz Lowlands and Tamarack Lowlands ecological subsections. These forests are also present to a lesser degree in the Eastern Broadleaf Forest (Forested Rich Peatlands and Acid Peatlands), and Prairie Parkland and Tallgrass Aspen Parklands Provinces (Forested Rich Peatlands and Acid Peatlands). The soils are peat or mucky mineral soil that is usually saturated with water deficient in oxygen and low in nutrients. Coniferous forest wetlands occur as part of large peatland complexes (Patterned Peatlands) in association with open bogs (see also Non-forested Wetlands sub-chapter) as well as in shallow basins along lakes, wetlands, or streams. See also the DNR's Trees and Forests website for an overview of forests in Minnesota.

Coniferous forest wetlands are dominated by black spruce (*Picea mariana)*, tamarack (*Larix laricina)*, or white cedar (*Thuja occidentalis*). Tree height and density vary from nearly closed canopies with moderate heights (>30') on richer sites to scattered, stunted coniferous trees (<30') in the most nutrient-poor black spruce bogs. The understory of this habitat is characterized by a mossy ground layer with an abundance of forbs, sedges, and broad-leaved evergreen shrubs. Brown mosses predominate in the richer environments, whereas the more acid-loving species of Sphagnum dominate the bogs. Typical shrubs include labrador tea (*Rhododendron groenlandicum*), leatherleaf (*Chamaedaphne calyculata*), and bog rosemary (*Andromeda glaucophylla*). Richer examples of this habitat (that is, swamps more so than bogs) also support species characteristic of surrounding upland forests, but these species are limited to tree bases and moss hummocks elevated above the water table.

*Photo: Northern Poor Conifer Swamp, Sax-Zim bog, Rachel Kranz*

Plant adaptations to the harsh growing conditions in lowland conifer forests include evergreen leaves (conifers and ericaceous shrubs), reliance on ectomycorrhizal fungi to facilitate nutrient uptake, capture of insects to provide additional nutrients (pitcher plants [*Sarracenia purpurea*] and sundews [*Drosera* spp.]), and secondary compounds in leaves to reduce herbivory.

Old growth forest in this habitat type is lowland conifer old growth. Locations of this forest type were not designated with the other types in 2003 and are undergoing a designation process (Managing Old Growth Forests). Characteristics are productive northern white

cedar, black spruce, or mixed tamarack forest types with average tree age of at least 150 years old, in stands with low disturbance and in a resilient landscape context (Lowland Conifer Old Growth Evaluation Approach).

## Habitat Map

To depict Coniferous Forest Wetland habitat (see Figure 3.12), we compiled spatial data from several sources: DNR's Native Plant Communities, the Minnesota National Wetland Inventory, and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological Systems

### Acid Peatland (AP)

APn81 Northern Poor Conifer Swamp (PDF)

APn80 Northern Spruce Bog (PDF)

### Forested Rich Peatland (FP)

FPn63 Northern Cedar Swamp (PDF)

FPn62 Northern Rich Spruce Swamp (Basin) (PDF)

FPn71 Northern Rich Spruce Swamp (Water Track) (PDF)

FPn72 Northern Rich Tamarack Swamp (Eastern Basin) (PDF)

FPn81 Northern Rich Tamarack Swamp (Water track) (PDF)

FPn82 Northern Rich Tamarack Swamp (Western Basin) (PDF)

FPw63 Northwestern Rich Conifer Swamp (PDF)

FPs63 Southern Rich Conifer Swamp (PDF)

FPn73 Northern Rich Alder Swamp (PDF)

### Wet Forest (WF)

WFn53 Northern Wet Cedar Forest (PDF)

## National Wetlands Inventory

From the National Wetland Inventory for Minnesota (NWI) Layer we included the Coniferous Bog and Shrub Wetland Simplified Plant Community Class types.

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Eastern North American Boreal-Subboreal Bog and Acidic Fen, Laurentian-Acadian Alkaline Swamp, and Laurentian Acadian Wet Meadow and Shrub Swamp.

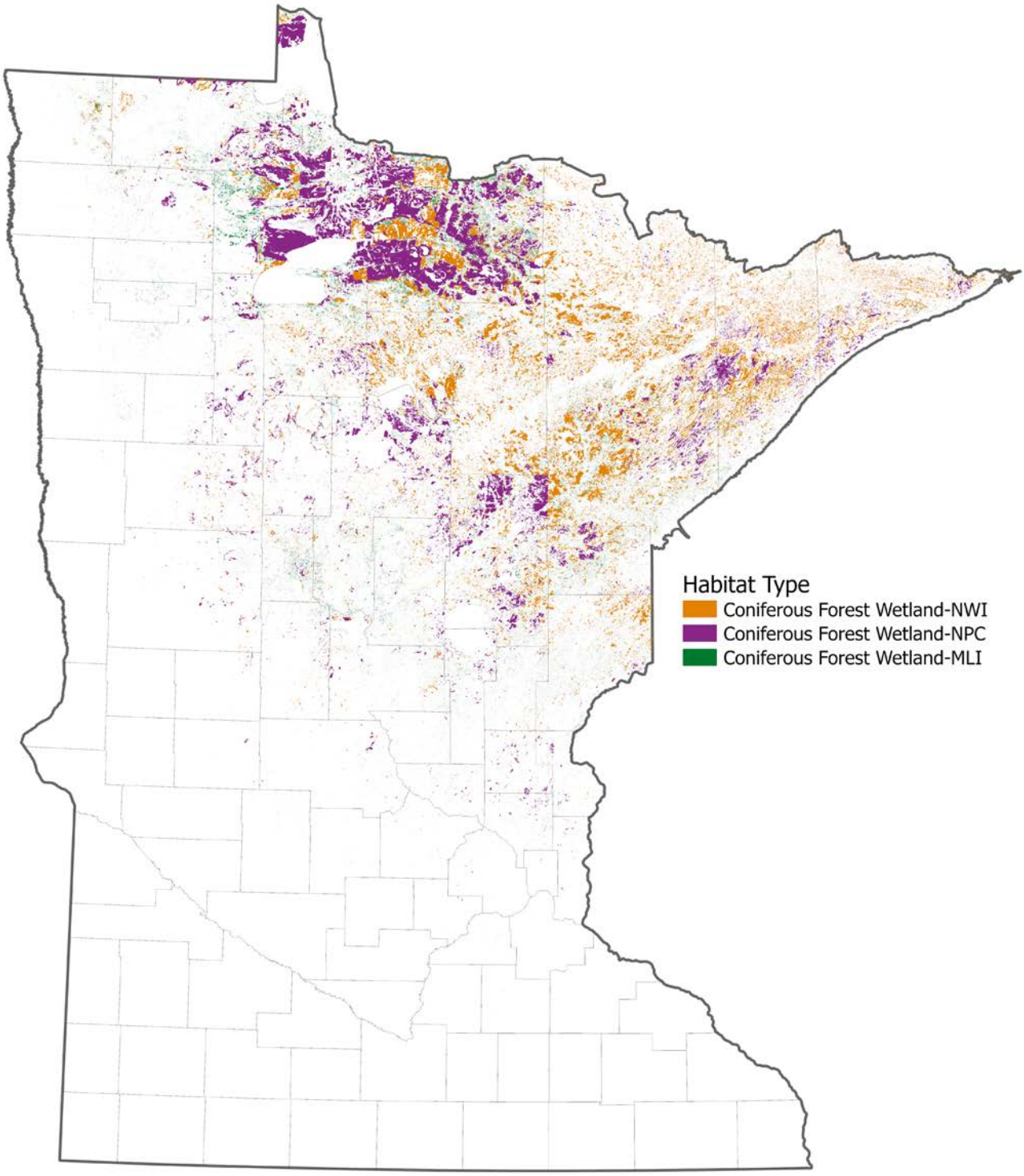


Figure 3.12. A map depicting Coniferous Forest Wetland habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological Systems of Wet Forest, Forested Rich Peatland, and Acid Peatland, two types from the National Wetland Inventory, and three types from the Midwest Terrestrial Habitat System (see narrative).

## Conservation Overview

Despite numerous attempts at drainage in the early 20th century, lowland conifer forests still cover vast areas, primarily in large peatlands complexes in the northern part of the Laurentian Mixed Forest Province. Minnesota's coniferous wetlands, specifically peatlands, are not only unique because of their expanse, remoteness, and unique landscape forms (e.g., patterned water tracks and raised bogs), they also are a significant component of the global carbon cycle. Like all vegetation, peatland plants absorb carbon dioxide for photosynthesis. Unlike vegetation on drier or mesic soils, the water-logged, oxygen-deficient peatland soils reduce the rate of plant decomposition, thereby slowing the release of carbon dioxide, a major contributor to greenhouse gas emissions. Although peatlands only cover 3% of the world's land area, they collectively store nearly 30% of the world's terrestrial carbon, thus reducing the amount of carbon in the atmosphere and helping to mitigate the effect of warming temperatures due to the release of greenhouse gas emissions. In Minnesota alone, peatlands cover at least 10% of the land area (7 million acres statewide) and store over 4 billion metric tons of carbon which accounts for at least 37% of the state's stored terrestrial carbon (Walker, 2011 and Peatlands Resilience Initiative). Peatlands are vulnerable to peat mining and drainage for agriculture or development. An estimated 1/6 of the peatland in the state has been drained, according to The Nature Conservancy (Peatland Restoration and Research in Minnesota). MPCA indicates that 405,000 acres of croplands on drained organic soils create the largest source of carbon dioxide from the agricultural sector - greater than the amount sequestered by the 20 million acres of crops on mineral soils (Greenhouse gas emissions in Minnesota 2005-2022).

*Photo: Forested Peatland within Patterned Peatlands, Erika Rowe*

According to the DNR Native Plant Community (NPC) Field Guides (listed under Associated Native Plant Community Classes above), prior to European settlement catastrophic disturbances within the Coniferous Forest Wetland habitat type were relatively uncommon. These events occurred approximately every 365 to over 1,000 years. Smaller disturbances resulting in partial mortality of the forest canopy were somewhat common and usually consisted of patchy blowdowns and surface fires. The frequency of these events varied greatly across the habitat type from 40 to 90 years on many sites.

Much of the coniferous forest wetland habitat in Minnesota occurs on publicly managed lands. Sites with merchantable densities or volumes of trees are identified for timber harvesting using even-aged silvicultural practices to produce pulpwood or firewood, address forest health concerns, and incidentally create young forest habitat. Black spruce, and to a lesser extent tamarack, are the main commercially important tree species in this habitat, as white cedar is often difficult to regenerate and has historically had a lower harvest rate. Timber harvest amounts for black spruce have declined since 2015, tamarack and white cedar utilization rates have remained relatively low, and white cedar has seen a slight increase in utilization since 2015 (Deo & Fauskee, 2023).

Old growth forests are recognized in Minnesota for their ecological, scientific, educational, aesthetic, and spiritual significance, including biological features that have developed over centuries (see DNR's Old Growth Forests). In addition to the presence of taller, older trees, these forests include relatively complex stand structure with more snags (dead standing trees), fallen logs and woody debris, all of which contribute to providing nesting, foraging, and denning sites for wildlife including more than 40 species of birds and mammals. The DNR manages network of old growth forest sites on state lands (estimated at 44,000-acres across all types in 2025) with the goal of maintaining "a viable network of high-quality old growth forest sites along with relatively undisturbed, natural-origin younger forests that will be managed to promote old growth characteristics in the future (i.e., future old growth)" (Old Growth Forests). In general, stands of old growth forest are protected from harvest, road-building, and other similar disturbances, unless for ecological benefit. Site-level management decisions in old growth forests typically mimic natural processes to promote regeneration and maintain and restore ecosystem integrity, and use the least intensive methods available, such as hand tools rather than mechanical equipment (Managing Old Growth Forests).

## Climate Profile for Coniferous Forest Wetland

This Coniferous Forest Wetland sub-chapter includes several more specific habitat types, which relate to two ecosystem profile reports published by the United States Geological Survey Midwest Climate Adaptation Science Center in support of revisions of State Wildlife Action Plans: "Effects of Climate Change on Midwestern Ecosystems: Temperate Flooded and Swamp Forest" (Ratcliffe et al., 2025a), and "Effects of Climate Change on Midwestern Ecosystems: North American Bog and Fen" (Ratcliffe et al., 2025b). We draw content from both reports in this section, and all content in this section is derived from those reports.

For swamp forests, the most impactful changes in climate include more frequent and larger flood events and more frequent late summer droughts. For boreal-subboreal bogs and acidic fens, warming temperatures with declines in summer rainfall will increase evapotranspiration (vapor pressure deficits; VPD). Northern bogs and fens, already at the southern extent of their range, may be particularly stressed by these shifts in hydrologic conditions and warming trends (Ratcliffe et al., 2025b).

In the Northern Forest ecoregion that includes northeastern Minnesota, projected changes in annual temperature by end of century (2070-2099) are 6 – 11 degrees Fahrenheit higher

than historic (1970-2000), depending on the carbon emissions level and using the mean of 20 climate models (see Table 9 in Ratcliffe et al., 2025b). Rainfall projections include greater expected winter and spring rain and more summer drought.

## Wet Forests

More flooding will mean more erosion and increase the frequency of succession cycles. Pioneer species will be favored under these conditions. Drought-tolerant species will also be favored as summers become drier and hotter. These changes may lead to less species diversity, especially in fragile wetland ecosystems. Pests, pathogens, and invasive species will all benefit from these changes while more sensitive native plants will be hurt the most. Last, herbivores will see population increases and do more damage to selected forage plants.

Key Climate Change Effects:

- **Habitat Structure:** More frequent flooding will benefit flood-tolerant and early successional species. Early successional species will also benefit during the summer as wildfires become more common. Trees may become more vulnerable to windthrow events as soil conditions changes, and warmer temperatures increase pest and pathogen viability.
- **Community Composition:** Increases in flooding and droughts will affect the plant community. Warmer temperatures may force some species to move north, and extreme heat during summer will increase the risk of seedling mortality. Again, early successional species will benefit from these changes.
- **Invasive Species:** More frequent disturbance will provide more opportunities for invasive species to establish themselves.
- **Pests and Pathogens:** Pest and pathogen populations are expected to increase as warmer winters prevent large die-offs. Hosts are also expected to become more susceptible to pests and pathogens during large droughts and other climate-related events.
- **Herbivory:** Deer are expected to increase in population as winters become warmer, and food becomes more available. This will lead to overpopulation, negatively affecting understory plant populations, as well as natural regeneration. Lastly, deer-browse resistant species, like black spruce, will gain an advantage over other more selected species.

*Photo: Northern Cedar Swamp, Ladies Tresses Swamp Scientific and Natural Area, Kelly Randall*

## Eastern North American Boreal-Subboreal Bog and Acidic Fen

This habitat type will be hit particularly hard by dryer and hotter summers.

Key Climate Change Effects:

- **Habitat Structure:** Drier conditions will mean lower water tables, which will hurt important species such as sphagnum moss (*Sphagnum spp.).* These drier conditions will mean reduced water retention and more frequent wildfire.
- **Community Composition:** Increase in temperatures are predicted to hurt species like black spruce and tamarack, while benefiting species such as highbush blueberry (*Vaccinium corybosum).*
- **Invasive Species:** Longer growing seasons and more available nutrients will benefit invasives such as reed canary grass (*Phalaris arundinacea)* and cattail (*Typha spp.*).
- **Pests and Pathogens:** Climate change will make pests and pathogens more viable and will make hosts more susceptible to their effects.

## Species in Greatest Conservation Need

Coniferous forest wetlands provide primary or secondary habitats for 38 animal and 21 plant SGCN (Table 3.12). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants).

Coniferous forest wetlands provide primary or secondary habitat for 20 vertebrate SGCN, 15% of the total number of terrestrial vertebrate SGCN. Birds represent 12 of the total SGCN. Coniferous wetlands are also important to terrestrial invertebrate fauna with a total of 17 SGCN, including 12 moths. This habitat is the primary habitat for 21 plant SGCN (5% of the 448 that are designated as SGCN). Examples of SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

**Table 3.12. Numbers of Species in Greatest Conservation Need associated with the Coniferous Forest Wetlands as either primary or secondary habitat.**

| Species Groups | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Birds | 9 | 3 | 12 |
| Mammals | 1 | 7 | 8 |
| Dragonflies and damselflies | - | - | 1 |
| Butterflies | - | - | 3 |
| Moths | - | - | 12 |
| Snails (terrestrial) | 1 | 1 | 2 |
| Plants | 21 | - | 21 |
| **Total** | **32** | **11** | **59** |

## Birds

Connecticut warblers (*Oporornis agilis)* nest in tamarack and spruce swamps with varying amounts of shrubby understory. Boreal chickadees (*Poecile hudsonicus)* prefer mature black spruce, where they require cavities for nesting. Olive-sided flycatchers (*Contopus cooperi*) breed in lowland conifers, generally requiring a fairly open canopy with tall prominent trees and snags. Black-backed and American three-toed woodpeckers feed by flaking bark off dead trees, particularly tamarack and black spruce. Great gray owls require trees large enough to support their nests.

*Photo: Connecticut warbler, Adobe Stock*

## Mammals

Northern bog lemmings (*Synaptomys borealis)* are limited to lowland conifer forests and open peatlands in extreme northern Minnesota; they have been shown to disappear from peatlands altered by human activities. Little is known about the species. Current populations are believed to be isolated relics of a larger population that occurred much farther south when glaciers advanced during the Pleistocene epoch. Fewer than 12 records have been documented in Minnesota since the species was first found in Lake County in 1932. Those records have been limited to open bogs, shrub carrs, and black spruce swamps.

Since the Eastern heather vole (*Phenacomys ungava)* was first documented in Lake County in 1940, fewer than 20 specimens have been collected in Cook, Lake, and St. Louis Counties. Like the northern bog lemming, it also prefers lowland conifer forests and open peatlands. Proximity to water and the presence of boulders, coarse woody debris, and ericaceous plants appear to be important habitat components. Larger species typical of conifer wetlands include the SGCN snowshoe hare, Canada lynx.

## Invertebrates

Two butterflies, the disa alpine (*Erebia disa*) and the bog copper (*Lycaena epixanthe)*, require lowland conifers with cranberries (*Vaccinium macrocarpon* or *V. oxycoccos*) and lowland black spruce forests, respectively.

## Plants

Many unique and rare plant species rely on the range of habitats provided by coniferous forest wetlands. Plants adapted to survive in the relatively harsh growing conditions of these coniferous forest wetlands are especially sensitive to changes in local hydrology, which maintain a range of soil pH and moisture availability that supports local plant communities.

White cedar swamps and forests often host diverse assemblages of native orchid species, sometimes with more than a dozen orchid species present on a site, including ram's-head lady's-slippers (*Cypripedium arietinum*), hooker's orchid (*Platanthera hookeri)* and fairy slipper orchids (*Calypso bulbosa*). These long-lived and charismatic plant species generally occupy a relatively sparse ground layer, maintained by partial to full tree canopy cover. More acidic spruce bog habitats harbor other rare orchid species including bog adder's-mouth (*Malaxis paludosa)* and tall white bog orchid (*Platanthera dilatata*), as well as plants with unique peatland adaptations, like the carnivorous English and linear-leaved sundews (*Drosera anglica*, *D. linearis*). These orchid species are typically long-lived perennial plants that rely on associations with soil mycorrhizal fungi for access to minerals, water, and carbohydrates and usually require insect pollination and reproduce through tiny seeds that rely on fungal partnerships to germinate and grow. While orchids are short in stature, there is evidence that long-distance wind dispersal can happen. Vegetative offshoots from parent plants have also been documented.

## Lichens

Coniferous wet forests are also home to unique lichen species. Lichen "species" are a complex that consists of two or more, typically obligate, symbionts. The dominant partner is a fungus, which creates the main body of the organism. The endosymbiont is either a green alga or a cyanobacteria that lives within the fungal tissue. Orange-tinted fringe lichen (*Heterodermia obscurata)* is a Minnesota State Species of Concern documented in only one county in Minnesota.  It occurs in forested peatland systems. While this species seems secure in other parts of its global range, we know very little about it or why it is so rare in Minnesota. Please see also Appendix B for the full list of lichen SGCN.

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1. Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms, such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Mining and Quarrying

Although the drainage of peatlands for agricultural use has been the primary cause of peatland loss in Minnesota, peat mining, where layers of peat are removed for horticultural use as a soil amendment and potting medium, can be a unique stress to some coniferous forested wetland communities. Peat mining leases cover a very small percentage of state managed peatlands (0.23% in 2025). All peat mining permits in the state, whether on public or private land, require reclamation and reestablishment of surface vegetation once operations cease. However, the peat layers once removed are not readily replaceable, as it takes hundreds to thousands of years for peat to form again.

### Roads, Trails, and Railroads

Roads, trails, and railroads can fragment large tracts of forest habitat, create edge effects, and alter hydrology. An increase in the number of roads and trails increases the potential for human disturbance and can introduce invasive species further into the forest. Coniferous forest wetlands are particularly susceptible to changes in local hydrology when roads and trails impede or channel water movement. Depending on the position of conifer swamps relative to the road and direction of groundwater movement, either localized draining or flooding can occur. When culverts are placed, beaver activity and blockages can further alter hydrology and expand the affected area to entire local basins.

Repeated use and soil compaction associated with roads and trails can modify the vegetation within the area of use. Trails, for example, are often very swampy with cattails and sedges compared to the adjacent forest understory, which is largely composed of sedges, mosses, and ericaceous (acid-loving) shrubs.

In northern Minnesota an extensive network of snowmobile trails through conifer wetland forests provides winter access to sites that are remote and largely inaccessible throughout the remainder of the year. Activity along these trails can disturb forest wildlife, especially species that begin nesting in late winter, such as many forest raptors.

### Utility Corridors

Utility corridors transect Coniferous Forest Wetland habitat throughout the state. These corridors can contain a variety of utility infrastructure. This includes pipelines, telephone lines, and power lines. These lines can be aerial, above ground, or below ground. Regardless of type, utility corridors can fragment habitat based on their size, purpose, and the upkeep that is required to maintain them.

The initial construction of the associated utility infrastructure as well as the long-term maintenance of that infrastructure can have lasting effects on native plant communities and the SGCN associated with them. Increased funding for rural broadband, conversion of aboveground powerlines to belowground, and development of new utilities (solar, wind, etc.) continue to threaten Coniferous Forest Wetland habitats.

These corridors and the increased travel from vehicles and equipment that they require act as vectors for invasive plant species. The required vegetative management practices often include herbicide applications, removal of woody vegetation, and/or mowing. This increased disturbance increases the likelihood of establishing invasive plant species within the corridors and then spreading to adjacent lands.

Although large utility corridor projects may be permitted to remove state listed plant species, the number and scale of these activities makes those efforts challenging, despite environmental review and permitting processes intended to minimize the negative consequences of these infrastructure projects.

## Gathering Plants and Fungi

Coniferous forest wetlands are an important habitat for many of Minnesota's 48 orchid species. Due to their showy flowers and unique forms, orchids are often a target for illegal collectors. While it is difficult to quantify the amount of illegal orchid harvesting that occurs, it is a significant enough threat that Minnesota has a statute (M.S. 17.23) pertaining to the conservation of certain wildflower species (including orchids) that requires landowner permission prior to collection, transplanting, or sale. Orchids are long-lived perennial plants that form close relationships with soil fungal partners and typically do not survive transplanting efforts, it is much better to take photographs and enjoy them where they are found naturally.

Spruce tree tops are considered a non-timber or decorative forest product (used in seasonal decorations) and interest in this harvest activity has been increasing regionally. Depending on local site conditions, gathering spruce tops for seasonal decorations from lowland conifer habitats has the potential to damage residual trees, ground layer plants, and the underlying peatland soils. These activities typically occur from late summer through late fall, and equipment operations in wetland sites outside of frozen conditions carry an increased risk of damage.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. The typical natural disturbance regime in lowland conifer forests consisted of patchy blowdowns and surface fires resulting in partial mortality of the forest canopy. These disturbances occurred every 40 to 90 years. Uneven-aged management techniques create conditions most similar to these documented natural disturbance regimes, yet current forest management typically uses even-aged management of black spruce and most lowland conifers. When conducted in moderate or large blocks following naturally large stand boundaries, these can create conditions more similar to stand-replacing events and less like the natural disturbance regime.

In coniferous forest wetlands, removing mature trees can occasionally affect local hydrology because of temporary reductions in evapotranspiration and resulting water table rise (also known as swamping).

Regeneration of conifers after disturbance such as fire or timber harvest may be problematic in areas with extremely low pH levels, poor nutrients, and saturated conditions. White

cedar regeneration is especially difficult. Seed germination and seedling growth can be slow in these ecosystems; for instance, regeneration success following disturbance should not be evaluated until 7 years have passed. Heavy snow or freezing rain can damage and even kill young white cedar trees before they are able to mature into a canopy tree.

Eastern dwarf mistletoe (*Arceuthobium pusillum*) is a native parasitic plant that can be a food source and nesting structure for wildlife but reduces the growth, vigor, and longevity of lowland conifers (see also Problematic Native Species). Silvicultural treatments to minimize mistletoe's impact (e.g. cutting all black spruce >5' tall; Minnesota DNR, 2019) can result in simplified forest structures.

Timber harvest can be used to shift lowland conifer forest age-class distributions towards younger forests on the landscape. Habitat patch sizes can also be changed; new, younger forest patches can be created; or age classes can be fragmented depending on the design of the timber harvest. In addition, slow growth rates and narrow tree rings make it difficult to estimate tree ages in some lowland conifer sites, and this may need to be considered when conserving primary old growth forest.

## Recreation

In addition to the effects that may be caused by recreational trails (discussed above), recreational activities themselves can spread invasive species. Seeds of invasive plants such as common tansy (*Tanacetum vulgare*) and garlic mustard (*Alliaria petiolata*) can become embedded in the wheels of vehicles or the shoes of individuals and eventually become established along compacted trails where conditions for their growth may be more favorable. Earthworm egg cases, which are problematic for moonwort (*Botrychium*) species, can also be spread in mud. Increased use of roads and trails also increases human disturbance in the forest.

## Fire Management

Due to the wetland nature of lowland conifer sites, wildfire has not been a significant natural disturbance agent of these habitats. However, with changing precipitation patterns and increasing human activity, fires can start and spread into these habitats and often lead to dramatic changes. Under extreme drought conditions, the organic peat substrates of coniferous forest wetlands itself can ignite and be consumed, resulting in changes to the depth to local water tables and altering the wetland plant communities altogether. Due to remote access and extreme conditions that accompany peat fires, the suppression tactics used to extinguish them can be detrimental themselves. When surface water is limited or unavailable to wildland firefighters, heavy equipment is sometimes used to turn and mix mineral and organic soils in an effort to smother peat fires (i.e. "mashed potatoes" approach). While these tactics are used as a last resort, the outcomes can severely affect a site and warrant substantial restoration efforts.

## Dams and Water Management

One of the most extensive disturbances to conifer lowlands is the attempt by early settlers to convert these wetlands into productive agricultural and forestry lands by constructing ditches. Constructed without any consideration of natural drainage patterns, the efforts were largely unsuccessful in the large expansive peatlands of northern Minnesota (Tester et al., 2020). Nevertheless, thousands of kilometers of ditches (Krause et al., 2021) remain intact despite not being actively maintained for decades. Unfortunately, they have left some lasting effects. The Nature Conservancy in 2024 estimated that 1/6 of Minnesota's peatlands have been drained (Peatland Restoration and Research in Minnesota).

Ditches alter peatland soils and hydrology, an effect that can extend as far as 100-150 meters away from the ditch itself. Soils for

example, become compacted, drier, and often subside while mosses that require cool, wet environs are replaced by vascular plants that prefer drier conditions. These disturbed soils also are less capable of storing carbon. Krause and his colleagues (2012) have estimated that the annual loss of carbon from the ditches crisscrossing the northern Minnesota peatlands averages 38,000 metric tons per year.

## Invasive Species (Problematic Non-native Species)

Sites where lowland conifer soils have been disturbed, such as along ditches and on and along trails, can become pathways for the introduction of wetland invasive plants such as purple loosestrife (*Lythrum salicaria*). Hydrologic disturbance may enable species like glossy buckthorn (*Frangula alnus*), reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), and cattails (*Typha* spp.) to establish, displacing native species and altering microhabitat structure (Faber-Langendoen et al., 2020; Kost et al., 2007 in Ratcliffe et al., 2025b).

## Problematic Native Species

The larvae of Eastern larch beetle (*Dendroctonus simplex)*, a native Minnesota insect, feeds on the inner bark of tamarack trees, which can result in tree mortality. Historically this beetle produced only small, localized outbreaks that lasted several years, but as climate change lengthens its growing and breeding season, beetle populations and activity have increased substantially. Since approximately 2000, an ongoing Eastern larch beetle outbreak has resulted in more than one million acres of tamarack mortality across northern Minnesota. While some SGCN bird species (e.g., black-backed woodpeckers) may benefit from heightened insect activity and resulting coarse woody debris habitat, the scale of these events and associated salvage harvesting operations continue to pose landscape and site level habitat concerns.

Eastern dwarf mistletoe (*Arceuthobium pusillum*) is a tiny unique plant of northern Minnesota peatlands that parasitizes black spruce trees by rooting directly into their branches. Mistletoe growth prompts the host tree to develop dense clusters of branches and foliage (known as witch's brooms) and eventually leads to the host tree's death with an estimated 75% of infected trees dying within 17 years (Baker & French, 1980). Mistletoe brooms and associated mortality pockets are used as habitat by numerous wildlife species, including boreal chickadees and great gray owls, and often increase structural and compositional diversity in the local ecosystem. As dense mistletoe populations can result in areas of dead or dying spruce trees and reduced productivity, forest managers are encouraged to manage the effects during timber harvest planning and operations. Eastern dwarf mistletoe plants primarily disperse their sticky seeds by launching them with internal hydrostatic pressure into adjacent areas (Baker & French, 1986), so forest management techniques currently recommend cutting all spruce trees over five feet tall to limit seed dispersal distances away from other suitable spruce tree hosts (Minnesota DNR, 2019). However, sticky seeds also disperse via movement on wildlife species that use witch's broom habitats; numerous birds and mammals have been implicated as potential vectors that could have a role in occasional long-distance dispersal (Worrall, 2015). This dispersal may reduce the efficacy of the tree removals designed to reduce spread. The goals and objectives for the stand and landscape should help determine a more or less intensive management of mistletoe (Skay et al., 2021).

Eastern spruce budworm is a native caterpillar and is the most destructive pest of spruce-fir forests in eastern North America. Caterpillars prefer to feed on balsam fir and white spruce, but minimal feeding damage can occur on black spruce, tamarack, hemlock, and various pines. Periodic outbreaks occur in the same sites approximately every 25 to 40 years. They may be induced by factors such as annual weather variation and climate change. Management for

balsam fir and white spruce stands infested with budworm favors commercially thinning mid-age stands (35-45 years old; UMN Extension). Although spruce budworm can negatively affect a stand's marketability, populations of several birds favor forest patches that are infested, including the bay-breasted, Cape May, and Tennessee warblers.

Finally, overbrowsing by deer can severely limit natural tree regeneration (Matonis et al., 2011; De Jager et al., 2013), especially for preferred species, such as white cedar (Cornett et al., 2000). Elevated deer populations also reduce populations of palatable ground layer plants, including orchids (Knapp and Wiegand, 2014), members of the lily family (Balgooyen and Waller, 1995; Augustine and Frelich, 1998; Fletcher et al., 2001), and rare species (McGraw and Furedi, 2005). Decades of cumulative effects have resulted in profound changes to the composition of native plant communities (Wiegmann and Waller, 2006; Frerker et al., 2014; Nuttle et al., 2014; Flagel et al., 2016; Sabo et al., 2017). The effects of deer browsing often interact with those of invasive earthworms (Fisichelli et al., 2013; Davalos et al., 2014).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al. 2025b).

*Photo: Northern poor conifer swamp, Iron Springs Bog Scientific and Natural Area, by Evan Host*

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al. 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate sub-chapter in Chapter 6. Implementation.

With respect to the conifer forest wetlands in Minnesota, in the Northern Forest ecoregion that includes northeastern Minnesota, projected changes in annual temperature by end of century (2070-2099) are 6 – 11 degrees Fahrenheit higher than historic (1970-2000), depending on the carbon emissions level and using the mean of 20

climate models (see Table 9 in Ratcliffe et al., 2025b). Warming temperatures could convert Minnesota's peatlands from a carbon sink to an active source of carbon emissions (Peatlands Resilience Initiative). A warmer climate also directly affects the community's unique vegetative composition and phenology (Antala et al., 2022). Many key species may lose suitable habitat, as they are already near the southern extent of their range and have heightened vulnerability and limited adaptive capacity, making them especially at risk from climate change (e.g., *Larix laricina*, *Picea mariana*; Ratcliffe et al., 2025b). Among the changes projected are an increase in shrubs and grasses at the expense of peatland mosses such as *Sphagnum* sp., while the flowering season for many vascular plants will begin earlier. See Climate Profile section.

## Changes in Precipitation and Hydrology related to Climate

Minnesota's climate is becoming wetter and more hydrologically variable. Between 1895 and 2020, the state's average annual precipitation increased by 3.4 inches (Climate Trends). In addition to this overall rise, the frequency and intensity of heavy precipitation events have also grown. Since 2000, very heavy rainfall events — defined as 6 inches or more in a single day — have occurred two to three times more often than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information, 2022). These extreme rainfall events have increased flooding, which disrupts ecosystems, damages infrastructure, and impairs water quality (Williams-Sether & Sanocki, 2025).

Looking ahead, climate models project continued increases in annual precipitation, particularly during winter and spring months. These wetter seasons are expected to elevate flood risks, while late summer is likely to become hotter and drier, intensifying drought conditions (Climate Change in Minnesota). By mid-century (2040–2059), average annual precipitation in Minnesota is projected to increase by up to 1.2 inches, depending on greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). This seemingly contradictory pattern — wetter winters and springs punctuated by drier late summers — has far-reaching implications for water availability, wetland integrity, soil stability, and species that rely on seasonal hydrologic cycles (Runkle et al., 2022). For guidance on climate-adapted management, see the Climate sub-chapter in Chapter 6. Implementation.

These changes are especially consequential for Minnesota's rich peatland ecosystems. Acidic peatlands, which rely exclusively on precipitation for water inputs, are highly sensitive to shifts in rainfall timing and volume. Greater spring rainfall may raise water tables and favor more open peatland systems, while prolonged summer droughts could dry peat layers, encouraging invasion by forest species and accelerating peat decomposition. Ecosystem models predict significant declines in dominant conifer species such as black spruce and tamarack under these conditions (Ratcliffe et al., 2025b). Many of these peatlands also harbor rare and endemic plant species that are presumed to be highly vulnerable to altered hydrology and substrate changes.

Compounding these risks, hotter and drier summers are expected to elevate vapor pressure deficit (VPD) — a key driver of plant and soil water loss — by 32–66% by the end of the century (2070–2099), relative to historical conditions (1970–2000), depending on emissions levels (Ratcliffe et al., 2025b, Table 11). Increased VPD accelerates evaporation, lowers water tables, and exposes peat to oxygen, promoting aerobic decomposition and the release of stored nutrients and carbon. Sustained heat and drought also threaten the productivity and dominance of *Sphagnum* mosses, which are vital to peat accumulation and long-term carbon storage (Bu et al., 2011; Norby et al., 2019 in Ratcliffe et al., 2025b).

An increase in late summer droughts also raises the risk of peatland fires. These fires are especially difficult to manage due to the remoteness of large peatland areas and the tendency for deep organic soils to smolder underground for extended periods. For example, during the severe drought of 2021, a lightning strike near Greenwood Lake in Lake County ignited a wildfire that burned over 28,000 acres, including extensive peatland areas. In some locations, more than one meter of peat was consumed, transforming long-standing carbon sinks into active carbon sources (USFS, 2024).

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Coniferous Forest Wetlands

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Identify priority areas for protected area designations to facilitate long-term conservation outcomes and protection against conversion of forest to different land uses. Use the Conservation Action Network or other sources of information to highlight high biodiversity areas or those providing connectivity between other protected areas that may provide disproportionately high conservation value. |

| Stressor | Action |
|---|---|
| | Engage in forest planning to collaborate and share interdisciplinary knowledge, supporting conservation of SGCN habitat and addressing values of biodiversity, rare features, structural and compositional plant diversity and wildlife needs. Maintain, adapt, or develop policies and procedures guiding habitat management that are based on the best available science. |
| | Support forest management approaches that are informed by ecological processes, increase structural and compositional complexity and diversity, and assist in resilience towards future stressors (e.g., climate change, disease outbreaks, invasion by non-native species). Promote forest management strategies that mimic landscape disturbance patterns (for example, retaining large blocks of mature habitat and creating more small forest openings as gaps or strips), maintain or enhance connectivity among forest patches to enable wildlife movement, and retain biological legacies (at site level) such as large trees with cavities. Consult Native Plant Community Classification silvicultural strategies for forest stand prescriptions. |
| | Apply knowledge of SGCN habitat use into landscape forest planning efforts, to help balance habitat for SGCN and other values according to management requirements and objectives. Consider natural area designations and other ways to enhance and preserve key mature stands |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Consider projected effects on high value conservation forests, old growth forests, and Important Bird Areas when making decisions and policy that are projected to affect coniferous wetland forests (e.g., mining and quarrying, planning for new development of energy sources, and any associated new road or trail construction). |
| | Encourage the use of existing corridors for new trails, roads, and utility corridor development to minimize the construction of new roads and trails that would increase forest fragmentation. |
| | Limit the use and operation of heavy equipment when road or site conditions are vulnerable to damage per best management recommendations. For instance, depending on the site characteristics, conducting timber harvests during frozen ground conditions can reduce soil compaction and rutting effects. Avoid rutting and damage to peat soils when harvesting spruce tops. |
| | Manage for a diversity of forest growth stages across the landscape to promote vegetation characteristics that maintain habitat for a wide range of plant and animal species, promote resiliency to insect and disease outbreaks, and mitigate the adverse effects of climate change. Ensure mature, older forest and old forest qualities are retained on the landscape in amounts and areas that provide critical habitat to SGCN animals and plants; encourage management that sustains mature and old growth forests in forest planning efforts. Apply management practices to create young, early successional forest on the landscape to provide vegetation characteristics and edge habitat between young and mature forest that support plant and animal species. |

| Stressor | Action |
|---|---|
| | Carefully consider hydrological, habitat, and landscape level disruption to conifer wetland forests when planning timber harvest operations in these delicate systems. Consider forest productivity and the ability of lowland conifers to regenerate prior to timber harvest. Conduct logging operations in wetland forests only after the ground is sufficiently frozen to prevent rutting and hydrological effects from road constructions and use. |
| | To prevent soil compaction and changes to site hydrology, minimize use of heavy equipment to suppress fires in conifer lowlands when possible. |
| | Implement best management practices for Eastern larch beetle management in addressing outbreaks. Encourage tree diversity by leaving other tree species such as black spruce and cedar on the site, or by planting or aerial seeding with a mixture of site-appropriate trees, including tamarack. |
| | Balance management of spruce budworm outbreaks with consideration of their benefits to warblers and other birds that serve an important role as budworm predators. |
| | Implement protective measures to reduce deer browsing on white cedar seedlings on sites that are suitable for cedar growth and establishment. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Increase outreach and capacity regarding enforcement to protect vulnerable orchid species (see Plant SGCN chapter). |
| | Collaborate across forest ownerships and among all stakeholders to promote effective management for the health and resilience of forests and their ability to provide ecological, wildlife habitat, and other values at the landscape level. |
| | Partner with other conservation organizations and natural resource agencies to protect intact peatlands from further degradation and to restore partially drained peatlands. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Support the collection of accurate and reliable forest stand inventory data for planning. |

| Stressor | Action |
|---|---|
| | Monitor the responses of SGCN to various types of forest management at the site-level and landscape-scale. Collaborate with MFRC site-level guideline monitoring and NPC silvicultural case studies to incorporate SGCN monitoring. Develop models of habitat configurations for various SGCN and consider how current harvest forecasts and conversion rates (i.e., one forest type to another; natural origin habitat to plantation) relate to those models in terms of sustainability for maintaining habitat for SGCNs. |
| | Monitor harvest of nontimber forest products such as spruce tops to avoid rutting and damage to sensitive peat substrates. Consider limiting spruce top harvesting in areas of biodiversity significance or sensitive hydrology. While pressure and effects have historically been dispersed and localized, monitoring can help alert where future management actions are needed to protect broader ecosystem functionality. |
| | Monitor eastern larch beetle and effects; predict susceptible areas. |
| | Investigate the efficacy of current management efforts to reduce the spread of Eastern dwarf mistletoe in addition to the benefits/effects to wildlife species. |
| | Learn more about the effects of deer browse on native vegetation (Minnesota White-tailed Deer Management Plan) and forest regeneration. |
| | Monitor, research, and manage effects of emerging stressors like increased temperatures, interactions with pest species, and altered hydrology anticipated with changes in climate. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Develop and share studies of harvest methods for black spruce, and support research and case studies utilizing shelterwood, gap and strip harvest techniques that retain greater habitat diversity (Anderson et al., 2020). |
| | Research techniques to promote forest regeneration for challenging species (i.e. white cedar) or in certain circumstances (i.e. where altered hydrology is a concern). |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. |
| | Implement strategies and approaches for climate-informed forest management, including increasing forest biodiversity for increased resilience towards future changes, including disease or pathogen outbreaks, extreme weather events, and invasions by non-native species. Apply the Climate Change Field Guide for Northern Minnesota Forests (Handler et al. 2017) for forest management guidance regarding harvest strategies and subsequent regeneration options. Learn about how climate may affect our forests in the future with this resource: Minnesota Forest Ecosystem Vulnerability Assessment and Synthesis. |

## Case Study: Peatland Forest Management for Bird SGCN

Initiated in 2018, the Natural Resources Research Institute (NRRI) and the University of Minnesota-Twin Cities (UMN) teamed up to provide foundational data for the management of vulnerable lowland conifer peatland forests. This work focused on two Species in Greatest Conservation Need (SGCN): the Connecticut Warbler (*Oporornis agilis*) and the Boreal Chickadee (*Poecile hudsonicus*). The overall goal was to quantify how timber management practices influence wildlife use and other ecological functions over time, and to collaboratively develop multiple-use management strategies. The initial phase of the project characterized habitat suitability across a chronosequence (sequence of ecosystems that represent different stages of development used to study ecological changes over time) of managed stands in three lowland conifer types: productive black spruce, stagnant black spruce, and tamarack.

Analysis across the managed chronosequence established that the abundance, richness, and diversity of habitat specialist birds (including SGCN) increased significantly with stand age and were strongly correlated with structural complexity (e.g., vertical layering and canopy cover). This indicates longer harvest rotations and a focus on managing for structural diversity would be beneficial for peatland specialists.

Findings on the Connecticut Warbler revealed an urgent need for conservation intervention, as the review found a 77% loss of previously known sites in Minnesota, emphasizing a sharp range retraction along the southern breeding limit. The Connecticut Warbler is a ground nester that requires a dense, low understory (moss, Labrador tea, leatherleaf) under a semi-open canopy for high nest concealment. The data support the use of small-scale disturbance methods such as gap harvests and narrow strip cuts to create the necessary light penetration to stimulate dense shrub growth while retaining the surrounding mature forest matrix.

*Photo: Boreal chickadee, Julia Geschke*

Research on the Boreal Chickadee confirmed its dependence on mature conifer habitat and revealed high sensitivity during the post-fledging period. Fledgling Boreal Chickadees showed a strong, consistent preference for productive black spruce and stagnant black spruce and a significant avoidance of large clearcuts and deciduous cover, especially during the post-fledgling time period. Effective management requires retaining mature lowland conifer canopy and prioritizing the retention of medium-sized snags and vertical complexity for nesting and foraging. Furthermore, the Boreal Chickadee's reliance on soft-bodied insects (vulnerable to drought) means management must maintain microclimatic refugia (e.g., canopy retention) to stabilize soil moisture and buffer the insect food web against climate change.

The second phase of the research involved partnering with the Minnesota DNR to test targeted silvicultural treatments designed to integrate the needs of both SGCNs. The alternative harvest treatments included 21-acre gap harvests, 25-foot and 100-foot strip harvests, and standard clearcutting. Preliminary findings suggest that alternative methods are beneficial compared to traditional clearcutting for these specialists. Initial post-harvest surveys show that the gap harvests and narrower strip harvests resulted in higher initial Connecticut Warbler abundance, while Boreal Chickadee numbers were highest in the unharvested control plots and the narrow-strip plots, which successfully retained the mature canopy. As this study continues over the next several years, the data will yield valuable information on how to implement a heterogeneous, variable-retention approach that creates a mosaic of mature structure (for the Boreal Chickadee) and dense, regenerating understory (for the Connecticut Warbler), translating research into new, science-based silvicultural guidelines for Minnesota's peatland forests.

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## RIPARIAN AND FLOODPLAIN FOREST

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Mississippi River Islands Scientific and Natural Area, Kelly Randall; DNR Ecological Monitoring Network crew in floodplain forest along the Mississippi River

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# Riparian and Floodplain Forest

## Habitat Description

Riparian and floodplain forest habitats occur primarily on floodplains and associated terraces along major rivers and their tributaries (see also Rivers and Streams Chapter). Floodplain and terrace forests are seasonally wet forests that flood following spring snowmelt as well as unusually heavy rains. These forests are found on sandy or silty alluvium (soil deposited by flowing water) associated with streams and rivers throughout the Eastern Broadleaf Forest Province and are extensive along the Mississippi, Minnesota, and St. Croix rivers. In the Laurentian Mixed Forest Province, these forests also occur along major rivers but are not as extensive as in the Eastern Broadleaf Forest Province. These forests also occur in the Prairie Parkland and Tallgrass Aspen Parklands Provinces.

The canopy of these forests is dominated by deciduous trees that are tolerant of saturated soils, prolonged inundation, frequent erosion, and sediment deposition. Species less tolerant of these conditions occur on terraces, which flood only in very wet years. In southern Minnesota, silver maple (*Acer saccharinum*) (which often occurs as nearly pure stands), black willow (*Salix nigra*), and eastern cottonwood (*Populus deltoides*) are common canopy dominants. Less common species include river birch (*Betula nigra*), elms (*Ulmus spp.*), green ash (*Fraxinus pennsylvanica*), and swamp white oak (*Quercus bicolor*). In the north, black ash and silver maple are important canopy trees with lesser amounts of green ash, American elm (*Ulmus americana*), bur oak (*Quercus macrocarpa*), and basswood (*Tilia americana*). Canopy coverage in these forests is highly variable; areas of continuous canopy are punctuated with large gaps, which may be vegetated with ephemeral herbaceous plants or remain largely unvegetated if flood disturbance is repeated and severe. The understory is typically open, with few shrubs or saplings. Pools or mucky depressions in old river channels are often present on actively flooded sites. See also the DNR's Trees and Forests website for an overview of Minnesota forests.

*Photo: DNR Ecological Monitoring Network crew in floodplain forest along the Mississippi River*

The characteristics of old growth lowland hardwood forests vary by location within the state, but trees are at least 120 years old, often with diameters greater than 10 inches. In addition to old and medium-aged trees, old growth lowland hardwood forests will include seedlings and young trees. It is rare to find old growth of willow, cottonwood, aspen, birch, and balsam poplar, which require a lot of light (Characteristics of Old Growth).

## Habitat Map

To depict Riparian and Floodplain Forest habitat (see Figure 3.13 we compiled spatial data from several sources: DNR's Native Plant Communities and the Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3. Habitats). We note included sub-types below; underlined items have links to online descriptions.

### Associated Native Plant Community Classes by Ecological Systems

#### Floodplain Forest (FF)

FFn57 Northern Terrace Forest (PDF)

FFn67 Northern Floodplain Forest (PDF)

FFs59 Southern Terrace Forest (PDF)

FFs68 Southern Floodplain Forest (PDF)

### Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Laurentian-Acadian Floodplain Forest and Midwest Floodplain Forest.

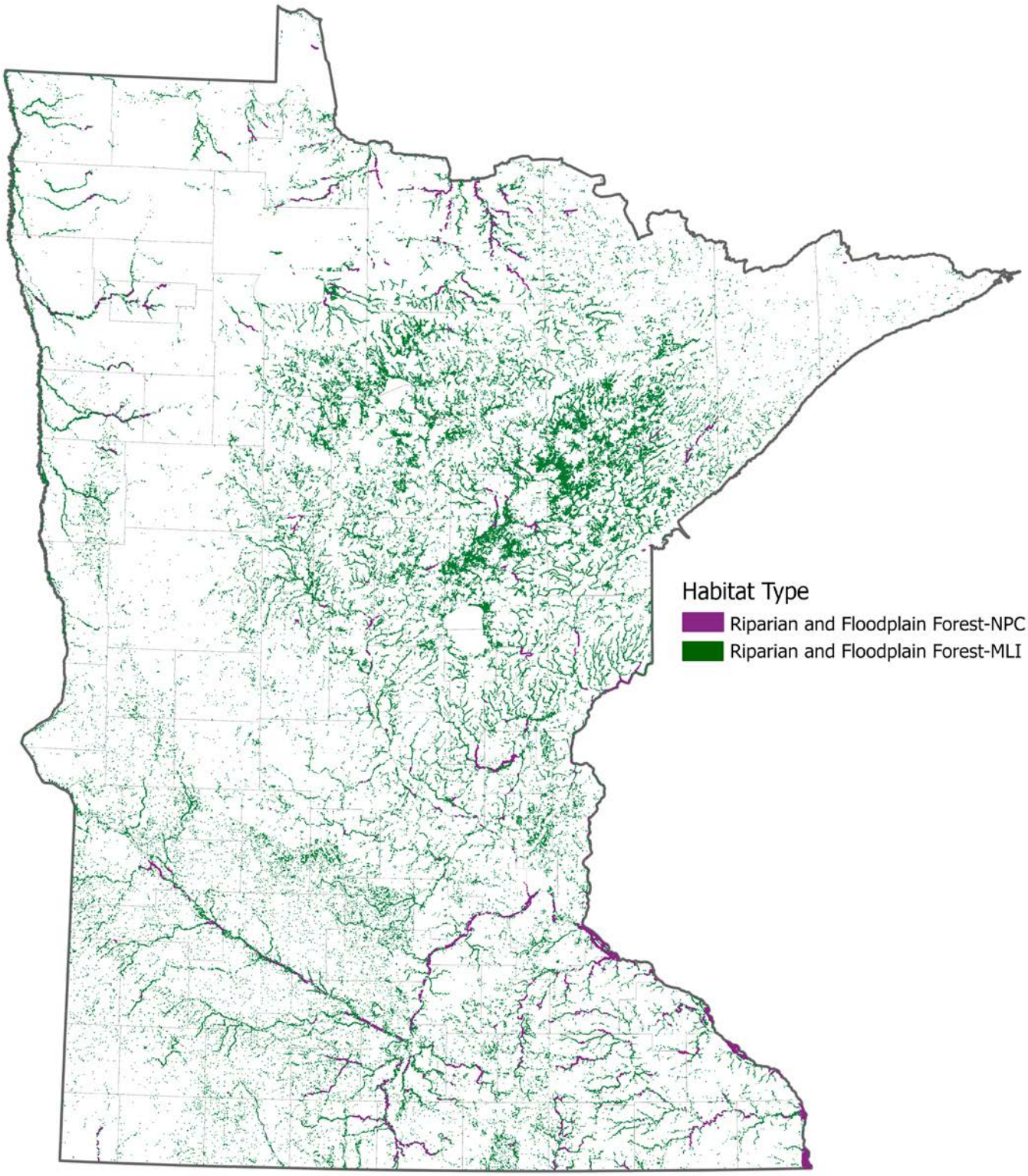


Figure 3.13. A map depicting Riparian and Floodplain Forest habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological System of Floodplain Forest, and the Laurentian-Acadian Floodplain Forest and Midwest Floodplain Forest from the Midwest Terrestrial Habitat System.

## Conservation Overview

Riparian and floodplain forest habitats occur along major rivers, rivers, and streams statewide (see also Rivers and Streams Chapter). Riparian and floodplain forests in southern Minnesota are among the most disturbed native habitats in the state. Even prior to European settlement, large swaths of forests were logged to provide fuel for riverboats. Since settlement by people of European descent, large areas of floodplain forests in southern Minnesota have been lost due to urbanization and conversion to agriculture. Now, these forests, which once formed continuous bands of habitat along the major rivers in southeastern Minnesota, persist as a broken chain of forest patches. In addition, the damming of major rivers has greatly reduced the annual pulse of flooding that maintained the ecological integrity of the floodplain forests. Other factors that have reduced the value of the habitat for wildlife include the loss of most canopy American elms from Dutch elm disease and the spread of reed canary grass (*Phalaris arundinacea*), which impedes establishment of seedlings of native plants. The recent loss of ash trees to emerald ash borer (*Agrilus planipennis*) and elm (*Ophiostoma spp.*) to Dutch elm disease shifted the composition of the Mississippi River floodplain forest towards a composition of largely Silver Maple and Oak, particularly along pools 1 – 10. The loss of ash trees is also pronounced along the Minnesota River.

Riparian and floodplain forests are prone to stress from larger and longer flood events (see Climate Profile) that facilitate the spread of invasive species and impede the recruitment of tree seedlings. There are also other disturbances such as windthrow and loss of trees to disease and pathogens in mature stands. In many places there appears to be reduced regeneration of riparian forest because of these changing flood patterns and a lack of advance tree regeneration under mature forest canopy, such that there are insufficient understory and midstory trees to rebuild future forest.

Protecting riparian forest along river corridors is important to facilitate movement of wildlife and the movement of nutrients and energy between the river and the surrounding landscape (see also the Rivers and Streams Chapter). In addition to the habitat they provide for many resident animals and nesting birds, millions of migrating birds depend on the Mississippi River and its associated floodplains each spring and fall as one of the most important migratory flyways in North America.

Old growth forests are recognized in Minnesota for their ecological, scientific, educational, aesthetic, and spiritual significance, including biological features that have developed over centuries (see DNR's Old Growth Forests). In addition to the presence of taller, older trees, these forests include relatively complex stand structure with more snags (dead standing trees), fallen logs and woody debris, all of which contribute to providing nesting, foraging, and denning sites for wildlife including more than 40 species of birds and mammals. The DNR manages network of old growth forest sites on state lands (estimated at 44,000-acres across all types in 2025) with the goal of maintaining "a viable network of high-quality old growth forest sites along with relatively undisturbed, natural-origin younger forests that will be managed to promote old growth characteristics in the future (i.e., future old growth)" (Old Growth Forests). In general, stands of old growth forest are protected from harvest, road-building, and other similar disturbances, unless for ecological benefit. Site-level management decisions in old growth forests typically mimic natural processes to promote regeneration and maintain and restore ecosystem integrity, and use the least intensive methods available, such as hand tools rather than mechanical equipment (Managing Old Growth Forests).

## Climate Profile for Floodplain Forests

Riparian and Floodplain Forest was profiled in the report "Effects of Climate Change on

Midwestern Ecosystems: Temperate Flooded and Swamp Forest" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025). The most impactful changes in climate for this system include more frequent and larger flood events (see Figure 3.14), also with more frequent late summer drought periods.

A major concern for Floodplain Forests is more frequent and more intense flooding events. More precipitation will mean more sediment deposition as well as habitat changes. This projected increase in flooding will favor pioneer and early successional species, while limiting the growth of more stable species. Large increase in flood frequency and intensity is projected to occur in the spring, as both winter and spring precipitation is projected to increase. Coupled with warmer temperatures leading to an earlier snowmelt, large floods are predicted to continue to greatly affect this system.

Floodplain Forests will also be affected by warmer and dryer summers, which will cause soil drying and an overall reduction of habitat in these water-dependent ecosystems. Further habitat change will occur due to more frequent summer droughts, which will affect plant growth and favor drought dependent species. These climate-induced changes may promote the spread of invasive species.

Key Climate Change Effects:

- **Habitat Structure:** Flooding events will cause erosion and remove valuable habitat components from Floodplain Forests such as streambanks and large woody debris, especially in flooding prone regions, such as agriculture dominated landscapes. Flooding also has a negative effect on tree mortality. Flooding may also increase habitat viability by bringing in new sediment, introducing water into usually dry areas, and carrying nutrients (as well as pollutants).
- **Community Composition:** Floodplain Forests will transition away from mast-producing oaks (*Quercus* spp.) and hickories (*Carya* spp.) to more flood resistant species, such as ashes (*Fraxinus* spp.), willows (*Salix* spp.) and maples (*Acer* spp.). Drought resistant species will be favored during warmer and dryer summers, while more moisture dependent species, like tamarack (*Larix larcinia*) and black Spruce (*Picea mariana).*
- **Invasive Species:** As the climate warms, species from warmer regions may begin to move into the Midwest in search of cooler conditions, pushing out native species, like willows (*Salix spp.)* and cottonwoods (*Populus spp.)*. Climate-driven disturbance such as flooding events, will increase the threat to native species, as opportunities for out-competition by non-natives increases.
- **Pests and Pathogens:** Increasing temperatures will also likely cause ranges of some pest species expand, populations increase, and hosts become more susceptible to infection with rising temperatures. Plant communities will be hit harder by pests as warmer winters protect pest populations and enable additional annual broods. Pests like the spongy moth (*Lymantria dispar)*, emerald ash borer, and hickory bark beetle (*Scolytus quadrispinosus)* are predicted to benefit from warmer winters and drying summers, leading to increased tree mortality.
- **Herbivory:** Warmer winters will benefit white-tail deer (*Odocoileus virginianus)* populations because of boosted survival rates and better access to forage, furthering the currently observed trend of white-tailed deer population growth. (All of this Climate Profile content is from Ratcliffe et al., 2025.)

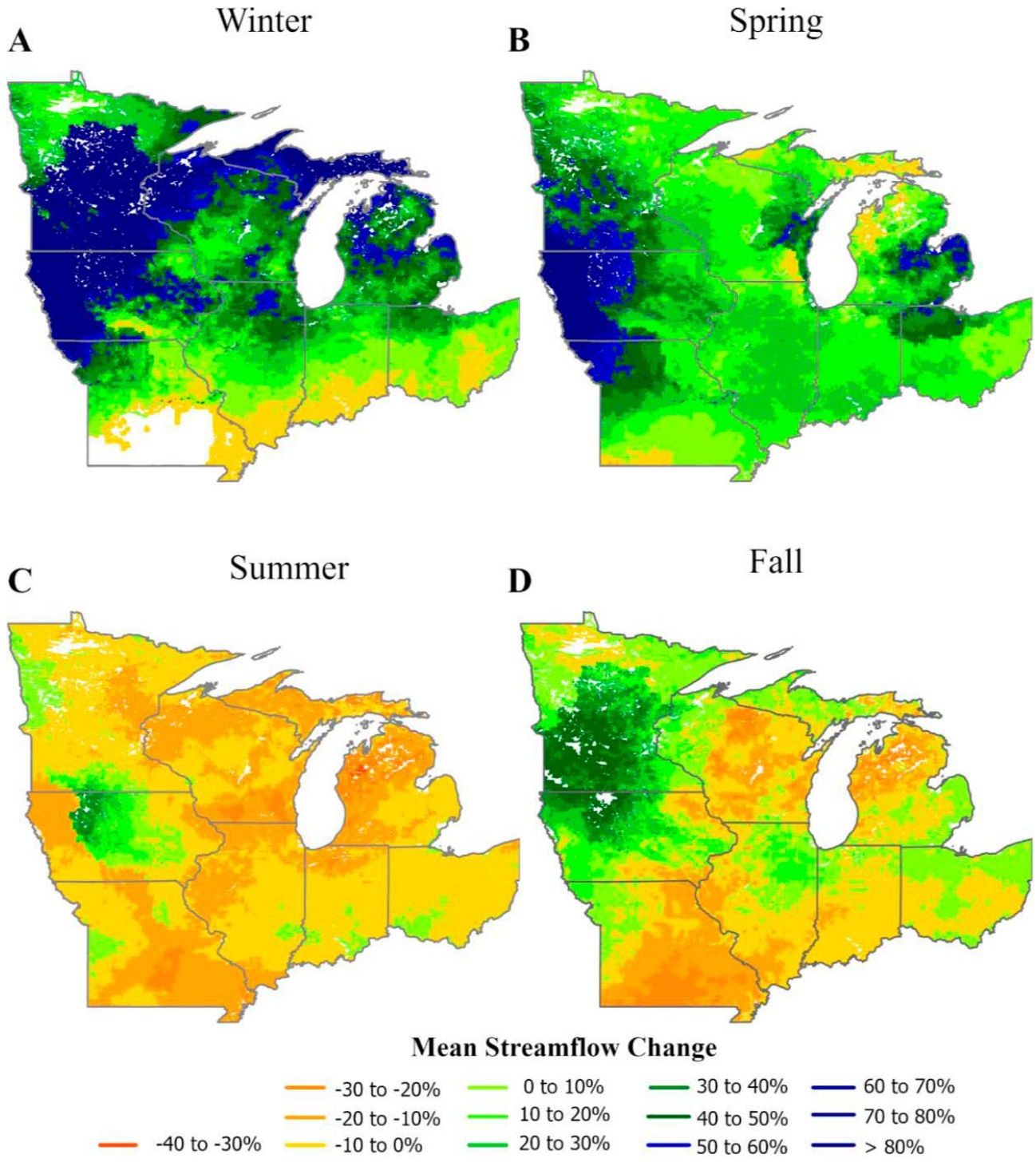


Figure 3.14. (Figure 1 in Ratcliffe et al. 2025). Projected changes in mean streamflow in the Midwest. Projections use gridded simulations of daily runoff based on CMIP5 climate models under the high-emissions (RCP 8.5) scenario. Values show the percent change in mean daily streamflow (cubic feet per second) for each season (winter, December–February; spring, March–May; summer, June–August; fall, September–November) at the end of the century (2070–2099) compared to historical data (1977–2006). Data and metric definitions are provided by the U.S. Stream Flow Metric Dataset (Authors (in review); U.S. Department of the Interior, Bureau of Reclamation, 2014; USDA Forest Service Office of Sustainability and Climate, 2022; Wenger and others, 2010).

## Species in Greatest Conservation Need

Riparian and Floodplain Forests provide primary or secondary habitat for 26 animal and 22 plant SGCN (see Table 3.13). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants). Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

Twenty-one (16%) of the 130 terrestrial vertebrate SGCN are associated with Riparian and Floodplain Forests, including ten of the mammals (31% of the 31 mammal SGCN). 22 plant SGCN associate with Riparian and Floodplain Habitats as their primary habitat (5% of plant SGCN).

**Table 3.13. Numbers of Species in Greatest Conservation Need associated with Riparian and Floodplain Forests as either primary or secondary habitat.**

| Species Groups | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 2 | 0 | 2 |
| Birds | 3 | 3 | 6 |
| Mammals | 1 | 9 | 10 |
| Reptiles | 2 | 1 | 3 |
| Beetles (terrestrial) | - | - | 2 |
| Moths | - | - | 1 |
| Spiders | 0 | 2 | 2 |
| Plants | 22 | | 22 |
| **Total** | **30** | **15** | **48** |

### Amphibians

Blanchard's cricket frog (*Acris blanchardi*) are found in riparian areas right along the water's edge; open areas with muddy shorelines and dense emergent vegetation are preferred. They reside near water throughout the summer but, during dry conditions, they may seek out wetter conditions elsewhere. Crayfish burrows or small openings along the bank of a wetland or river provide sites for hibernation. Less than 2 inches in size, their breeding call is similar to that of yellow rails and Virginia rails, making visual identification or expert verification via audio recording essential. A state endangered species, Blanchard's cricket frogs have a limited range in portions of central, southeast, and southwestern Minnesota as of 2025.

*Photo: Pickerel frog, Jeff LeClere*

Pickerel frogs (*Lithobates palustris*) are also found in Riparian Forests and Floodplains, preferring the edges of ponds, small rivers, and streams that flow through wooded areas or open habitats (Moriarty & Hall, 2014). They rarely venture far from the water's edge or from nearby wet meadows. Winter months are spent hibernating in their water habitats. Pickerel frogs are restricted to the far southeastern corner of the state; county records are available from Goodhue, Fillmore, Houston, Mower, Olmsted, and Winona counties (Moriarty & Hall, 2014).

### Birds

Floodplain forests in riparian zones provide key habitat to many SGCN. The only SGCN bird restricted to floodplain forest is the prothonotary warbler (*Protonotaria citrea*). They are most often found along medium- to large rivers such as the Mississippi, Minnesota, and St. Croix. A cavity-nesting species, it requires large trees or snags, often situated right over the water (Pfannmuller et al., 2017). See Climate Spotlight below.

## Climate Spotlight: Prothonotary Warbler

This profile is excerpted from "Effects of Climate Change on Midwestern Ecosystems: Temperate Flooded and Swamp Forest" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025).

*Photo: Prothonotary warbler, Julia Geschke*

"The prothonotary warbler (*Protonotaria citrea*) is a small cavity-nesting songbird that breeds in riparian and floodplain forests in the central Midwest and winters in mangrove forests of Central and South America. Climate-driven hydrological changes and sea-level rise threaten both its breeding and non-breeding habitats. The species has been documented expanding its breeding range northward, including into the Mississippi River Valley, and its population remains relatively stable (NatureServe, 2008).

Prothonotary warblers nest in tree cavities over standing water, making them highly sensitive to hydrological extremes (Cooper and others, 2009). High magnitude flooding with high water depths can directly affect reproductive success (Flaspohler, 1996; Graber and others, 1983). Prolonged floodplain inundation can also alter predator foraging behavior by limiting non-arboreal options, increasing warbler nest depredation by predators like raccoons (Cooper and others, 2009). However, partial flooding appears to provide optimal protection against predation (Cooper and others, 2009; Hoover, 2006; Hoover, 2009). Conversely, drier conditions expose dense ground cover, removing the protective influence of standing water and increasing rates of nest depredation (Cooper and others, 2009; Kirsch, 2009). Despite these direct influences of hydrology, altered hydrological regimes appear unlikely, except in the most severe instances of flooding, to reduce the abundance of most preferred nesting tree species, which include red maple (*Acer rubrum*), sugarberry (*Celtis laevigata*), and silver maple (*Acer saccharinum*) (Gabbe and others, 2002; Kirsch and Wellik, 2017; Wuebbles and others, 2021)....As forested wetlands face increasing climate stress, climate-informed restoration may be a key adaptation strategy for this species. For example, in the Cache River watershed, habitat restoration increased prothonotary warbler density and nesting success (Hoover, 2009). Additionally, artificial nesting structures offer a promising conservation strategy, as these warblers readily use nest boxes, which have shown no recorded depredation (Mueller and others, 2019)."

Other deciduous forest SGCN birds will occupy both upland and floodplain forests, with preferences often varying by region. Cerulean warblers require large tracts of mature deciduous forest. Although it is found in mesic hardwood stands in much of its Minnesota range this canopy-dwelling species occupies floodplain forests along the Minnesota, Mississippi, and St. Croix rivers. Similarly, red-shouldered hawks are most frequent in floodplain forests along larger rivers in southeastern and east-central Minnesota. Oxbow lakes and other floodplain forest openings are an important feature in broad floodplains. Red-shouldered hawks prefer nesting sites in large-diameter trees in high, thick canopies. Louisiana waterthrushes (*Parkesia motacilla*) are most closely associated with mesic hardwoods bordering small, clear water streams, but will also occupy mature floodplain forests, particularly along larger rivers in east-central Minnesota such as the Kettle and St. Croix. In these broad floodplain forests, smaller side channels seem to be a key feature. The Acadian flycatcher (*Empidonax virescens)* is much more frequent in mesic hardwoods but is occasional in true floodplain forests. The bird most tightly associated with mature riparian floodplain forests in Minnesota is the Prothonotary warbler. Although it is uncommonly found in floodplains of small streams and rivers, nearly all the records in Minnesota are along the Mississippi and Minnesota rivers. Although often thought of as species restricted to savannas or upland deciduous woodlands, red-headed woodpeckers are also found in floodplain forests in areas where excessive flooding or other disturbances have created openings with dead trees and snags lacking bark.

Many other birds also use river corridors, beyond those formally associated with it for a primary or secondary habitat, for breeding, migration, and wintering habitat. In particular, large, old trees provide important habitat for nesting herons, egrets, barred owls, wood ducks, and bald eagles. Riparian corridors provide vital migratory stopover habitat, and mortality during migration exceeds that during breeding or wintering periods for many adult migratory songbirds (Sillett and Holmes, 2002). Quality and availability of stopover habitat may be important factors affecting their populations. Some SGCN that do not specialize in riparian forest for breeding but may rely on it for stopover habitat include Connecticut warbler (*Oporornis agilis)*, black-throated blue warbler, olive-sided flycatcher, bay-breasted warbler, Swainson's thrush, and Cape May warbler. Because riparian forests are often linear and relatively contiguous, they are well suited to migration and may be especially important as stopover habitat compared to other habitats.

## Climate Spotlight: Red-shouldered Hawk

This profile is excerpted from "Effects of Climate Change on Midwestern Ecosystems: Temperate Flooded and Swamp Forest" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al., 2025).

"The red-shouldered hawk (Buteo lineatus) is a medium-sized raptor found throughout the eastern and central U.S. In the Midwest, these hawks typically occupy mature forests (Henneman and Andersen, 2009; Woodford and others, 2008) with favorable proximity to wetlands to forage for amphibians and reptiles (Balcerzak and Wood, 2003).

During the breeding season, while cooler temperatures combined with heavy precipitation may reduce nestling survival, warmer temperatures can increase prey activity, foraging efficiency, and reproductive rates, suggesting a positive effect of climate change on the species (Bednarz and Dinsmore, 1982; Craighead and others, 1969; Dykstra and others, 2021; Henneman, 2006; Jacobs and Jacobs, 2002). Climate change-driven loss of wetlands and reductions in forests, especially coniferous forests, adversely affect their reproductive success and survival (Dykstra and others, 2021). Despite these challenges, red-shouldered hawks demonstrate adaptive capacity through their flexible diet and habitat use, and even successfully occupying suburban habitats (Dykstra and others, 2019).

Climate change may reduce suitable habitat for red-shouldered hawks in the Midwest Floodplain Forest by decreasing contiguous forest cover and increasing the frequency and size of canopy gaps. These gaps are associated with increased rates of nest predation and increased competition from red-tailed hawks (Buteo jamaicensis) (Bednarz and Dinsmore, 1982; Craighead and others, 1969; Henneman, 2006; Jacobs and Jacobs, 2002). More frequent flooding may have mixed effects on prey populations, potentially reducing some small mammal populations while creating canopy gaps that benefit others (Chamberlain and Leopold, 2003; Scharine and others, 2009). Moreover, key nesting trees such as American beech (Fagus grandifolia), oaks (Quercus spp.), and sugar maple (Acer saccharum) are likely to be negatively affected by increased flooding and higher pest pressure from forest tent caterpillars (Malacosoma disstria) and spongy moths (Lymantria dispar) (Cuthrell and others, 2003; Jacobs and Jacobs, 2002).

Management implications. The goals and methods of forest management in response to climate change may offer the greatest opportunity for climate adaptation for this species. Although red-shouldered hawks tolerate small patches of open habitat, intensive and even standard harvest practices that reduce forest density produce unsuitable habitat for this species (Henneman and Andersen, 2009; Naylor and others, 2004). Active management that maintains relatively dense forests may include pest control, the establishment of fuel breaks to reduce fire risk, and the introduction of tree species suited to future conditions (Swanston and others, 2016). In addition, increasing tree species richness and diversity, increasing the quantity of down woody debris, and protecting forested wetlands can all foster the retention of red-shouldered hawks on the landscape (King and others, 2011)."

*Photo: Red-shouldered hawk, Julia Geschke*

## Mammals

Mammal SGCN that utilize Riparian and Floodplain Forests are nearly identical to those identified occupying Deciduous Wet Forests. The woodland vole (*Microtus pinetorum*) is the only species for which Riparian and Floodplains Forests has been designated its primary habitat. Other primary habitats for the species include Mesic Hardwoods and Deciduous Wet Forests. The voles prefer loose, well-drained soils and humus layers to construct burrows and sub-surface runways. Grazing by cattle, which compacts the soil, and the presence of invasive non-native earthworms, which destroy the humus, may make forests within its' limited range in southeastern Minnesota unsuitable for this species. Loose, well-drained soils and humus layers are important for constructing burrows and sub-surface runways. Grazing by cattle, which compacts the soil, and the presence of invasive non-native earthworms, which destroy the humus, may make forests within its' limited range in southeastern Minnesota unsuitable for this species. A state Special Concern species, the vole is restricted to two southeastern counties: Winona and Houston.

Other SGCN mammals that utilize riparian and floodplain forests include six of Minnesota's seven bat SGCNs (all except for the tri-colored bat (*Perimyotis subflavus*)). The edges of the water and riparian zone are ideal sites for drinking and foraging on insects.

## Reptiles

Many other species in greatest conservation need rely on a combination of upland and stream habitats to complete their life cycles. Both wetlands and sandy uplands are necessary for the Blanding's turtle (*Emydoidea blandingii*) to complete its life cycle. Fluvial outwash plains, such as those in Weaver Bottoms along the Mississippi River, provide nesting habitat for Blanding's turtles, gopher snakes (*Pituophis catenifer*), eastern hog-nosed snakes (*Heterodon platirhinos*), and map turtles (*Graptemys spp.*). The wood turtle (*Glyptemys insculpta*) hibernates in rivers, nests on undisturbed sandy banks, but spends much of its time in nearby upland forests. Floodplains and riparian are used as primary habitat when vegetative conditions are optimal and there is no flooding; this is especially true for males who tend to remain closer to water during the summer months. Fox snakes (*Elaphe vulpina*) live in forested riparian habitats See also the Rivers and Streams Chapter for more information on aquatic species such as mussels and fish.

## Plants

Dwarf trout lily (*Erythronium propullans*) is a federally endangered species endemic to Floodplain Forests in southeastern Minnesota. The plants are typically found on the lower to mid-portions of the slopes descending toward the floodplain. Habitat loss due to development is a main threat to this species. Also, large-scale precipitation events, made more likely by climate change, have recently increased erosion in this species' floodplain habitats, threatening the persistence of some populations. Erosion control or shoreline stabilization measures could minimize the effects of flash flood events.

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1. Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Urban development disproportionately expands to riparian corridors and adjacent landscapes. Because of their natural beauty, diversity, recreation opportunities, and abundant natural resources, riparian corridors and adjacent landscapes are appealing places to live. Urban development can directly remove habitat, but it can also have indirect effects on protected habitat. Development in landscapes adjacent to riparian forest can affect habitat quality, particularly for many bird species. Urban development in the adjacent landscape can reduce corridor width, reduce connectivity to other habitats, increase abundances of competitors and predators, alter microhabitat conditions, increase density of non-native plants, simplify habitat structure, increase direct human disturbance, and prompt avoidance by wildlife that evolved to use large chunks of habitat embedded in a landscape dominated by native ecosystems.

### Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest can result in failed regeneration and loss of a riparian forest if management activities do not take into consideration many of the unique aspects of these stands. These include the seasonal fluctuation and importance of changing water levels, invasive species, forest pathogens, and changing flood patterns due to climate change, dams, and watershed- wide land use changes. If a harvest is not well enough planned, a riparian forest may convert to a grassland (particularly reed canary grass) or a shrubland (particularly alder, or buckthorn [*Rhamnus cathartica*] in more upland areas). Many riparian and floodplain forests lack young trees to regenerate and succeed the older trees after they are harvested. Selective harvest practices that initially focus on logging the largest and healthiest trees, followed by a second harvest years later, can also result in a stand dominated by reed canary grass, and shrubs. Assessing site-specific characteristics and designing management including timber harvest or invasive species control and prevention measures can help meet management goals and objectives while minimizing negative outcomes.

## Recreation

Recreational use can contribute to altered hydrology through soil compaction on trails as well as the introduction of non-native invasive species by inadvertently bringing in seeds on footwear, gear, and boats.

## Dams and Water Management

Dams alter the hydrology and ecology of adjacent floodplain forest. For example, seasonal flood cycles are disrupted, the deposition of sediments and nutrients are reduced, water quality declines, the amount of forest cover decreases, and the natural regeneration of trees is disrupted and altered. Additional run-off from precipitation changes observed with climate change and land use changes are also problematic. This can be seen on the Mississippi River corridor south of the Minneapolis/St. Paul area. The resulting habitat may lack species and structural diversity and ability to regenerate following disturbances including flooding, disease or windstorms.

## Invasive Species (Problematic Non-native Species)

Riparian areas and floodplain forests are particularly vulnerable to colonization by invasive species due to the constant influx of seed sources via waterways and the high frequency of flooding events that scour substrates and make open substrates for invasive species to colonize. Garlic mustard (*Alliaria petiolata*), a biennial herbaceous plant, does well in shaded, moist, and disturbed environment and is a common invasive in Minnesota's floodplain forests. In addition to its rapid establishment, studies have documented its ability to disrupt the symbiotic relationship of the roots of many native species with soil fungi, a mechanism that can reduce diversity in the herbaceous ground layer (Rodgers et al., 2022).

Emerald ash borer is an invasive insect that has killed millions of ash trees throughout the eastern half of the U.S. and southeastern Canada. In floodplain forests in northern Minnesota, black ash is often a dominant canopy tree. Its loss is predicted to have major effects on the structure, composition, and nutrients in ash-dominated habitats. Black ash is also a culturally important tree to some Native American Tribes in the state.

Eurasian earthworms are another invasive disruptor of natural communities, including floodplains. They upend the traditional soil profile (Hale et al., 2005; Fahey et al., 2013), remove the accumulated layers of organic leaf litter (Holdsworth et al., 2008, 2012), and alter the community of soil mycorrhizal fungi (Paudel et al., 2016). These changes cascade through the ecosystem, including ground layer vegetation (Hale et al., 2006; Holdsworth et al., 2007), leaf litter fauna (McCay and Scull, 2019), and salamanders (Maerz et al., 2009; Ziemba et al., 2016). In addition, the presence of earthworms may also benefit invasive plant species (Nuzzo et al., 2009, Whitfeld et al., 2014). Jumping worms (*Amynthas* and *Metaphire* species) are newer species to Minnesota that are predicted to have negative effects on Minnesota forests as they spread.

*Photo: Goats helping with management in riparian forest, browsing on invasive species including buckthorn and garlic mustard*

## Problematic Native Species

Reed canary grass (*Phalaris arundinacea*) is a hardy, aggressive, cool-season grass that can form dense, monotypic stands in wetlands. Despite recent research suggesting that reed canary grass found in Minnesota is predominantly native, it can outcompete other native wetland species, posing challenges for wetland restoration and mitigation efforts. Source: University of Minnesota Extension (Reed canary grass).

## Diseases and Pathogens

Dutch elm disease was first found in Minnesota during the summer of 1961 (French, 1993). Peak losses to all three native elm species that occur in the state (American elm, *Ulmus americana*; red or slippery elm, *U. rubra*; and rock elm, *U. thomasii*) occurred in the late 1970s and 1980s. American elm, in particular, was a dominant species in floodplains across the northeastern United States; today large elm trees are uncommon in floodplain forests and have largely been replaced by silver maple. When present, elms rarely reach heights over 10 meters; this is the height when they become susceptible to Dutch elm disease (UMN extension).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al. 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate sub-chapter in Chapter 6. Implementation.

Higher summer temperatures with decreased summer precipitation are projected to increase evaporation, decrease soil moisture, and increased water vapor deficits (Ratcliffe et al., 2025). See Climate Profile section above for more detailed information. Warming temperatures are not likely to directly adversely affect most of the tree species that comprise riparian forest. Indeed, many of the species that comprise riparian forest in Minnesota are southerly-distributed and may respond positively to warming temperatures. However, many of the invasive plants that compete with these trees, especially as seedlings, also are likely benefitting from warming temperatures; an example is garlic mustard.

The ranges of some birds are shifting in response to warming temperatures (NAS 2019). Some of the more southerly-distributed birds that use riparian forest in Minnesota and are predicted to move north as the climate warms include Acadian flycatcher, Louisiana waterthrush, and prothonotary warbler (NAS 2019).

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

*Photo: Mississippi River Islands Scientific and Natural Area, Kelly Randall*

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Flood timing has shifted so they occur both earlier and later in the season and with longer durations. Though the plants in these riparian forests evolved to survive in floods and even exploit flooding, these changing patterns can result in unsuitable conditions. They may not kill mature trees, but they affect the vegetation and structure of the vegetation on the forest floor, reduce regeneration of young trees, and favor invasives. In particular, these conditions make it difficult for many tree seedlings to establish and survive. Today we are witnessing reduced regeneration of riparian forest because of these changing flood patterns. Combined with other disturbances, such as windthrow in mature stands, and a lack of advanced regeneration of trees under mature forest canopy, there might be insufficient understory and midstory trees to replace future forests. One example of the detrimental effect of increased large-scale precipitation events can be seen in declines in the quality of habitat and subsequent population declines among populations of the federally endangered dwarf trout lily (*Erythronium propullans*). These high-intensity events have led to the erosion and scouring of finer, silty soils preferred by the species.

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). Also see Climate Profile section above. By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al. 2022). For more information and resources for climate-adapted management strategies, see the Climate sub-chapter in Chapter 6. Implementation.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Riparian and Floodplain Forests

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Landscape and urban planning can ameliorate development pressure on floodplain forests and riparian areas by guiding where and how this development occurs and considering where increased habitat protection and management would be most beneficial. Support local governments in measures that minimize fragmentation and encroachment into high quality forests such as protecting high quality areas, zoning that guides housing developments, lot sizes that support local forests, and incorporate ecological values into land use planning and development guidance. |

| Stressor | Action |
|---|---|
| | Since many animals require both upland and stream habitats for their life cycles, it is essential to manage for connectivity of both habitat types. Planning at watershed scales should maintain the corridor characteristics of the floodplain and strong connectivity from upland to aquatic habitat. Protect habitats along river corridors to allow movement of wildlife and facilitate movement of nutrients and energy between the stream and surrounding landscape. Management options include modified lock or dam construction and operation, such as rock arches or weirs, and removal of obsolete dam structures, as well as larger scale watershed actions such as erosion control measures. |
| | Prioritize protection and management of habitat that provides the elements required by floodplain forest wildlife, but that are less prone to flooding. In particular, maintain and restore floodplain forest along the primary tributaries to the Mississippi River including the Root, Vermillion, Whitewater, and Zumbro rivers in southeastern Minnesota. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, bio-diversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Planting tree saplings prior to harvest may help prevent riparian forest from converting to problematic species after harvest (i.e. to grassland, (particularly reed canary grass) or shrubland (alder or buckthorn)). Planting a diversity of species provides an opportunity to maintain a riparian forest habitat and increase its resilience in the face of changing climatic conditions and greater flooding intensities and frequencies. |
| | Timber harvest activities in floodplain forests require careful planning for imperiled species that rely on mature riparian forest, such as cerulean warbler, Acadian flycatcher, and red-shouldered hawk. Adequate acreage of suitable mature riparian forest should be available in the landscape before a harvest is implemented. Manage stands to retain biological legacies (at site level) such as large trees with cavities. |

| Stressor | Action |
|---|---|
| | Consider restocking floodplain forests with larger tree saplings rather than seedlings. Because there is minimal natural regeneration of forests along the Mississippi River floodplain planting tree seedings is often a requirement to get sufficient regeneration to ensure lowland forest is maintained and persists at a site. Direct seeding can be successful given the right site conditions, site preparation, and abiotic factors. However, container stock that is larger than bare-root stock has been increasingly used in the region (such as by the DNR, the National Audubon Society, and the Army Corps of Engineers. For instance, larger container stock (e.g., 3-gallon) has a better chance of survival than bare roots; they can survive long-term floods where the bare root seedlings would likely drown with 10-20 days of flooding and can be held for planting any time the site isn't flooded. The larger trees are 4-6 feet in height and can be protected from deer browse with tree tubes or deer repellent; protection from other animals, like voles that can girdle trees, may also be needed. Once the leaves are above the level of reed canary grass and the deer browse, the trees have a better chance of surviving to maturity. Fall plantings may be effective because spring floods are uncertain and can affect access to sites where restoration is planned. The planting could occur prior to harvest, prior to anticipated disturbance (such as an area prone to flooding), or as the forest ages and trees are near dying. If the saplings survive and grow, they can reduce growth of reed canary and other problematic species that respond to an opening canopy. Primary challenges for this strategy are the relatively high cost for saplings versus seeds and having a suitable seed source and vendors that grow and sell these trees. |
| | Explore countering increased flood intensities by raising the elevation of the habitat so it is less prone to flooding but still maintained as riparian forest. This might be most applicable and feasible during a planned habitat restoration effort. An example of this is thin layer placement on constructed islands along the main channel of the Mississippi River by the U.S. Army Corps of Engineers. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Maintaining the contiguity, resilience, and diversity of native habitats will depend on local people conserving privately owned lands because they have incentives to maintain ecological integrity on their land and in the surrounding landscape. |
| | Participate and collaborate in interdisciplinary and interagency forest planning, providing information on important habitat types, landscape configurations, and conditions most beneficial for SGCN. Pursue opportunities to collaborate across forest ownerships and encourage the implementation of sustainable forestry at the site and landscape levels to create and maintain habitat conditions important to SGCN. Values such as regional biodiversity, rare species protection, native plant community growth stage diversity, and certain wildlife habitat needs are best considered at larger landscape scales (DNR 2025). |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Promote and consider further development of tax incentives that enable landowners to gain value for maintaining conservation values on their properties. Provide increased levels of incentive payments for woodland owners to help protect woodlands and forests from further reduction due to development pressure. Support and promote education and technical assistance to maintain or restore forest habitat. |
| | Encourage climate-smart forestry practices (see Case Studies). |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. |
| | Research and develop management practices for minimizing the effects of reed canary grass on open substrate, plant diversity, and new tree growth. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# NON-FORESTED WETLANDS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Non-forested Wetlands

## Habitat Description

This chapter describes a set of wetland plant communities dominated by herbaceous plants or low-growing woody plant species (shrubs). Non-forested wetlands are found throughout Minnesota and consist of several major types: marshes, wet meadows, fens and bogs. Like all wetlands, non-forested wetlands occur on sites that are flooded or saturated at least seasonally, if not much of the year. Because of periodic or permanent water inundation, soils in these habitats often become anaerobic. Many dominant plants in wetland communities are tolerant of persistent water levels and have stems, leaves and roots that contain intercellular air spaces (aerenchyma) that store oxygen and diffuse it from above-water structures to roots during waterlogged conditions. See also the Coniferous Forest Wetland sub-chapter and the DNR's Wetlands website.

**Marshes** occur on frequently inundated sites. These communities are typically inundated by nutrient-rich water. They include emergent marshes and open marshes. Emergent marshes are dominated by vascular plants, such as cattails (*Typha* spp.), that can survive indefinitely with their roots and lower stem submerged and their aerial shoots above water. In addition to cattails, emergent marshes are characterized by perennial emergent plants, such as bulrushes (*Scirpus* spp.) and arrowheads (*Sagittaria* spp.), mixed with annual forbs during low-water periods when substrates are exposed, and with floating-leaved and submergent aquatic plants in settings with persistent standing water. Emergent plants provide important habitat for a variety of wetland bird species. Plants with floating leaves, such as water lilies, dominate open marshes, which are sometimes classified as aquatic communities.

*Photo: Fen, Maplewood State Park, Amy Kendig*

Variation in species composition over time occurs in response to changes in hydrological conditions. See also the Marsh System summaries for the Laurentian Mixed Forest Province, Eastern Broadleaf Forest Province and the Prairie Parkland and Tallgrass Aspen Parklands Provinces.

**Wet meadows** are graminoid-dominated wetlands that are subjected to periodic relatively brief inundation and drawdowns during the growing season. The dominant graminoids are broad-leaved species such as lake sedge (*Carex lacustris*), tussock sedge (*C. stricta*), and bluejoint (*Calamagrostis canadensis*). Peak water levels are persistent enough to prevent trees from becoming established. However, there may be little or no standing water present during much of the growing season. As a result, the substrate surface alternates between aerobic and anaerobic conditions. Any organic matter that accumulates over time is usually oxidized during periodic drawdowns and may even burn during severe droughts. Soils range from mineral soils to muck and peat. Because surface water is derived from runoff, stream flow, or groundwater, it is approximately neutral (pH 6.0–8.0) and has high mineral and nutrient content. Wet meadows are present statewide on the fringes of wetland basins, along streams and drainageways, in drained beaver ponds, at higher elevations of shallow bays and as semi-floating mats along sheltered lake shorelines. Wet meadows can grade into lowland shrub communities (called carrs) where water levels are lower and less persistent. See also the Wet Meadow/Carr System summaries for the Laurentian Mixed Forest Province, Eastern Broadleaf Forest Province, and the Prairie Parkland and Tallgrass Aspen Parklands Provinces.

**Peatlands** cover more than six million acres (or approximately 10% of the state), primarily in northern Minnesota, and are a defining feature of its natural landscape (see Minnesota Scientific and Natural Areas Patterned Peatlands).

*Photo: Red Lake Peatland Scientific and Natural Area, Erika Rowe*

These wetlands formed over thousands of years through the slow accumulation of partially decomposed plant material in saturated, low-oxygen conditions. Peatlands may be dominated by mosses such as sphagnum moss (*Sphagnum* spp.) or other plants such as sedges (*Carex* spp.). Some peatlands are forested, primarily by black spruce (*Picea mariana*) and tamarack (*Larix laricina;* also see Conifer Forest Wetland sub-chapter). The resulting deep organic soils, or peat, sequester and store vast amounts of carbon and support unique hydrologic functions, including flood attenuation, water filtration and baseflow regulation (read more about the DNR's Peatland Resilience Initiative). Minnesota's peatlands are broadly categorized into bogs and fens, distinguished primarily by their hydrology and nutrient availability. In 2024, the DNR published a mapping resource entitled Potentially Wet Histosols in Minnesota to display the extent of peatlands across the state.

**Bogs** receive water only from precipitation. Over time, accumulating sphagnum moss raises the peat surface above the surrounding groundwater table, resulting in acidic (pH < 5.5), nutrient-poor conditions. These environments limit species diversity and are often dominated by black spruce (see Coniferous Forest Wetland sub-chapter) and acid-tolerant sphagnum species. Bogs are most prevalent in northern Minnesota, particularly within the Laurentian Mixed Forest Province, where cool temperatures and high precipitation enable extensive peat development. See also the acid peatland system summaries for the Laurentian Mixed Forest Province, the Eastern Broadleaf Forest Province, and the Prairie Parkland and Tallgrass Aspen Parklands Provinces.

**Fens** receive mineral-rich groundwater, resulting in more neutral pH conditions (5.6–7.5) and higher concentrations of nutrients such as calcium and magnesium. Fens are divided into forested rich peatlands (see Coniferous Forest Wetland sub-chapter) and open rich peatlands, depending on their vegetation structure. Open rich peatlands are graminoid- or low-shrub dominated communities characterized by sedges (*Carex* spp.), brown mosses, and minerotrophic *Sphagnum* species. These environments favor sun-loving, shade-intolerant species that thrive in wet, nutrient-poor but mineral-rich conditions. Species such as buckbean (*Menyanthes trifoliata*), tufted bulrush (*Scirpus cespitosus*) and Kalm's lobelia (*Lobelia kalmii*) are commonly found in these systems. Adaptations such as aerenchyma tissue allow these plants to survive in saturated soils, while others, like tufted bulrush, form hummocks that lift the plant above anaerobic conditions. Open rich peatland communities are widespread in the Laurentian Mixed Forest Province, where abundant precipitation, cool climate, and poorly drained glacial basins support sustained peat development. However, these communities also extend into the Eastern Broadleaf Forest and Prairie Parkland and Tallgrass Aspen Provinces provinces, where they are typically found near the southern and western margins of the peatland range. In these warmer, more evaporative regions, open rich peatlands are restricted to floating mats or areas with sufficient groundwater input to maintain saturation throughout the growing season.

**Calcareous fens** are a rare type of fen that develops in areas with particularly high calcium content, often where calcareous glacial till or limestone bedrock is present. These systems support a number of plant Species in Greatest Conservation Need, including highly specialized and rare species such as twig rush (*Cladium mariscoides*) and hairlike beak rush (*Rhynchospora capillacea*), as well as grass of Parnassus (*Parnassia* spp.), a calciphilic (calcium loving) indicator species. Calcareous fens are predominantly located in western and southern Minnesota, including the Minnesota River Valley and parts of the southeastern karst region, where conditions favor calcium-rich groundwater discharge (see also the DNR's Calcareous Fens webpage and Calcareous Fens overview sheet).

*Photo: Calcareous fen, Skandia Wildlife Management Area, Megan Benage*

## Habitat Map

To depict non-forested wetland habitat (see Figure 3.15), we compiled spatial data from several sources: DNR's Native Plant Communities, National Wetland Inventory for Minnesota and Midwest Terrestrial Habitat System created by the USFWS Midwest Landscape Initiative (for more information, see Habitat Map Methods in Chapter 3. Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological Systems

### Marsh (MR)

MRn83 Northern Mixed Cattail Marsh (PDF)

MRn93 Northern Bulrush-Spikerush Marsh (PDF)

MRu94 Lake Superior Coastal Marsh (PDF)

MRp83 Prairie Mixed Cattail Marsh (PDF)

MRp93 Prairie Bulrush-Arrowhead Marsh (PDF)

### Wet Meadow / Carr (WM)

WMn82 Northern Wet Meadow/Carr (PDF)

WMs83 Southern Seepage Meadow/Carr (PDF)

WMs92 Southern Basin Wet Meadow/Carr (PDF)

WMp73 Prairie Wet Meadow/Carr (PDF)

### Open Rich Peatland (OP)

OPn81 Northern Shrub Shore Fen (PDF)

OPn91 Northern Rich Fen (Water Track) (PDF)

OPn92 Northern Rich Fen (Basin) (PDF)

OPn93 Northern Extremely Rich Fen (PDF)

OPp91 Prairie Rich Fen (PDF)

OPp93 Prairie Extremely Rich Fen (PDF)

### Acid Peatland (AP)

APn90 Northern Open Bog (PDF)

APn91 Northern Poor Fen (PDF)

## National Wetlands Inventory

From the National Wetland Inventory for Minnesota (NWI) Layer we included these Simplified Plant Community Class types: Shallow Marsh, Deep Marsh, Seasonally Flooded/Saturated Emergent Wetland, Shrub Wetland, Open Bog and Shallow Open Water Aquatic Community.

## Midwest Terrestrial Habitat System

From the Midwest Terrestrial Habitat System we included these groups: Eastern North American Boreal-Subboreal Alkaline Fen, Midwest Prairie Alkaline Fen, Eastern North American Freshwater Marsh, Eastern North American Ruderal Meadow & Shrubland and Eastern Ruderal Wet Meadow & Marsh.

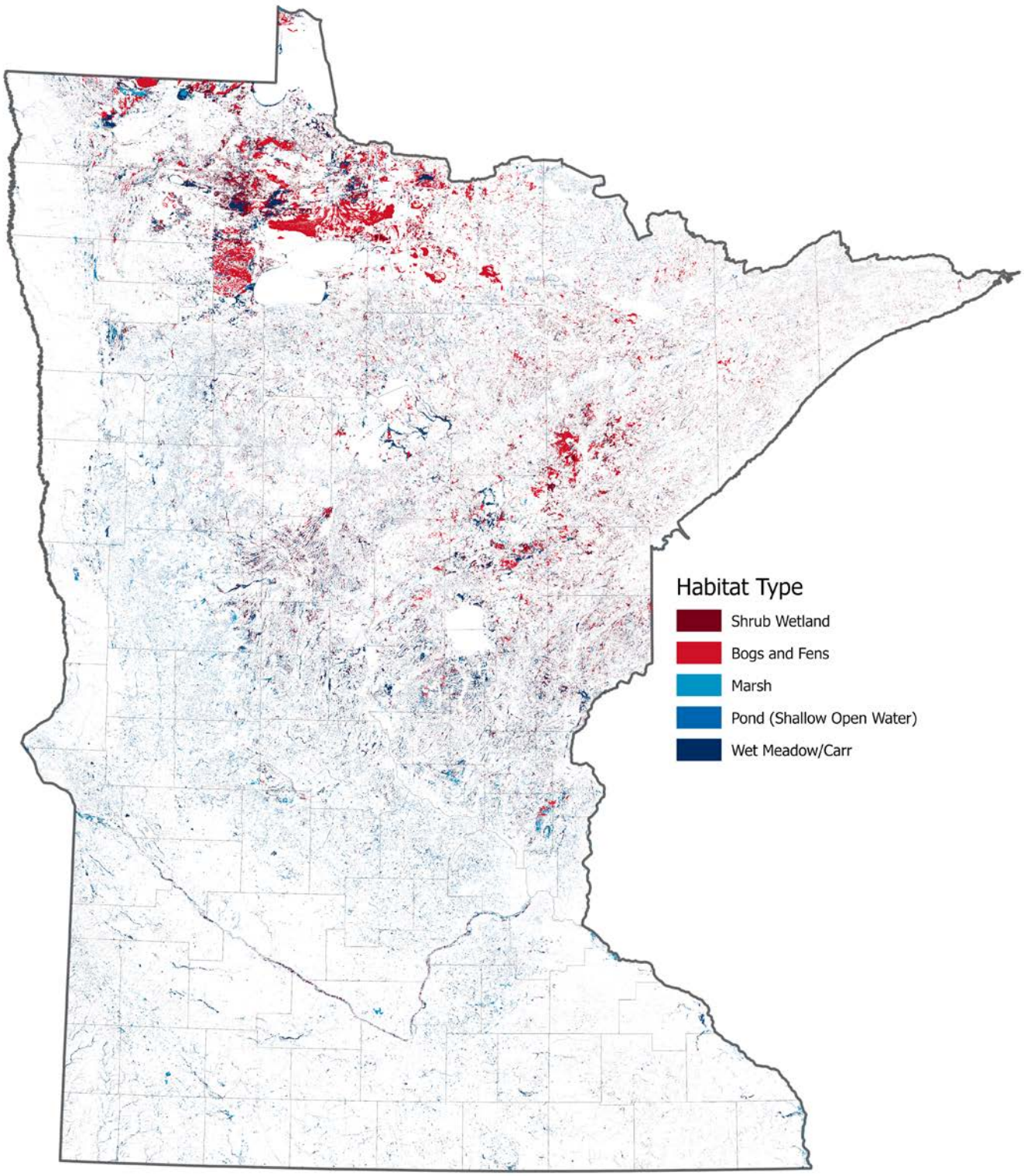


Figure 3.15. A map depicting Non-forested Wetland habitat in Minnesota, including DNR Native Plant Community Classes in the Ecological Systems of Marsh, Wet Meadow/Carr, Open Rich Peatland and Acid Peatland, as well as several types from the National Wetland Inventory for Minnesota and Midwest Terrestrial Habitat System (see narrative).

## Conservation Overview

Wetlands provide a number of ecological benefits to the landscapes in which they are found, including erosion control, flood control, groundwater recharge and discharge, water quality, recreation, habitat for rare plant and animal species, and economic and cultural value.

Prior to European settlement, Minnesota's wetlands covered about 18.5 million acres, accounting for nearly 35 percent of the state's landscape (Phillips, 1997). Since then, approximately half of those wetlands have been lost, primarily through conversion and drainage for agriculture, urban development and other land use changes, leaving just over 10 million acres of wetland today (Haga, 2015). Losses have been most severe in southern and western Minnesota, where up to 95 percent of original wetlands have vanished. Northern wetland complexes remain relatively intact and high-quality (Minnesota Pollution Control Agency, 2025). Although Minnesota's 1991 Wetland Conservation Act has largely limited acreage losses, overall wetland quality continues to face threats from invasive species, altered hydrology and nutrient loading (Marohn, 2024). While there are new additions to wetland acreage in Minnesota, replacement wetlands can lack the diversity and complexity of natural wetlands (Whigham, 1999). Of particular note are peatlands, one of Minnesota's most ecologically significant landscapes. Historically, peatlands were considered as unproductive and unusable land, and European settlers drained them for conversion to agriculture and forestry uses (The Nature Conservancy, 2025). Peat was also harvested for fuel and horticultural use, and in the 1970s and 1980s, proposals emerged to develop peat as an energy resource (Keirstead, 1992). However, most of these plans were abandoned due to economic, environmental and regulatory concerns, coupled with increasing recognition of the ecological importance of peatlands.

Today, peatlands are valued for the many ecosystem services they provide. They are globally significant carbon sinks, storing vast amounts of carbon and helping to regulate greenhouse gases. When disturbed or drained, however, peatlands can become major sources of carbon dioxide and methane emissions. Ecologically, they support unique plant and animal communities adapted to wet, acidic, nutrient-poor conditions, including carnivorous plants, rare orchids, boreal birds and several SGCN. Peatlands also play an important role in hydrology, storing and slowly releasing water to moderate flood risks and maintain base flows, while filtering sediments and nutrients to improve water quality (Bonn et al., 2016). Their relative intactness also makes them likely refuges for species as climate conditions shift.

Recognizing their ecological value, Minnesota has taken steps to conserve peatlands through legislation and land protection. The Minnesota Peatland Protection Act of 1991 established a system for identifying and safeguarding high-quality peatland ecosystems, including the designation of Scientific and Natural Areas (SNAs) such as the Red Lake and Lost River peatlands. Many peatlands are now managed under state or federal ownership, with careful consideration given to land use, restoration potential and climate resilience. These efforts reflect the growing understanding that peatlands are not only biologically rich and hydrologically important but also essential in mitigating climate change.

Calcareous fens are one of Minnesota's rarest and most ecologically unique wetland types, which supports an assemblage of specialized and often endangered plant and animal species, many of which are found nowhere else in the state (Walker et al., 2023). Historically, calcareous fens were more common across Minnesota's landscape, particularly in the western and southern regions where glacial activity and underlying calcareous bedrock created suitable conditions (see also Calcareous Fens). However, their extent has been dramatically reduced since European settlement due to agricultural drainage,

groundwater pumping and development (Bart, 2011). Their location on flat or gently sloping lands made them attractive for conversion to cropland, and many were drained or filled before their ecological importance was fully understood. In the 20th century, some fens were also affected by excavation for peat or marl and by groundwater withdrawals that altered the delicate hydrology required to sustain fen ecosystems (Prince, 1997).

Today, calcareous fens are recognized as exceptionally valuable and fragile ecosystems. Minnesota's 1991 Wetland Conservation Act specifically protected calcareous fens stating that they cannot be filled, drained, or degraded, by any activity unless under an approved management plan where mitigation is sought (MN Statue 103G.223). They are home to a diversity of rare and state-endangered plant species, such as the flowering plant valerian (*Valeriana edulis*), sterile sedge (*Carex sterilis*), hair-like beak rush (*Rhynchospora capillacea*), and slender reedgrass (*Calamagrostis stricta*), as well as rare orchids, mosses, and invertebrates including many SGCN (see Calcareous Fens). Because they are groundwater-fed, calcareous fens are especially sensitive to changes in hydrology and land use, including groundwater withdrawals from nearby municipal, industrial, or agricultural wells (Bart, 2022). Their ecological function depends on maintaining stable, clean and abundant groundwater flow, which not only sustains fen vegetation but also buffers downstream water bodies against sedimentation and nutrient overload. The DNR identifies and maintains a list of over 200 documented calcareous fens, and active efforts are in place to monitor, research and protect these critical habitats (see also Calcareous Fens).

## Climate Profile for Non-forested Wetlands

We provide information on anticipated future climate effects in non-forested wetland habitat types from two reports created by the U.S. Geological Survey Midwest Climate Adaptation Science Center in support of State Wildlife Action Plans. All content in this section is derived from these reports: "Effects of Climate Change on Midwestern Ecosystems: Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland" (Ratcliffe et al., 2025a) and "Effects of Climate Change on Midwestern Ecosystems: Bogs and Fens" (Ratcliffe et al., 2025b).

The primary stressor for marsh and wet meadow/carr wetlands is fluctuating hydrology. There is anticipated more frequent and severe flooding driven by increased spring precipitation in more frequent extreme events. In addition, summer and fall droughts will likely be more frequent, driven by higher temperatures and evapotranspiration demands.

Projected changes in annual temperatures in the Mixed Wood Plains ecoregion of central Minnesota for the late century (2070-2099) are 6 – 11 degrees F over historical (1971-2000), depending on emissions and using the mean of 20 climate models (Table 2 in Ratcliffe et al., 2025a). Spring precipitation is projected to rise 25% over historical conditions by end of century (Table 4 in Ratcliffe et al., 2025a). The frequency of 30-yr droughts is projected to be as much as 917% over historical rates by end of century (Table 5 in Ratcliffe et al 2025a).

**Marshes** (from the North American Freshwater Marsh section of Ratcliffe et al., 2025a)

Marshes are adapted to fluctuating hydrology, typically with plants suited for various inundation levels in zones within them. However, shallow marshes may be sensitive to water deficits.

- **Habitat Structure** - Flooding may increase nutrient inputs and sediment deposition from adjacent developed or agricultural areas, increasing eutrophication, the distribution of invasive species and altering habitat structure through scouring and deposition. Increased drought phases may accelerate decomposition, carbon dioxide release and mineralization during dry periods.

- **Community Composition** – Due to the increased incidence of flooding as well as drought, the particulars of which species will be favored under future climate conditions is likely quite site-specific. More frequent, severe drought may favor facultative wetland species rather than obligate and promote meadow and shrub species more typical of drier-adapted communities. Wild rice (*Zizania palustris*) marshes may be particularly vulnerable to hydrological change, because as annuals they can be easily uprooted during flooding or outcompeted under both flooding and drought.
- **Problematic Species** – Prolonged flooding and increased nutrient loads may favor species such as reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis ssp. australis*) and cattails (*Typha* spp.).

**Wet Meadow/Carr** (from the Midwest Wet Prairie, Wet Meadow, and Shrub Swamp of Ratcliffe et al., 2025a)

These wetlands are typically shallow, seasonally or intermittently flooded wetlands. Their hydrology is largely reliant on precipitation and snowmelt, and increased evapotranspiration rates driven by higher temperatures may exacerbate their vulnerability to drying.

- **Habitat Structure** - Flooding may increase nutrient inputs and sediment deposition from adjacent developed or agricultural areas, increasing eutrophication, the distribution of invasive species and terrestrialization. Increased drought phases may reduce wetland habitat extent through drying soils. Frequent shifting of soil between aerobic and anaerobic states may slow decomposition, denitrification and plant nutrient uptake during saturation and accelerate decomposition, carbon dioxide release and mineralization during drought.
- **Community Composition** – Given the projected increase in both flooding and drought, the plants that will be favored under future climate conditions will likely vary considerably from site to site. Flood-tolerant species may become more dominant. Drought may facilitate dominance by annuals and rhizomatous graminoids, shifting communities toward shrubs and graminoids typical of drier-adapted communities.
- **Problematic Species** – Prolonged flooding and increased nutrient loads may favor species such as reed canarygrass, European common reed and cattails. Warming trends may also create conditions favorable to expansion of invasive taxa from more southern regions.

**Bogs (acid peatlands)** – (from the Eastern North American Boreal-Subboreal Bog and Acidic Fen section of Ratcliffe et al., 2025b)

In the Northern Forest ecoregion of northeastern Minnesota, projected changes in annual temperature by end of century (2070-2099) are 6 – 11 degrees higher than historic (1970-2000), depending on the carbon emissions level and using the mean of 20 climate models (see Table 9 in Ratcliffe et al. 2025b). Rainfall projections include greater expected winter and spring rain and more summer drought. Less summer rainfall paired with higher temperatures is projected to raise the vapor pressure deficit (VPD) 32-66% by end of century (2070-2099) over historic (1970-2000), depending on emissions levels, using the mean of models (Table 11 in Ratcliffe et al., 2025b).

Anticipated climate change effects:

- **Habitat Structure** - Higher VPD corresponds with rapid evaporation and water loss from plants and soils and reduced water table levels. When water levels drop, peat becomes more exposed to oxygen, and this leads to accelerated aerobic decomposition and

release of nutrients including carbon. Sustained heat and lack of moisture can hurt the productivity of Sphagnum moss (*Sphagnum* spp.) and diminish its dominance (Bu and others, 2011; Norby and others, 2019 in Ratcliffe et al. 2025b). Drier conditions lead to peat subsidence, compaction and cracking, which reduces water retention, limits hydraulic conductivity, and increases probability of wildfire (Ratcliffe et al. 2025b).

- **Community Composition** – climate changes, particularly increased temperatures that enhanced nutrient availability and extended growing seasons, are anticipated to be unfavorable for black spruce, tamarack and sphagnum moss species, while being more favorable for ericaceous shrubs such as highbush blueberry (*Vaccinium corymbosum*), bog rosemary (*Andromeda polifolia*) and small cranberry (*Vaccinium oxycoccos*) (Ratcliffe et al., 2025b).
- **Problematic Species** – Increased nutrient availability and longer growing seasons create more favorable conditions for species such as glossy buckthorn (Frangula alnus), reed canarygrass, common reed and cattails.
- **Pests and pathogens** – In general, climate change may increase populations and facilitate spread of pests and pathogens, as well as decreasing the fitness of dominant species, making them more susceptible to outbreaks, such as tamarack (*Larix laricina*) being vulnerable to eastern larch beetle (*Dendroctonus simplex*) and black spruce (*Picea mariana*) to spruce budworm (*Choristoneura fumiferana*) (Bellemin-Noël and others, 2021; McKee and others, 2022; Ren and others, 2020 in Ratcliffe et al., 2025b).

**Fens** – (from Midwest Prairie Alkaline Fen section in Ratcliffe et al. 2025b)

Anticipated climate change effects:

- **Habitat Structure** – warming paired with reduced summer rainfall creates water deficits that can lower water tables and expose peat to oxygen, increasing decomposition and releasing nutrients and carbon. Drier conditions lead to peat subsidence, compaction and cracking, which reduces water retention, limits hydraulic conductivity and increases probability of wildfire. These changes could reduce conditions for fen-adapted specialists while making these habitats more available to more generalist forbs and graminoids.
- **Community Composition** – more frequent water deficits from drought may create difficult growing conditions for some species such as spikerushes (*Eleocharis* species) and grass of parnassus (*Parnassia glauca*), while favoring more deep-rooted plants and facilitate encroachment by woody shrubs and trees. Longer growing seasons and enhanced nutrient availability will shift competitive dominance by fen specialist forbs and mosses while creating conditions more favorable to ericaceous shrubs and graminoids.
- **Problematic Species** – Longer growing seasons along with increased nutrient availability may facilitate conditions favorable for species such as glossy buckthorn (Frangula alnus), reed canarygrass, common reed and cattails.
- **Pests and pathogens** – Pest and pathogen pressure is anticipated to increase directly through higher pest and pathogen populations and indirectly through heightened host susceptibility due to temperature and water deficit related stress.

## Species in Greatest Conservation Need

Non-forested wetlands provide primary or secondary habitat for 97 animal Species in Greatest Conservation Need (SGCN) and 51 plant SGCN (see Table 3.14). Primary habitats are those that species rely on and use most consistently, and the loss or degradation of which would most greatly affect the species. Secondary habitats are used by species less frequently.

Animals with more general habitat requirements were associated with multiple habitats, while specialists were associated with fewer. Primary and secondary habitat associations were distinguished for vertebrate and some invertebrate animals but not for insects, which are shown in 'total'. Plants were only associated with a single primary habitat for each species. Detailed tables associating each of the SGCN with each of the 15 habitats can be found in Appendix D for animals and Appendix E for plants.

Non-forested wetlands provide habitat for one-third of the 130 terrestrial vertebrate SGCN identified in the 2025-2035 SWAP (36%; 47 species). Thirty of these SGCN are bird species, and the 30 birds utilizing these wetlands comprise 38% of the 79 avian SGCN. The 51 plant SGCN found in this habitat constitute 12% of the 448 that are designated as SGCN. Examples of some of the SGCN and their significance are described below; state-listed species are linked to their account in the Rare Species Guide.

**Table 3.14. Numbers of Species in Greatest Conservation Need associated with Non-forested Wetlands as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 4 | 1 | 5 |
| Birds | 18 | 12 | 30 |
| Mammals | 3 | 3 | 6 |
| Reptiles | 1 | 5 | 6 |
| Bees | - | - | 20 |
| Beetles | - | - | 1 |
| Butterflies | - | - | 6 |
| Dragonflies and damselflies | - | - | 7 |
| Moths | - | - | 14 |
| Mussels | 0 | 1 | 1 |
| Spiders | 1 | 0 | 1 |
| Plants | 51 | - | 51 |
| **Total** | **78** | **22** | **148** |

## Amphibians

Non-forested Wetlands are a rich and important habitat for amphibian SGCN. Five of the seven amphibian SGCN are found in this habitat. It is especially critical for four species: Blanchard's cricket frog (*Acris blanchardi*), spotted salamander (*Ambystoma maculatum*), pickerel frog (*Lithobates palustris*) and eastern newt (*Notophthalmus viridescens*). As noted in the Riparian and Floodplain Forest chapter which also provides critical habitat, the cricket frog is found right along the water's edge; open areas with muddy shorelines and dense emergent vegetation are preferred. They reside near water throughout the summer, but during dry conditions they may seek out wetter conditions elsewhere. Crayfish burrows or small openings along the bank of a wetland or river provide sites for hibernation. Less than 2 inches in size, their breeding call is similar to that of yellow rails and Virginia rails, making visual identification or expert verification via audio recording essential. A state endangered species, Blanchard's cricket frogs have a limited range in portions of central, southeast and southwestern Minnesota as of 2025.

*Photo: Blanchard's cricket frog, USFWS*

Spotted salamanders (*Ambystoma maculatum*), a state Special Concern species, also have a very limited distribution in the state, restricted to two east-central counties: Carlton and Pine. Found in forests with seasonal ponds or in shallow emergent wetlands that do not contain predatory fish to ensure successful reproduction. Mature, close-canopy forests that provide sufficient shade and organic soils with woody debris for foraging are important habitat features.

Pickerel frogs are also found in Riparian Forests and Floodplains as well as open non-forested wetlands, preferring the edges of ponds, small rivers and streams that flow through wooded areas or open habitats (Moriarty & Hall, 2014). The wetlands they use are typically on a valley floor near a river or stream, are permanent, and are never far from forested habitats. They rarely venture far from the water's edge or from nearby wet meadows. Winter months are spent hibernating in their water habitats. Pickerel frogs are restricted to the far southeastern corner of the state; county records are available from Goodhue, Fillmore, Houston, Mower, Olmsted, and Winona counties (Moriarty & Hall, 2014). Eastern newts have a much wider state distribution in Minnesota than other amphibian SGCN. They can be found temporary or permanent wetlands throughout deciduous and coniferous forests across the eastern half of the state. A rich, organic understory with abundant leaf litter and woody debris is required (Moriarty & Hall, 2014). They are known to be very active during warm, rainy days and hide under the leaf litter when it is drier.

The fifth amphibian found in open wetlands is the Great Plains Toad (*Anaxyrus cognatus*). It is more prominent in prairies and other grasslands but can also be found in shallow wetlands during the breeding season. They are not especially selective about their wetland breeding sites; they also utilize any shallow pool of water, including low, ephemeral sites in agricultural fields that form following a heavy rainstorm.

## Birds

Yellow rails (*Coturnicops noveboracensis*) and Nelson's sparrows (*Ammodramus nelsoni*) are almost entirely restricted to rich fens and wet meadows. Permanent water depth during the nesting season ranging from a few centimeters to about 25-30 centimeters seems critical to

occupancy. A canopy of dead sedges (previous years' growth) is a key habitat feature. Nelson's sparrows often utilize isolated shrubs or small clumps of cattails as singing perches. However, neither species is found in cattail-dominated wetlands, or wetlands with dense shrub cover. Sedge wetlands of acid peatlands, with dense sphagnum mosses or ericaceous shrubs, are also avoided.

Sedge wrens (*Cistothorus stellaris*) and LeConte's sparrows (*Ammospiza leconteii*) are also found in wet meadows and rich fens, but will utilize mesic upland grasslands with dense, tall grasses. Wilson's phalaropes (*Phalaropus tricolor*) have similar habitat requirements, but typically require at least small patches of shallow, open water within fens, wet meadows, or upland grasslands. Northern harriers (*Circus hudsonius*) and short-eared owls (*Asio flammeus*) may occupy the same sedge-dominated habitats as well as open acid peatlands, marshes, shrub swamps, and upland grasslands.

*Photo: Wilson's phalarope, Bob Dunlap*

Emergent marshes provide key habitat for king rails (*Rallus elegans*), common gallinules (*Gallinula chloropus*), Franklin's gulls (*Leucophaeus pipixcan*), black terns (*Chlidonias niger*), Forster's terns (*Sterna forsteri*), least bitterns (*Botaurus exilis*) and American bitterns (*Botaurus lentiginosus*). Each of these species have slightly different microhabitat requirements. In general, a vital habitat characteristic is a moderate to high degree of interspersion of emergent vegetation and open water. Dense cattail stands without accessible open water are avoided by all of these species. Exposed bare soil, floating mats of vegetation, or muskrat house provide important nesting and loafing sites, particularly for Franklin's gulls, black terns and Forster's terns. Common gallinules often utilize areas of open water with water lilies within hemi-marshes. Least and American bitterns are restricted to marsh vegetation, typically foraging at the vegetation-open water interface. While least bitterns are largely restricted to cattails (as well as patches of phragmites), American bitterns will also occupy shrub swamps, wet meadows and sometimes acid peatlands.

Another group of wetland-dependent SGCN birds utilize the open water and/or shorelines of non-forested wetlands, particularly emergent marshes, as well as lakes (also see Lakes sub-chapter). This includes ducks, grebes, and common loon (*Gavia immer*). Common terns (*Sterna hirundo*) and American white pelicans (*Pelecanus erythrorhynchos*) forage in/over open water but nest on shorelines (typically islands). Black-crowned night herons (*Nycticorax nycitcorax*) forage at wetland edges or shoreline, but nest colonially in trees or sometimes marshes. Buff-breasted sandpipers (*Calidris subruficollis*) utilize very short vegetation, often associated with wetlands.

### Mammals

Northern bog lemmings (*Synaptomys borealis*) are limited to lowland conifer forests and open peatlands in extreme northern Minnesota; they have been shown to disappear from peatlands altered by human activities. Little is known about the species. Current populations are believed to be isolated relics of a larger population that occurred much farther south when glaciers advanced during the Pleistocene epoch. Fewer than 12 records have been documented in Minnesota since the species was first found in Lake County in 1932. Those records have been limited to open bogs, shrub carrs, and black spruce swamps. Since the Eastern heather vole (*Phenacomys ungava*) was first documented in Lake County in 1940, fewer than 20 specimens have been collected

in Cook, Lake, and St. Louis Counties. Like the northern bog lemming it also prefers lowland conifer forests and open peatlands but may be found in upland fire-dependent habitats as well. Proximity to water and the presence of boulders, coarse woody debris, and ericaceous plants appear to be important habitat components. Larger species typical of conifer wetlands include the SGCN snowshoe hare (*Lepus americanus*), Canada lynx (*Lynx canadensis*).

Franklin's ground squirrel (*Poliocitellus franklinii*) is strongly associated with prairie, other grasslands, and savanna habitats. However, the grasslands it selects usually include wooded banks and gullies for its underground burrows (Missouri DNR). The species is declining throughout its range and is under consideration for federal status.

## Reptiles

Where they have access to them, Blanding's turtles (*Emydoidea blandingii*) have been documented using bogs and fens as well as open wetland complexes that are adjacent to sandy uplands for nesting. For example, adult females have been tracked to fens prior to and following nesting; both to hydrate and to forage. Potentially, hatchlings may seek the deep muck for protection. Shallow waters with abundant aquatic vegetation are preferred. Ephemeral wetlands are utilized in spring and early summer, while deeper marshes and backwater pools are utilized in both the summer and winter. In southwestern Minnesota, meandering streams and rivers, fens, prairie marshes, backwaters and oxbows are important aquatic habitats, and upland habitats include adjacent agricultural lands. In addition to Blanding's turtle, four snakes may also be found in or near open non-forested wetlands: plain hog-nosed snake (*Heterodon nasicus*), Eastern hog-nosed snake (*Heterodon platirhinos*), smooth greensnake (*Opheodrys vernalis*) and gopher snake (*Pituophis catenifer*).

## Invertebrates

Many insects both terrestrial and aquatic are associated with Non-forested Wetlands, including 50 SGCN. Please see the Aquatic Invertebrates and Terrestrial Invertebrates sub-chapters for more information.

## Plants

Minnesota's peatlands provide refuges for several endangered, threatened, or special concern plant species in the state, including linear-leaved sundew (*Drosera linearis*), English sundew (*Drosera anglica*), coastal sedge (*Carex exilis*), twig rush (*Cladium mariscoides*), bog rush (*Juncus stygius var. americanus*), sooty colored beak-rush (*Rhynchospora fusca*) and montane yellow-eyed grass (*Xyris montana*) (see also Minnesota Scientific and Natural Areas Patterned Peatlands).

Marshes and wet meadow are habitat for rare species including: sweet-smelling Indian plantain (*Hasteola suaveolens*), marginated rush (*Juncus marginatus*), auricled twayblade (*Listera auriculata*), sea milkwort (*Lysimachia maritima*), autumn fimbry (*Fimbristylis autumnalis*), neat spikerush (*Eleocharis nitida*), smooth-sheathed sedge (*Carex laevivaginata*), upswept moonwort (*Botrychium ascendens*), stream parsnip (*Berula erecta*), yellow bartonia (*Bartonia virginica*) and great Indian plantain (*Arnoglossum reniforme*).

## Climate Spotlight: Zigzag Darner

This profile is excerpted from "Effects of Climate Change on Midwestern Ecosystems: Temperate Flooded and Swamp Forest" published by the Midwest Climate Adaptation Science Center (Ratcliffe et al. 2025c).

The zigzag darner (*Aeshna sitchensis*) is a boreal species of Odonata [dragonfly] found in northern Minnesota, Wisconsin, and Michigan (DuBois and others, 2004). While little is known about the direct effects of climate change on zigzag darners, research on other Odonata (e.g., dragonfly and damselfly) species has documented climate-driven changes such as advanced phenology, altered development time, pigmentation changes, behavioral adjustments in time spent basking and other activities and shifts in geographic distribution (Hassall and Thompson, 2008; Zeuss and others, 2014). Additionally, higher temperatures may increase Odonata sensitivity to environmental stressors, including insecticides and other pollutants (Ishiwaka and others, 2024; Sirois-Delisle and Kerr, 2022). As generalist aquatic predators, larval Odonata are unlikely to be directly affected by changes in prey phenology (Hassall and Thompson, 2008). However, rising temperatures may alter their ability to capture prey. One study found that at higher temperatures, zigzag darner larvae showed decreased activity, while their prey, wood frog (*Lithobates sylvaticus*) tadpoles, became more active (Hayden and others, 2015). However, this relationship is complex, as the number of larval attacks also increased with temperature.

Zigzag darners breed in cool-water bogs and fens with little to no emergent vegetation. In the Great Lakes region, these habitats are vulnerable to climate-driven changes in water temperature, ice-cover and water-level fluctuations (DuBois and others, 2004; DuBois and others, 2018; Magee and others, 2021). This species prefers small pools that often dry during summer (DuBois and others, 2004), but increasing rainfall variability, with cycles of drought and deluge, may lead to more frequent early drying or pool connections to larger water bodies, reducing suitable breeding habitat. Maintaining and restoring boreal, cool-water bogs and fens will be essential to zigzag darner persistence under warming temperatures and variable precipitation patterns. Additionally, because warming temperatures often amplify other environmental stressors, management strategies may include reducing exposure to toxins, such as insecticides (Ishiwaka and others, 2024) and copper (Hayden and others, 2015).

*Photo: Zigzag darner, Jeff Fischer*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts (e.g. catastrophic wildfire following a prolonged period of fire suppression) while serving as valuable conservation tools in others (e.g., appropriately planned and applied prescribed fire).

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Pressure for urban and exurban development puts pressure on wetlands, both directly, such as in the Anoka Sandplain, and indirectly in the use and alteration of groundwater hydrology, which is particularly detrimental to groundwater-fed wetlands such as calcareous fens.

### Crop Production

Wetlands in general and calcareous fens in particular are affected by agricultural practices either by direct use, chemical inputs such as fertilizers or pesticides, or by changes to the flow of groundwater to the wetlands, such as by installation of wells or drain tile, which once disrupted, is essentially not possible to reinstate and causes extirpation of the wetland.

Open wetlands, particularly seasonal and temporary wetlands, have been lost from the landscape due to being able to be farmed in some years, in some cases through the placement of drain tile, conversion of these to farmland reduces rich, seasonally available habitat for migratory waterfowl and shorebirds.

### Livestock Management

Large livestock facilities create runoff that can affect receiving waters and the habitats that many species depend upon. They can also affect groundwater resources and surface waters depending on the source of water being used.

### Mining and Quarrying

Mining and quarrying operations can threaten wetlands directly with insufficient buffers and indirectly through changes in hydrology, including effects to the level or flow of water in the water table.

Although the drainage of peatlands for agricultural use has been the primary cause of peatland loss in Minnesota, peat mining, where layers of peat are removed for horticultural use as a soil amendment and potting medium, can be a unique stress to some coniferous forested wetland communities. Peat mining leases cover a very small percentage of state managed peatlands (0.23% in 2025). All peat mining permits in the state, whether on public or private land, require reclamation and reestablishment of surface vegetation once operations cease. However, the peat layers once removed are not readily replaceable, as it takes hundreds to thousands of years for peat to form again.

## Wind and Solar Energy Infrastructure

Siting of solar development can affect wetland hydrology and associated communities.

## Roads, Trails, and Railroads

The development of roads and trails can disrupt wetlands directly and indirectly by changing hydrology, both above and below ground in the aquifer, including in some cases the flow of cold groundwater into wetlands. Road and railroad herbicide application along existing right of ways affects sensitive plant communities like calcareous fens.

## Utility Corridors

Powerlines present a risk to waterfowl when situated between feeding and roosting areas. This is especially true for lines near lakes, rivers and wetlands. Less agile birds, such as trumpeter swans are particularly susceptible to collision with overhead lines located near waterbodies (APLIC, 2012). Utility corridor herbicide application for maintenance has affected calcareous fen communities.

Gas pipelines can fragment wetlands habitats and disrupt groundwater hydrology.

## Recreation

Recreational use can contribute to altered hydrology through soil compaction as well as the introduction of non-native invasive species to recreational sites with wetlands by inadvertently bringing in seeds on footwear or gear.

## Dams and Water Management

Water impoundments and surface water diversions can disrupt the upwelling of groundwater that maintains fen and open rich peatlands unique chemistry and hydrology. For wet meadows and sedge-dominated systems, dams and irrigation can elevate water levels which favor invasive or more water-tolerant species like cattails (*Typha* spp.) and reed canary grass (*Phalaris arundinacea*) (Apfelbaum & Sams, 1987; Boers et al., 2007). Water impoundments reduce the natural variability in flow and moisture regimes, potentially degrading habitat for species dependent on specific hydrologic conditions such as nesting birds, amphibians and rare wetland invertebrates (Winter & Woo, 1990).

## Invasive Species (Problematic Non-native Species)

Numerous invasive plant species with detrimental effects are present in Minnesota wetlands. For example, purple loosestrife (*Lythrum salicaria* L.), invasive cattail (*Typha angustifolia* L., *Typha x glauca*) and invasive common reed (*Phragmites australis australis (Cav.) Trin. ex Steud.)* are all associated with habitat declines for birds, homogenization and dominance of wetland plant communities, and modification of wetland soil and nutrient cycling. In addition to these emergent plants, multiple submerged species including curlyleaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) have effects including increasing internal phosphorus loading and outcompeting native plant species, respectively. Human mediated movement of species means that in addition to the current distribution of invasive species, there is a persistent risk of additional introductions of invasive species. Hybridization of native and invasive species is an additional concern, with hybrid cattail and hybrid Eurasian watermilfoil both wetland examples of species with documented hybrid vigor (hybrids are superior competitors relative to parent strains) and hybrid Eurasian watermilfoil having documented herbicide tolerance.

The invasive subspecies of Phragmities (*Phragmites australis subsp. australis*) is a tall densely growing perennial grass that can be found in wetlands, shorelines, wet ditches, and

other wet areas. The species can rapidly spread through seed, stolons, rhizomes and stem fragments, forming dense stands that alter wetland hydrology, lower plant diversity and reduce habitat quality for invertebrates, fish and waterbirds. There is a native subspecies of Phragmites that can be difficult to distinguish from its invasive counterpart. This makes it difficult to estimate the distribution of the invasive species throughout the state. Source: Minnesota Aquatic Invasive Species Research Center (MAISRC)

## Problematic Native Species

Reed canary grass (*Phalaris arundinacea*) is a hardy, aggressive, cool-season grass that can form dense, monotypic stands in wetlands. Despite recent research suggesting that reed canary grass found in Minnesota is predominantly native, it can outcompete other native wetland species, posing challenges for wetland restoration and mitigation efforts. Source: University of Minnesota Extension (Reed canary grass).

## Water-borne Pollution

Nonpoint source pollution, including phosphorus, nitrogen, sediment, bacteria and other contaminants generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. As runoff flows, it picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, groundwater and estuaries (EPA NPS Webpage). These nonpoint source pollutants represent the largest combined contribution (an estimated 86%) to the state's water pollution (MPCA Water Quality Initiatives). Water quality measured by nutrients and contaminants has been shown to decline with higher agricultural or urban development in the watershed. Some key effects include excess algal growth, reduced plant diversity and reduced diversity in fish and invertebrate communities (DNR Water quality non-point sources).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency & Minnesota Department of Commerce, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

Looking ahead, this warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). Also, projected temperature increases are likely to affect ecosystems unevenly. For example, peatlands are sensitive to changes in temperature and hydrology and may experience reduced capacity to provide critical ecosystem services such as carbon and water storage. For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Non-forested Wetlands

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Protections for rare calcareous fens are in place. However, early project planning is needed to limit the installation of new wells in aquifers that support them and to site projects such as mining far enough from fens so that groundwater is not affected. Consider acquiring lands where calcareous fens occur, along with a buffer area, to protect them and their hydrology. |
| | Preserve and prevent loss or degradation of all types of nonforested wetlands, especially in the Eastern Broadleaf Forest and Prairie Parkland provinces. Focus on protecting wetlands larger than 10 hectares (25 acres) and wetland complexes. Enforce wetland protection regulations (“no-net loss”). |
| | Consider ways to reduce the effects of pipelines. Also develop clearer rules around pipelines for human and environmental safety, including for CO2 pipelines. Protect calcareous fens within utility easements such as by restricting the use of herbicides in favor of mechanical maintenance using low ground pressure equipment. |

| Stressor | Action |
|---|---|
| | Ensure mining operations stay above and do not affect the water table, to protect the hydrology of calcareous fens. |
| | Ensure mining and quarrying operations and solar and wind development operate with sufficient buffers and provide sufficient mitigation for any damage to wetlands. Increase incentives to avoid all wetlands, including wet meadows. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Restore large wetland complexes, with attention to the habitat features required by SGCN. |
| | Maintain vegetated buffers comprised of locally native vegetation adjacent to waterways. Avoid or reduce mowing, burning, grazing or chemical application on these buffers. Support and promote state and federal programs incentivizing buffers and other best practices for lakes, streams, wetlands and ponds. |
| | Control non-native and hybrid cattails to promote a diversity of plants. Minimize the spread of invasive plants in nonforested wetlands (e.g., purple loosestrife, Phragmites). Mitigate effects and manage potential invasive species dominance in affected areas. |
| | Reverse ditching and try to restore hydrology to drained peatlands. |
| | Implement bridges and boardwalks to prevent damage to wetlands from recreational use. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Avoid creating impoundments that flood wet meadows, except during wetland restoration projects. |
| | Farmed wetlands can be restored, with resources such as provided through the Natural Resource Conservation Service, or in cooperation with Soil and Water Conservation Districts or Minnesota Board of Water and Soil Resources. This can be particularly helpful when fields are too wet for planting or for crops to come in properly, which is happening more frequently with heavier and more prolonged spring rain events and with projections of even greater spring rainfall in the coming years. |

| | |
|---|---|
| | Increase early coordination with counties and local governmental units in the early pre-planning stages to ensure avoidance of wetlands. Review and comment on plant seed mixes for restoration actitvities. |
| | Restrict the use of herbicides or establish buffers along utility easements and road and railroad right of ways near calcareous fens. In these areas mechanical vegetation management is prefered using low ground pressure equipment or operating in frozen groundn conditions. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| NA | Wetlands identification, mapping, and monitoring are ongoing in several projects, with current focus on less well-known wetlands such as vernal pools (see Vernal Pools sub-chapter) and calcareous fens. Also see Chapter 4: Monitoring. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | To reduce the effects of agriculture, mining and development on wetlands (in particular, calcareous fens), several actions are needed: technical support to identify and study hydrological contexts, information about tiling and groundwater depletions that may affect calcareous fen hydrology, sharing of information with local governments and entities including counties and Soil and Water Conservation Districts, and political support to address tough conservation issues. |
| | Education and outreach to promote soil and hydrological management among agricultural producers and other water consumers to reduce soil and chemical runoff, noting buffer rules, listening to barriers and finding solutions and taking advantage of financial incentives, including discussions of hydrology associated with drain tiles. |
| | Increase awareness of importance of peatlands, recognize relative abundance in Minnesota compared to other states, explain the importance of restoring previously degraded peatlands, and consider reducing a demand for peat. Increase awareness about anticipated stress from warming and effects it could have on our state's ability to store carbon and changes that may need to be made in the timing of management activities and the amount of area needed to be set-aside. |

## Case Study: Peatlands Resilience Initiative

Minnesota's Peatland Resilience Initiative, led by the DNR, aims to sustain and restore the state's vast peatland ecosystems, over 7 million acres or roughly 10% of Minnesota's land area, recognizing their critical role in carbon storage, water regulation, and wildlife habitat. Peatlands accumulate partially decomposed plant material under saturated conditions, creating some of the deepest organic soils in the world and storing carbon for millennia. As the second most peat-rich state in the continental U.S. after Alaska, Minnesota's peatlands are vital for both regional biodiversity and global climate mitigation.

Under the initiative, the DNR is advancing a science-based strategy to protect peatlands within Minnesota's Climate Action Framework. Central actions include mapping deep organic soils and wetlands to identify priority areas, developing criteria for conserving or restoring peatland sites, and executing demonstration projects. One such effort evaluates restoration at Winter Road Lake Peatland SNA to quantify changes in greenhouse gas fluxes and mercury export, thereby measuring ecological as well as climate benefits. This is complemented by a demonstration project with the Office of School Trust Lands aimed at safeguarding peatlands while maintaining sustainable economic benefits.

Beyond carbon storage, sequestration, and emissions reduction benefits, the initiative supports additional co-benefits, including improved flood water storage and filtration, reduced mercury and sediment loading in water bodies and enhanced wildlife habitat for peatland-dependent species. Restoration work focuses on increasing hydration to drained peatlands on state lands, often by raising water levels, to reestablish saturated conditions crucial for peat accumulation and ecosystem resilience.

By integrating mapping and prioritization, cross-agency collaboration, targeted restoration, and rigorous monitoring, the Peatland Resilience Initiative provides a strategic, climate-forward model for peatland conservation. It aligns ecological restoration with climate mitigation goals, establishing Minnesota as a leader in leveraging natural landscapes to address the challenges of a warming world.

*Photo: Fen, Red Lake Wildlife Management Area, Eric Ogdahl*

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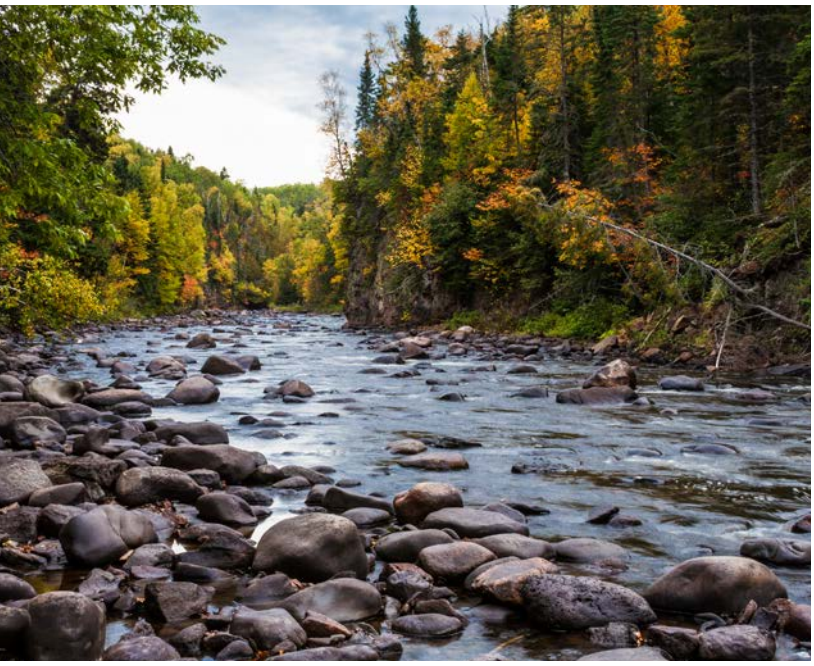
# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# RIVERS AND STREAMS



DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Brule River, Judge C.R. Magney State Park, Beau Liddell; Wood turtle nesting habitat, St. Louis County, Gaea Crozier

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# Rivers and Streams

## Habitat Description

This chapter focuses on the aquatic habitat within streams and rivers and the shore directly adjacent. Please see the Riparian and Floodplain Forest sub-chapter for information about forested riverine habitat. Minnesota contains streams and rivers representing a continuum of size and volume ranging from headwaters to the great rivers of the Minnesota, Mississippi, Red River of the North and the St. Croix. Rivers and streams are commonly categorized by size using the Strahler Stream Order classification system (SSO; Strahler, 1957). This system ranks streams based on the hierarchy of their tributaries, with each increase in order reflecting an additional level of branching, including small rivers (i.e., 'streams'; SSO 1-4), medium-large rivers (i.e., 'rivers'; SSO 5-6) and large rivers (i.e., SSO 7-8). Within each size class, rivers and streams differ considerably in their hydrology, geomorphology, water quality, connectivity and biological communities — variations that are often shaped by their geographic location or ecoregion. For example, headwater streams (i.e., origins for river networks) are usually characterized by cooler temperatures, fast flow velocities and shallower pools. In contrast, larger streams and rivers generally exhibit warmer water, slower flow rates and deeper pools. Smaller streams, owing to their limited watershed size, often maintain higher water quality and experience less exposure to contaminants, excess nutrients and sediment loads.

The River Continuum Concept describes a river system as a continuous gradient of physical, chemical and biological changes from headwater to mouth (Vannote et al., 1980). Along this gradient, longitudinal connectivity, refers to the uninterrupted pathways that link the entire length of a stream. As the water flows downstream, shifts in physical conditions drive corresponding changes in chemical dynamics and biological communities, reflecting the natural integration of upstream and downstream processes.

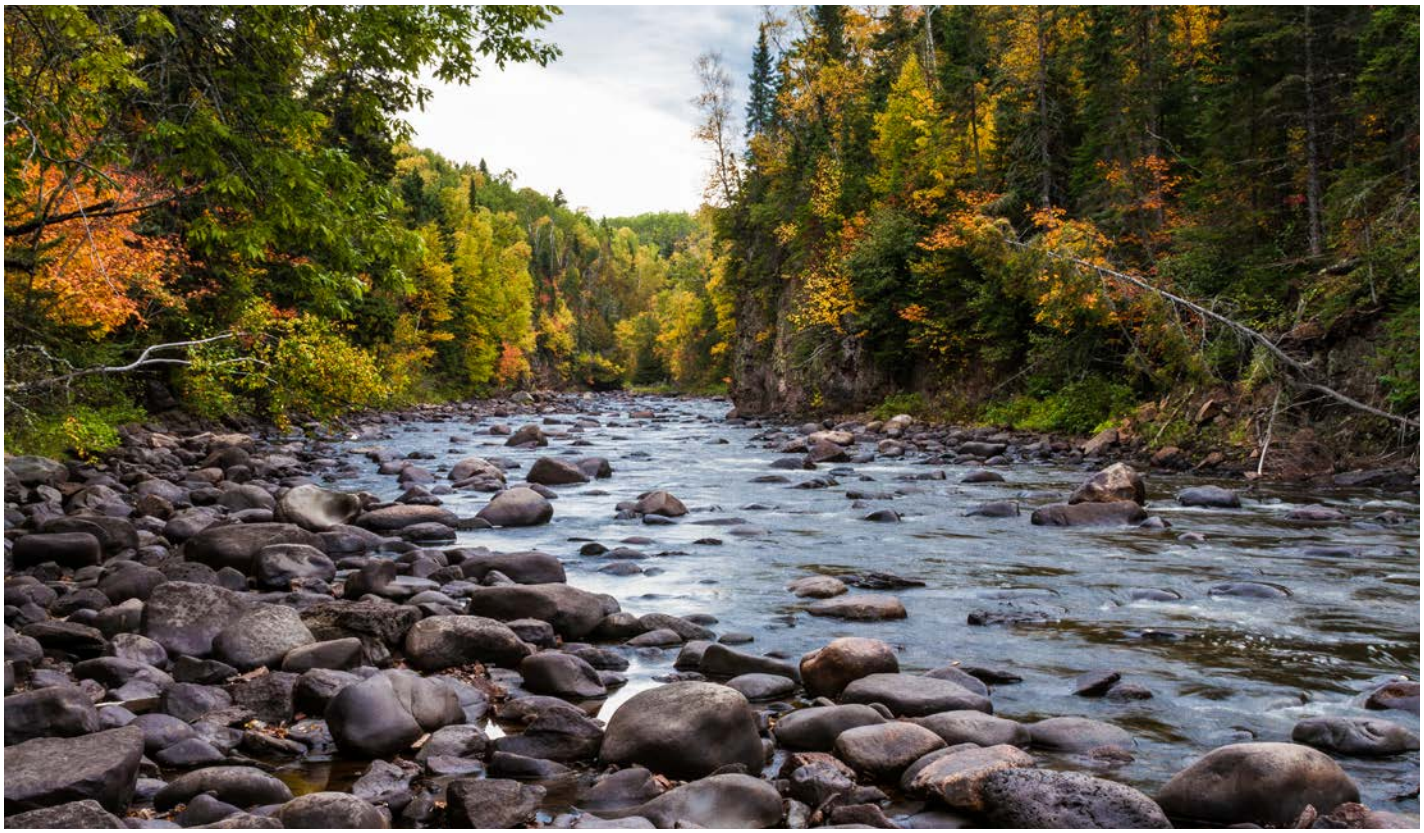

*Photo: Brule River, Judge C.R. Magney State Park, Beau Liddell*

## Streams

Streams in Minnesota exhibit considerable variation in hydrology, geomorphology, temperature and water quality, shaped largely by regional geology, land use and climate. For example, prairie streams in western and southern parts of the state tend to have slower velocities, higher turbidity and greater lateral movement within broad floodplains. Prairie streams are also highly productive and often hotspots of biodiversity (American Prairie Foundation, 2025). In contrast, streams in the eastern portion of the state are typically more constrained by rocky substrates and steeper gradients, which result in faster flows and clearer water. Coldwater streams, primarily located in southeastern and northeastern Minnesota (see Figure 3.16), are strongly influenced by consistent groundwater discharge. These inputs help maintain cool, stable water temperatures throughout the year—conditions that are critical for supporting coldwater biota, including native brook trout (*Salvelinus fontinalis*) and other species of special concern. Many of these streams are formally designated as trout streams due to their ecological and recreational value (see also Trout fishing in southeastern Minnesota).

In heavily agricultural regions of Minnesota, especially those shaped by glacial activity, hydrological conditions have been profoundly altered by human intervention. Thousands of miles of artificial surface and subsurface drainage systems — such as ditches and tile drains — have been installed to increase the arability of poorly drained soils. As a result, the density of stream-like channels on the landscape has dramatically increased. In some cases, it can be difficult to distinguish natural streams from constructed ditches due to similar morphology and vegetation, though they often differ in ecological function and stability (Schottler et al., 2014). These modifications accelerate runoff, increase sediment and nutrient loads, and disrupt natural hydrologic regimes, all of which can degrade aquatic habitat and reduce biodiversity.

Smaller streams are particularly vulnerable to anthropogenic stressors and extreme weather events due to their proximity to surrounding landscapes, limited capacity to buffer effects and diminished regulatory protection. Because of their smaller size, agricultural or urban development can have immediate and pronounced effects on water quality, sedimentation and temperature regimes (Freeman et al., 2007). Their small volume and low dilution capacity makes them vulnerable to significant ecological harm from even modest pollutant inputs such as nutrients, pesticides or heavy metals (Alexander et al., 2007). These streams also respond more dramatically to hydrologic extremes, such as flash floods or droughts, which are increasing in frequency and intensity with climate change (Jackson et al., 2001; Wohl, 2017). Despite their ecological importance, many small streams remain underregulated or unprotected, particularly intermittent or ephemeral channels, leaving them especially susceptible to anthropogenic disturbance and extreme weather events (Leibowitz et al., 2008).

## Rivers

As rivers progress from headwaters to larger downstream segments, their structure typically becomes more complex, with wider channels, more developed floodplains and increasingly intricate channel features such as meanders, oxbows and backwaters (Leopold, Wolman, & Miller, 1995). These changes also correspond with a rise in human modifications, particularly the prevalence of dams, levees, and other impoundments that disrupt the longitudinal connectivity of river systems. Dams can fragment habitats, alter sediment and nutrient transport, and affect flow regimes, which in turn disrupt the life cycles of many aquatic organisms, including migratory fish and invertebrates that depend on free-flowing conditions (Poff et al., 1997).

As rivers enlarge and receive flow from multiple tributaries, their pollutant loads tend to increase in both quantity and diversity. Larger rivers collect contaminants from across

their watershed, including industrial effluents, municipal wastewater discharges and nonpoint source runoff, leading to cumulative effects on water quality (Allan, 2004).

Additionally, the natural increase in flow volume downstream tends to elevate sediment transport capacity, particularly in prairie and agricultural landscapes where erosion rates are often higher. Many large river species have evolved to tolerate or even require these sediment-rich environments. However, excessive sedimentation, especially when combined with nutrient loading, can smother benthic habitats, reduce water clarity and fuel harmful algal blooms, disrupting aquatic ecosystems (Waters, 1995). In contrast, many species in headwaters are dependent on clear, cool waters with stable substrates and minimal pollution, underscoring the importance of protecting these upstream habitats for overall watershed health.

## Large Rivers

Minnesota's large rivers — the Red River, the Minnesota River, the Lower St. Croix River and the Mississippi River south of St. Anthony Falls — represent some of the state's most ecologically and hydrologically significant waterways. These wide river systems carry large volumes of water and are characterized by slower velocities, meanders and oxbows, numerous islands and significant backwater systems. These rivers periodically experience significant flooding events that shape the physical landscape and sustain the biological integrity of associated floodplain forests, wetlands and aquatic habitats (Naiman, Décamps, & McClain, 2005).

*Photo: Wood turtle nesting habitat, St. Louis County, Gaea Crozier*

Notably, several segments of these large rivers widen into lake-like expanses such as Lake Pepin on the Mississippi River and Lake St. Croix on the Lower St. Croix River.

These large rivers are also among the most biologically diverse freshwater ecosystems in Minnesota. The Mississippi River supports more than 120 species of fish, along with a rich assemblage of mussels, aquatic invertebrates, amphibians, waterbirds and floodplain plant communities (Houser, 2022). The dynamic hydrology and variety of habitat types, ranging from main channels and side channels to sloughs and marshes, create a mosaic of ecological niches that support high biodiversity. Similarly, the Minnesota and St. Croix rivers serve as important migration corridors and spawning grounds, linking upstream and downstream habitats essential for the life cycles of many aquatic and semi-aquatic species (see also 2005 Minnesota Wildlife Action Plan; St. Croix National Scenic Riverway: Natural Features & Ecosystems).

## Habitat Map

To depict Rivers and Stream habitat (see Figure 3.16), we compiled spatial data from several sources: DNR's Native Plant Communities, the National Wetland Inventory for Minnesota and the Stream Routes with Strahler Stream Order (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

### Associated Native Plant Community Classes by Ecological Systems

#### River shore (RV)

RVx32 Sand/Gravel/Cobble River Shore (PDF)

RVx43 Rocky River Shore (PDF)

RVx54 Clay/Mud River Shore (PDF)

### National Wetlands Inventory

From the National Wetland Inventory for Minnesota (NWI) Layer we included the 'Riverine' Wetland Type.

### Stream Routes with Strahler Stream Order

From the Stream Routes with Strahler Stream Order, we classified stream orders 1-4 as small, 5-6 as medium large and 7-8 as large.

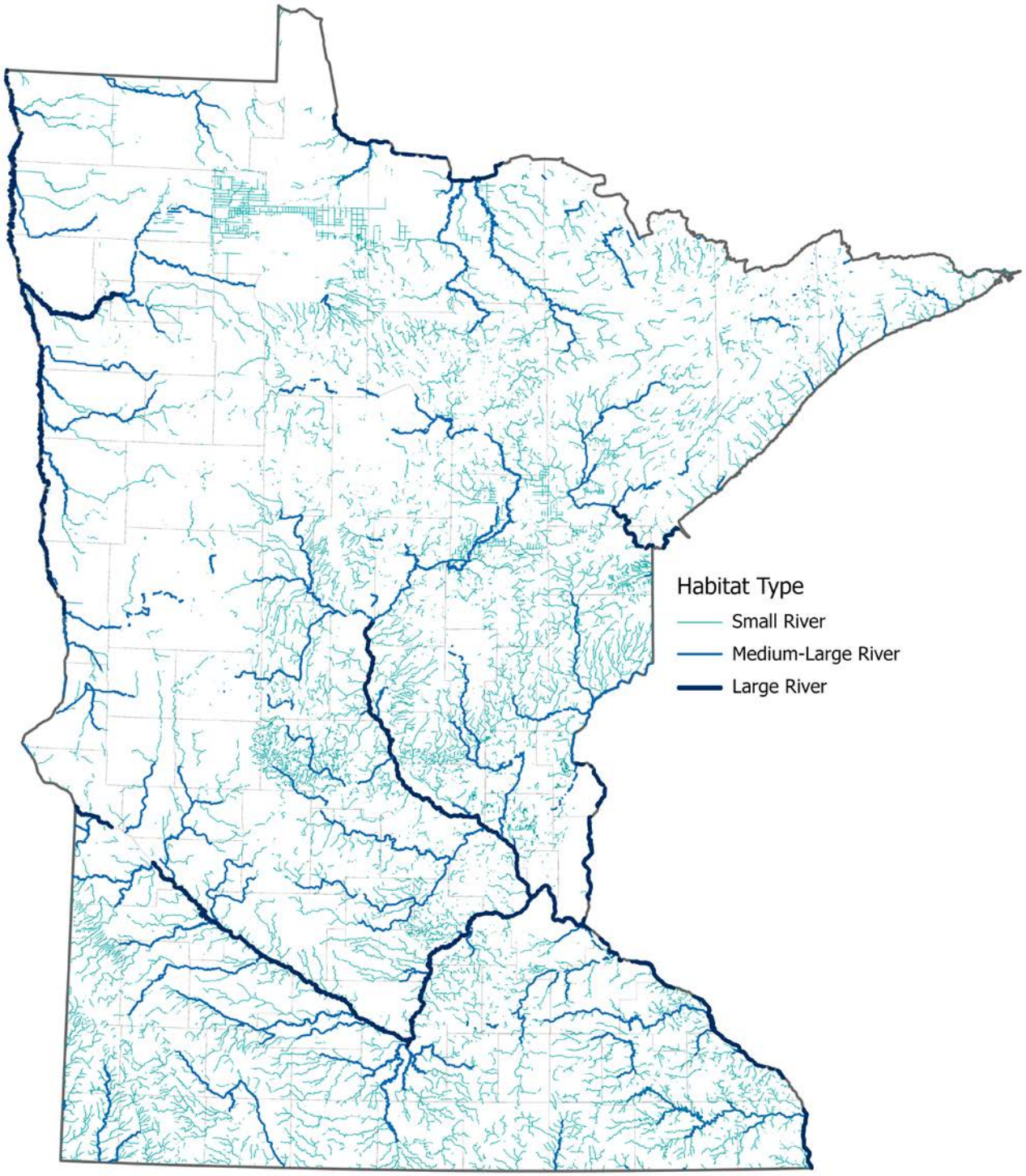


Figure 3.16. A map depicting River and Stream habitat in Minnesota, including the Wetland Type, Riverine, from the National Wetland Inventory for Minnesota and the Stream Order Field from the Stream Routes with Strahler Stream order Layer. River shore habitats were not depicted in this map but are included in the data.

## Conservation Overview

The rivers and streams of Minnesota provide important aquatic habitat as a connected system of flowing water. In addition to in-stream habitat, the adjacent shoreline and riparian habitats provide essential interactions for a wide diversity of plant and animal communities.

In the western prairie region, healthy riparian vegetation along prairie streams consists mostly of sedges, grasses and at times shrubs, such as willows or dogwood (Thornton and Sather 2007; Dodd et al. 2004). Historically, western riverine landscapes supported greater tree cover, particularly in areas where prairie fires occurred infrequently. These "fire shadows" were shaped by local topography and proximity to large rivers or lakes, which reduced the likelihood of fire reaching them.

Elsewhere in the state, streams developed diverse riparian vegetation corridors over time. Coldwater streams often supported overhanging grasses; expansive riverine floodplains were lined with water-tolerant tree species and forbs; and more topographically dissected stream and river valleys in forested regions supported hardwood, pine and shrub communities.

Backwater areas represent an important habitat type occurring adjacent to flowing waters, from small streams to large rivers. Characterized by low or absent current, these habitats serve as critical spawning grounds for several fish species and provide essential refuges for a wide array of wildlife. For instance, Blanding's turtles (*Emydoidea blandingii*), Topeka shiner (*Miniellus topeka*), plains topminnow (*Fundulus sciadicus*) and Blanchard's cricket frogs (*Acris blanchardi*) are frequently associated with oxbows in the Prairie Coteau. Expansive backwater complexes along large rivers form mosaics of land and water that support high biodiversity while also playing a vital role in flood mitigation by moderating both high- and low-flow conditions.

Connectivity of these rivers (the free-flowing condition that maintains pathways that move organisms, energy and matter throughout the watershed) is an important ecological feature. Historically, unconstrained flowages influenced the distribution of fish populations and likely other taxa as well. Some natural barriers such as St. Anthony Falls located in what is now Minneapolis, limited the range of Minnesota fish species, such as yellow bass (*Morone mississippiensis*), pirate perch (*Aphredoderus sayanus*), pugnose minnow (*Opsopoeodus emiliae*), and warmouth (*Lepomis gulosus*), limiting those species to waters downstream of the falls.

*Photo: A restored oxbow, habitat for Topeka shiner and other SGCN, Scott Ralston, USFWS*

Today, many important features of these river systems, such as connectivity, balanced sediment loads and water quality, are jeopardized by multiple human activities. In particular, the construction of dams and the placement of culverts has restricted movement of aquatic species that otherwise would migrate significant distances. For example, restricting fish motility has consequences for the distribution of freshwater mussels. Mussels often rely on a specific host fish and when the movement of the host fish is blocked it will limit the viability of the mussel population. Barriers that limit the range of the skipjack herring (*Alosa chrysochloris*) as the host fish for the state endangered elephant-ear (*Elliptio crassidens*) and ebonyshell (*Reginaia ebenus*) mussels is an example that has been well documented (Watters, 1994). Dams and hydropower plants also change the natural variability in river flows, leading to sediment buildup in some areas and reduced flow in others, while also preventing seasonal flooding that sustains healthy backwater habitats and the low-flow conditions necessary for aquatic plant germination. Dredging to maintain the 9-foot navigation channel in the Mississippi River for commercial barge traffic presents other challenges including directly destroying mussel beds or burying beds by increased sedimentation or turbidity downstream of the dredging. Water levels in the vicinity of the dredging may lower and river channels erode; sites to place the removed material must also be found (Pinter et al., 2003). Many of Minnesota's smaller-order streams carry flow laden with heavy amounts of sediments, nutrients and pollutants from upland activities. As these streams flow together, these contaminants continue downstream. This problem is most pronounced in the agricultural areas where streams and ditches carry pollutants to the Minnesota and Red Rivers. A map of Minnesota's impaired waters illustrates the wide extent that smaller rivers and streams throughout the state have been affected, especially in southern watersheds (Minnesota Pollution Control Agency Impaired Waters Viewer 2024). Many aquatic species in greatest conservation need have been extirpated from these two rivers, including the Higgin's eye mussel (*Lampsilis higgins*), while relatively stable populations still occur in the St. Croix and Mississippi Rivers.

The Watershed Health Assessment Framework (WHAF), developed by the DNR, uses five core components to assess the condition of natural systems across the state's watersheds: biology, connectivity, geomorphology, hydrology and water quality. Together, these components provide a holistic view of watershed function and resilience, emphasizing how natural processes and human actions interact within a watershed context (for details see The Five Component Framework).

- **Biology** reflects the living systems within a watershed, focusing on the diversity, abundance and composition of species, particularly aquatic organisms like fish and macroinvertebrates. Biological communities integrate and respond to physical, chemical and ecological changes over time, making them strong indicators of overall watershed health.
- **Connectivity** examines the degree to which natural systems such as rivers, wetlands and uplands remain physically and ecologically linked across the landscape. This includes both longitudinal connectivity (upstream to downstream) and lateral connectivity (stream to floodplain), which are essential for species movement, gene flow, sediment transport and nutrient cycling. Fragmentation by roads, dams and land development can disrupt these vital connections.
- **Geomorphology** addresses the shape and structure of the landscape, focusing on how sediment moves through stream systems and how stream channels respond to flow and land use changes. Stable stream systems maintain a balance between erosion and deposition. Altered geomorphology can indicate instability, leading to degraded habitat and increased sediment loading.

- **Hydrology** evaluates the timing, magnitude and duration of water movement through a watershed. It reflects both natural precipitation and groundwater contributions, as well as alterations from impervious surfaces, drainage systems and water withdrawals. Changes in hydrology can influence flooding, baseflow conditions and the ecological integrity of aquatic habitats.
- **Water Quality** assesses the chemical, physical and biological characteristics of water in relation to ecosystem and human health. It includes measures such as nutrient levels, temperature, clarity and contaminants. Degraded water quality can result from runoff, point source pollution or landscape disturbances and is a key factor affecting both biodiversity and watershed function.

## Species in Greatest Conservation Need

Rivers and streams serve as primary or secondary habitat for 138 animal and 10 plant SGCN (see Table 3.15). Primary habitats are those most consistently used and relied upon by a species, where loss or degradation would have the greatest negative effect on populations. Secondary habitats, by contrast, are used less frequently or opportunistically.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for some insects were not differentiated into primary and secondary habitats and are shown only in the total column. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants). Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

**Table 3.15. Numbers of Species in Greatest Conservation Need associated with Rivers and Streams as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 3 | 0 | 3 |
| Birds | 1 | 0 | 1 |
| Fish | 31 | 0 | 31 |
| Mammals | 0 | 9 | 9 |
| Reptiles | 3 | 0 | 3 |
| Bees | - | - | 1 |
| Beetles | - | - | 1 |
| Caddisflies (Trichoptera) | 31 | 2 | 33 |
| Dragonflies and Damselflies (Odonata) | - | - | 12 |
| Mayflies (Ephemeroptera) | 8 | 0 | 8 |
| Mussels | 31 | 0 | 31 |
| Stoneflies (Plecoptera) | 5 | 0 | 5 |
| Plants | 10 | - | 10 |
| **Total** | **123** | **11** | **148** |

Rivers and streams provide primary habitat for 31 species, or 86%, of SGCN fish. Fish dominate the vertebrate SGCN in rivers and streams, followed by a number of aquatic invertebrates. All but one of the 30 SGCN mussels are restricted to rivers and 87% of all the caddisfly SGCN inhabit rivers and streams. A more detailed breakdown of what size of stream and river stretches these species utilize can be found in the Fish and Aquatic Invertebrate SGCN sub-chapters. The 10 vascular plant SGCN found in these flowing waters represent only 2% of all the SGCN vascular plant flora.

## Amphibians

Three SGCN amphibians are primarily dependent on streams and rivers in Minnesota. Mudpuppies (*Necturus maculosus*) are fully aquatic salamanders that typically prefer rocky substrates and structures in medium and large rivers and lakes. This is their only habitat and is therefore critical to their survival. Blanchard's frogs are typically found along the water's edge in wetlands, lakes streams and smaller rivers in southeastern and southwestern Minnesota; rivers and streams serve as travel corridors allowing this rare frog to colonize new wetland habitat. Pickerel frogs (*Lithobates palustris*) breed in the backwaters of rivers and streams, and spend summer in clear, cool streams under dense forest canopies in southeastern Minnesota.

*Photo: Mudpuppies, Krista Larson*

## Birds

The Louisiana waterthrush (*Parkesia motacilla*) is closely tied to small streams, or less often stream channels along larger rivers, but only in mature, closed canopy forest (with a strong preference for Mesic Hardwood Forest). Louisiana waterthrushes nest in eroded stream banks and forage on small, aquatic invertebrates. Because they are a small songbird, suitable foraging microhabitat must have a shallow water interface such as small, exposed rocks, woody vegetation (e.g., small logs or dead branches), or in-stream leaf litter. Optimal streams are typically rocky, with rapids and riffles, and have good water-quality that supports the aquatic invertebrates that waterthrushes eat.

The vast majority of SGCN birds associated with rivers and streams are dependent on emergent wetlands, floodplain forests or other riparian habitats. Though not formally associated as using rivers and streams as primary or secondary habitat, many birds use rivers as habitat. For example, marshes with emergent and submergent vegetation, particularly those in large river backwaters, provide important habitat for several bird SGCN. American bitterns (*Botaurus lentiginosus*), least bitterns (*Botaurus exilis*), and common gallinules (*Gallinula galeata*) require relatively dense emergent vegetation. Black terns (*Chlidonias niger*) build floating nests anchored to emergent vegetation or on piles of rotting plant matter and require shallow open water for foraging. Birds typical of sedge wetlands, including Yellow rail (*Cotunicops noveboracensis*), Wilson's phalarope (*Phalaropus tricolor*), and Nelson's sparrow (*Ammospiza nelsoni*), can nest on relatively broad, floating sedge mats associated with the shorelines of shallow, slow-moving rivers.

## Case Study: Lower Mound Creek Restoration

The Lower Mound Creek Restoration at Blue Mounds State Park entailed removal of an old dam after it had failed and restoring the stream and adjacent prairie. It has been a successful multi-disciplinary approach to improve watershed health including biology, hydrology, connectivity, water quality and geomorphology. Species in Greatest Conservation Need were a key consideration, including Topeka shiner and plains topminnow, which have returned to this section. When their requirements are incorporated, similar restorations can benefit other SGCN of the Prairie Coteau that co-occur in streams such as Blanding's turtle, Blanchard's cricket frog, and pondmussel (*Sagittunio subrostratus*). There are many other "stackable" benefits for the ecosystem and for humans. This DNR video gives an excellent overview from several perspectives.

*Photo: Plains topminnow, Andrew Herberg*

## Fish

The redside dace (*Clinostomus elongatus*), a fish species in greatest conservation need, is most abundant in clear, spring-fed, coldwater streams. It typically occurs in pools with moderate current and overhanging vegetation and spawns in riffles or shallow flowing pools. Another fish SGCN, the plains topminnow (*Fundulus sciadicus*), is also most common in headwater streams of high water quality but does not require cold water.

The largescale stoneroller(*Campostoma oligolepis*), black redhorse (*Moxostoma duquesni*), and greater redhorse (*Moxostoma valenciennesi*) are all found in moderate-sized warmwater streams. Largescale stonerollers require clear water with moderate to swift current, often in deep, fast riffles. They require gravel bottoms and are intolerant of siltation, as they feed by overturning small stones, hence the name stoneroller. Black redhorses prefer pools with gravelly to rocky, occasionally sandy and silty, bottoms. They spawn in gravel and fine rubble runs and riffles in water about 8 - 24 inches (20- 60 centimeters) deep. The greater redhorse also requires clear water with moderate to fast-flowing currents, and clean sand or gravel substrates.

The least darter (*Etheostoma microperca*) occurs in moderate to large warmwater streams, as well as large, deep lakes. It prefers heavily vegetated areas with sluggish flow, immediately downstream of pools in the spawning and growing season and overwinters in the deep water of pools.

The crystal darter (*Crystallaria asprella*) occurs in large to very large, warmwater rivers. It is usually in water more than 24 inches (60 centimeters) deep with strong current, and along expanses of clean sand and gravel, where it buries itself in sand with only its eyes protruding.

## Mammals

No SGCN mammals were formally associated with riverine habitat (but see Riparian and Floodplain Forest sub-chapter).

## Mussels

Twenty-two of Minnesota's 48 native freshwater mussel species exclusively or primarily occur in large river systems. Many of these mussel species are presently restricted to the lower St. Croix River and the Mississippi River below St. Anthony Falls, where water quality, flow regimes and/or substrates such as boulders or gravel beds are present in sufficient quality and quantity to allow for their persistence. Freshwater mussel diversity typically declines as streams become smaller due to mussel life history characteristics like host fishes utilized. Only three mussel species are typically strongly associated with small streams. One example is the creek heelsplitter (*Platynaias compressa*), found in headwater to moderate sized, warmwater streams. It is usually found in swift currents with a substrate of sand, fine gravel and mud, often downstream of riffles in small pools. Most others are generalists, occurring across stream sizes with only a few occurring predominantly in medium sized rivers (Hornbach et al. 2024).

## Case Study: Reconnecting the Pomme de Terre River

The Appleton Milldam, built in 1872, cut off connectivity within the Pomme de Terre River, and the Marsh Lake Dam separated the lower Pomme de Terre River from the Minnesota River. Over a century later, these dams were no longer providing the benefits they once had. A series of dam removal, channel rerouting, and dam modification projects between 1999 and 2018 reconnected these divided waterways. Ten native mussel species have recolonized the historical river channel and abundances of five species appear to be increasing. An earlier restoration project on the Pomme de Terre River in 2001-2005 involved channel stabilization after the Appleton Dam washed out. Since that time, state threatened elktoe mussels (*Alasmidonta marginata*) were documented for the first time upstream of the dam and have expanded their distribution in the Pomme de Terre River 30 miles upstream to the next dam near Morris. This further highlights the importance of river connectivity to aquatic animals. For more details, see Reconnecting the lower Pomme de Terre River

*Photo: Young deertoe mussels from reconnected section of the Pomme de Terre River*

## Reptiles

Many reptiles rely on a combination of upland and stream habitats to complete their life cycles. Blanding's turtles prefer calm, shallow wetlands associated with rivers and streams as their primary habitats. Fluvial outwash plains, such as those in the Driftless Area along the Mississippi River, provide nesting habitat for Blanding's turtles while the flowing waters are important travel corridors and, where open wetlands are scarce, may be used as overwintering sites. Wood turtles (*Glyptemys insculpta*) hibernate in small to medium fast-moving rivers and streams with sand and gravel substrates, nest on undisturbed sandy banks and spend much of their time in nearby upland forests. Smooth softshell turtles (*Apalone mutica*) require large, unpolluted rivers with sand substrates for their complete life cycle. Sandbars within or along the river's edge provide essential nesting habitat. Lakes are avoided, as are rivers with muddy substrates.

## Plants

There are a wide variety of plant SGCN dependent on rivers and streams. For example, small white waterlily (*Nymphaea leibergii*) is found in slow-moving streams, especially those impounded by beaver dams, and is suspectable to being choked out by invasive aquatic plants. Glade mallow (*Napaea dioica*) found in forests on the banks of small to medium-sized streams, is also directly tied to stream health. Encroachment of its stream-side habitat by reed canary grass is a major threat to this species, and natural flooding processes seem to be necessary for seedling establishment. Similarly, sessile-flowered Yellow Cress (*Rorippa sessiliflora*) is a very rare annual plant dependent on the natural rising and falling of the Minnesota and Mississippi rivers to expose and maintain its very specialized mud flat habitat.

## Climate Spotlight: Blanding's Turtle

This profile is excerpted from "Effects of Climate Change on Midwestern Ecosystems: Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland" published by the USGS Midwest Climate Adaptation Science Center (Ratcliffe et al. 2025).

Blanding's turtles are long-lived, semiaquatic freshwater turtles found across the northern and eastern United States and southern Canada. In the Midwest, their reliance on a variety of aquatic and upland habitats during their annual activity cycle, combined with low thermal tolerance, make them potentially vulnerable to both the direct and indirect effects of climate change (Lyons and others, 2023, p. 202). Of all North American freshwater turtles, Blanding's turtles have the lowest critical thermal threshold, and summer maximum temperatures are increasingly likely to exceed this threshold, reducing foraging time (Lyons and others, 2023). Warmer winters and increasingly variable freeze-thaw conditions may also increase mid-winter movements, raising energy demands during a time when food is scarce (Newton and Herman, 2009). Additionally, temperature fluctuations may prompt premature emergence from overwintering sites (Markle and Chow-Fraser, 2014).

Climate change also poses risks to Blanding's turtle reproduction. Higher temperatures during incubation are likely to skew hatchling sex ratios toward females if not compensated by selecting cooler, shaded nest sites or nesting earlier in the season (Gutzke and Packard, 1987). More frequent extreme precipitation events may increase nest failure due to flooding, while drought may hinder nest construction, cause nest collapse, or increase embryo and hatchling mortality through desiccation (Congdon and others, 2000).

Blanding's turtles depend on freshwater ponds, bogs, and marshes for overwintering and foraging and upland, well-drained sites with sparse vegetation for nesting. In the Midwest, these aquatic habitats are likely to face growing effects from more frequent and intense cycles of drought and deluge. Prolonged summer dry periods may reduce foraging habitat, leading to food shortages and increased movement in search of suitable conditions (Hall and Cuthbert, 2000).

These movements during low water periods may increase mortality risk due to road collisions (Ruane and others, 2008) and heightened exposure to predators (Gasbarrini and others, 2021). While some degree of behavioral plasticity, such as earlier nesting or shorter incubation periods, may buffer against these risks, additional adaptive management strategies will likely be necessary, including the installation of turtle road crossings and the implementation of head-starting programs, which raise hatchlings in captivity through their most vulnerable early stages before releasing them into the wild.

*Photo: Blanding's turtles, Julia Geschke*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Straightening and ditching rivers and streams has been done to try to contain the footprint of riverine systems to make space for urban and other forms of development (see also Dams and Water Management and Use). Built infrastructure, such as rip-rap, can impede movement by animals such as turtles, even trapping them, and also can diminish the extent and replenishment of sandy areas used by nesting turtles. Development results in habitat loss and habitat fragmentation along rivers, as well as an increase in roads and trails.

### Crop Production

Some areas of crop production depend greatly on groundwater appropriation to sustain improved and reliable crop yields. These areas may also influence flows and water levels of rivers and streams that provide critical habitat to a variety of species. Direct surface water appropriation may also be used for crop production which more immediately affects water levels and flows of the surface water. Reduction in flows and water levels during critical times of the season, such as August, may affect certain species sensitive to warmer water temperatures and reduced habitat.

Runoff from cropland can bring sediments, excess nutrients, and chemicals into streams and rivers. Drainage from fields reduces the natural absorption of the landscape for heavy rain events and increases sheet flow. Agricultural practices such as the installation of wells or drain tile can also change the flow of groundwater to streams and are often associated with straightening of the channel (Blann et al., 2009). These changes result in flashy hydrology and incised channels that cause streams to function poorly (Blann et al., 2009). Smaller headwater streams are disproportionately affected by agricultural practices (Wohl, 2017).

### Livestock Management

Cattle grazing in streams and rivers can cause erosion, reduce habitat quality by trampling and grazing, and degrade water quality (O'Callaghan et al., 2019). Livestock effluent in proximity to streams can introduce E. coli into the water. Large livestock production facilities can also affect groundwater resources and surface waters (flow, water levels) depending on the source of water being used.

## Mining and Quarrying

Potential mines near and potentially within rivers pose pollution and sedimentation risks to water quality within rivers.

## Roads, Trails, and Railroads

Roads, trails and railroads can be a source of erosion, pollution, and reductions in connectivity. Reductions in connectivity are due to crossing structures, such as culverts, that can be insufficiently sized, poorly placed, improperly installed, or sedimentation. These factors prevent regular access and movement for aquatic species such as fish. Many riverine wildlife species, especially turtles, are often compelled to cross roads, trails and railroad tracks which interrupt their natural movement paths in the proximity of river corridors. Nesting females are particularly vulnerable during these movements; they are frequently drawn to road edges and adjacent areas for nesting, significantly increasing their risk of fatal encounters with vehicles (Steen et al., 2006). Studies have found that adult females suffer disproportionately from road mortality, leading to skewed sex ratios and diminished reproductive output in turtle populations (Steen et al., 2006; Gibbs & Shriver, 2002). Because female turtles are long-lived and mature slowly, even modest increases in adult mortality can have long-lasting negative effects on population viability (Steen et al., 2006; Piczak, Markle, & ChowFraser, 2019). Another concern, according to the Minnesota Pollution Control Agency, is chloride, as de-icing salts dispersed on roadways increase the salinization of rivers.

## Shipping Lanes

The maintenance of shipping lanes, including locks and dams, create stressors on the natural movement of sediments, nutrients and organisms in the Mississippi River. Dredging of the channel creates a constant disturbance that prevents natural channel formation, movement and sediment transport. Dredging activities can actively remove and prevent freshwater mussels from colonizing an area and impede the presence of dense mussel beds that aid in stabilizing the river bottom, provide habitat for macroinvertebrates and fish, and filter the water (Vaughn, 2018). Nutrient cycling is reduced because levees keeping the river in the navigation channel under most flow conditions limits access to floodplain habitats that offer an exchange of terrestrial and aquatic nutrients (Schramm et al., 2015). Impounded sections of river upstream of locks and dams trap sediment and create warmer water temperatures (Poff and Zimmerman, 2010). Wakes and turbulence from barges can cause excess sedimentation (Spear et al., 2024).

*Photo: Mucket, a species of freshwater mussel*

## Hunting and Collecting Animals

Illegal collection of threatened and endangered species, such as wood turtles, is a concern along rivers, particularly as roads, trails and development increase access to the rivers creating the opportunity for illegal collection to occur.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive

effects for some species and negative effects for others. Runoff from timber harvest sites may introduce sediments into waterways including streams and rivers, particularly if riparian buffer areas are not scaled appropriately. Loss of riparian canopy along streams can result in increased stream temperatures. In northern Minnesota, timber harvest has shifted the forest composition along rivers from later successional, older pine forest to early successional, younger aspen forest in many areas. Managing for early-successional habitat like aspen can increase the presence of beavers in rivers and streams. Downed large diameter trees in rivers are very important for providing habitat for aquatic wildlife. These trees can be lacking if adequate riparian buffers are not implemented.

## Fishing

The potential for ingestion of lead fishing tackle (Getting lead out of fishing tackle), entanglement in fishing line and lures, and unintentional capture poses a threat to wildlife in Minnesota rivers and streams.

## Recreation

Recreational use on sandbars and beaches can disturb sand-nesting SGCN (i.e., ATVs, picnicking, bonfires, party beaches). These activities can destroy nests and attract predators to nest sites. Increased recreation also increases the chances of illegal collection of listed species.

Boat wakes from recreational boaters have the potential to create large waves that can erode shorelines and re-suspend sediments that increase turbidity (Lorenz et al., 2013, Marr et al., 2022, Spear et al., 2024).

Recreational use can contribute to the introduction of problematic non-native invasive plants and animals through incomplete decontamination of footwear or gear, including boats.

## Fire Management

Historically, fires may have helped create openings in forests and riparian areas along rivers, creating nesting habitat for turtles.

## Dams and Water Management

Dams, culverts, bridges and levees impede the free flow and hydrologic connectivity of riverine habitats. Hydrologic connectivity refers to the flow, exchange and pathways that carry water and move organisms, energy and matter throughout the watershed system. These interactions create complex, interdependent processes that vary over time. When these stream processes are interrupted, the effect on aquatic biota is far-reaching. Examples include the complex relationship between fish migrations and the mussel populations that are dependent on the presence of a specific host fish. When fish migrations are limited, mussel dispersal and persistence can be negatively affected.

Straightening and ditching rivers and streams has been done to try to contain the footprint of riverine systems to make space for development. Around 50% of Minnesota's streams and rivers have been altered from free-flowing systems into ditched, straightened or drained systems. This extreme level of alteration changed these river systems from natural meandering streams with complex habitats into simplified channels that move water quickly off the landscape, removing aquatic habitats, limiting water storage and increasing erosion.

Large rainfall events cause large flows of water to enter the river and spill out over the riverbanks and into the floodplain. These pulses of water are important for creating sand/gravel points, maintaining riparian habitat, and terrestrial-aquatic nutrient exchange. When large portions of a watershed are developed or managed as young forest, the natural dynamics of rivers are altered resulting in increased volumes of water running into the

river. This can lead to erosion of the riverbed and banks, with slopes becoming steep enough to disconnect the river from its floodplain. The energy of floodwaters then becomes concentrated within the river's banks, causing sand points and gravel bars to wash away. All these effects are worsened when stream channels are artificially straightened. These changes can fundamentally change the river and its habitat (Blann et al., 2009).

## Invasive Species (Problematic Non-native Species)

Invasive carp including bighead (*Hypophthalmichthys nobilis*), silver carp (*H. molitrix*), black carp (*Mylopharngodon piceus*) and grass carp (*Ctenopharyngodon idella*) are a threat to native ecosystems, local economies and recreation. Minnesota has acted as a sink for the invasive carp populations that are reproducing further downstream, and the movement of invasive carp into Minnesota appears to be dependent on river connectivity (Fritts et al., 2024). When dams are open or are passable, invasive carp move further upstream. Although reproduction has not yet been documented in Minnesota, monitoring data indicate that invasive carp abundance has increased in recent years. The DNR has recently updated its statewide Invasive Carp Action Plan (DNR, 2024) to identify priority actions to prevent and manage invasive carp.

Sea lamprey is an invasive species that reproduce in fast-moving waters, specifically in tributaries to Lake Superior. To reduce their impacts on native and desirable fish such as lake trout, the Great Lakes Fishery Commission (GLFC) and the U.S. Fish and Wildlife Service (USFWS) maintain a sea lamprey control program (GLFC, 2025). This program focuses on treating spawning streams to eliminate larval sea lamprey and maintain strategic barriers that prevent the species from expanding its spawning range. When considering the removal or modification of dams or other structures to improve passage for aquatic organisms, it is essential to evaluate whether those barriers also serve as critical controls for sea lamprey movement.

## Problematic Native Species

Reed canary grass (*Phalaris arundinacea)* is a hardy, aggressive, cool-season grass that can form dense, single-species stands in wetlands. Previously considered an invasive species, recent research suggests that reed canary grass found in Minnesota is predominantly native. It can outcompete other native wetland species, posing challenges for wetland restoration and mitigation efforts.

## Water-borne Pollution

Nonpoint source pollution is pollution that comes from many diffuse sources (like pollution from many agricultural fields) and includes phosphorus, nitrogen, sediment, bacteria and other contaminants, in part. Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. As runoff flows, it picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, groundwater and estuaries (EPA NPS Webpage). These nonpoint source pollutants represent the largest combined contribution (an estimated 86%) to the state's water pollution (MPCA Water Quality Initiatives). Water quality measured by nutrients and contaminants has been shown to decline with higher agricultural or urban development in the watershed. Some key effects include excess algal growth, reduced plant diversity and reduced diversity in fish and invertebrate communities (DNR Water quality non-point sources).

Polyfluroalkyl Substances (PFAS) and Polychlorinated biphenyls (PCBs) are human-made chemicals that are both banned in Minnesota, but persistent in the environment. PFAS may get into rivers from industrial discharge, leaching from landfills into groundwater and from firefighting foam products. The specific effects of these

pollutants on wildlife are poorly known, but their presence is documented in many riverine fish and the Minnesota Department of Health has fish consumption guidelines due to contaminated fish (Rivers Waterbody Specific Guidelines April 2025).

Mercury is emitted into the atmosphere and moves long distances with wind and weather and can deposit in aquatic systems like rivers. Mercury contamination is prevalent in aquatic food webs and bioaccumulates, causing species higher on the food chain, like large fish, to accumulate elevated mercury concentrations. As a result, fish in many of Minnesota's rivers have concerning levels of mercury (Rivers Waterbody Specific Guidelines April 2025).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce, 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

Looking ahead, this warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Low water levels due to frequent and prolonged droughts are forecast to affect Minnesota streams as the climate continues to change. Warming summer air temperatures will likely cause many streams to become warmer, especially during times of low water. Impounded stream reaches associated with dams may be disproportionately affected by these warming temperatures (Climate trends affecting lakes and rivers, Minnesota DNR). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Fish spawning habitat can be disturbed by the sedimentation caused by such high flow events and species like turtles may be killed, washed downstream, buried under sand, or experience nest failure (Climate trends affecting lakes and rivers, Minnesota

DNR). The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

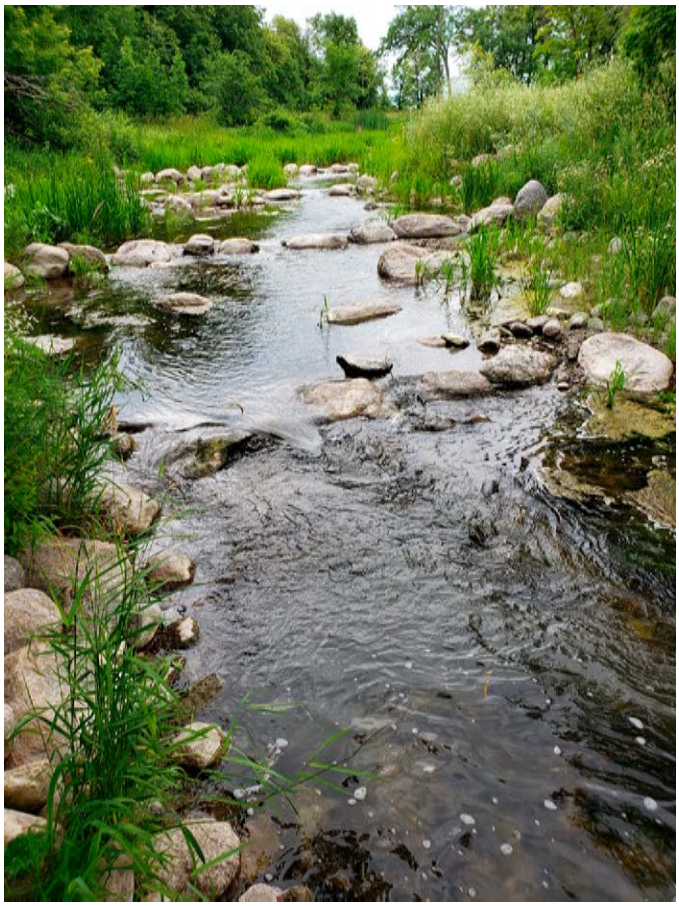

*Photo: Fish passage project, Lost River, Red Lake Watershed District, Nicholas Kludt*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are prevalent as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Rivers and Streams

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Look for opportunities to restore or protect (acquisition, conservation easements, use designations) key river or stream reaches. Consider the following criteria in prioritizing project areas: rivers and streams that lack or have limited barriers to aquatic organism passage or with high potential for restoration; Rivers/streams with significant groundwater inputs; Rivers/streams with intact floodplains, meanders and potentially associated oxbows; Rivers and streams with documented SGCN are necessary for SGCN population connectivity, genetic exchange and climate resiliency. |
| | Since many animals require both upland and stream habitats for their life cycles, it is essential to keep these physical habitats connected. Protect habitats along river corridors to allow movement of wildlife and facilitate movement of nutrients and energy between the stream and surrounding landscape. Management options include near shore riparian corridor conservation and habitat restoration to improve longitudinal as well as lateral connectivity. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Support the removal of dams or replacing or upgrading dams with structures that allow better passage of aquatic organisms such as fish, turtles, amphibians and mussels that will assist in the health and connectivity of free-flowing rivers. |
| | To protect and enhance water quality parameters such as sediment loads and chemical pollution, options include improved stormwater systems, water filtration ponds, soil erosion control techniques and point - nonpoint source pollution abatement. Create and maintain vegetated buffers comprised of locally native vegetation adjacent to waterways to reduce water-borne pollutants entering bodies of water. Minimize mowing, burning, grazing or chemical application in the buffers. |
| | Culvert replacement with larger capacities and naturalized bottoms will maximize aquatic habitat connectivity and can hold up with resilience under future climatic conditions that entail heavier spring rain events. Where indicated, include other tested means to improve wildlife connectivity such as passage benches, J-fencing, wing walls and other measures (Hernick et al., 2019, DNR/MNDOT, 2014). |
| | Restore sinuosity to rivers and streams that have been previously straightened with considerations for SGCN in both restoration design and during the construction process to avoid or minimize adverse effects. Advocate for maintenance of natural flow regimes. |
| | Map drain tile and wells to better understand and document hydrological changes in groundwater levels, flow, and inputs to streams. Consider new agricultural practices such as irrigating from below with agri-drains installed on drain tiles to reduce hydrological effects on streams. |
| | Experiment with control methods for reed canary grass (native and non-native) to maintain open areas along rivers used for nesting by SGCN. |
| | Develop and implement better stream management and restoration designs that will be resilient under the higher flows from heavier and more prolonged rainfall events as well as maintain flow during late summer droughts. |
| | Implement riparian restoration that increases shade on streams to ameliorate the effects of ambient temperature increases. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Watershed scale restorations involving multiple landowners are complex and expensive but necessary. |

| Stressor | Action |
|---|---|
| | Incentive programs, technical assistance and outreach to livestock producers to reduce effects of cattle in stream and river corridors, such as providing alternative water access and partnering on riparian habitat restoration. Successful programs will entail long-term relationships among farmers and cattle producers, increased technical guidance at the community level and a support network that goes beyond governmental participants. |
| | Best management practices, mitigation and cross-training and increased collaboration within and among agencies can normalize expectations of aquatic habitat connectivity and reduce the effects of roads and road crossings on riverine water flow and quality. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Continue monitoring of rivers and streams, including the Index of Biological Integrity program. Supporting collaborative research projects that aim to identify the conditions that enable SGCN to thrive. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Outreach, education and sharing success stories about dam removals or upgrades can help overcome the fear of change and the sense that the dams cannot be removed, upgraded or enhanced. |
| | Provide technical assistance and incentives to support best management practices and the maintenance of native vegetation in riparian areas. |
| | Education and outreach campaigns encouraging fewer chemical inputs to yards and lawns and other municipal practices to minimize pollutants are warranted. |
| | Incentivize agricultural practices that create and maintain buffers around streams, reduce erosion and runoff and increase soil organic carbon to reduce sedimentation into streams. |
| | Promote best management practices for timber management near riparian zones, assuring sufficient buffer areas and that woody material is left intact in riparian and in-stream locations. Contribute to MFRC Forest Management Guideline revision processes by providing up-to-date literature to support science-based guideline updates. Consider prioritizing riparian forests – those adjacent to rivers and streams – for management aimed at maintaining older forest conditions. |
| | Develop and share educational materials to alert recreational users of sandbars and beaches when there may be sand-nesting SGCN present, such as shorebirds and turtles. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# LAKES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Lakes

## Habitat Description

Lakes are iconic and ecologically important in Minnesota, numbering over 11,800 at least 10 acres in size. Glacial activity formed most of Minnesota lakes (Schwartz & Thiel, 1954) with the physical characteristics of each individual lake differing based on factors including the local geology and hydrology at each site. Lakes vary from shallow to 280 feet deep for Lake Saganaga — Minnesota's deepest inland natural lake. Lake Superior is 1,290 feet deep. Minnesota has several other very large lakes: Lake of the Woods (950,400 ac, shared with Canada), Upper and Lower Red Lake (288,800 ac), Mille Lacs (132,516 ac), and Leech Lake (111,527 ac) (Lakes, Rivers, and Wetlands Facts). There are many ways to classify lakes but for simplicity, here we categorize lakes based on depth.

## Deep Lakes

Here, we use 'deep lakes' to refer to water bodies greater than 15 feet (5 meters) deep. Deep lakes vary in productivity, ranging from low productivity northeastern Minnesota lakes with clear water, cold temperatures and minimal aquatic vegetation to high productivity southern Minnesota lakes with high nutrient concentrations, low water clarity and lesser amounts of rooted aquatic vegetation or dominated by filamentous or planktonic algae. A combination of factors related to climate, geology, hydrology, land use and land cover results in the general trend of lakes increasing in water clarity and decreasing in productivity and alkalinity from southwestern to northeastern Minnesota. Communities of fish and other aquatic organisms also vary along this distribution of lake types in Minnesota (Schupp, 1992).

The close association between aquatic plant communities and fish communities is well recognized. Aquatic plants provide food and oxygen, shelter and spawning areas and improved water quality for fish. Plants also provide excellent food and habitat for zooplankton, insects, waterfowl and other wildlife. Aquatic vegetation also anchors sediments, maintaining water clarity. Radomski and others (2019) provides a short synthesis of the scientific studies and management of aquatic plants to highlight lake vegetation management actions that may benefit fisheries.

Deep, thermally stratified lakes with abundant dissolved oxygen throughout the water column are especially threatened in Minnesota. These lakes are commonly referred to as Coldwater Lakes. They support cold-adapted fish species, including lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), cisco (*C. artedi*) and burbot (*Lota lota*). In Minnesota, there are about 1000 lakes that support these coldwater fish communities. In northeast Minnesota, these lakes also support a variety of isoetids plant species, which are submerged aquatic plants that are slow-growing, evergreen, and forming basal rosettes, such as quillworts (*Isocetes* spp.), which are unique to these low nutrient coldwater lakes. Eutrophication (excessive nutrients) and climate change is reducing the number of lakes that support these two communities.

*Photo: Teal Lake, Grand Portage Indian Reservation, Beau Liddell*

## Shallow Lakes

There are an estimated 4000 shallow lakes in Minnesota, permanent or semi-permanent water bodies less than 15 feet (5 meters) deep at the deepest and over 50 acres (20 hectares) in size (see DNR's Shallow Lakes Program). These lakes are typically dominated by wetland habitat (see also Non-forested Wetlands sub-chapter). While shallow lakes can support fish populations, often low levels of dissolved oxygen in winter limit their numbers.

Shallow lakes may have abundant aquatic plant growth due to sunlight reaching much of the lake bottom in these basins. Stands of emergent and floating-leaved aquatic plants such as cattails (*Typha* spp.), bulrush (*Schoenoplectus* spp.), bur-reeds (*Sparganium* spp.) and water lily (Nymphaeaceae), as well as submerged plants such as stoneworts (Characeae), coontail (*Ceratophyllum* spp.) and pondweeds (*Potamogeton* spp.), may be present throughout the entire basin. These plants provide excellent food and habitat for zooplankton, insects, fish, waterfowl and other wildlife. Aquatic vegetation also anchors sediments, maintaining water clarity.

Shallow lakes are dynamic ecosystems that often express considerable ecological variability. Nutrients in shallow lakes, unlike in deeper lakes, are regularly mixing. Shallow lakes do not thermally stratify for long periods of time so there is a constant exchange of nutrients between the sediments and water column. Wave action also can often reach the bottom of the lake, suspending sediments in the water. Droughts lower water levels in shallow lakes resulting in exposed sediments. This exposure stimulates beneficial aquatic plant growth. Low water levels can produce conditions for fish winterkills that can decrease or eliminate fish populations. Such low water cycles have been affected by higher levels of precipitation and watershed alterations including draining of wetlands into larger water bodies. Persistent and high water levels restrict plant growth and reduce water quality, allowing significant algal growth. Milder winters also favor fish such as bullheads (*Ameiurus* spp.) and common carp (*Cyprinus carpio*), which in shallow lakes can reduce water quality and diminish the abundance of rooted aquatic plants.

Some shallow lakes can support wild rice (*Zizania palustris*, also known as *manoomin*), designated as a SGCN plant in this Plan due to cultural significance to many of the Tribal Nations in Minnesota. *Manoomin* is harvested traditionally each fall. Minnesota supports more acres of wild rice than any other state in the country. Wild rice has been historically documented in 45 of Minnesota's 87 counties and is thought to have been even more broadly distributed prior to European settlement (see Wild Rice Management).

*Photo: Encountering dense wild rice on a shallow lake survey in Beltrami County, Amy Westmark*

## Habitat Map

To depict Lake and Lakeshore habitat (see Figure 3.17), we compiled spatial data from several sources: Shallow Lakes Identified by DNR Wildlife, Lake Basin Morphology, the National Wetland Inventory, and the DNR Native Plant Community Layer (for more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological Systems

### Lakeshore (LK)

LKi32 Inland Lake Sand/Gravel/Cobble Shore (PDF)

LKi43 Inland Lake Rocky Shore (PDF)

LKi54 Inland Lake Clay/Mud Shore (PDF)

LKu32 Lake Superior Sand/Gravel/Cobble Shore (PDF)

LKu43 Lake Superior Rocky Shore (PDF)

## National Wetlands Inventory

From the National Wetland Inventory for Minnesota (NWI) Layer we included only the Non-Vegetated Aquatic Community type from the Simplified Plant Community Classification attribute field.

## Lake Basin Morphology

We included all lakes identified by the Lake Basin Morphology layer.

## Shallow Lakes Identified by DNR Wildlife

We included all Lakes identified in the Shallow Lakes Identified by DNR Wildlife layer.

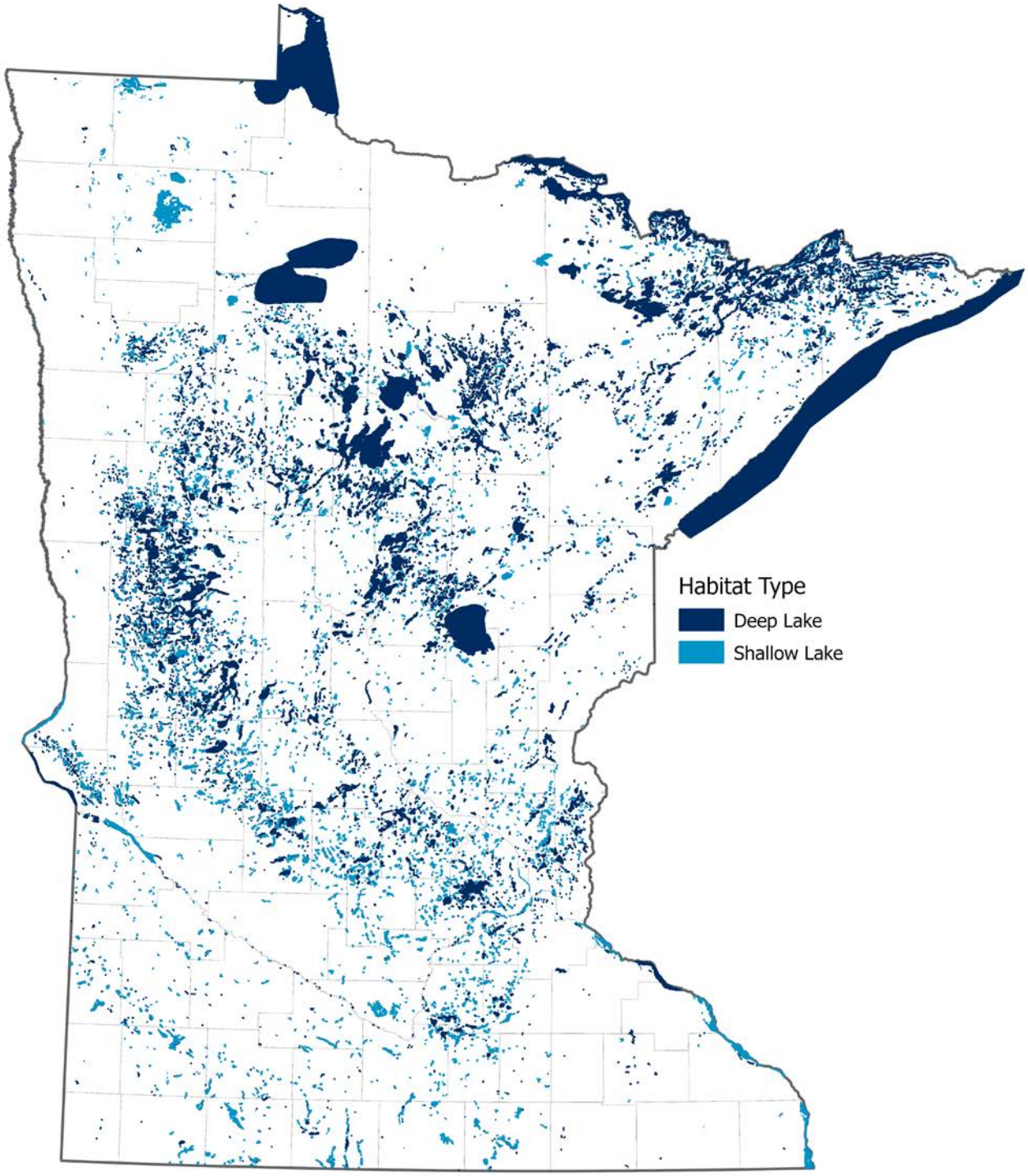



Figure 3.17. A map depicting Lake habitat in Minnesota including Non-Vegetated Aquatic Communities from the National Wetland Inventory for Minnesota as well as all lakes from the Shallow Lakes Identified by DNR Wildlife and the Lake Basin Morphology layers. Lakeshore habitat is not depicted in the map but is included in the data.

## Conservation Overview

Minnesota's lakes receive considerable recreation and development, and are faced with threats from invasive species, shoreline alteration, altered hydrology, eutrophication and other pollution and climate change. Minnesota lakes face serious changes due to human alteration of land, water and air. Shorelines are altered by lakeshore property owners. Minnesota has currently lost 40 to 50% of its natural shorelines, and the rate of loss is estimated to be 1 to 2% per decade (Minnesota Natural Shoreline Partnership, 2023). As a lake's watershed becomes more developed, nutrient levels increase and water quality decreases due to pollution runoff, poor stormwater management, and shoreline phosphorus pollution from subsurface sewage treatment systems (septic systems). Nutrients reaching lakes from this pollution result in eutrophication, where lakes receive surplus nutrients which can result in excessive plant and algal growth. Agricultural lands shed large amounts of sediment and pollution and can contribute to lake water quality impairments. These lands are also drained with ditches and tiling, and thousands of acres of Minnesota's shallow lakes have been affected.

Recreation can be problematic in lake ecosystems. Boating in or near shallow water suspends lake sediments, destroys aquatic plants and erodes shoreline, especially when shoreline vegetation is removed and replaced with lawn down to the lake. Boat strikes can kill wildlife; species like turtles and loon chicks are particularly vulnerable. Fish stocking has altered the native aquatic faunal communities, and homogenized fish assemblages in Minnesota lakes (Radomski & Goeman, 1996). Aquatic vegetation can be affected by docks and shallow water disturbance (Radomski et al., 2010). Aquatic vegetation loss for north central Minnesota lakes was estimated at 15% (Radomski, 2006). Lead, a toxic element, is extensively used in fishing tackle. In popular angling lakes, tackle loss results in many metric tons of lead across lake bottoms annually (Radomski et al., 2006). Waterbirds ingest this lead, which is often lethal. Additionally, other tackle and discarded fishing line can entrap wildlife.

Several invasive aquatic species are present in many Minnesota lakes, moved among lakes by gear and watercraft. The invasive aquatic plants Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) have been present in Minnesota lakes for decades. Eurasian watermilfoil can grow to the water surface and compete with native plants. Several invasive aquatic animals also occur in many Minnesota lakes, including common carp and zebra mussels (*Dreissena polymorpha*). Common carp is widely distributed in central and southern Minnesota; this fish severely affects shallow lakes as their feeding habits uproot aquatic plants and suspends fine sediments into the water. Zebra mussels filter the water, which reduces food for larval fish and other animals and increases water clarity. Zebra mussels can change the food web and reduce the carrying capacity for popular fish such as walleye (*Sander vitreus*) (Infested Waters List).

Air pollution also degrades Minnesota lakes, including a range of chemicals such as mercury primarily from coal burning, pesticides via drift from farm and residential lands, microplastics and nanoplastics via wind and waves moving broken down plastic waste fragments, and greenhouse gases via combustion of coal and gas. Mercury bioaccumulates and biomagnifies through lake food webs, which affects wildlife and human health as a potent neurotoxicant (Mercury, Minnesota Pollution Control Agency). Fish from lakes in the northeast generally have the higher mercury concentrations (Radomski et al., 2024). Of particular concern, due to the magnitude of change, is climate change from burning fossil fuels. In Minnesota, lakes now have warmer water and shorter ice cover seasons. Fish communities are changing; those changes and other widespread environmental changes are anticipated to accelerate under future emissions scenarios (Climate trends affecting lakes and rivers).

## Species in Greatest Conservation Need

Lakes provide habitat for 87 animal and 36 plant SGCN as primary or secondary habitat (see Table 3.16). Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for most insects were not differentiated into primary and secondary habitats and are shown in the total column. Plant species were only associated with their single most primary habitat. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D (animals) and Appendix E (plants). Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

**Table 3.16. Numbers of Species in Greatest Conservation Need associated with lakes as either primary or secondary habitat.**

| Species Groups | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 2 | 1 | 3 |
| Birds | 18 | 6 | 24 |
| Fish | 8 | 3 | 11 |
| Mammals | 0 | 9 | 9 |
| Reptiles | 1 | 0 | 1 |
| Bees | - | - | 4 |
| Beetles | - | - | 2 |
| Caddisflies | 12 | 3 | 15 |
| Dragonflies and Damselflies | - | - | 13 |
| Mayflies | - | - | 2 |
| Mussels | 1 | 0 | 1 |
| Snails (aquatic) | 1 | 0 | 1 |
| Spiders | - | - | 1 |
| Plants | 36 | - | 36 |
| **Total** | **79** | **22** | **123** |

## Amphibians

The mudpuppy (*Necturus maculosus*) is Minnesota's only fully aquatic salamander and is restricted to medium or large rivers and lakes (primarily in deep lakes but secondarily with shallow lakes). Lakes may be used more often in western Minnesota than farther east. Submerged rocks or logs provide cover and important breeding habitat. Eastern newt (*Notophthalmus viridescens*) occupies shallow lakes and will be threatened by a pathogenic fungus if or when it arrives to North America. Blanchard's cricket frog (*Acris blanchardi*) may utilize lakes, particularly when they are fed, or are near, rivers and streams. Large, deep lakes, even with predatory fish, may be used but generally only if they are associated with a river or stream.

## Birds

Of 24 SGCN bird species using lakes, 8 are primarily limited to shallow lakes such as the American bittern (*Botaurus lentiginosus*), common gallinule (*Gallinula galeata*) and Wilson's phalarope (*Phalaropus tricolor*). Together, the 22 bird SGCN utilizing lake habitats represent 28% of all bird SGCN.

Both shallow and deep lakes are well recognized for their importance to waterfowl and other waterbirds. Many of these species will use open water during migration, as well as for foraging and loafing during the breeding season. However, most SGCN waterbirds require emergent vegetation, or in some cases islands or other shoreline habitat, for nesting.

Waterfowl species, such as the American black duck (*Anas rubripes*), canvasback (*Aythya valisineria*) and northern pintail (*Anas acuta*) nest in emergent marsh or grassland vegetation adjacent to lake shores or open water in marshes. Buffleheads (*Bucephala albeola*), restricted to far northwestern Minnesota during the breeding season, are cavity-nesters. American bitterns, least bitterns (*Ixobrychus exilis*) and common gallinules require relatively dense emergent vegetation, so only nest on portions of shallow lakes with suitable marsh vegetation. Four SGCN grebe species (Horned (*Podiceps auritus*), red-necked (*Podiceps grisegena*), eared (*Podiceps nigricollis*) and western (*Aechmophorus occidentalis*)), plus Franklin's gulls (*Leucophaeus pipixcan*), black terns (*Chlidonias niger*) and Forster's terns (*Sterna forsteri*), build floating nests anchored to emergent vegetation, or on platforms or piles of vegetation. Franklin's gulls are commonly observed when migrating and during the breeding season, but only nest in very large colonies on one or two large, marshy lakes in northwestern Minnesota.

*Photo: Canvasback ducks, Julia Geschke*

American white pelicans (*Pelecanus erythrorhynchos*) nest on higher portions of shore habitats, typically on treeless islands, but feed or loaf on a wide variety of lakes and marshes. Black-crowned night herons (*Nycticorax nycticorax*) are a colonial-nesting species that forages along shorelines and in marshes. In Minnesota, they usually nest either in trees on islands, or (less commonly) on floating platforms of marsh vegetation.

During migration, many shorebird species use lake shoreline communities as resting and feeding sites. Two SGCN shorebirds do not nest in Minnesota but solely occur in the state as migrants. The red knot (*Calidris canutus*) is a relatively rare migrant, most often found on sand beaches of Lake Superior (particularly those on Minnesota Point). They can also be found, very rarely, on beaches or other types of shorelines away from Lake Superior. Buff-breasted sandpipers (*Tryngites subruficollis*) are

a migrant most often found in open uplands with very short or sparse vegetation. When they are in areas associated with lake shores they do not occur at the water-shoreline interface (wave zone), but may use higher, drier portions of shore habitats.

The Wilson's phalarope is a shorebird species that nests in Minnesota, often associated with sedge or grass dominated wetlands such as rich fen and wet prairie. Suitable nesting habitat includes relatively wide, floating sedge mats associated with the shorelines of lakes and rivers. Breeding sites include the shores of large, deep lakes (e.g., Lake-of-the-Woods and Leech Lake). Phalaropes are more aquatic than most shorebirds, frequently feeding while swimming in open water, usually in relatively shallow water close to shore.

Piping plovers (*Charadrius melodus*) now nest sporadically in only one location in Minnesota, along sand beaches on the south shores of Lake of the Woods, although they once nested along the dunes of Lake Superior. Critical habitat for this species has been designated by the U.S. Fish and Wildlife Service on Pine and Curry islands and also in the Duluth Harbor area. Common terns (*Sterna hirundo*) nest in a handful of colonies on islands with rocky or sandy shorelines in large lakes such as Leech Lake, Mille Lacs Lake, Lake of the Woods and Lake Superior (Duluth Harbor).

## Fish

Lake-dwelling fish SGCN include several species. Pugnose shiner (*Miniellus anogenus*), Northern sunfish (*Lepomis peltastes*) and least darter (*Etheostoma microperca*) are associated with or depend on aquatic vegetation. These fish species are adversely affected by alterations to natural shorelines and increased nutrient loads. Lake sturgeon, a fish of large rivers and lakes, is affected by loss of connectivity due to dams (see River subchapter). Deepwater sculpin (*Myoxocephalus thompsonii*) inhabit deep lakes with cold waters, which are threatened by eutrophication and climate change. See also the Fish sub-chapter of Chapter 2.

*Photo: Pugnose shiner, Matthew Kvam*

## Mammals

Perhaps the mammal SGCN most closely identified with lake habitats is the moose (*Alces alces*). Moose depend on lakes for drinking water. During the spring and summer, they are also attracted to lakes and their shoreline habitats for an abundance of favorite foods including sedges, horsetails, and aquatic plants such as pondweeds and water lilies. SGCN bat species not only utilize lakes for drinking but are also attracted to lakes and their riparian shorelines during the summer months for the aquatic insects that emerge from the water's surface.

## Reptiles

Blanding's turtle (*Emydoidea blandingii*) use a variety of aquatic habitat, including wetlands and lakes. Deep lakes are usually avoided when shallow, well-vegetated wetlands are nearby. Populations in the southern portion of their range are threatened by warming water temperature due to climate change.

## Insects

Lakes provide primary habitat for 12 species of caddisflies (Trichoptera) as well as secondary habitat for an additional 3 species, as well as habitat (unspecified as to primary or secondary) for 13 species of dragonflies and damselflies (Odonata). Please see the Aquatic Invertebrates sub-chapter for more information.

## Mussels

Minnesota is home to the only known lake endemic freshwater mussel species, the lake floater (*Pyganodon lacustris*), which requires silt or soft mud bottoms, and low to non-existent flow. This species historically occupied lakes as far south as the Iowa/Minnesota border but now is only known from central to northern Minnesota.

## Plants

The 36 vascular plant SGCN found associated with lake habitat represent 8% of all the SGCN plants.

Moyle (1945) suggested three aquatic floral regions of the state based on water chemistry data, which included soft-water, hard-water, and alkaline (Table 3.17).

A relatively small group of plants have evolved to live in the Minnesota's aquatic environments with special adaptations to survive unique habitat conditions across the state. In soft-water lakes of the northeast, American awlwort (*Subularia aquatica ssp. americana*), algae-like pondweed (*Potamogeton confervoides*) and lavender bladderwort (*Utricularia resupinata*) occur in the shallow sandy sites of low nutrient, clear water lakes. Human-caused nutrient increases in these lakes can result in lower clarity and a shift to more leafy aquatic plants at the detriment of the small, low-nutrient adapted, rare species. In central Minnesota, purple-flowered bladderwort (*Utricularia purpurea*) and spotted pondweed (*Potamogeton pulcher*) appear restricted to very few lakes but may grow locally abundantly within sites. Direct removal of vegetation for recreational use as well as declines in water clarity threaten these species. Widgeon grass (*Ruppia maritima*) and spiny naiad (*Najas marina*) are "salt-loving" submerged plants that are adapted to the naturally higher alkalinity of western Minnesota lakes. Drainage and upland development have degraded many of these habitats.

**Table 3.17. Limnologists (lake specialists) and biologists have classified midwestern lakes into biologically meaningful categories, often using a combination of hydrology and water chemistry (Sather 1991).**

| Aquatic Flora | Region | Alkalinity | Sulphate | pH |
|---|---|---|---|---|
| Soft-water | northeast | <40 ppm | <5 ppm | 6.8-7.5 |
| Hard-water | central | 90-250 ppm | <50 ppm | 8.0-8.8 |
| Alkaline | western | >150 ppm | >125 ppm | 8.4-9.2 |

## Case Study: Minnesota Common Loon Restoration Project

In 2010, the Deepwater Horizon oil spill negatively affected the wildlife and ecosystems in the Gulf of America, and an environmental damage settlement of over $20 billion was approved. Minnesota's state bird, the common loon, winters on coastal waters. Radio telemetry work and chemical analysis of eggs indicated that loons overwintering in the areas affected by the spill breed in Minnesota. The Open Ocean Trustee Implementation Group provided funds to Minnesota DNR to restore loons lost from the spill in a project spanning 2021-2025.

A partnership between the DNR, United States Geological Survey USGA, U.S. Fish and Wildlife Service and Minnesota Pollution Control Agency (MPCA) was established to accomplish the following goals: 1) acquire and protect lakeshore nesting and foraging habitat, 2) enhance habitat and increase lake stewardship and 3) reduce lead exposure through advocacy of non-toxic tackle.

Progress on goals:

1. As of July 2025, over 6.5 miles of lakeshore habitat across four parcels has been purchased and protected perpetually as DNR Aquatic Management Areas or Wildlife Management Areas. Two more acquisitions are planned for later in 2025. Extensive surveys confirm nesting and foraging use of the protected habitats by loons.

2. Artificial Nesting Platforms (ANPs) are floating platforms covered in natural vegetation that loons use to nest. They reduce nest failure from predation and water fluctuation. Volunteers were recruited to build and deploy 44 artificial loon nesting platforms to enhance nesting success of loons on lakes with low reproductive output, and the DNR and USGS has engaged in a research study to assess the efficacy of these nesting platforms as conservation tools. Teams of researchers monitored loons on these lakes throughout the reproductive season and provided detailed data on habitat use, nest success/failure, and productivity from nesting platforms. Platform use increased each consecutive year of deployment (1% in 2023, 18% in 2024, and 34% in 2025). Efforts are currently underway to continue the nest platforms project beyond 2025. Additionally, substantial outreach efforts have increased public engagement and interest in loon conservation and shoreline preservation and restoration (see Public Engagement Chapter)

3. The MPCA led a non-toxic fishing advocacy effort that has included 213 public engagement events and has provided 33,700 free non-toxic tackle sample packs between 2022-2024 (Getting lead out of fishing tackle)

This loon conservation work will continue. By leveraging partnerships with local sports teams (Minnesota United Football Club; The Loons) the DNR has created a new permanent position, the Loon Program Coordinator, to continue and develop loon conservation, research, and outreach efforts across the state and to coordinate citizen science loon monitoring efforts. For more information on the Loon Restoration Project, see Minnesota Loon Restoration Project and the annual reports: 2021, 2022, 2023, 2024.

*Photo: Loon on artificial nesting platform, Luke Fara, USGS*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors. See also: Stressors to Biological Communities in Minnesota's Lakes.

### Development

Minnesota has currently lost 40 to 50% of its natural shorelines, and the rate of loss is estimated to be 1 to 2% per decade (Minnesota Natural Shoreline Partnership, 2023). Shorelines are often altered by lakeshore property owners. As a lake's watershed becomes more developed, nutrient levels increase and water quality decreases due to pollution runoff, poor stormwater management, and shoreline phosphorus pollution from subsurface sewage treatment systems (septic systems), and a lack of natural shoreline vegetation between lawns and the lake.

Both permitted and illegal removal of aquatic vegetation (via mechanical or herbicide) can be threats to lake habitats, as aquatic vegetation is important for many species including fish and loons. Common Loons (*Gavia immer*) nest near the water edge on lakes and use mud and aquatic vegetation to create the nest. Minnesota is losing natural shorelines due to shoreline development and property management practices that include clearing of natural vegetation and mowing of grasses; these are threats to loon nesting success and lake water quality (Minnesota's Vanishing Natural Shorelines: A Loss that Contributes to Degraded Lake Quality).

Artificial shoreline stabilization structures are built to protect human infrastructure and prevent erosion. Riprap, bulkheads, jetties and other shoreline protection strategies are designed to alter the behavior and movement of sand and sediments. These strategies can effectively retain or increase sediment in select locations while eroding shoreline down shore. Artificial structures can eliminate access to beaches for some shore nesting species and beach erosion can degrade or eliminate nesting and foraging habitat for shore nesting SGCN (Prosser et al., 2018).

### Crop Production

Some areas of crop production depend greatly on groundwater appropriation to sustain improved and reliable crop yields. These areas may also influence water levels of lakes that provide critical habitat to a variety of species. Direct surface water appropriation may also be used for crop production which more immediately affects water levels and flows of the surface water. Reduction in flows and water levels during critical times of the season, such as August, may affect certain species sensitive to warmer water temperatures and reduced habitat.

Drainage from agricultural fields within the watershed of a lake, either by surface flow, or by drain tiles, can affect downslope hydrology and water quality through the transmission of sediments and chemicals. Agricultural lands contribute as a leading cause of lake water quality impairments and contribute substantially to lake eutrophication. Over half of Minnesota's wetlands and shallow lakes have been ditched and drained. Wetland losses have been the greatest in the Prairie Parkland ecoregion where well over 90% of the wetlands have been drained or filled. 40% to 50% of remaining wetlands have altered hydrology from storm water inputs, roads, or drain tiles (Genet et al., 2019). The water conveyed through drainage systems often has increased levels of sediments, nutrients and chemicals that further impair the receiving water bodies. Excess phosphorus and silt remain in lakes and wetlands and result in degraded water quality and wildlife habitat. Tile drainage bypasses natural riparian areas that would normally serve to filter some of the nutrients and sediments so many of the wetlands remaining are in poor condition. Blann et al. (2009) is a thorough review of effects of agricultural drainage on aquatic ecosystems.

## Livestock Management

Large livestock facilities can create runoff that may affect receiving waters and the habitats that many species depend upon. They can also affect groundwater resources and surface waters depending on the source of water being used.

## Mining and Quarrying

Mining or quarrying operations may affect hydrology or produce sediments that can affect waters with sediments and chemicals.

## Roads, Trails, and Railroads

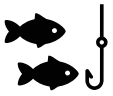
Roads and railways can disrupt connectivity to lake habitats. In general, increased impervious surfaces adjacent to lakes and in watershed lead to increased sedimentation, turbidity, and chemical levels. De-icing salts dispersed on roadways increase the salinization of the lakes (Chloride, Minnesota Pollution Control Agency).

## Utility Corridors

Powerlines present a risk to waterfowl when situated between feeding and roosting areas. This is especially true for lines near lakes, rivers and wetlands. Less agile birds, such as trumpeter swans are particularly susceptible to collision with overhead lines located near waterbodies (APLIC, 2012).

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Runoff from timber harvest sites may introduce sediments into waterways including lakes, particularly if buffer areas are not scaled appropriately.



## Fishing

A leading cause of mortality in the common loon and other waterbirds is ingestion of lead fishing tackle. In popular angling lakes, tackle loss results in many metric tons of lead across lake bottoms annually (Radomski et al., 2006). This can occur when loons eat fish that have ingested lead tackle, eating bait with lead tackle attached, or from eating tackle directly off the lake bottom. Loons may also get entangled in loose fishing line or injured from ingested hooks. Lead is particularly toxic when ingested as the grinding mechanisms and acidic environment of the gizzard cause the lead to be transported into the blood and organs. A small lead fishing split shot weight can kill a loon in a matter of weeks (Get the lead out, Minnesota DNR, Lead Poisoning in Loons, U.S. Fish & Wildlife Service).

## Recreation

Large powerful boats, and particularly the use of wake boats (designed to throw a big wake for watersports) can disrupt vegetation and nesting waterbirds including loons and leads to erosion. Boat strikes commonly kill wildlife like loon chicks and turtles during the summer.

Human disturbance on beaches and islands serving as nesting and foraging areas for birds such as piping plovers and common terns disrupts nesting behavior and can limit reproductive success (DeRose-Wilson et al., 2018; Stantial et al., 2021). Beach access at times is a threat and temporary beach closures are needed.

Boats, docks, and fishing bait that are moved among lakes and not properly decontaminated contribute to the spread of invasive species (see below).

## Dams and Water Management

Drainage of wetlands and fields in watersheds of lakes can affect seasonal hydrology of the remaining water bodies by delivering water at a faster rate through drainage networks. Dissolved nutrients and sediments can also be elevated in this runoff, leading to excess nutrients in the receiving water bodies. Natural connections between water bodies have been influenced by dams, bridges and culverts and impede species movement and alters habitat. See also Rivers sub-chapter.

*Photo: Pickerelweed on Moose Lake, Rachel Kranz*

Loons nest near the water's edge, and waterbodies that undergo large fluctuations in water levels may flood nests and reduce reproductive success of loons and other shore nesting species. (Windels et al. 2013). Water level fluctuations affect nesting and foraging habitat conditions for shore nesting bird species. High water levels erode or eliminate nesting sites (Maxson & Haws, 2000). Water level fluctuations also affect the nesting habitat of overwater nesters such as western grebes and red-necked grebes, black and Forster's terns. Water level management that results in rapid water level changes during the nesting season can destroy nests (Bracey et al., 2024).

## Invasive Species (Problematic Non-native Species)

Several invasive aquatic species are present in Minnesota lakes. Eurasian watermilfoil and curly-leaf pondweed have been present in Minnesota lakes for a century and decades, respectively. Eurasian watermilfoil can grow to the water surface and compete with native plants. Curly-leaf pondweed is well adapted to nutrient-rich or nutrient polluted lakes. A newer invasive species, starry stonewort (*Nitellopsis obtusa*), is associated with native species declines and drastic changes in the structural complexity of plant communities.

Invasive aquatic animals present in many Minnesota lakes include common carp, spiny water flea, rusty crayfish and zebra mussels. Common carp is widely distributed in central and southern Minnesota, disrupting shallow lakes as their feeding habits uproot aquatic plants and suspends fine sediments into the water. Zebra mussels filter the water, which reduces food for larval fish and other animals and increases water clarity. So, zebra mussels can change the food web and reduce the carrying capacity for popular fish such as walleye.

Shipping in the Great Lakes does not pose a direct threat to Lake Superior's fish, but the ships themselves are a vector for the introduction of invasive species when they release their ballast water. As of April 2010, 89 non-native aquatic species had already been introduced into Lake Superior. Among the long list of non-native species are the following fish: ruffe (*Gymnocephalus cernuus*), round goby (*Apollonia melanostomus*), sea lamprey (*Petromyzon marinus*), alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus ordax*). Changes to ballast water regulations have reduced the rate of invasive species introduction by an estimated 85% since 2006 (Ricciardi & MacIsaac, 2022). Many biologists consider aquatic invasive species the biggest threat to the Great Lakes (Lake Superior Binational Program, 2014; see also Non-native Invasive Species and Infested Waters List, Minnesota DNR).

## Water-borne Pollution

Eutrophication occurs when a lake becomes enriched in nutrients which leads to excessive plant and algal growth and is a major threat to Minnesota lakes. Nonpoint source pollution comes from many diffuse sources and includes phosphorus, nitrogen, sediment, bacteria and other contaminants, in part. Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. As runoff flows, it picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, and groundwater and estuaries (EPA NPS Webpage). These nonpoint source pollutants represent the largest combined contribution (an estimated 86%) to the state's water pollution (MPCA Water Quality Initiatives). Water quality measured by nutrients and contaminants has been shown to decline with higher agricultural or urban development in the watershed. Some key effects include excess algal growth, reduced plant diversity, and reduced diversity in fish and invertebrate communities (DNR Water quality non-point sources).

Polyfluroalkyl Substances (PFAS) and Polychlorinated biphenyls (PCBs) are

human made chemicals that are both banned in Minnesota, but persistent in the environment. PFAS may get into lakes from industrial discharge, leaching from landfills into groundwater, and from firefighting foam products. The specific effects of these pollutants on wildlife are poorly known, but their presence is documented in many fish and is reported on the DNR Lakefinder website for specific lakes.

Sulfates are naturally occurring chemicals that can be found in discharges from wastewater treatment plants and industrial facilities such as mines. Sulfates may be detrimental to wild rice; to protect this valuable resource, in Minnesota there is a long-standing water quality standard of 10 mg/L sulfate for waters used for production of wild rice (Protecting wild rice waters, Minnesota Pollution Control Agency).

## Air-borne Pollution

Air pollution includes a large range of chemicals, from mercury via primarily from coal burning, pesticides via drift from farm and residential lands (Introduction to Pesticide Drift, U.S. EPA), microplastics and nanoplastics via wind and waves moving broken down plastic waste fragments, to greenhouse gases via combustion of coal and gas. Mercury bioaccumulates and biomagnifies through lake food webs, which affects the wildlife and human health as it is a potent neurotoxicant. Fish from lakes in the northeast generally have the higher mercury concentrations (Radomski et al., 2024).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4° F, with average winter low temperatures increasing even more significantly by 6.8° F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

Minnesota's lakes, including coldwater and small shallow lakes, are vulnerable to rising temperatures driven by climate change. Coldwater lakes capable of supporting species like lake trout (*Salvelinus namaycush*) and cisco (*Coregonus artedi*) require cool, oxygen-rich waters to sustain their sensitive aquatic communities. However, as average temperatures rise, particularly in winter and summer, these lakes are experiencing thermal stress that threatens the long-term viability of cold-adapted species (Jacobson et al., 2010; Fang et al., 2012). Warming water reduces the volume of suitable cold, oxygenated habitat, often referred to as an "oxythermal squeeze," which can lead to population declines or local extirpations (Jane et al., 2024).

Rising air temperatures have also disrupted the natural freeze-thaw cycles of Minnesota's lakes.

Ice-in now occurs later in the fall and ice-out earlier in the spring, significantly shortening the duration of seasonal ice cover. These shifts change the probability of winterkill in shallow lakes, alter stratification and mixing patterns, and affect the timing and productivity of aquatic food webs (Magnuson et al., 2000; Sharma et al., 2019).

The ecological and recreational consequences of these changes may be severe. Angling opportunities for coldwater species may diminish, while lakes become more susceptible to algal blooms and invasive species like common carp (*Cyprinus carpio*) and Eurasian watermilfoil (*Myriophyllum spicatum*), which thrive in warmer, nutrient-rich conditions.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

More specifically in lake systems across Minnesota, an anticipated higher incidence of heavy storms may increase flooding, runoff, affect water level fluctuations in lakes and alter hydroperiods in shallow lakes. Also, high wind events on large lakes can generate intense wave action which threatens shorebird nesting habitat and aquatic plant establishment. Snow on frozen lakes acts as an insulating barrier, and influences ice formation and ice melt, and light penetration during winter. Changing patterns of snowfall will accordingly affect lakes as well (Climate trends affecting lakes and rivers, Minnesota DNR).

## Case Study: Monitoring Minnesota's Lakes

In the Land of 10,000 Lakes, a suite of complementary lake monitoring programs provides necessary information for proper lake management. Below, we highlight several of the DNR's lake monitoring programs.

**Lake Index of Biotic Integrity**: The DNR and Minnesota Pollution Control Agency (MPCA) monitor the health of many lakes by tracking the fish and plants with indices of biological integrity (Lake Index of Biotic Integrity). Indices of biotic integrity (IBI) use the diversity and species composition of community to describe the relative health or impairment of the ecosystem as compared to what would be expected if the ecosystem was undisturbed by anthropogenic activities. When applied to plants these are termed 'floristic quality indices' (FQI). For Minnesota lakes, aquatic ecosystem health is described by the fish community with a fish IBI, supplemented by a plant FQI. The fish IBI was developed for four different lake types to accurately evaluate different expectations for their associated fish communities: deep lakes with complex shaped shorelines, moderately deep lakes with rounder shorelines, moderately shallow, heavily vegetated lakes, and shallow lakes (where more than 80% of the lake is 15 feet or less deep). Fish-based IBI scores are used by DNR staff to place lakes into one of six assessment categories: exceptional, fully supporting, vulnerable, not supporting (impaired), inconclusive information and insufficient information.

**Lake Water Quality Monitoring**: All lakes over 500 acres and a subset of smaller lakes are assessed for water quality by MPCA (Lake Water Quality Monitoring). The goal of this monitoring is to determine if water quality supports recreation, compare regional differences in water quality, and identify long term trends. Based on these results, a total maximum daily load (quantity of pollutants a watershed can receive without violation quality standards) and a watershed and restoration and protect strategy are completed for each watershed. These reports are the foundation for restoration and protection projects in each watershed, and acknowledge various unique needs of different waters (e.g. oxygen and temperature standards for coldwater lakes) (Lake aquatic life and recreation, Minnesota Pollution Control Agency).

**Fisheries Surveys:** Routine lake surveys by the DNR Section of Fisheries include monitoring of fish populations, water chemistry, and fish habitat to guide fisheries management. Lake survey data is used to track fish population trends, evaluate the effectiveness of management actions such as stocking, and establish management goals for a given lake. On average, the Section of Fisheries conducts 650 lake surveys each year. Most of the important fishing lakes are surveyed once every 3-5 years. The 11 largest lakes, including Mille Lacs, Superior, and Lake of the Woods, are surveyed annually. Fisheries and other information helpful to the public is shared in the popular Lake Finder website.

*Photo: DNR Fisheries staff with northern sunfish during lake surveys*

**Sentinel Lakes Program:** This program is an intensive, long-term lake ecosystem monitoring program created to detect and understand the physical, chemical and biological changes occurring in Minnesota's lakes. Long-term monitoring on a set of 25 Sentinel Lakes includes water chemistry, fisheries, zooplankton, phytoplankton, habitat, groundwater as well as watershed development (see Monitoring Minnesota's Changing Lakes). This program documents biological, physical and chemical trends, identifies mechanisms behind them, and directs management solutions for long-term sustainability.

**Watershed Health Assessment Framework:** The Watershed Health Assessment Framework (WHAF) is program that assesses three components of aquatic ecosystem health: biology, hydrology, and water quality. The WHAF integrates numerous metrics to derive lake health scores for about 4000 Minnesota lakes (Watershed Health Assessment Framework - Lakes).

**Lakes of Biological Significance**: High-quality lakes based on biological sampling are listed and updated every five years by DNR. The list is used to focus lake protection efforts. Unique plant and animal presence is the primary measure of a lake's biological significance. Lakes are rated and grouped for each of the following communities: aquatic plants, fish, birds and herpetofauna (amphibians and a turtle species). Lakes are assigned to one of three biological significance classes (Outstanding, High, or Moderate); see Lakes of Biological Significance - Resources - Minnesota Geospatial Commons.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

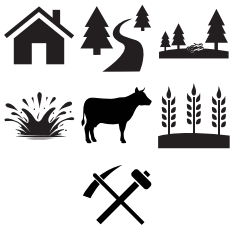
Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Lakes

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Utilize Aquatic Management Areas to protect shorelines and wetlands (Aquatic Management Areas, Minnesota DNR). |
| | Prevent loss or degradation of all types of shallow lakes. Preserve shallow lakes and wetlands, especially in the Eastern Broadleaf Forest and Prairie Parkland provinces. Focus on protecting larger shallow lakes (> 4 acres [10 hectares]) and shallow lake and wetland complexes. Protect known nesting areas of black terns and Forster's terns. |
| | Enforce wetland protection regulations ("no-net loss") as they pertain to shallow lakes and wetlands. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

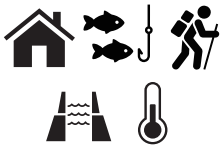
| Stressor | Action |
|---|---|
| | Restore large complexes of shallow lakes and wetlands, with attention to the habitat features required by SGCN. |
| | Enforce shoreline development and aquatic vegetation removal restrictions. |
|  | Maintain vegetated buffers comprised of locally native vegetation adjacent to waterways. Avoid or reduce mowing, burning, grazing or chemical application on these buffers. Support and promote state and federal programs incentivizing buffers and other best practices for lakes, streams, wetlands and ponds. |
| | Manage the spread of new invasive species, particularly in rare very deep-water habitats. Manage the encroachment of invasive plants in shallow lakes. See the DNR's Aquatic Invasive Species webpage for up-to-date information on the DNR's suggested actions regarding reducing the spread. |
| | To address altered hydrology of shallow lakes, encourage restoration of wetlands and grasslands and natural hydrological function in the watershed. |
| | Manage for natural water regimes in lakes. |
| | Prevent problematic practices in key watersheds to reduce external nutrient loading in lakes. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | To address boat traffic and wake boats disturbing nesting habitat and causing erosion, ensure appropriate provisions are in place to limit the use of wake boats to protect loon nesting habitat. Work with lake associations and county governments. Ensure there is sufficient enforcement. Invest in research and education on the topic. |
| | When SGCN shorebirds are nesting on lakeshores, temporary beach restrictions can be beneficial to protect the nests from recreational disturbance. Participation by agency, conservation partners, and volunteers can help to implement, explain, and enforce the closures. Seasonal beach restrictions protect nesting and foraging areas of birds such as piping plovers and common terns (Hillman et al., 2015). Wildlife sanctuary signage placed around breeding habitat reduces recreational disturbance to these sites. Local support from landowners, conservation partners and enforcement officers is important in supporting these beach closures. |

| | |
|---|---|
| | Encourage anglers to voluntarily phase out lead tackle through education and outreach. Provide a directory of non-toxic tackle manufacturers. Encourage tackle retailers to stock non-toxic lead alternatives for anglers. There are several programs underway with partnerships with the Minnesota Pollution Control Agency aimed at these goals, linked under key partnerships below. |
| | Promote early coordination on utility corridor design and siting. Avoid routing lines near or across lakes where feasible. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Continue surveys, monitoring, and research into the health and biodiversity in Minnesota's lakes (see Case Study: Monitoring Minnesota's Lakes); work to maintain long-term funding for these programs. |
| | Examine efficacy of floating artificial nest platforms for common loons. Floating platforms may improve reproductive success on waterbodies with considerable water-level fluctuations (Artificial Nesting Platforms (ANPs) for common loons, Minnesota DNR). |
|  | Long term monitoring efforts are underway for loons. Two different volunteer programs, the Minnesota Loon Monitoring Program and the Volunteer LoonWatcher Survey continue to provide useful data about the status of loons and will be critical to keep track of long-term population trends. The Minnesota Loon Restoration Project partnership continues to protect habitat, deploy and measure the efficacy of Artificial Nesting Platforms, support non-lead tackle initiatives, and monitor loon populations. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | To protect lake shorelines from development pressure, promote initiatives to preserve sensitive shorelines, promote shoreline restorations, and implement shoreline setbacks. Lack of education and public buy-in can be addressed by education at the local level within communities (e.g. lake associations, see Loon Restoration Case Study), governments, and managers. Develop BMPs for technical staff. In addition, more funding is needed for lakeshore preservation, restoration, and research to inform decision-making. |
| | Continue outreach, education and enforcement regarding movement of invasive species, including Watercraft Inspection Program, mobile invasive species decontamination sites, DNR's What You Should Do actions for different water activities like kayaking and waterfowl hunting, and Clean in, Clean Out laws that reduce invasive species spread. |
| | Consider changes in regulation of ditching, tiling, and erosion to prevent shallow lake losses due to sedimentation. Support agricultural policies for crop production incentives to further develop and deliver programs that are lucrative for landowners to maintain working lands that protect and restore habitat. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# VERNAL POOLS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

## Acknowledgments

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Cover Photos: Vernal pool, Hill River State Forest, Spencer Rettler; Vernal pool in Nemadji State Forest, Andrew Herberg

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# Vernal Pools

## Habitat Description

Vernal pools are naturally occurring ephemeral wetlands generally found in depressions embedded within upland forests of the Eastern Broadleaf Forest and Laurentian Mixed Forest Province within Minnesota. Within these ecological provinces, the Western Superior Uplands, Northern Minnesota Drift and Lake Plains, and Minnesota and Northeast Iowa Morainal ecological sections host higher concentrations of vernal pools due to topographical features driven by historical glacial ice movement patterns. At a more local scale, the presence of vernal pools is strongly influenced by the surrounding forested environment including elements of topography, canopy shading, and leaf litter.

Vernal pools are typically small, shallow, fishless, confined basin wetlands less than 2.4 ac/1 ha in size. They are considered hydrologically "isolated" wetlands because there is no continuous surface water connection to permanently flooded water bodies. Pools typically receive most of their water from snow melt runoff or rain, however, in settings where pools intersect the water table, groundwater inputs may be important. Based on local topography and surrounding forest characteristics, vernal pools can also be part of larger intricate pool complexes and can be connected to other wetlands or experience overflow from other wetlands/streams, still, any flow connections to permanently flooded water bodies remain temporary.

Vernal pools are characterized by seasonal water fluctuations and temporary flooding. They experience alternating periods of flooding and drying and must go through a drying phase annually or every few years (e.g., 3 out of 5 years). Pools typically fill with water in the spring and dry down by later in the summer, however, some pools also fill again after fall or winter rains or after large precipitation events. Flood duration and timing, as well as the frequency of flood events, can vary widely from pool basin to pool basin and even from year to year given both temporal and spatial differences in precipitation amounts. The hydroperiod, or length of time that the pool is inundated (as well as the amount of water held), has a strong effect on the type of vegetation and wildlife that occupy and utilize vernal pool habitats. Additionally, maintenance of surrounding forest conditions for canopy shading is important for minimizing effects on wetland hydrology, plant communities, nutrient cycles, and thermal regimes.

*Photo: Vernal pool, Hill River State Forest, Spencer Rettler*

These wetlands are not well captured by Minnesota's or the national wetlands inventory and therefore not yet comprehensively mapped for the state of Minnesota. Efforts are currently underway to better understand their distribution. They are thought to be distributed mostly within Mesic Hardwood Forests and Deciduous Wet Forests (and to a lesser extent in Upland Deciduous Forest and Woodland; see those sub-chapters).

Soils are typically hydric (wet) and often covered by leaf litter. Large coarse woody debris is common and contributes to the microsite heterogeneity and complexity of vernal pools. Other variables that influence conditions within the wetland include basin

(depression) configuration and topography, light availability (canopy cover), composition of surrounding forest (and litter quality and availability), landscape setting, infiltration or drainage capacity of soil, and water inputs (which can vary spatially and temporally).

## Habitat Map

There is not currently a comprehensive map of vernal pools in Minnesota. To depict Vernal Pool habitat, we compiled spatial data from the National Land Cover Database (NLCD) and the National Wetland Inventory (for more information, see Habitat Map Methods in Chapter 3: Habitats). The map in Figure 3.18 depicts a model of where vernal pools may exist based on the parameters outlined below.

### National Wetlands Inventory

From the National Wetland Inventory for Minnesota (NWI) Layer we used the Circular 39 attribute field to include Seasonally Flooded Basins or Flat, Shrub Swamp, and Wooded Swamp that were in forested areas and 1 hectare in size or smaller.

### National Land Cover Database

From the National Land Cover Database, we narrowed our search for vernal pools by including only those in Mixed or Deciduous Forest parcels that were larger than 10 hectares in size.

### Native Plant Communities

Vernal pools have not been characterized in Minnesota's Ecological Classification system, so we cannot classify them here by a particular ecological system or native plant community. At the time of this publication, the DNR is actively investigating the locations and ecological characteristics of vernal pools.

Emerging information about the vegetation composition of vernal pools is based on survey work in the northcentral part of the state within the range of the four-toed salamander (*Hemidactylium scutatum*). In the paragraphs below we share what preliminary information has been gathered to date.

Vegetation composition of sampled vernal pools varies widely across pools and even within pools. As noted above, hydroperiod can also vary dramatically between pools (and within a pool if basin topography is complex) and has a direct influence on the vegetative response.

Vegetation in pools (or portions of pools) may be dominated by trees like black ash (*Fraxinus nigra*) or yellow birch (*Betula alleghaniensis*) or other woody species like the shrub speckled alder (*Alnus incana*). Pools may also be dominated by herbaceous vegetation or be nearly devoid of vegetation altogether. Vegetation of deeper and/or more open pools can include plants often observed in wet meadow or marsh/aquatic systems like Canada bluejoint (*Calamagrostis canadensis*), water parsnip (*Sium suave*), northern water plantain (*Alisma triviale*), and duckweed (*Lemna* spp.). Species that were encountered more regularly across a variety of pool types include: brownish sedge (*Carex brunnescens*), tuckerman's sedge (*C. tuckermanii*), bladder sedge (*C. intumescens*), spinulose woodfern (*Dryopteris carthusiana*), and marsh marigold (*Caltha palustris*). Mosses are often present in abundance, sometimes forming larger hummocks (*Sphagnum* species) and growing on leaf litter substrate (non-sphagnum species).

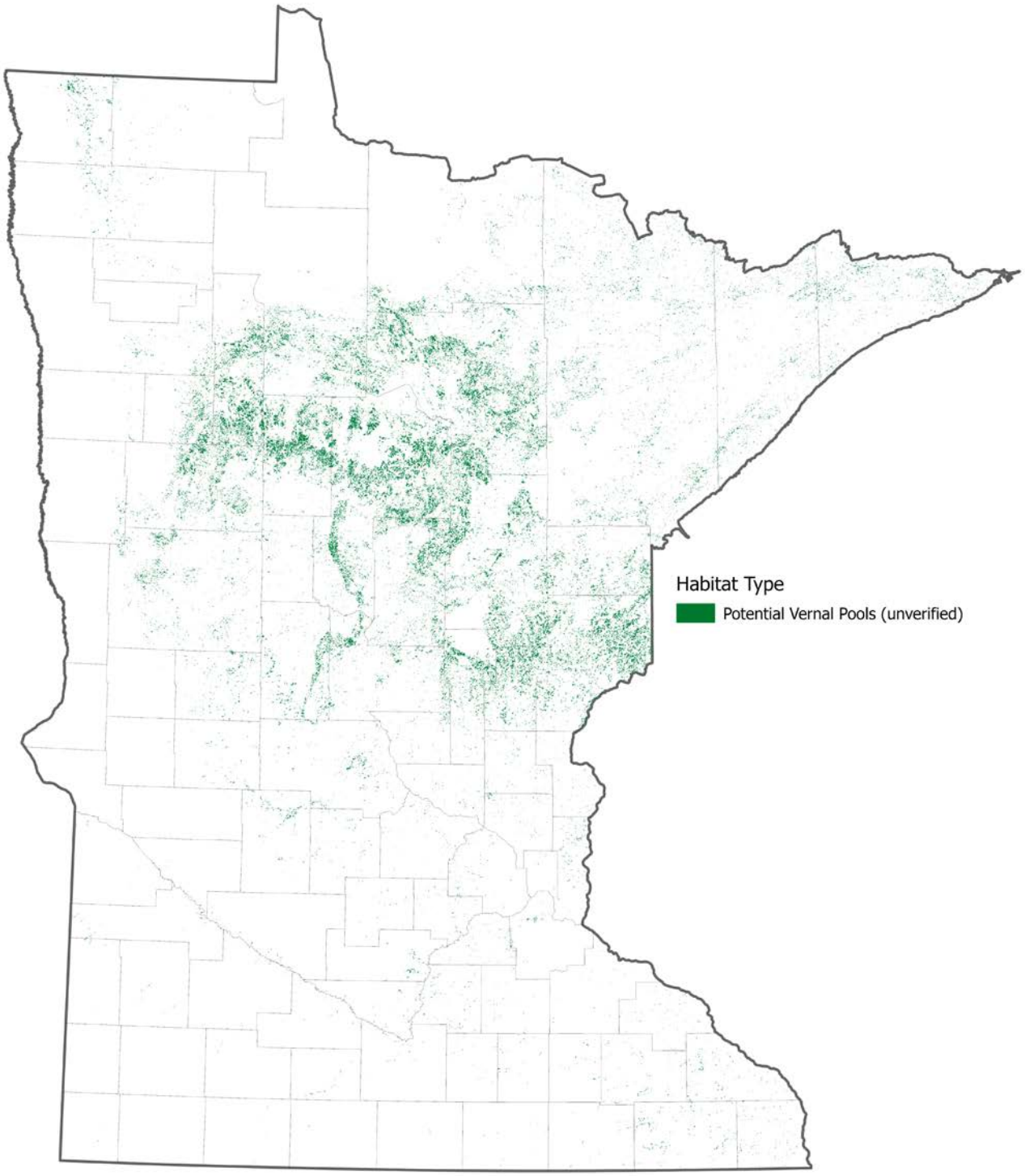


Figure 3.18. A map depicting potential (unverified) Vernal Pool habitat in Minnesota, modeled from three wetland types from the National Wetland Inventory for Minnesota, limited to those found within Mixed or Deciduous Forest parcels larger than 10 hectares in size from the National Land Cover Database. Investigations of the locations of vernal pools are ongoing.

## Conservation Overview

Vernal pools are a unique and dynamic habitat feature that many animals and plants depend upon for reproduction and survival. Due to their ephemeral nature, these wetlands act as a resource pulse that is available for only a few months of the year and often become a biodiversity hotspot during this time. Several SGCN animals and plants utilize these wetlands; therefore, there is a strong need to understand and protect these sensitive habitats.

Conversion of forested lands to development, agriculture, and other land-uses may result in the degradation and/or loss of vernal pools. Unlike wetlands that hold permanent water, vernal pools are not protected under Minnesota's Wetland Conservation Act (WCA) and often only receive limited protection during forest management activities. Additionally, climate change presents new challenges and many unknowns for the future of vernal pools and the organisms that rely on them. These wetlands are not a readily replaceable resources on the landscape and artificial vernal pools have been met with mixed success. Thus, our primary conservation approach is the protection and enhancement of existing vernal pools.

For these reasons, vernal pools are in need of additional research and monitoring in Minnesota. Efforts are currently underway to classify vegetation composition within these wetlands to categorize different types of vernal pools and understand their connection to the surrounding forest. Furthermore, research is being conducted to understand how vernal pools, and the SGCN that rely upon them, respond to forest disturbance and to identify strategies to minimize detrimental effects. Through these efforts, our hope is to raise awareness of these important forested wetlands, identify effectiveness techniques to protect the plants and animals using these habitats, and ensure that vernal pools continue to thrive in Minnesota.

## Species in Greatest Conservation Need

Vernal pools, despite being ephemeral, very small, and poorly documented, provide primary habitat for 9 animal Species in Greatest Conservation Need (SGCN) and secondary habitat for two others (see Table 3.18). Habitat associations for dragonflies and damselflies were not differentiated into primary and secondary habitats and are shown in the total column. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

**Table 3.18. Numbers of Species in Greatest Conservation Need associated with vernal pools as primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 3 | 0 | 3 |
| Birds | 0 | 1 | 1 |
| Reptiles | 0 | 1 | 1 |
| Dragonflies and Damselflies | - | - | 6 |
| **Total** | **3** | **2** | **11** |

A detailed table associating each animal SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found for animals in Appendix D. Plants were associated only with a single primary habitat type, based on Minnesota's native plant classification (Appendix E). Because vernal pools are not yet incorporated into that system, none were formally associated to the vernal pool type. However, some SGCN plants that may be found in vernal pools are discussed in the section below.

It should be noted that although the Eastern fairy shrimp (*Eubranchipus vernalis*) is endemic to vernal pools, they are not represented in the table above because habitats were not delineated for any of the SGCN Branchiopoda (shrimp). Also, given the ephemeral nature of this habitat, some additional species mentioned in the text below, while not associated formally with the habitat, opportunistically use these pools.

Vernal pools provide critical habitat for a whole suite of animal species in Minnesota. Due to the periods of prolonged drawdown in vernal pools, permanent fish populations are not able to survive. This provides habitat for organisms that require or benefit from fishless conditions for successful reproduction. Some of these are obligate species and include organisms that use vernal pools almost exclusively for breeding and larval development. Many of the species that utilize vernal pools also rely on the integrity of the upland forest surrounding the pool for things like cover, foraging sites, and overwintering habitat.

## Amphibians

Three SGCN salamanders associate with vernal pools as their primary habitat. As a quintessential vernal pool obligate species, spotted salamanders (*Ambystoma maculatum*) depend upon these fishless, seasonal wetlands for successful reproduction. As soil and air temperatures increase and spring rains fall, adults migrate from upland forests to vernal pools to breed in late March - April (Sexton et al., 1990, Moriarty & Hall, 2014). Additionally, four-toed salamanders also use these forested wetlands for reproduction and seek out vernal pools with abundant sphagnum moss hummocks as their preferred nesting habitat (Chalmers & Loftin, 2006; Moriarty & Hall, 2014). While adult spotted salamanders generally leave the vernal pools soon after breeding, female four-toed salamanders will continue to guard their eggs for approximately one month after oviposition (Banning et al., 2008). Larval development for both species occurs within these pools and can last until late summer. In general, these species need these pools to hold water (or ample moisture in leaf litter) until approximately mid-July for successful reproduction in Minnesota (Moriarty & Hall, 2014). In some rare cases, spotted salamander larvae may overwinter in the vernal pools and complete their development the following spring (Whitford & Vinegar, 1966). Both species eventually migrate to adjacent upland forests for the remainder of the active season. Eastern newts (*Notophthalmus viridescens*), another SGCN salamander, may also breed within vernal pools, yet they are not as dependent on these specific wetland features as the other two SGCN salamanders. Adult eastern newts will also frequent vernal pools in the spring to forage on other amphibian eggs. See also Case Study on next page.

*Photo: Spotted salamander, Bob Dunlap*

## Birds

Several SGCN birds breed and forage within mature upland hardwood forests with interspersed vernal pools. Wetland openings such as vernal pools are a key component of forests occupied by Red-shouldered hawks (*Buteo lineatus*), which often prey on amphibians and reptiles that inhabit vernal pools (King et al., 2011). While not formally associated with

this habitat, Acadian flycatchers (*Empidonax virescens*), and cerulean warblers (*Setophaga cerulea*) that use mature deciduous forest are often loosely associated with vernal pools. They may be responding to foraging opportunities provided by invertebrate prey linked to vernal pools, or simply the forest structural diversity associated with small canopy gaps.

## Mammals

Although not formally associated with vernal pools, several forest bat SGCN, such as northern long-eared bat (*Myotis septentrionalis*), little brown myotis (*Myotis lucifugus*), and big brown bat (*Eptesicus fuscus*), may forage in forest openings above vernal pools (Francl, 2008).

## Reptiles

Blanding's turtles (*Emydoidea blandingii*) use vernal pool habitat early in the spring for foraging, thermoregulation, and breeding opportunities (Beaudry et al., 2009). These turtles capitalize on highly abundant and concentrated food resources like amphibian eggs, tadpoles, and various invertebrates. These wetlands are also some of the first water features to ice out in the spring and provide opportunities to thermoregulate via basking and water submersion. Also, vernal pools may attract numerous individuals at once, thus providing breeding opportunities for adult turtles.

## Invertebrates

Some invertebrate species, such as the crustacean Eastern fairy shrimp, are endemic to vernal pools and live out their entire life cycle within these wetlands. Over the course of approximately three weeks, fairy shrimp larvae hatch from dormant cysts, develop into adults, reproduce, and die off (usually by mid-to late May; McCafferty et al., 2010).

Other aquatic invertebrates that utilize vernal pools to forage, reproduce, and undergo larval development include numerous insect species such as caddisflies (Trichoptera), dragonflies and damselflies (Odonata), water bugs (Hemiptera), midges (Chaoboridae and Chironomidae), beetles (Coleoptera), as well as some mollusk species like snails (Lymnaeidae, Physidae, and Planorbidae), and clams (Sphaeriidae) (Colburn, 2004; Batzer et al., 2004; Bischof et al., 2013). Dragonflies SGCN associated with vernal pools include the following six species: springwater dancer (*Argia funebris*); arrowhead spiketail (*Zoraena obliqua*), azure bluet (*Enallagma aspersum*), elfin skimmer (*Nannothemis bella*), ocellated darner (*Boyeria grafiana*), and Quebec emerald (*Somatochlora brevicincta*).

*Photo: Arrowhead spiketail, Jeff Fischer*

## Plants

The intersection of vernal pools and the upland forest that surrounds them can provide a key habitat for many SGCN plant species. When the transition zone or ecotone is gradual and rich and mesic or wet-mesic in nature, it can provide habitat conditions that support some of Minnesota's most rare interior forest species of moonworts (*Botrychium*) and grapeferns (*Sceptridium*) as well as the mycorrhizal fungi associates that they rely upon. This includes SGCN species such as narrow triangle moonwort (*Botrychium angustisegmentum*), swamp moonwort (*B. tenebrosum*), and blunt-lobed grapefern (*Sceptridium oneidense*).

Shallow, sparsely vegetated vernal pools with shorter hydroperiods also provide key habitats for grape ferns, including blunt-lobed grapefern, a SGCN species with a state conservation status of imperiled (S2).

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Conversion of forests to developed landscapes can result in the direct loss of vernal pools, degradation of vernal pools and their surrounding terrestrial habitat, increased road mortality of vernal pool wildlife, inhibited animal movement due to impervious surfaces, as well as reduced gene flow between wetlands (Windmiller & Calhoun, 2007; Hamer & McDonnell, 2008; Beaudry & deMaynadier, 2009; Evans et al., 2017).

### Crop Production

Forest conversion to agriculture may result in the loss and degradation of vernal pools. Additionally, proximity to agricultural lands can increase the likelihood of herbicide and pesticide introductions into vernal pools, which can have profound effects on plant and invertebrate communities (Battaglin et al., 2009).

### Roads, Trails, and Railroads

Roads and trails can produce hazardous run-off (such as salt, fertilizer, and pesticide/herbicide) that may alter water quality and chemistry within vernal pools. For example, salinization of these freshwater pools may occur from road deicers found in spring snowmelt. This has been shown to negatively affect zooplankton and cyanobacteria communities, as well as a reduction of dissolved organic matter, creating unsuitable conditions for various invertebrates and amphibians (Eakin et al., 2019; Vigil & Schuler, 2024). Additionally, roads may act as a movement barrier and/or source of mortality (via car strikes) as herpetofauna migrate to and from vernal pools (Colino-Rabanal & Lizana 2012).

### Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Forest management can alter forest composition and cover (shade), thereby affecting water levels and temperature, litter source, quality, and quantity, vegetation composition within pools, and seasonal food availability with an overall effect on pool food webs. This can affect both plant and animal

SGCNs that utilize the pools directly as habitat for at least part of their life history as well as species utilizing the transition zone of the pools and the surrounding upland forest with close proximity to pools.

Runoff from timber harvest sites may introduce sediments into wetlands such as vernal pools, particularly if buffer areas are not scaled appropriately. Several studies have examined the effects of forest management on hydrology, plant and animal communities of vernal pools. One study suggested that buffers around vernal pools help maintain similar hydrology to those of undisturbed sites, whereas thinning or clearcutting up to the pool boundary resulted in greater water depths and took several years to return to pre-harvest water depths (Kolka et al., 2011). Palik and Kastendick (2010) determined that harvesting up to the margins of the vernal pool resulted in significant changes in plant communities in the ground layer and shrub/tree regeneration within the wetland. Furthermore, this study demonstrated that a 15.25-m (50 ft) uncut buffer around the vernal pool helped mitigate changes in the plant community. The utilization of buffers around vernal pools generated mixed results when attempting to mitigate effects on invertebrate communities (Batzer et al., 2004, Bischof et al., 2013). More specifically, some species (such as Eastern fairy shrimp) appear to be more sensitive to changes in the surrounding forests and the subsequent alterations to hydrology and sediment load (Hanson et al., 2010). Another study examined the long-term effects that timber harvest had on vernal pool obligate species that also utilize the adjacent upland forests: spotted salamanders and wood frogs (*Lithobates sylvaticus*). Within vernal pools that experienced timber harvests, researchers found that occupancy of breeding adults and egg mass abundance significantly decreased over time for both species, with wood frogs experiencing a more drastic decline (Wiewel et al., 2023). Furthermore, it was also noted that many of the vernal pools within harvested forests were smaller in size and held less water than those in unharvested forests. While these results contradict Kolka et al.'s (2011) assessment that timber harvests resulted in greater water depths, it should be noted that there are many other habitat factors that influence vernal pool depth and size such as precipitation frequency and amount, previous winter's snow depth and surrounding topography.

## Recreation

Recreation (OHV, mountain biking, horseback riding, etc.) within a vernal pool may significantly degrade sensitive features, especially with repeated disturbance. The bottoms of these pools are often mucky and soft; therefore, human activity within the wetland may affect the topography and alter how water is distributed within the pool. Additionally, if recreation activity occurs during a sensitive period, such a breeding and larval development of amphibians, this can result in mortality of breeding individuals and loss of reproductive potential. Finally, recreational traffic may act as a vector for disease and invasive species if care is not taken to disinfect and clean equipment.

## Invasive Species (Problematic Non-native Species)

Increasing density and species diversity of invasive European earthworms can drastically alter the leaf litter/humus, as well as soil horizon composition, within the adjacent forest around a vernal pool (Hale et al., 2005). In turn, this affects soil nutrient availability and ultimately plant species composition (Alexander et al. 2022). Areas with high earthworm invasion may result in a loss of SGCN plants (such as rare ferns of *Botrychium* and *Sceptridium;* Gundale, 2002; Alexander et al., 2022), as well as a loss of vital cover for forest-floor dwelling animals.

Emerald ash borer (*Agrilus planipennis*) poses a risk to vernal pools since black ash is a common species within vernal pools. The mortality of ash within these wetlands may affect the hydrology, canopy cover, wetland depth, and plant species

composition. This may result in the vernal pool becoming unsuitable for various species. Grinde et al. (2022) conducted experimental manipulations of black ash wetlands to mimic EAB damage and examined the response of bird, amphibian, and small mammal communities. While there was an initial increase in species richness attributed to the change in forest structure, researchers suggested that there would be a shift from forest-dependent wildlife to more open-canopy, wetland-associated species within these wetlands.

One study found that a metabolite released by the invasive plant species common buckthorn (*Rhamnus cathartica*) contributed to significant embryo mortality and malformation in frog species. The more buckthorn present around a vernal pool, the higher the concentration of the metabolite, which could lead to amphibian population declines in the long-term (Sacerdote & King, 2014).

## Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (Minnesota Pollution Control Agency and Minnesota Department of Commerce 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Warmer temperatures may result in shorter hydroperiods and create challenges for larval development of some animals that require water availability (Montrone et al., 2019). However, amphibian eggs and larva may develop faster under warmer water conditions, thus, some animals may be able to adapt better than others. Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate

Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

More specifically for vernal pools, increased frequency, duration, and intensity of droughts may drastically reduce hydroperiods. In some extreme cases, this may result in water shortages for an entire season, which may inhibit some animals' ability to successfully reproduce (Wiewel et al., 2023). Alternatively, large increases in precipitation will increase the hydroperiod, but may also flood previously suitable habitat. For example, sphagnum moss hummocks used for nesting by four-toed salamanders may become inundated with water after extreme rainfall events, which may affect the viability of deposited egg masses.

*Photo: Vernal pool in Nemadji State Forest, Andrew Herberg*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Vernal Pools

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | A minimum of a 50 ft “no impact” buffer should be maintained year-round around the whole perimeter of the vernal pool. This includes no removal of overstory and understory vegetation, as well as no use of heavy equipment. |
| | If habitat disturbance surrounding a vernal pool is unavoidable, plan work from October 1 through March 15 and conduct work under frozen soil conditions only. |

| Stressor | Action |
|---|---|
| | Maintain habitat corridors between adjacent vernal pools (especially those within 300 ft of each other) to enable wildlife movement and promote genetic diversity. |
| | Avoid development of roads or trails in proximity to vernal pools to minimize an alteration of hydrology. For existing or new roads/trails, ensure run-off cannot enter the vernal pool. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Avoid herbicide/pesticide application within forested habitat surrounding vernal pools. |
| | Avoid or minimize soil compaction and rutting if operating heavy equipment in proximity to vernal pool. |
| | In the case of forest management, ensure the slash is distributed evenly and not piled into or surrounding a vernal pool. |
| | Avoid ditching or draining of vernal pools during any land conversion process. |
| | Follow proper disinfecting protocols if traveling between isolated vernal pools to prevent the movement of invasive species or diseases that may affect amphibians (see Amphibian sub-chapter). |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas.

| Stressor | Action |
|---|---|
| | Work with land managers, including private landowners, to implement habitat conservation practices that support the habitat needs of rare forest species that rely upon vernal pools. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Prior to any work in forested habitat that may contain vernal pools, locate and assess the condition of these wetland features in the spring/early summer to ensure proper delineation of vernal pool boundary. |
| NA | Given that this habitat is not yet well-mapped and understood in Minnesota, continue studies to identify and map the habitat and learn more about the plant communities and animals reliant on the habitat. Continue building and sharing knowledge about managing for healthy vernal pool systems. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Promote and consider further development of tax incentives that enable landowners and farmers to gain value for maintaining conservation values on their properties. Provide increased levels of incentive payments for woodland owners to help protect woodlands and forests from further reduction due to development pressure. |
| | Support and promote education and technical assistance to maintain or restore forest habitat. |
| | Research and communicate alternative management techniques (i.e., variable density thinning, natural seeding), reference to natural disturbance intervals, natural regeneration methods, and to increase habitat quality for SGCN. |
| | Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. Prioritize high recreation use areas where invasive species have not yet established. |

## Case Study: Four-toed Salamanders and Forest Management

Understanding how a species and their habitat responds to forest management is a vital piece to conserving rare forest-dependent wildlife. Initiated in 2022, the DNR Nongame Wildlife Program began a study to explore how four-toed salamander populations respond to forest management activities in proximity to their preferred nesting habitat: vernal pools. This study utilizes a Before-After-Control-Impact (BACI) study design to tease apart natural annual variation in salamander abundance from the effect that forest management may have on these populations. Within the range of four-toed salamander in Minnesota, 45 vernal pools were identified for long-term monitoring with approximately half of these vernal pools scheduled for forest management activities within 350 meters of the pool boundary (i.e., treatment vernal pools). The other half of the survey pools were identified as controls and not planned for forest management. Survey pools were selected based on historical and recent observations of four-toed salamanders or pools that consisted of suitable nesting habitat. Survey work involves conducting nesting surveys that consist of 30 minutes of "active" search time or until all suitable nesting habitat within a vernal pool has been searched, whichever comes first. “Active” search time is defined as any time spent searching suitable nesting habitat (moss hummocks, woody debris, sedges clumps, etc.) within the highwater mark of a vernal pool for female four-toed salamanders and/or eggs. Relative abundance is determined by counting the occurrence of nesting activity (i.e., presence of salamander guarding eggs, gravid female salamanders, or unattended egg masses) within each wetland. All wetlands are surveyed at least once during the nesting season (May 1 – June 15).

*Photo: Four-toed salamander with eggs, Andrew Herberg*

Started in 2024, vegetation surveys and trail cameras deployment occurred within several survey pools (both treatments and controls) to better understand vegetation composition and hydroperiod of vernal pools, respectively. Vegetation surveys were conducted in August after the drying period within these vernal pools to allow for ample growing season and to minimize effects on salamander larval development. These surveyed employed a relevé sampling structure and documented species abundance, diversity, and other vernal pool characteristics. The goals of these surveys are to document vegetation composition/ diversity within vernal pools and to develop a classification structure for this understudied wetland type. Additionally, these data establish a baseline of vegetation composition and provide the opportunity to examine changes in vegetation after forest management has occurred. The objectives of the trail camera deployment are to record spatial and temporal variation in hydroperiod across most of the study vernal pools, and to determine whether hydroperiod significantly changed after forest management operations. These cameras are programmed to record timelapse photos of the wetlands and identify how many days standing water was present/visible. The deepest location of the wetlands was located during nesting surveys and a measuring post and camera was installed to monitor this location.

As of 2024, four-toed salamanders were detected in approximately 90% of the study vernal pools. Over 500 nests have been detected with over 290 female four-toed salamanders observed during nesting surveys. The mean egg mass size is 39.5 eggs (StDev: 53.2). The majority of vernal pool depths ranged from 24 – 35 cm at the time of nesting surveys. With May 1 as the start day for hydroperiod monitoring, most vernal pools held water for 74 to 152 day (July 14 and September 30, respectively) with a mean hydroperiod of 103 days (August 12). To date, few vernal pools have experienced the planned forest management activities; thus, not enough data exists to make any inference on the effects of forest management on four-toed salamander abundance. As this study continues for the next several years, additional data will yield valuable information on how best to protect these sensitive vernal pools and the species that rely on them.

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## CLIFF, TALUS, AND ROCK OUTCROP

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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# Cliff, Talus, and Rock Outcrop

## Habitat Description

This chapter features several types of habitat that are composed of sparsely vegetated native plant community types. These habitats, which include cliffs, talus slopes and rock outcrops, all have extensive areas of exposed substrate. They occur as small patches or long linear strips throughout the state (see Figure 3.19).

## Cliff and Talus

Cliff and talus communities are present on cliffs or talus slopes on steep-sided bluffs, along lakes and streams, on margins of bedrock ridges and in other settings with sheer bedrock exposures. Cliffs and talus slopes are often associated with one another because talus slopes are composed of rock fractured either from cliffs or smaller areas of exposed bedrock on steep hillsides. The vegetation of these communities is generally open. Lichens and mosses are often the dominant life forms, and vascular plants are sparse or patchy because of scarcity of soil.

In the Laurentian Mixed Forest Province, cliffs and talus communities are mostly restricted to the North Shore Highlands and Border Lakes subsections, where the Precambrian bedrock is frequently at or just below the surface and rugged topography is common. In the Eastern Broadleaf Forest Province, these communities are abundant in the Blufflands Subsection of southeastern Minnesota, where sedimentary bedrock is typically at or near the surface and topography is rugged. Scattered cliffs are present on bedrock formations elsewhere in the state.

## Rock Outcrop

Rock outcrop communities are open plant communities on horizontal or sloping bedrock exposures. Some outcrops are relatively level whereas others are very rugged. They are common in landscapes with thin soils over bedrock and are typically, although not always, small in size (i.e., less than 25 acres (10 hectares). Crustose and foliose lichens

*Photo: Northern Dry Mafic Cliff and Northern Dry Open Talus, Brule Lake, Michael Lee*

typically cover exposed rock surfaces, and fruticose lichens are also common. Vascular plant cover is sparse to patchy, depending on the amount of fracturing of the bedrock surface and accumulation of soil in cracks, crevices, and shallow depressions. Outcrops that have minimal fracturing and little accumulation of soil are dominated by lichens, with scattered shrubs and herbaceous plants. Outcrops with deep crevices provide vital year-round habitat, including for overwintering below the frostline, for some SGCN reptiles, like the common five-lined skink (*Plestiodon fasciatus*).

Many plants on bedrock outcrops are adapted to frequent desiccation because of the low moisture-holding capacities of substrates, and exposure to direct sunlight and strong winds. Plants must also withstand rapid fluctuations in substrate temperatures, which are significantly colder at night than in surrounding forests and much warmer during midafternoon on sunny days. Limited availability of nutrients in outcrop communities strongly influences community composition and limits growth rates of plants. Fire, as well as frequent drought and scarce soils, play a role in maintaining the open vegetation characteristic of these communities. Rock outcrop communities are most common in the Border Lakes and North Shore Highlands subsections and in the upper Minnesota River valley.

## Habitat Map

To depict Cliff, Talus, and Rock Outcrop habitat (see Figure 3.19), we compiled spatial data from several sources: DNR's Natural Plant Community layer and the Minnesota Geological Survey. (For more information, see Habitat Map Methods in Chapter 3: Habitats). We note included sub-types below; underlined items have links to online descriptions.

## Associated Native Plant Community Classes by Ecological Systems

### Cliff/Talus

CTn11 Northern Dry Cliff (PDF)

CTn12 Northern Open Talus (PDF)

CTn24 Northern Scrub Talus (PDF)

CTn32 Northern Mesic Cliff (PDF)

CTn42 Northern Wet Cliff (PDF)

CTu22 Lake Superior Cliff (PDF)

CTs12 Southern Dry Cliff (PDF)

CTs23 Southern Open Talus (PDF)

CTs33 Southern Mesic Cliff (PDF)

CTs43 Southern Maderate Cliff (PDF)

CTs46 Southern Algific Talus (PDF)

CTs53 Southern Wet Cliff (PDF)

### Rock Outcrop (RO)

ROn12 Northern Bedrock Outcrop (PDF)

ROn23 Northern Bedrock Shrubland (PDF)

ROs12 Southern Bedrock Outcrop (PDF)

## Minnesota Geological Survey

From the Minnesota Geological Survey we used the Minnesota Bedrock Outcrop polygons.

*Photo: Rock outcrop, Swedes Forest Scientific and Natural Area, Deb Rose*

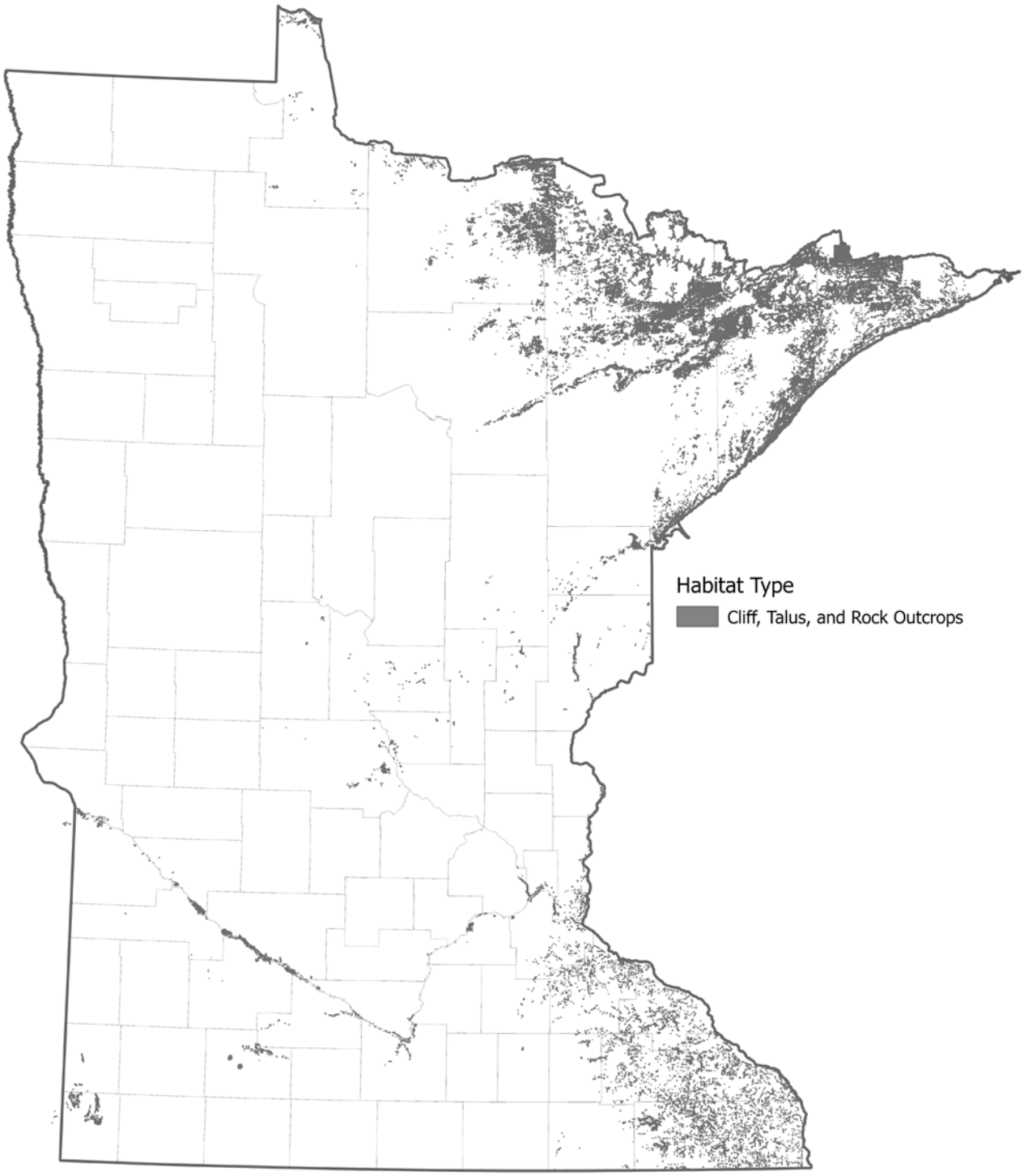


Figure 3.19. A map depicting Cliff, Talus, and Rock Outcrop habitat in Minnesota including DNR Native Plant Community Classes in the Ecological System of Rock Outcrop as well as rock outcrop data from the Minnesota Geological Survey.

## Conservation Overview

Maderate cliffs (and associated algific talus slopes) are globally rare, distributed only in Minnesota, Wisconsin, Iowa, and Illinois. Found in deep, narrow valleys in the Blufflands Subsection of southeastern Minnesota, they have a unique cold microclimate that is created by ridgetop sinkholes and subterranean ice caves. Temperatures can remain cool throughout the summer, even on the warmest days. These cliff and talus communities provide a cool, moist, equable climate required for several rare SGCN land snails, some of which only occur a couple of locations. A variety of human activities, either within these communities (such as rock climbing) or affecting the sinkholes on lands above these cliffs, may threaten these communities.

Rocky outcrops are critically important for protecting specialized flora and fauna and for maintaining biodiversity at multiple spatial scales (Fitzsimons & Michael, 2017). Their locations as dispersed across the landscape make designing conservation strategies challenging. Rock outcrop communities along the Minnesota River are threatened by woody encroachment (e.g eastern red cedar (*Juniperus virginiana*) and common buckthorn (*Rhamnus cathartica*), mineral extraction and residential and recreational development.

## Species in Greatest Conservation Need

Despite taking up a small proportion of the land in terms of acres, cliffs, talus and rock outcrops provide habitat for 74 animal and 71 plant SGCN as primary or secondary habitat (see Table 3.19).

Primary habitats are those that species rely on and use most consistently; if these habitats were degraded or lost, it would have the greatest effect on the species. Secondary habitats are those in which a species can be found some of the time, but less frequently than a primary habitat. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. For plants, only a single primary habitat was identified per species. Tables associating each SGCN with the 15 habitats identified in this SWAP can be found in Appendix D (animals) and Appendix E (plants). Examples of SGCN are described below; state-listed species are linked to their account in the Rare Species Guide.

**Table 3.19. Numbers of SGCN with Cliff, Talus, and Rock Outcrops as primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Birds | 2 | 0 | 2 |
| Mammals | 2 | 12 | 14 |
| Reptiles | 8 | 0 | 8 |
| Bees | - | - | 15 |
| Beetles (terrestrial) | - | - | 4 |
| Butterflies | - | - | 8 |
| Moths | - | - | 14 |
| Snails (terrestrial) | 8 | 0 | 8 |
| Spiders | 0 | 1 | 1 |
| Plants | 71 | - | 71 |
| **Total** | **91** | **13** | **145** |

## Birds

Common nighthawks (*Chordeiles minor*) associate with rock outcrops as a primary habitat. They nest on sparsely vegetated sites, especially rock outcrops in the upper Minnesota River valley and the Border Lakes Subsection, as well as sites in prairies and oak savannas, and in recently burned or logged areas. The peregrine falcon (*Falco peregrinus*) is an SGCN whose primary habitat association is with cliffs. This species had been extirpated in Minnesota due to DDT poisoning by the 1960's, and after the ban of DDT and active reintroduction efforts, a breeding population has been re-established in Minnesota and their range in the United States continues to expand (see Rare Species Guide profile for more details). Both of these species also nest on buildings and are associated therefore with urban and other developed spaces.

## Mammals

Although found in a variety of habitats in northeastern Minnesota, rock voles (*Microtus chrotorrhinus*) are most often associated with frost-fractured rock outcrops and rocky streambeds. Moist conditions and boulders or crevices seem to be important habitat features. The smoky shrew (*Sorex fumeus*) is also found in a variety of northern forest habitats, but its preferred microhabitat includes cool, damp forests with mossy covered rocks and decaying debris. They also have been documented in glacial boulder streams and within talus slopes. Although these two SGCN closely associated with talus slopes, rock outcrops and boulder piles, many other mammal SGCN may be observed using these habitats, including the Eastern heather vole (*Phenacomys ungava*), Western harvest mouse (*Reithrodontomys megalotis*), and American badger (*Taxidea taxus*).

## Reptiles

In Minnesota, the common five-lined skink is found in or near granite or gneiss outcrops (PDF) in the Minnesota River Valley (Lang,1982), and in exposed limestone and sandstone outcrops and bluff prairies (PDF) in the eastern part of the state (Oldfield and Moriarty 1994). The areas inhabited by skinks generally have abundant cover and basking areas. The presence of rocks or bedrock outcrops is a very important habitat component for this species (Lang,1982; Howes & Lougheed, 2004; Gelvin-Innvaer et al., 2025).

The timber rattlesnake (*Crotalus horridus*) occurs in the eastern and central United States. Minnesota is on the northwestern periphery of its range, which extends north along the Mississippi River from Illinois to Minnesota. Timber rattlesnake specimens have been collected from 8 counties in southeastern Minnesota, but survey efforts in the late 1990s and early 2000s found that populations were substantially reduced or extirpated from several areas where they occurred historically (Keyler & Oldfield, 2003). In Minnesota, the ideal habitat for timber rattlesnakes includes forested bluffs, south-facing rock outcrops (rock outcrops PDF), and bluff prairies (bluff prairies (PDF), particularly in the Mississippi River valley. Bluff prairies located on steep, south or west-facing hillsides, with rock outcroppings and ledges, are essential habitat components because over-wintering dens are often located in these areas. Surrounding forests, prairies, and agricultural lands are used as summer feeding grounds. Two necessary habitat components for this species are open areas for thermoregulation and dens for over-wintering.

*Photo: Timber rattlesnake on a rock outcrop, Julia Geschke*

## Case Study: Common Five-Lined Skink Microhabitat Research

Gelvin-Innvaer et al. (2025) describes an initiative by the DNR Nongame Wildlife Program and the Minnesota Biological Survey, in cooperation with other partners, to assess microhabitat use of and response by the common five-lined skink, a SGCN, to outcrop management along the Upper Minnesota River Valley. This resulted in recommendations for management thresholds for this population. These recommendations will help to update the DNR's Rare Species Guide Account for this species.

See the Case Study at the end of this chapter, which includes companion initiatives for protection, restoration and management of rock outcrops in the Upper Minnesota River Valley. Collectively, these constitute multi-faceted, integrated initiatives that involved many, diverse partners and funding sources.

*Photo: Juvenile five-lined skink, Deb Rose*

See also Gelvin-Innvaer, 2018; Reptile Renaissance: July–August 2018, Minnesota Conservation Volunteer

## Invertebrates

Several species and subspecies of rare tiger beetles of the genus *Cicindela* are found in the shoreline-dunes-cliff/talus habitat. The laurentian tiger beetle (*Cicindela denikei*) is limited to rock outcrops and sandy openings in hardwood forests in the Border Lakes Subsection.

The bluff vertigo (*Vertigo meramecensis*) and other species of Pleistocene land snails are found on steep, moist, shaded, cool north-facing slopes and cliff faces in the Blufflands Subsection. This small land snail also occurs on algific slopes and maderate cliffs but generally avoids areas with continuous cooling from cold air or water discharge. Although researchers have raised questions recently about the taxonomic distinctness of some of the SGCN land snails, all are rare and associated with the same habitats.

## Plants

In western Minnesota, waterhyssop (*Bacopa rotundifolia*) is found primarily in small rainwater pools on bedrock outcrops (PDF) and occasionally along the margins of shallow prairie ponds (PDF). The water is rarely more than inches deep and typically evaporates by July, leaving the sediments at the bottom of the pool moist or sometimes dry and cracked. *Bacopa rotundifolia* is generally able to persist for a couple more weeks after the pools dry up and then completely disappears from view.

The known habitats of wolf's spikerush (*Eleocharis wolfii*) in Minnesota are primarily associated with level outcrops in the southern part of the state (Minnesota River Prairie and Inner Coteau subsections) of bedrock (PDF). Specifically, they grow in the margins of shallow rain water pools that form in depressions on the bedrock or in thin sediments over the bedrock within a prairie or savanna (PDF) setting.

While associated primarily with the muddy margins of prairie ponds in non-forested wetlands, short pointed umbrella-sedge (*Cyperus acuminatus*) also occurs at the edge of shallow rock pools (PDF). The shallow rock pools where *C. acuminatus* has been found are mostly level with shallow depressions where rainwater accumulates. The pools are typically only a few meters across and 5-7 cm (2-3 in.) deep. Plants are typically rooted in a thin layer

of organic sediment that accumulates at the bottom. This is a sparsely vegetated, ephemeral habitat that may support only a few scattered plants or several hundred, depending on habitat conditions.

Another extremely rare plant in Minnesota is the ball cactus (*Coryphantha vivipara*), which occurs in crevices on granite outcrops. New occurrences of these and several other SGCN plant species were documented in a systematic survey of ephemeral rock pools by Harris (2010) during the summers of 2006-2008.

In southeastern Minnesota Leedy's roseroot (*Rhodiola integrifolia* ssp. *leedyi*), a SGCN that is also federally threatened, is restricted to shallow ledges on north-facing dolomite cliffs that can be nearly 100 feet high. It is further limited to sites where groundwater seeps through the sinkholes and openings amidst the region's karst landscape, releasing cool air through subsurface vents along the cliff face. Dependent on these cool, moist conditions, the species is considered a glacial relic, "a plant that was more widespread at the end of the last glaciation, but which has since become isolated because of the loss of appropriate habitat in intervening areas as the climate has warmed" (Sather, 1993). The four populations known in Minnesota are among just six that exist; the remaining two sites are in New York, one of which supports only a single plant. As the climate continues to warm, the unique habitat where this species is found faces another threat. Increased precipitation, especially several storm events, can disturb the cliff environment, dislodging vegetation and substrate materials. Indeed, in recent years plants were found in the talus at the base of cliffs at three sites and, at another site, the entire cliff face had been dislodged.

## Lichens

Rock outcrops are home to many unique lichen species. Lichen 'species' are a complex that consists of two or more, typically obligate, symbionts. The dominant partner is a fungus, which creates the main body of the organism. The endosymbiont is either a green alga or a cyanobacteria that lives within the fungal tissue. Usnea mutabilis (Bloody Beard Lichen) is a Minnesota State Threatened species that occurs primarily on sandstone outcrops near cool rivers associated with a variety of other lichen and moss species. It has been documented living on wood in other parts of its global range, but we know very little about why it is restricted to outcrops in Minnesota.

*Photo: Leedy's roseroot, Welby Smith*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Mining and Quarrying

Pit quarries and dimensional stone quarries occur on mapped bedrock sources with visible rock outcrops in the Minnesota River Valley. Some of these are adjacent to protected conservation lands with documented or potential for rare features associated with rock outcrops. Some of these conservation lands exhibit evidence of quarrying prior to protection. It is unclear from available GIS data layers how many of these quarries are still active, although some appear to be. Sustained quarrying would result in habitat loss and fragmentation for species dependent on rock outcrops which can exacerbate geographic isolation and limit gene flow. Active quarrying also increases the potential for direct injury or mortality.

Arguably one of the rarest plant species in Minnesota, ball cactus (*Coryphantha vivipara*), occurs in cervices on granite outcrops. Historically, it also occurred in thin-soiled prairies which were largely converted to agriculture; much of its potential habitat in the state has already been removed. Its remaining populations could be affected by granite quarrying.

### Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. SGCN like rock vole and smoky shrew require rocky outcrops with moist, cool conditions. If too much canopy is lost around these outcrops, they become exposed to the sun and dry out.

### Recreation

Rocky habitats are often not considered fragile when in fact they can be very sensitive to disturbance. Surface rocks that are even slightly displaced (e.g rock collecting, moved for trails, etc.) can change thermal conditions considerably and affect their value as refuges for reptiles (Pike et al., 2010). Foot traffic, mountain bikes, OHVs (off-highway vehicles) and horses can damage fragile and endemic plants. Increased recreational trails and human presence are often associated with the spread of invasive species and increases in commensal predators (domestic and wild). Rock climbing may affect sensitive vegetation (Clark & Hessl 2015; March-Salas et al., 2023; Johanson et al., 2024).

## Fire Management

With fire suppression since Euro-American settlement, woody plant cover is increasing in many rock outcrop communities. Prescribed fire is a valuable tool for managing woody encroachment on outcrops (Johanson et al., 2024). However, often fires do not "carry" well on outcrops when there are limited natural fuels. In fact, large rock outcrops can act as natural fire breaks. High intensity fires on open rock outcrops typically are naturally rare (Fitzsimons et al., 2017). Further, burning large piles of down woody debris atop outcrops (such as those that remain from large woody removal projects) can result in intense flames that can sterilize thin soils hosting rare endemic plants.

## Invasive Species (Problematic Non-native Species)

European and glossy buckthorn affect rock outcrop ecosystems in a variety of ways. These include reducing the availability of open habitats (sunlight and thermal effects) and altering soil and litter properties which in turn can affect native vegetation and invertebrates which may have broader trophic effects (Gelvin-Innvaer et al., 2025).

## Problematic Native Species

Eastern red cedar and sumacs encroaching on rock outcrops can reduce the suitability of the habitat for some SGCN, such as the five-lined skink and timber rattlesnake (Gelvin-Innvaer et al., 2025).

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

Increases in precipitation, especially heavy rainfall events, may affect some of the more geologically unstable (i.e., friable) cliff features in the southeast, causing steep rock faces or cliffs to crumble more easily when disturbed. Some increases in cliff sloughing and crumbling at sites have been detected where the federally threatened Leedy's roseroot (*Rhodiola integrifolia subsp. leedyi*) is found.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Cliff, Talus, and Rock Outcrop

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Protect algific talus and maderate cliffs, as well as rock outcrops that are habitats for SGCN from mining and other development activities. |
| | Restrict recreational access to and use of cliffs, talus slopes and rock outcrops, including but not limited to hiking, rock climbing, rock collecting and mountain biking. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Maintain sufficient canopy closure to maintain rocky outcrops characterized by cool, moist conditions. |
| | Manage rock outcrops to prevent woody encroachment that may be advancing due to a history of fire suppression. This includes invasive species like European and glossy buckthorn, the presence of problematic native species like red cedar and sumac. Consider the application of grazing, especially by goats, to help reduce woody encroachment on rock outcrops. |
| | When using fire to manage invasive species or woody encroachment, consult habitat specialists to ensure that fires are not so intense as to negatively affect the habitat. |

*Photo: DNR staff conducting surveys for Leedy's roseroot, Derek Anderson*

## Case Study: Protecting Granite Rock Outcrops on the Minnesota River

Granite rock outcrops along the Upper Minnesota River are among the oldest exposed rock in North America, dating back approximately 3.6 billion years. These outcrops are also home to rare and specialized plant and animal communities rarely found elsewhere in Minnesota, including several types of cacti and one of Minnesota's only three lizard species, the five-lined skink. However, these rock outcrops are increasingly threatened by mining, overgrazing, and development. With funding from the Minnesota Environment & Natural Resources Trust Fund, the Renville County Soil and Water Conservation District worked with Minnesota's Board of Water and Soil Resources to acquire conservation easements that will permanently preserve portions of this endangered habitat.

Soil & Water Conservation District (SWCD) employees saw a need to protect the natural environment and to provide economically viable choices for the landowners. The Minnesota River Valley contains exposed ancient granite rock outcrops that provide unique landscape features and habitat for specialized plant and animal communities rarely found elsewhere in Minnesota. No programs existed that would give landowners a payment if they chose to protect the area from development by mining, overgrazing and other development interests. Rock outcrops are a component of the Minnesota River's riparian zone, and destruction of this unique habitat degrades water quality and wildlife habitat in the Minnesota River and its tributaries. Removal of the rock results in severe degradation and permanent loss of these unique landscape features. The Minnesota River Corridor is easily susceptible to fragmentation because it comprises such a small percentage of the Minnesota River Watershed. Past development activities and mining operations have already fragmented large areas of the fragile Minnesota River Corridor.

A total of 748.4 acres of rare and unique Minnesota River Valley landscape were permanently protected and sixteen landowners were paid $1,741,580 for voluntarily placing perpetual conservation easements on those acres. Five counties participated in the project including Lac qui Parle, Chippewa, Yellow Medicine, Redwood and Renville. Easement applications were scored by resource professional teams and funding was based on those scores. For more information, see: Protection of Granite Rock Outcrop Ecosystem.

*Photo: Devil's Tongue (Opuntia  macrorhiza), Blue Mounds State Park, Rachel Kranz*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# CAVES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Exploring Mystery Cave, Forestville/Mystery Cave State Park, Dawn Ryan; Old mystery cave, Forestville/Mystery Cave State Park

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# Caves

## Habitat Description

Karst landscape features are formed by the dissolution of soluble rocks like limestone and dolomite. The resulting porous and soluble rock in the Upper Mississippi Valley has been recognized as one of the most "important karst regions" (Herak & Stringfield 1972, p. 470-471). Key features of karst landscapes include springs, disappearing rivers, sinkholes, cool and stable temperatures, high humidity and caves.

Cave and karst features are concentrated in the southeast corner of Minnesota where thick units of limestone and dolomite rock exist (Alexander & Brick, 2021) and more than 400 caves are found. Fillmore County has the highest concentration of caves in southeast Minnesota, where caves are primarily formed in the Dubuque and Galena formations (Alexander, 1980). Caves exist in other counties of southeastern Minnesota including those formed in the Prairie du Chien Group, St. Peter Sandstone and Platteville limestone.

The largest cave in Minnesota, with over 13 miles of cave passage, is Mystery Cave, located in Forestville/Mystery Cave State Park. Mystery Cave is an important bat hibernaculum and provides habitat for many cave invertebrates. Water from the South Branch Root River sinks underground at Mystery Cave and emerges at Seven Springs Wildlife Management Area, about 1.5 miles east of the cave (Forestville/Mystery Cave State Park).

In Fillmore County, another significant area of caves is Cherry Grove Blind Valley Scientific and Natural Area (SNA). Cherry Grove SNA protects a large cave system including Goliath Cave, as well as several hydrologically connected smaller caves. Water that sinks into the Cherry Grove Blind Valley travels underground and reemerges approximately 2.7 miles to the northeast at springs on Canfield Creek in Forestville/Mystery Cave State Park (Cherry Grove Blind Valley SNA).

*Photo: Old mystery cave, Forestville/Mystery Cave State Park*

Spring Valley Wildlife Management Area, also in Fillmore County, includes a sinkhole that has been hydrologically linked to Spring Valley Caverns and nearby Bly Spring. Other sinkholes on the property are likely hydrologically connected to Spring Valley Caverns as well. Spring Valley Caverns is privately owned with nearly 6 miles of mapped passages. Bat River Cave, also in Fillmore County and privately owned, is ecologically significant because it once supported the largest hibernating colony of bats in Minnesota.

Additional important sites for bats in Minnesota include sandstone caves in Pine and Washington counties, including Robinson's Ice Cave and Leslie Cave. In addition, in Lake County, two natural caves, Hole-in-the-Head and Gnomen, provide habitat for hibernating bats (Knowles, 1992). Due to the geology in the northeast region, natural caves are uncommon, and these sites are likely of regional importance to hibernating bat populations. Other geologic features in the north that can offer alternative overwintering habitat for bats include talus slopes and deep vertical rhyolite crevices (Gerda Nordquist, DNR, pers. comm.).

## Habitat Map

We created a map of important caves (Figure 3.20), we compiled spatial data from DNR's Natural Heritage Information System database of caves hosting bat colonies and Open Street Map.

### Natural Heritage Information System

From the Natural Heritage Information System we used data relating to the location of bat colonies.

### Open Street Map

From Open Street Map, we digitized Public/ semi-public caves.

## Conservation Overview

Caves provide habitat for rare and unique species of animals, the majority of which in Minnesota are invertebrates specially adapted to living in subterranean environments. Many of these species are troglobites, or organisms that spend their whole life in caves. Many of these species have evolved specialized traits, such as the loss of eyes and pigmentation. Minnesota cave ecology is only partially understood and the animals living there are exposed to extreme conditions with few food sources, no light, yet a stable and consistent temperature of approximately 48° Fahrenheit (F) (8.8° Celsius; C) and nearly 100% humidity. Other surface-dwelling animals such as bats, flies, moths, flies, raccoons, rodents and snakes will use caves to overwinter.

Groundwater within the cave forming karst landscape of southeastern Minnesota is critical to maintaining healthy coldwater stream habitats for trout in southeast Minnesota. Water traveling through bedrock aquifers typically cools as it travels underground. When groundwater emerges at a spring, it provides cool isothermal temperatures critical for coldwater trout species. Native brook trout (*Salvelinus fontinalis*) are found in some of these stream environments. Recreation opportunities provided by trout streams are of great economic importance to communities throughout southeast Minnesota (Anderson, 2016). These fisheries, like the caves themselves, can be affected by nitrate contamination and pesticide run-off (see also Water-borne Pollutants below).

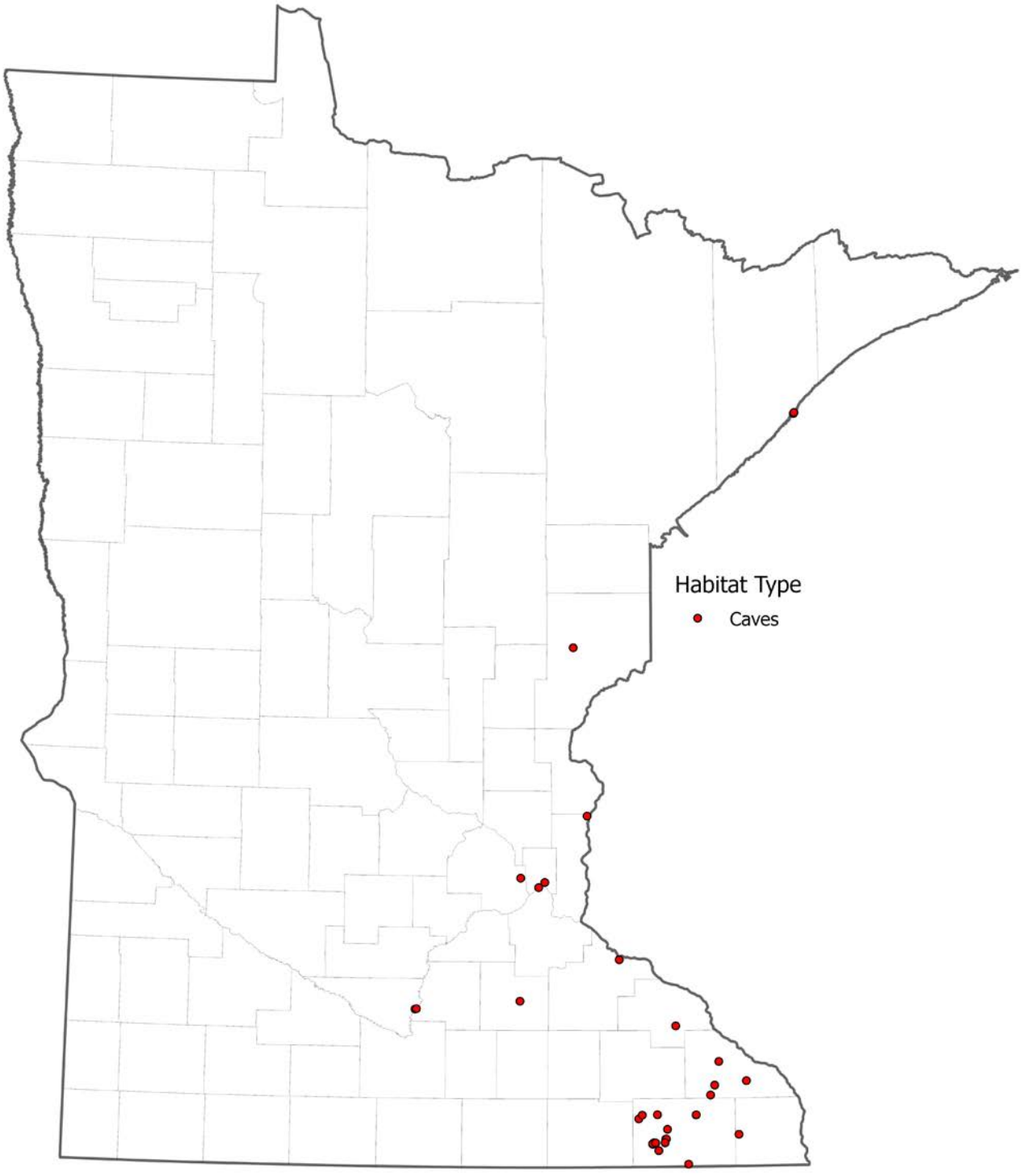


Figure 3.20. A map depicting significant caves in Minnesota including DNR Natural Heritage Information System data of caves used as bat hibernacula and digitized public/semi-public caves from Open Street Map.

# Species

## Bats

Four Species in Greatest Conservation Need species in Minnesota rely on caves and mines for winter survival: little brown bats (*Myotis lucifugus*), big brown bats (*Eptesicus fuscus*), tricolored bats (*Perimyotis subflavus*) and northern long-eared bats (*Myotis septentrionalis*).

Caves and mines have been an important habitat for early documentation of bat species in Minnesota. The first account of winter ecology for bats was published in 1934 by Charles A. Evans (Evans, 1934), which was followed by a period of scientific intrigue for bats in the state into the 1950s. Studies over the years added more sites with known hibernacula, more recently well described in the Distribution and Status of Bats in Minnesota report (Nordquist & Birney, 1985).

Caves provide the narrow range of ideal conditions for bats to hibernate for extended periods (Kunz, 1982). To hibernate, bats seek out subterranean environments that do not fluctuate with above-ground weather conditions, where cool temperatures and high humidity remain stable year-round.

This stability provides ideal conditions for bats to enter torpor, a physiological state characterized by a controlled reduction in body temperature, metabolic rate, and overall energy expenditure (Barclay et al., 2001). Torpor is a critical mechanism that allows bats to maintain fat reserves when ambient temperatures are unfavorably cool, and food availability is low (Geiser, 1988). During the long harsh winters in Minnesota, caves provide protective and stable environments where bats can use extended bouts of torpor with sparse active periods to survive without foraging for up to eight months underground.

*Photo: two big brown bats hibernating, by Melissa Boman*

While there are 490 listed caves described in Minnesota (Alexander & Brick, 2021), not all are suitable for bats. Suitable hibernating conditions within caves are primarily found in large cavities which have small entrances that reduce fluctuation with outside air temperatures. Nordquist and Birney 1985 describes “culd-de-sac or labyrinth passages that protect bats from drafty corridors.” Stable caves in Minnesota generally maintain a constant year-round temperature of 8° C or 47° F, and variation in temperature and humidity levels can be found based on the site entrance exposure, level of water seepage and site size (Nordquist & Birney, 1985). This variation results in differing levels of importance for each cave in supporting bat populations.

The majority of the important bat hibernaculum in Minnesota are localized to southeastern Minnesota where the karst region is found (Nordquist & Birney, 1985). Located in Fillmore County, Mystery Cave is the largest limestone cave system in Minnesota. Thus, this site supports generally constant temperature and humidity levels beneficial to bat populations, particularly species like little brown bats. Bat counts and banding efforts were conducted by the Minnesota Speleological Survey beginning in the late 1970s. Other important sites were mentioned above.

Considering the limited number of suitable hibernacula across Minnesota, combined with concentrations of vulnerable bat populations, and the narrow range of conditions that make caves irreplaceable habitat for bats, caves are extremely important environments to protect for the health and persistence of bat populations in Minnesota. White-nose syndrome threatens cave-wintering bats in Minnesota (see Diseases and Pathogens section below).

## Invertebrates

Three species of springtails (arthropods in the class Collembola) were designated as Species in Need of Information (SNI). These were highlighted for inclusion due to having global conservation status ranks of vulnerable or imperiled (*Arrhopalites dubius* and *Tullbergia hades*, G2, imperiled; *Onychiurus obesus*, G3, vulnerable). These organisms are completely confined to cave systems and adapted to subterranean life. As detritivores, these springtails feed on microbial films, fungi, and decomposing organic matter lining cave pools, playing a vital role in nutrient cycling and supporting food webs in the nutrient-poor conditions of cave ecosystems. Their troglobotic (i.e., obligated to underground living) lifestyle makes them excellent bioindicators of cave habitat integrity as they depend completely on stable subterranean conditions (Christiansen, 1964). They are also likely to be very sensitive to water quality, particularly pollutants from agricultural runoff, which also makes them bioindicators for assessing cave ecosystem health. These species are found in Mystery Cave and associated caves, as well as Goliath cave and associated caves at Cherry Grove Blind Valley Scientific and Natural Area. Due to a lack of information about these species, they were designated SNI rather than SGCN.

*Photo: Elongate springtail, Goliath's Cave Cherry Grove Blind Valley Scientific and Natural Area*

Caves provide a unique environment for the evolution of specially adapted species, and due to the disparate distribution of caves across the landscape, many fauna from caves are likely to be significantly rare. However, the taxonomy for many invertebrate groups remains poorly understood, and there is a shortage of active taxonomists. As a result, even though some collections exist, such as a 2022 survey of Forestville/Mystery Cave State Park (by Zara Environmental LLC; Krejca & McDermid, 2022), our understanding of representative invertebrate communities remains limited and there is not enough information to determine if any cave-dwelling species should be designated SGCN.

Several species of mites in the family Rhagidiidae (Acari), including some troglobitic forms, have been reported from caves across the United States (Elliott & Strandtmann, 1971; Zacharda, 1985). These tiny arachnids, which are relatives of spiders and ticks, are a common but often overlooked component of cave ecosystems. In the 2022 invertebrate inventory

of Mystery Cave, a member of the Rhagidiidae was recorded for the first time, marking a new addition to the known fauna of the cave and contributing to the broader understanding of subterranean biodiversity in the region (Krejca & McDermid, 2022). Like springtails, these animals play vital roles in cave ecosystems as predators, nutrient recyclers, and indicators of environmental health. Their presence likely helps maintain ecological balance in sensitive cave environments, and their loss could disrupt entire subterranean food webs. Additionally, many Rhagidiid mites remain poorly studied, so their conservation protects not only biodiversity but also future opportunities for scientific discovery.

Small, shrimp-like crustaceans known as amphipods (Order Amphipoda) were recorded for the first time in Mystery Cave during a 2021 biological survey (Krejca & McDermid, 2022). This finding is noteworthy, as a previous study by Montz (1993) specifically highlighted the absence of amphipods in this cave. The newly collected specimens may represent a range extension of known Driftless Area species or possibly a previously undescribed species. Either scenario highlights the ecological significance of the discovery and underscores the need for continued biological exploration and conservation of subterranean habitats like Mystery Cave.

Spiders (Araneae: Nesticidae) are often among the most diverse and ecologically important invertebrates found in cave ecosystems, including species that are either fully adapted to life underground (troglobites) or partially so (troglophiles). While it is not yet clear how specialized the spiders found in Mystery Cave are, or whether they represent unique endemic species, the individuals collected during recent surveys are notable and merit further investigation (Krejca & McDermid, 2022).

Continued research could reveal important insights into the cave's biodiversity, the evolutionary adaptations of subterranean spiders, and the role that spiders play in subterranean food webs.

*Photo: Cave cobweb spider, Forestville/Mystery Cave State Park*

Bathynellacea are an order of minute, groundwater-dwelling crustaceans typically found in caves, wells, and sometimes within the interstitial spaces of other aquatic environments (Schminke & Noodt, 1988). Despite their global distribution, occurring on every continent except Antarctica, they are notably absent from the fossil record. Their presence is also generally limited in regions previously covered by glacial ice, with only sparse recolonization documented in such areas (Grzimek, 2004). A 2021 collection in Mystery Cave marked the first recorded occurrence of Bathynellacea within the park, representing a species adapted specifically to groundwater environments (Krejca & McDermid, 2022). As such, it is restricted to subterranean habitats like caves and aquifers, highlighting the unique and specialized biodiversity found in Minnesota's karst systems.

Between 1989 and 1993, Montz (1993) documented the presence of several copepod and cladoceran species in the Mystery Cave system. Three copepod species representing two orders were identified from the Disappearing River: *Acanthocyclops vernalis* (tentatively identified) and *Eucyclops speratus* from the order Cyclopoida, and *Phyllognathopus viguieri* from the order Harpacticoida. More recently, in 2021, copepods were collected from several locations within the cave system, including Coon (Goliath's) Cave, Old Mystery

Cave, Woodchuck Cave, the Big Spring complex and Seven Springs (Krejca & McDermid, 2022).

Water fleas (order Cladocera) were also found in the system. Montz (1993) reported six cladoceran species from the Disappearing River and one additional species from Blue Lake within Mystery Cave.

In a 2021 survey, specimens resembling cladocerans were collected from Coon (Goliath's) Cave, Old Mystery Cave, Big Spring and Seven Springs (Krejca & McDermid, 2022). However, these were not identified to species level. These findings suggest that both copepods and cladocerans are relatively widespread in the Mystery Cave hydrological network and may play an important role in the cave's aquatic food web.

In summary, cave-dwelling invertebrates are highly specialized organisms that play essential roles in nutrient cycling and food web dynamics within subterranean ecosystems. Despite their ecological importance, little is known about their population status, distribution or specific ecological functions. Many species are adapted to stable, low-light environments and are highly sensitive to environmental changes, making them valuable indicators of groundwater and habitat health. Improved surveillance and monitoring of these invertebrates are critical for understanding and conserving the unique biodiversity of cave ecosystems in Minnesota.

*Photo: Exploring Mystery Cave, Forestville/Mystery Cave State Park, Dawn Ryan*

## Primary Stressors for Caves

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Crop Production

Commercial agriculture dominates southeast Minnesota where Minnesota has its highest concentration of caves. The use of nitrogen-based fertilizers, herbicides, pesticides and other chemicals can degrade water quality in cave environments. In karst areas of southeast Minnesota, human influences on groundwater and surface water quality have been documented for decades (Mohring, 1983; Jameson & Alexander, 1994 Kuehner et al., 2025).

The main Goliath Cave sinkhole entrance has been completely filled with sediment from run-off. The Scientific and Natural Area is surrounded by farm fields that are tiled. When sediments, including agricultural plant material (like corn stalks), and manure run off farm fields, it can significantly alter the cave's hydrology and introduce pollutants that threaten the unique underground ecosystem. A recent inventory noted approximately 20 different species of invertebrates found in Goliath Cave (Krejca & McDermid, 2022). These highly specialized species, such as blind isopods, cave beetles or springtails, have evolved in stable, low-nutrient, low-light environments with little tolerance for change and are therefore threatened by a sudden influx of sediments and pollutants.

### Livestock Management

Livestock operations, particularly concentrated feed lots, can threaten caves through pollution. Manure and agricultural runoff can contaminate water sources, which can enter caves through sinkholes, sinking streams, and fractures in bedrock. Caves act as conduits for groundwater and can transport pollutants very quickly downstream. For instance, Mystery Cave has an underground stream that is a meander cut-off of the South Branch Root River. Agriculture and grazing operations are active on the surface above Mystery Cave. The caves' river flows underground two miles and resurfaces at Seven Spring Wildlife Management Area, which is an important trout habitat. Goliath's Cave in Cherry Grove Blind Valley has its own underground river which flows five miles and resurfaces in Canfield Creek in Forestville/ Mystery Cave State Park another important trout habitat. Goliath Cave is surrounded by agriculture and livestock operations.

### Mining and Quarrying

Mining, including limestone extraction, can directly impact caves, eliminating habitat for cave adapted species. Mining operations can also affect cave and karst systems in other ways such as thermal effects on springs and surface-water streams, changes to water turbidity and lowering of groundwater and surface-water levels from mine dewatering (Green et al., 2005).

## Recreation

During the fall and winter months (September 1 – May 1) when bats are likely to be present in caves, human presence can disturb and wake bats similar to white-nose syndrome symptoms that result in mortality. In addition, recreators can inadvertently spread the causative fungus of white-nose syndrome if shoes and gear taken underground are not sufficiently decontaminated. For these reasons, major bat hibernacula in Minnesota are protected with gated entrances and restricted access for safety of bats and people.

The presence of visitors in caves can also elevate air temperatures. In Mystery Cave, tours cause an elevation in temperature of about 1.5 degrees F every time a group of visitors passes by a set of data loggers over the past five years (Dawn Ryan, DNR, pers. comm.).

## Diseases and Pathogens

As critical habitat for overwintering bats, caves have also been at the heart of white-nose syndrome (WNS), an epidemic that has devastated hibernating bat populations across North America. This disease affects hibernating bats by disturbing the delicate hibernation cycle, resulting in bats waking from torpor more frequently and burning the fat reserves needed to survive the winter with no insects (Frick et al., 2010). The causative fungus, *Psuedogymnoascus destructans*, is a non-native, subterranean, cold-loving fungus that thrives in the same areas of caves where bats hibernate. The fungus infects tissues of hibernating bats, vulnerable with no immune response while in torpor, and becomes visible white patches on the forearms, ears or nose of the bat, giving the disease the WNS namesake. The confirmation of WNS in Minnesota during the winter of 2015-2016 has been followed by declines averaging greater than 90% for hibernating bats across the state, particularly for the little brown bat, Northern long-eared bat, and tricolored bat.

## Water-borne Pollution

One of the most frequently detected contaminants in groundwater and surface waters of southeastern Minnesota is nitrate-nitrogen (commonly referred to as nitrate). Nitrate concentration is commonly elevated in the root zone underlying row-crop agriculture in Minnesota, where concentrations collected from lysimeters average greater than 20 ppm (Kuehner et al., 2020). Nitrate is leached in cultivated row-crop settings following precipitation and snowmelt and moves to shallow groundwater where it migrates to underlying aquifers and streams. Depending on the timing of recharge, nitrate concentrations in shallow karst may rapidly increase or decrease (Barry et al., 2020). In southeastern Minnesota, trout-stream baseflow nitrate concentration positively correlates to the percentage of row crop agriculture in the watershed (Watkins et al., 2013).

Elevated levels of nitrate may indicate that other surface contaminants have the potential to reach an aquifer. Pesticides frequently co-occur with nitrate, with the likelihood of detecting at least one pesticide compound increasing as the concentration of nitrate increases (MDA, 2019; Goedjen et al., 2024). Trout fisheries are also affected by nitrate contamination directly as well as fed by underwater sources from caves as noted above.

Southeastern Minnesota has several karst aquifers with different properties. In general, the shallow Galena karst aquifer (which is present across Fillmore County) has high nitrate levels and short groundwater residence time (Kuehner et al., 2025). Groundwater residence time is the time it takes water to travel from the surface to the point it was sampled; residence time is related to the amount of nutrient removal it provides. The Prairie du Chien aquifer, more common across counties east of Filmore, has longer residence times and lower nitrate levels.

## Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Increased flooding events carry pollutants from agricultural run-off, faulty septic systems, and pesticide, which can affect springtails and other animals who live in caves. While many cave-dwelling animals are aquatic, they are adapted to near constant temperatures. In addition, flooding events cause increases in cave temperatures. In Mystery Cave, increases in temperature of close to 10 °F have been detected during floods, and the cave takes months to return to normal temperatures (Dawn Ryan, DNR, pers. comm.).

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al., 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

## Case Study: Goliath Cave and Cherry Grove Blind Valley SNA

Cherry Grove Blind Valley Scientific and Natural Area (SNA) was established in March 2000 after the landowner applied for a quarry permit to mine limestone on the property. Goliath Cave and several other small caves in the SNA would have been mined away and lost, had the state not purchased the property. Goliath Cave includes ancient rock formations dating back to the Ordovician Period (443.7-488.3 million years before present), when what is now Minnesota was located south of the equator and covered in shallow seas. The cave system also provides cold water to trout streams in the area. See Cherry Grove Blind Valley Scientific and Natural Area for more information.

*Photo: Dawn Ryan, cave manager, by cave opening, Cherry Grove Blind Valley Scientific and Natural Area*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

## Potential Conservation Actions for Caves

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. In some cases, actions were not identified for all strategies. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Consider protection measures, such as purchase of land easements above known caves to help reduce run-off into caves and ground water. |
| | Increase protection of important cave ecosystems from mining and quarrying. |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience.

| Stressor | Action |
|---|---|
| | Maintain stock limits and reduce capacity of confined feedlots in sensitive karst habitats where caves receive runoff than can contain contaminants. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| NA | Encourage cave-related research, such as through the Cave Research Foundation |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Encourage and reward landowners who properly buffer sinkholes and other karst features that have direct relationships to groundwater. Promote best practices regarding runoff such as properly sealing wells and maintaining septic systems, reducing the use of nitrates, pesticides and fertilizers, increasing cover crops and developing denitrification wetlands. |
| | Encourage adoption of best practices for cavers and spelunkers to reduce effects when exploring caves, such as in guidelines set forth by the National Speleological Society. |
| | Follow decontamination procedures when visiting caves to avoid spreading the causative fungus of White-Nose Syndrome. While effective treatments for widespread containment of the fungus causing white-nose syndrome or prevention of disease have yet to be developed, there are actions that can be taken to protect bats. Preventing the spread of fungal spores between caves and avoiding disturbance to hibernating bats are key methods to reduce further harm. Spores are not visible to the human eye and readily attach to clothing or gear carried into caves. Follow protocol for decontaminating gear after visiting any cave or underground feature, particularly if you travel to multiple caves. |

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# URBAN AND OTHER DEVELOPED LANDS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Bird City actions include communities providing boardwalks that provide accessibility to natural areas while protecting underlying habitat, with signage that engaging and educational, Joanna Eckles, American Bird Conservancy; A wind turbine placed amongst cropland

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# Urban and Other Developed Lands

## Habitat Description

This chapter is devoted to the places where we live and work. Developed lands include those urban, exurban, or rural areas for housing, business, and municipal or community uses. These developed areas contain parklands with a variety of land cover types including grasslands, woodlands, forests, lakes, and rivers as well as managed wetlands such as water treatment facilities. Road rights-of-way extend beyond typically developed areas forming a network throughout the state. Areas developed for energy generation and transmission include mines, gas pipelines, nuclear, wind, and solar power generation facilities, and transmission lines. Working lands refers to agricultural lands managed for crop and livestock production, and forest land cultivated for timber harvest (see Prairie and Other Grassland and various forest sub-chapters).

These developed and working lands can also provide habitat for a subset of SGCN that inhabit, visit, or fly through. These are also important places where many conservation actions may be implemented to assist SGCN because of the number of willing and interested community members who can contribute.

*Photo: A wind turbine placed amongst cropland*

## Habitat Map

For many of the other habitat sub-chapters, we referenced Minnesota's Ecological Classification System, noting Native Plant Community (NPC) Classes or Types in each. However, developed lands are not represented within the NPC system. In the Midwest Landscape Initiative Midwest Landcover map they are included as Developed and Ruderal types. Developed is used for areas with less permeable surfaces. Ruderal references vegetative communities that are dominated by non-native plant species or are otherwise heavily human-influenced. Agricultural lands are also included in this map (see Figure 3.21).

## Associated Habitat Types

### Developed

Urban – residential, corporate, municipal, manufacturing, data centers, etc.

Developed grasslands (examples: urban parks, airstrips, solar arrays)

Developed aquatic habitats (examples: water treatment ponds)

Rights-of-ways (the areas directly adjacent to roads, railroads, and trails)

### Mining and Energy

Sand and gravel mines

Solar farms

Wind farms

Power and pipeline corridors

### Agricultural

Cropland

Hayfields (cross-list to Prairies and Other Grasslands)

Pasture and rangelands (cross-list to Prairies and Other Grasslands)

Animal rearing and livestock production facilities

CRP and other restoration lands (cross-list to Prairies and Other Grasslands)

Woodlots and Tree Plantations

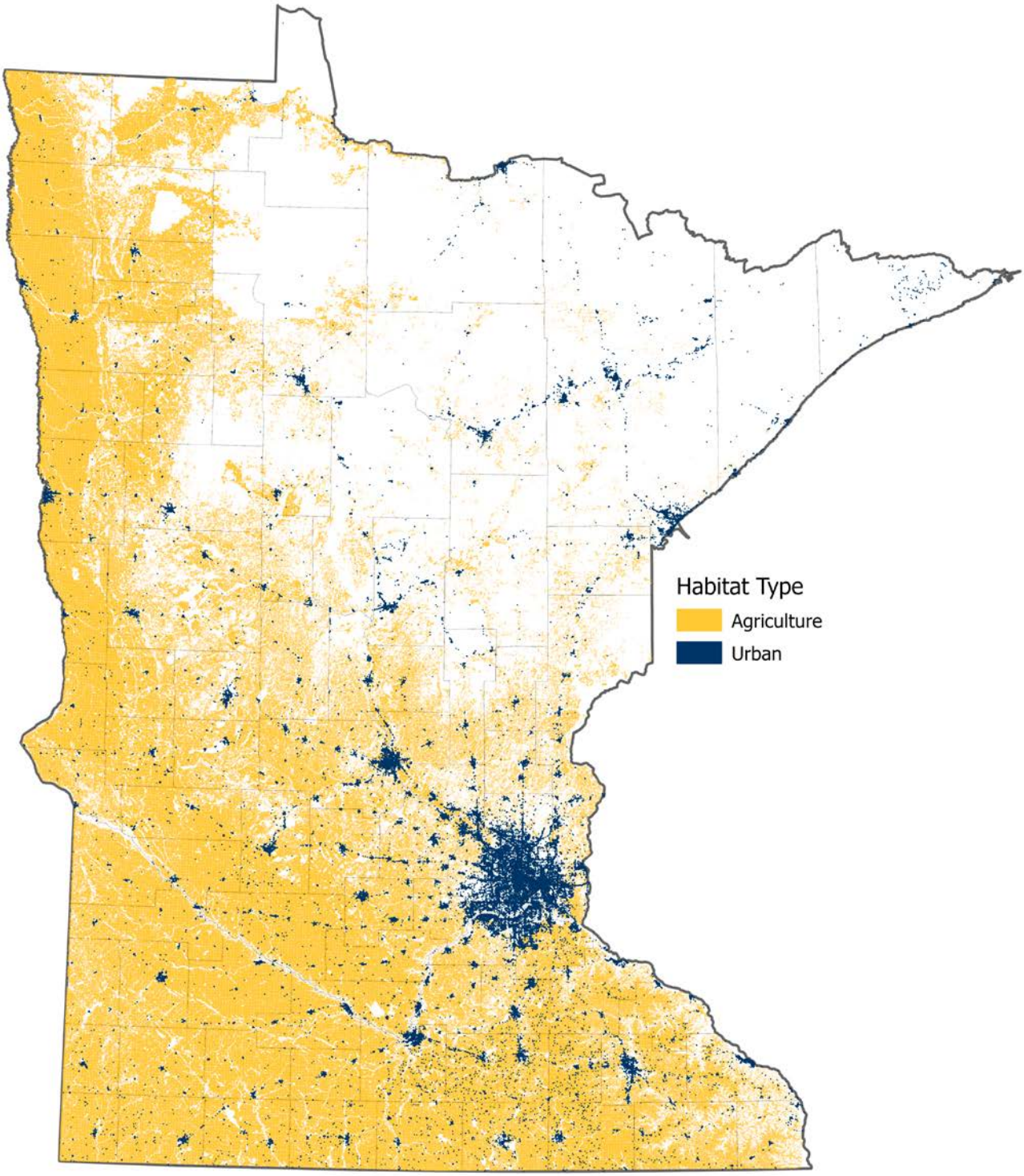


Figure 3.21. A map depicting Urban and Agricultural landcover in Minnesota from the Midwest Terrestrial Habitat System (see narrative).

## Conservation Overview

Conservation within urban and developed landscapes is unique. These landscapes are typically fragmented due to development for housing, business, energy, industry, and transportation or in the case of working lands, agricultural, livestock, or timber production. These are the places that provide services to our communities. Because of their proximity to where we live and work, these lands also represent excellent opportunity locations to engage community members in conservation actions.

Urban conservation efforts over the last 30 years have been successful at identifying tracts of land that contain unique habitat types or those with high ecosystem function and proactively protecting them from development through conservation easements or fee title purchase as open space, natural areas or parks. These lands have become focal points for current conservation efforts as well as drawing the attention of residents to the benefits of those habitats to wildlife, watershed health, and proper ecosystem function. Through local outreach efforts, public engagement, and conservation programs, urban and suburban landowners have grown to understand the benefits of these habitats and implement small scale practices such as pollinator plantings, prairie restoration and the use of native species in landscaping and lawns.

Landowners that manage working lands have access to federal, state, local, and private conservation resources focused on helping them implement grazing management, soil health, and conservation practices that minimize or mitigate potential negative environmental effects. Agricultural producers have access to and incentives to implement conservation practices such as cover cropping, precision agricultural practices, and various crop management techniques. Livestock managers can implement rotational grazing systems that can enhance soil and ecosystem health and may be tailored to certain habitat types and long-term conservation goals.

Even with all the progress mentioned above, pressure from urbanization continues to threaten working lands, and remaining wildlife habitats alike. Once these lands have been developed, they will never return to their previous state. Future conservation efforts need to capitalize on past and current successes while focusing on partnerships between private landowners, non-governmental conservation organizations, state, federal and local governments that proactively coordinate conservation efforts that aim to mitigate the effects of development on wildlife habitats.

*Photo: Nest box providing habitat for American kestrel in suburban landscape, being checked by an intern, also providing an educational opportunity, Kristin Hall*

## Species in Greatest Conservation Need

Urban and Other Developed Lands provide primary or secondary habitat for 37 animal SGCN (see Table 3.20) Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently. Plant SGCN were not associated with this habitat type. Animals with more general habitat requirements are associated with multiple habitat types, while specialists are associated with one or few. Habitat associations for insects were not differentiated into primary and secondary habitats and are shown in the total column. Detailed tables associating each SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found in Appendix D for animals and Appendix E for plants. Examples of selected SGCN are described below; state-listed species are linked to their account in the Rare Species Guide. SGCN that use urban or other developed habitats should not be interpreted as requiring this habitat type, rather we acknowledge developed land uses are part of the landscape where SGCN can persist, and conservation opportunities can be highlighted. For example, urban and other developed lands may serve an important role in providing stopover habitat for highly mobile species and migrating birds.

### Amphibians

Minnesota's only endangered amphibian, the Blanchard's cricket frog (*Acris blanchardi*), readily exploits aquatic habitats that have been or are significantly altered by human actions. This species appears to express some preference for aquatic habitats with limited aquatic vegetation which are sometimes created by sand and gravel mining and artificial water level manipulation. Once nearly lost from Minnesota, some of the habitats this species has persisted in and recolonized as they recover, include active sand and gravel mines, river barge docking areas, streams in agricultural landscapes and urban parks.

### Birds

Several bird SGCN are almost entirely dependent on human-created nest structures. Formerly nesting in large, hollow trees or other natural cavities, chimney swifts (*Chaetura pelagica*) now build their nests almost exclusively inside of chimneys. Suitable chimneys usually occur in urban areas, often in either large cities or small-town centers. Chimney swifts may also use artificial nest structures created specifically for them. Purple martins (*Progne subis*) are dependent on artificial nest structures built, placed, and maintained by humans. Nest structures must be built following specific guidelines to minimize predation and competition with other bird species. Suitable purple martin nest structures are usually close to water, often placed near lakeshores.

**Table 3.20. Numbers of Species in Greatest Conservation Need associated with Urban and Other Developed Habitat as either primary or secondary habitat.**

| Species Group | Primary Habitat | Secondary Habitat | Total |
|---|---|---|---|
| Amphibians | 0 | 1 | 1 |
| Birds | 3 | 6 | 9 |
| Mammals | 2 | 14 | 16 |
| Reptiles | 0 | 5 | 5 |
| Bees | - | - | 2 |
| Beetles (terrestrial) | - | - | 3 |
| Butterflies | - | - | 1 |
| **Total** | **5** | **26** | **37** |

*Photo: Purple martins on artificial nest structures, Adobe Stock*

Common nighthawks (*Chordeiles minor*) and peregrine falcons (*Falco persegrinus*) often nest on artificial structures in developed habitats, but both species also nest in native habitats. Common nighthawks will nest on gravel rooftops on buildings, as well as on native rock outcrops and other barren microhabitats. Changes in roofing practices, eliminating many gravel rooftops, may be one factor in common nighthawk population declines. Historically, peregrine falcons nested on native cliff habitats, but during reintroduction efforts were largely dependent on artificial nest boxes placed on bridges, buildings, or other human-created structures, as well as on cliff faces. As the population has increased, some peregrines have returned to native cliffs, but artificial structures continue to be very important nest sites.

Red-headed Woodpeckers (*Melanerpes erythrocephalus*) nest in native habitats such as oak savanna and floodplain forest, but in rural, agricultural regions they commonly nest in small woodlots at rural farmsteads. These farmsteads, particularly in southwestern Minnesota, support a significant red-headed woodpecker population. However, woodpeckers nesting in these areas often forage along roads, where they are susceptible to mortality from being struck by motor vehicles.

Various bird SGCN use urban areas as stopover habitat during migration. Migration has been identified as the primary period determining survival (or mortality) of adult migrating birds (Hutto, 1998; Sillett & Holmes, 2002). There may be untapped potential for urban habitat restorations (particularly replacement of turfgrass with native plantings) to support migrating birds as stopover habitat.

## Case Study: Bird City Program by American Bird Conservancy

Bird City started with a single program in Wisconsin in 2009 and expanded to almost a dozen programs recognizing communities across the U.S. and Canada by 2021. Bird City is a conservation program that brings people together to create healthier communities benefiting both people and birds. The program serves as a guide - individuals working together in the community learn about the problems birds face and about potential solutions. They view a list of specific, locally appropriate, bird-friendly actions and select a subset they want to complete or in many cases, are already in motion. Once the required number of actions are complete, the community can apply and be designated as a Bird City. Actions are focused on improving habitat, addressing threats, engaging people, and promoting sustainability. American Bird Conservancy and Environment for the Americas have joined forces to help deliver solutions on the ground through the Bird City Network with over 200 communities across 4 countries currently working to become healthier for birds and people.

*Photo: Bird City actions include communities providing boardwalks that provide accessibility to natural areas while protecting underlying habitat, with signage that engaging and educational, Joanna Eckles, American Bird Conservancy*

## Mammals

Two SGCN mammals are associated with now human dominated habitat types of grazed pastures, developed grasslands, and road rights-of-way: the Richardson's ground squirrel (*Urocitellus richardsonii*) and Northern pocket gopher (*Thomomys talpoides*). Both can be found in open habitats preferring dry well-drained soils for burrowing. Richardson's ground squirrels, a species of tallgrass and short grass upland prairies, prefer short vegetation as high visibility is important for detecting potential predators and can also be found in grazed pastures and open urban areas in western Minnesota. Broadly distributed across western North America, the Northern pocket gopher can be found in a range of habitats. In Minnesota, however, it is limited to suboptimal habitat associated with agricultural fields and roadways in the extreme northwestern part of the state. Competition with the larger and more numerous plains pocket gopher (*Geomys bursarius*), combined with bounties for the species, may be responsible for its restricted distribution here.

All seven SGCN bat species frequent urban and other human-altered habitats. They may be observed foraging in parks, along boulevards and under streetlights. Cave bats, such as little brown myotis (*Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*), also roost in developed spaces such as bridges and attics during summer and hibernate in tunnels, mines and buildings during winter.

## Reptiles

In the upper Midwest, timber rattlesnakes (*Crotalus horridus*) live in the hills and valleys of the Mississippi River drainage. South to west-facing bluffs or hillsides with rock outcrops are used as overwintering sites. Due to cold winter weather, most snakes are inactive and in their dens from mid-October to mid-April. Nearby forests and grasslands are used as summer feeding grounds where snakes eat mostly small mammals. In summer, snakes like to be anywhere there is a food source for them. In some cases, this can include residential yards with bushes, rocks, mulch, a water source, bird feeders or any other feature that attracts rodents; all these features can also attract snakes. Another SGCN snake, the North American racer (*Coluber constrictor*), also occurs in the southeastern region of Minnesota and uses woodland margins and field edges as a preferred summer habitat.

Many turtles in Minnesota, including the wood turtle (*Clemmys insculpta*) and Blanding's turtle (*Emydoidea blandingii*), can be found using developed land types, especially with respect to nesting or dispersal between aquatic habitats. Roadways, gardens and yards, agricultural fields, and sand or gravel mines often provide a loose substrate suitable for digging their nests.

## Invertebrates

The ghost tiger beetle (*Cicindela lepida*) and two other SGCN tiger beetles persist and even thrive in human dominated habitats that create or maintain open soil like sand and gravel mines. Tiger beetles are dependent on bare or sparsely vegetated soil for the development of their larva and to facilitate their hunting strategies. Soil stabilization, invasion of invasive plants (which may readily exploit bare soil habitats) and artificial water level manipulation can limit the availability of the habitats this group of insects require.

The rusty patched bumble bee (*Bombus affinis*) is a generalist forager and relies on consistent food sources throughout the growing season from a wide array of flowers. Worker bees have been observed in a variety of habitats, including forests, wetlands, grasslands, roadsides, agricultural fields, and residential lawns and parks (Colla & Packer, 2008). Rusty-patched bumble bee occupancy is positively associated with developed land uses (Boone, 2023), and this bee can be found foraging on native and non-native flowering plants in urban and suburban gardens and parks within its range.

*Photo: Rusty-patched bumble bee, Rachel Kran*

The monarch butterfly (*Danaus plexippus*) is another insect SGCN that can thrive in developed habitat types such as roadsides, fields, gardens, wetlands and parklike settings, if milkweed is present for the caterpillar phase of their life cycle. During migration, adult monarch butterflies forage for nectar on a wide range of blooming plants. Minnesota is within the reproductive and migratory ranges for the eastern migratory monarch population that overwinters in Mexico.

## Plants

Although none of the plant SGCN were associated with Urban and Other Developed Lands as their single primary habitat, open spaces within developed and working lands can provide valuable habitat for SGCN plant species and act as connections to more intact habitat. Even altered or fragmented habitat can retain the necessary habitat characteristics required by SGCN to persist. These areas are often under surveyed, and the value of the habitat is not recognized until a development action is proposed.

Lance-leafed violet (*Viola lanceolata*) is a prime example of a species that is frequently found persisting in altered or fragmented habitat. Lance-leafed violet is a pioneer species that does not compete well with larger, later successional species. It requires some disturbance to its habitat to be successful. In some cases, anthropogenic disturbance that removes competing vegetation and releases the seed bank can be beneficial to the species. However, development remains the biggest threat to the species and was the basis for listing the species as State Threatened in 1995. A large percentage of Minnesota's *Viola lanceolata* element occurrences (EOs) are found in the Anoka Sand Plain in the north Minneapolis-St Paul metro area. The north metro has and likely will continue to have a great amount of development pressure which results in the destruction of lance-leafed violet habitat and the take of individual plants. The loss of lance-leafed violet from this part of the state would greatly reduce its range and ability to survive in Minnesota.

Projects such as pollinator gardens, rain gardens and conservation plantings often use Minnesota plant SGCNs. Examples include rattlesnake master (*Eryngium yuccifolium*), beachgrass (*Ammophila breviligulata*) and plains wild indigo (*Baptisia leucophaea*). These species are SGCNs in Minnesota because they are believed to possess unique genetic composition that allows them to survive at the extreme edge of their natural range. Knowing the origin of seeds purchased commercially is important as there is concern that plants imported from other regions may hybridize with native strains.

## Case Study: Rare Plant Rescue Project

Anoka Sand Plain Rare Plant Rescue Program is a collaborative partnership led by the UMN Landscape Arboretum and focused on protecting rare plants in the Anoka Sand Plain (ASP) region. The ASP spans across several metro counties and supports 59 of Minnesota's state-listed species (or nearly 20%) while representing only 2.2% of Minnesota's land area. This program collaborates with the DNR, landowners and developers to rescue rare plants from permitted development project areas before construction begins. They accomplish this with a team of ecologists and dedicated volunteers who help us to quickly mobilize and implement rescues. Rescued plants are transplanted into permanently protected natural areas with ecologically appropriate habitat and are monitored overtime.

Since the 2019 inception of the ASP Rare Plant Rescue Program, 10,384 rare plants have been rescued and transplanted into permanently protected habitats. Plants have been rescued from 11 development sites and transplanted into 230 monitored plots on 13 recipient sites. Rescues have involved 10 different state listed species including: three Endangered, five Threatened, one Special Concern and one Watchlist.

*Photo: Toothcup, a rare plant frequently encountered in areas of the Anoka Sand Plain under development, Scott A. Milbur*

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key "stressors" that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the "Stressors" section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as "stressors" can also be used to advance conservation goals. Broad terms such as "fire management" reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

Information about a subset of primary stressors specifically affecting this habitat is included below, followed by a set of conservation actions addressing those stressors.

### Development

Habitat loss and fragmentation, loss of movement or connectivity corridors and increased competition from invasive species are more prominent in developed landscapes. Yet the remaining patches of wildlife habitat or natural areas within developed infrastructure can provide benefits for SGCN. There are three sub-categories of development: commercial and industrial areas, housing and urban areas, tourism and recreation areas.

Bird collisions with glass claims the lives of hundreds of millions of birds each year in the United States. It is second only to domestic cats as a source of mortality linked directly to human action. Glass is dangerous for strong, healthy, breeding adults, as well as sick or young birds; it can have a particularly serious effect on populations (Sheppard and Phillips, 2015). Bird glass strikes often happen in the day and are due to reflective glass mimicking sky or

clear glass not being recognized as an obstacle. While these collisions are often documented in more urban settings and associated with large glass skyscrapers, even small windows in residential settings can be high strike hazards. Bright lights on buildings at night can exacerbate the threat of nocturnal collisions (see also Light and Noise Pollution stressor below) and have been documented as causing mortality events of nocturnal migrant birds. Especially during storms or low ceiling events, birds can become disoriented and either collide with lighted structures or circle for hours leading to exhaustion and death.

Another known threat associated with developed areas is unsupervised domestic and feral cats which can pose a serious threat to local wildlife populations. According to Loss et al. (2013) an estimated 164 million cats reside in the United States, with 30-80 million unowned (barn cats, human-fed strays, feral). The effect of free-ranging cats has often been downplayed with comparison to anthropogenic threats, like habitat destruction, pollution, and direct collisions with man-made structures (Loss et al., 2013). Yet, studies have found that cat-induced wildlife mortality, especially for birds, is comparable or can exceed additional mortality factors. It's been estimated that just in the contiguous United States cats kill between 1.3 and 4 billion birds annually, with most mortality (69%) caused by un-owned cats (Loss et al., 2013). For mammals, Loss et al. (2013) estimated that cats are responsible for the mortality of 6.3-22.3 billion mammals annually, with 89% caused by un-owned cats. Although there is no statewide estimate for domestic cat populations in Minnesota, Lepczyk et al. (2010) highlighted the steady increase in domestic house cat populations in the United States. Current research is limited in the United States, however there may also be significant effects on reptiles and amphibians. An Australian study, for example, found that 609 million reptiles were killed annually by cats (Stobo-Wilson et al., 2022). Generally, free-ranging cats can cause mortality, and population declines of native wildlife through direct predation, injury, nest failure, and indirect mortality through spreading disease and harassment which may lead to behavioral changes that can reduce prey species fitness.

## Crop Production

In the Midwest there is increasing pressure to produce greater quantities of food, livestock feed and fuel, while better protecting environmental quality. Key environmental issues in this region include water contamination from the runoff of nutrients, soil degradation from the aerial and ground applications of herbicides and pesticides, increasingly intensive agricultural practices, and a lack of non-agricultural habitat to support diverse communities of native plants and animals. Projected changes in climate, which include increases in the proportion of precipitation coming from extreme events, are an increasing concern, making soil and water conservation in existing cropping systems more difficult (Liebman et al., 2013).

According to the Minnesota Department of Agriculture's 2023 Minnesota Agricultural Facts and Stats, Minnesota is ranked 6$^{th}$ in the nation for agricultural production, 5$^{th}$ for crop production and 8$^{th}$ in livestock production. Minnesota is also ranked 10$^{th}$ in the nation for the number of organic farms. Clearly crop production, and agriculture in general, is foundational to Minnesota's economy. In the action portion of this chapter, we highlight some opportunities to focus on the environmental quality opportunities within the agricultural landscape.

## Tree Plantations

Tree plantations convert native landscapes to lands planted for the main purpose of timber harvest. The threats tree plantations pose vary depending on how different the tree plantation is from the native landscape. The threat of tree plantations to SGCNs is especially apparent in the Anoka Sand Plain Subsection. Prior to European settlement the Anoka Sand Plain was primarily an assemblage of fire dependent native plant communities including oak savanna and prairie,

both of which included large openings and barrens. These open spaces have been lost due to urban development, agriculture, and tree plantations. The Anoka Sand Plain Subsection Forest Resource Management Plan (Anoka Sand Plain SFRMP) highlights the threats tree plantations pose to the area including the loss biodiversity and loss of ecologically intact landscapes. The Anoka Sand Plain SFRMP recognizes the need for the removal of tree plantations and restoration of the subsection to oak savanna and prairie.

## Livestock Management

In Minnesota, livestock production includes poultry/eggs, dairy, cattle/calves, and hogs as described in the Minnesota Livestock Profile: 2023. The key issues of concern regarding the environmental effects of livestock production are overgrazing, and runoff from livestock impoundment and production facilities. Both concerns can affect soil health and water quality, as well as watershed function. Overgrazing, if left unchecked, can reduce diversity in vegetative cover and structure, and have severe negative effects on biodiversity, ecosystem function, soil health, and forage production.

## Mining and Quarrying

Mining and quarrying can permanently destroy large areas of key habitats, including aquatic habitats as sand mining potentially expands to the beds of public waters.

## Wind and Solar Energy Infrastructure

According to Our Minnesota Climate "The amount of energy our state produces from renewable resources like solar power and wind has risen 60% over the past decade. Today, renewable energy accounts for 28% of Minnesota's electricity generation, with 52% of our energy coming from carbon-free sources like renewables, nuclear, and hydropower." These successes in renewable energy production can be complex in the context of wildlife and habitat effects. Direct effects on birds and bats are a particular concern, especially during migration, with wind turbine collisions documented as a high source of mortality for both groups. Loss and his colleagues (2013b) estimated between 140,000 and 328,000 birds are killed annually at wind turbines across the contiguous United States; mortality increased with the height of the turbine hub. Foliage and tree-roosting bats, such as hoary bats and eastern red bats, also are frequently found dead below wind turbines (Arnett et al., 2008). Although variable in timing, most mortality occurs during late summer and fall, corresponding with migration and mating seasons. Estimates place the loss at approximately 888,000 bats per year (Smallwood, 2013). To date, lighting and noise appear to not influence the level of mortality.

Similarly, land-use effects in and around solar arrays can negatively affect native plant communities (predominantly prairie) and rare features. Taking lessons from traditional power infrastructure and development, we can be mindful to wildlife considerations in the siting and design of emerging alternative energy resources.

*Photo: Solar panel array*

## Roads, Trails, and Railroads

Animals being struck and killed by vehicles has been recognized as a global threat to wildlife and human safety and presents significant economic and conservation challenges (Balčiauskas, 2025). Road mortality due to collisions with cars is one of the leading contributors to decline for some species groups. According to a study synthesis and review in 2009, amphibians and reptiles tended to show negative effects in association to roads. Birds showed mainly negative or no effects, with a few positive effects for some small birds (e.g. seeking food, water, grit or roadside perches along utility lines and fences) and for vultures (feeding on roadkill). Small mammals generally showed either positive effects or no effect, mid-sized mammals showed either negative effects or no effect, and large mammals showed predominantly negative effects (Fahrig & Rytwinski, 2009). Animal life history and behavior plays a role in determining the effects of roads and transportation corridors on their survivorship. Some species, for example, are attracted to roadways for access to resources, such as carrion or minerals, therefore increasing their potential for direct collisions (Jacobson et al., 2016).

In addition to direct mortality, roads, trails and railways can have many effects which include the creation of barriers, habitat fragmentation, isolation of local populations, noise pollution that interferes with behavior and reproduction (Parris, 2015), altered hydrology (runoff), and water pollution. These corridors also can facilitate the establishment and spread of invasive species, including noxious weeds; this, in turn, can lead to the increased application or roadside spraying of herbicides (Forman & Alexander, 1998). Pollutants from de-icing salts, vehicle wear and tears, and the legacy of leaded gasoline are present in Minnesota roadside soils and plants (Mitchell et al., 2020; Shephard et al., 2022).

Roadside mowing is necessary for maintaining sight lines for safety. However, frequent mowing reduces the ability for monarch butterflies to successfully reproduce on milkweed that is often present in that habitat (Hopwood et al., 2015). When road rights-of-way are planted in non-native plants, there is a missed opportunity to provide native plants on the landscape, which can be used by a wide variety of wildlife, particularly insects (Mitchell et al., 2024).

## Utility Corridors

Utility corridors contain both above ground electricity transmission lines as well as gas pipelines. These corridors and their associated infrastructure can cause local-scale and landscape-scale disturbances. Locally, there can be soil disturbance, compaction, displacement of rare plant species, introduction of invasive species, disturbance to groundwater and surface water flows, and vegetation management activities including use of herbicide, mowing, and woody removal. Bird collisions are problematic, particularly for some transmission line designs, and in wetlands that support waterfowl and other waterbirds. More broadly, utility corridors fragment habitat of all types which can be an added stressor for reptiles and amphibians. Among mammals, DNR staff have found that pine martens require narrow corridors, with few disturbances. On the other hand, grassy, open corridors can attract predators that find hunting prey in open areas can be more efficient.

## Hunting and Collecting Animals

Unlicensed hunting or poaching is illegal and a threat to some species groups more than others. Amphibians, turtles and other reptiles are subject to collection more prominently than other animal groups due to their predictable life-history and slow movements. More education is needed to foster appreciation and connection with wildlife without the need to take them out of their environment and into our homes.

## Gathering Plants and Fungi

Commercial harvest of ginseng (*Panax quinquefolius*) and goldenseal (*Hydrastis canadensis*) is controlled by legislation, but foraging for personal use is not. Guidelines for where and how to forage responsibly are needed. Several native plant SGCNs are also known to be taken directly from the wild for use in urban gardens. This is especially true for orchids in the genera *Platanthera* and *Cypripedium* which are very difficult to grow from seed and are not available commercially. These species often occur in small, fragile, remnant habitats that cannot withstand the removal of large, reproducing individuals.

## Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest in fragmented landscapes such as those dominated by human use can further fragment, eliminate or reduce the availability of required habitats for SGCN. Management such as timber harvest must account for a modern landscape often dominated by islands of habitat among a matrix of inhospitable human systems. While timber harvest is often a temporary loss of habitat until trees re-grow, islands of trees in an urban matrix can leave displaced wildlife nowhere to persist for the 40-100+ years most forests take to recover. On the other hand, urban areas often lack timber harvest which can affect the populations of early successional species, such as the chestnut-sided warbler (*Setophaga pensylvanica)*. Where there are opportunities, homeowners, local governments, and commercial landscape operations should be encouraged to plant native tree species adapted to local environments.

## Fishing

Fishing creates and fosters a connection to nature which will be required for the continuation of the hobby. Fishing pressure can be high in urban and developed areas just based on the sheer number of people and easy access. However, anglers should employ good stewardship practices to avoid harming the resources they love. Numerous studies have documented the effects on waterbirds and fish-eating raptors of consuming lead-based fishing tackle and lead sinkers.

## Recreation

Minnesotans are known for their love of the outdoors. Particularly in urban and developed habitats, high recreational use can threaten sensitive plant communities and the wildlife they support. Intense use of popular hiking areas may reach a threshold where certain rare plants are trampled, and the level of foot traffic is high enough to degrade the plant community. Greater levels of foot traffic also increases the risk of spreading invasive species.

Moving wood for campfires can inadvertently move pests such as emerald ash borer in the firewood, so firewood is not to be moved across the state.

Boaters and beach goers can limit turtle nesting by compacting and overusing sandy soil habitat that turtles require for nesting. Boats can also affect waterbirds such as loons and eagles and cause erosion of lakeshore habitats through their wake action.

## Fire Management

Fire management in urban and other developed settings is not like fire management in other non-developed habitat types. Human health and safety are the top priority and fire prevention practices are paramount. Effects of fire on SGCN in this landscape focus more on controlling unintended fires due to high human activity

(accidental, electrical, arson) that may affect SGCN that have adapted to human structures such as chimney swifts or bats; these species can be directly affected by catastrophic or accidental fires in developed settings. The use of prescribed fire as a management tool does occur in agricultural and forested lands, more information can be found in those habitat sub-chapters.

## Dams and Water Management

Ditching, channeling and draining wetlands to increase the amount of arable land was a major contributor to the loss of Minnesota's wetlands and wet prairies over one hundred years ago. Today, the loss continues at a smaller scale and is often affected directly by commodity prices. Farmers are more likely to make such conversions when commodity prices are high and the potential return on their investment in the cost of tiling is much higher.

Water level manipulation (draw downs, flooding, water level maintenance) are common management tools in human dominated landscapes. Wide varieties of SGCN depend on these human-dominated aquatic habitats and can be killed or harmed by water level manipulation that does not account for their persistence.

The maintenance of navigable channels in navigable waterways in Minnesota results in the disruption of benthic aquatic habitats as well as the upland habitats upon which the dredged material is stored and moved. While this activity is necessary to maintain commerce along Minnesota's navigable waterways plans should always account for and seek to minimize effects on SGCN and their habitats through informed, long-range planning.

## Invasive Species (Problematic Non-native Species)

Changes in habitat can give invasive species an advantage. Moving soil and equipment around can spread invasive species such as invasive plants and earthworms. Some invasive plant species have been introduced purposefully as ornamental plants for yards and gardens. They then spread from the urban and developed areas to natural areas. Jumping worms (*Amynthas* and *Metaphire* species) can have effects on yards and gardens as well as to natural areas.

## Problematic Native Species

Residents in urban, suburban and even rural areas can easily identify a list of problematic native species that regularly visit their properties and can cause some damage, especially to landscape plantings, vegetable gardens, and building structures. The list includes such species as white-tailed deer, coyotes, raccoons, rabbits, squirrels, chipmunks and woodpeckers. Once the culprit is accurately identified, many of these problems can be dealt with by implementing non-lethal actions that exclude, repel or deter wildlife. Numerous websites provide ample advice to homeowners.

## Water-borne Pollution

Nonpoint source pollution, including phosphorus, nitrogen, sediment, bacteria, and other contaminants generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. As runoff flows, it picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, and groundwater, and estuaries (EPA NPS Webpage). Water quality measured by nutrients and contaminants has been shown to decline with higher agricultural or urban development in the watershed. Some key effects include excess algal growth, reduced plant diversity, and reduced diversity in fish and invertebrate communities (DNR Water quality non-point sources).

A significant example of non-point source pollution is chloride. It enters Minnesota's lakes, streams, wetlands, and groundwater from a variety of sources, predominantly road salt use, fertilizers, and wastewater treatment.

Chloride is toxic to aquatic organisms and its presence in high concentrations can alter the function of aquatic communities. In turn, individual populations and communities may become too small or impaired to perform an essential ecosystem function. Up to 70% of road salt applied on Minneapolis–St. Paul metro roads ends up in groundwater aquifers and nearby lakes, many of which exceed regulatory limits for chloride concentrations. Potassium acetate, a de-icing alternative poses its own issues (Gulliver et al., 2022). MPCA (2020a, b) discusses effects on plants, wildlife, and ecosystems.

Lead in fishing tackle and ammunition can become toxic to wildlife species through eating contaminated fish or wildlife, such as has been well documented in some species such as common loons and bald eagles.

*Photo: Condos with boat docks built along the St. Croix River*

## Air-borne Pollution

Experiments under controlled greenhouse conditions have shown that increased levels of atmospheric carbon dioxide may favor the competitiveness of woody plants and cool season invasives by stimulating photosynthesis and growth. It may also reduce mild to moderate abiotic stress in woody plants if root growth and nutrients are not limited.

Nitrogen levels in the atmosphere are driven by natural processes as well as transportation and agricultural sources, primarily fertilizer (Burke et al., 2002; Wall et al., 2013). A study indicates that increased atmospheric deposition of nitrogen reduced plant species numbers by 17% by increasing soil acidity and increasing above ground production of certain plants that reduces light availability to other plant species. This can lead to competitive exclusion. This suggests that chronic but low-level nitrogen deposition may have a greater effect on diversity than previously thought (Clark & Tilman, 2008).

## Light and Noise Pollution

Nearly half of the United States land surface has light-polluted skies (Falchi et al., 2016). Sources of light pollution at night include interior and exterior lights on homes, buildings, billboards, parking lots, and streets as well as lighted sports fields, industrial plants, and airports (DarkSky International, 2025a). Studies also point to the ecological effects created during the daytime by polarized light that reflects off surfaces such as asphalt roads, glass panes, and solar panels (Chock et al., 2020; Horvath et al., 2009). Because most of the nation's large urban areas (with multiple artificial light sources every night), are embedded in the Temperate Deciduous Forest biome, biota occupying temperate forests are the most vulnerable to these effects (Aubrecht et al., 2010).

Effects of light pollution include disrupting the behavior of amphibians whose breeding calls are delivered at night, drawing nocturnal insects to artificial lights that increase their predation risk, and disorienting birds that use environmental cues to guide their nighttime migration (Darksky International 2025a, 2025b). Bright nighttime lighting can exacerbate the threat of collisions with buildings causing mortality events of nocturnal migrant birds, especially during storms or low ceiling events. In addition, the phenology, growth rates and biomass of plants are affected (Bucher et al., 2023). Bright day and dark night cycles synchronize the internal clocks of plants and animals, and alterations to these cycles can affect hormone production, reproductive

behavior, neural activity, and metabolic functions (Bumgarner & Nelson, 2021).

Noise pollution from aircraft, vehicles, boats, and other human causes is pervasive. Anthropogenic noise was detected in 36% of national parks surveyed (Buxton et al., 2019), and 12% of wilderness areas had anthropogenic noise levels 3 decibels higher than levels predicted to occur naturally (Buxton et al., 2017). Exposure to increasing noise levels can change the spatial distribution and movement patterns of wildlife, cause avoidance of feeding and nesting areas, and interrupt sleeping patterns and communications (Kok et al., 2021). For plants, noise can reduce seedling recruitment (Phillips et al., 2021).

### Changes in Temperature related to Climate

Minnesota has experienced a clear warming trend over the past century. Between 1895 and 2020, average statewide temperatures increased by 3.0 degrees Fahrenheit (°F; Climate Trends). This warming has become more pronounced in recent decades and during the winter months. Since 1985, average winter temperatures in Minnesota have risen by 5.4°F, with average winter low temperatures increasing even more significantly by 6.8°F (Climate Change in Minnesota). These changes have led to a shortened season of snow cover and a reduction in lake ice duration by 10-14 days over the past 50 years (MPCA 2025). Furthermore, these shifts in thermal regimes are ecologically significant. Many species are adapted to narrow temperature ranges, and such rapid changes can result in increased thermal stress, the spread of invasive species, and heightened disease and pathogen risks (Ratcliffe et al., 2025).

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; Climate Change in Minnesota). Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.

Green spaces utilized by SGCNs can help mitigate the urban heat island effect, which is intensified by the high density of impervious surfaces in urban environments (Purohit, 2025). A Heat Watch report conducted in July 2024 for the Twin Cities modeled the distribution of urban temperatures, confirming patterns observed in previous studies: the hottest areas contain more impervious surfaces, while the coolest areas benefit from shade, vegetation, or nearby water bodies (Urban Heat Island Study, Ramsey County). Preserving and enhancing green spaces for SGCNs not only supports biodiversity but also provides co-benefits for human health and well-being as urban temperatures continue to rise.

### Changes in Precipitation and Hydrology related to Climate

From 1895 to 2020, Minnesota's average annual precipitation increased by 3.4 inches (Climate Trends). The state has also seen a notable rise in the frequency and intensity of heavy precipitation events. Since 2000, very heavy rains (6 inches or more in a single day) have occurred two to three times more frequently than during the 20th century (Williams-Sether & Sanocki, 2025; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). These extreme events have led to a corresponding increase in flooding, which can disrupt ecosystems, human infrastructure, and water quality (Williams-Sether & Sanocki, 2025).

Future projections indicate continued increases in annual precipitation, especially during the winter and spring months, which are likely to exacerbate flooding risks. Increased frequency

of heavy rainstorms leads to more frequent high-flow events in streams, often carrying elevated sediment loads from sheet flow and erosive forces. These processes can alter channel morphology, including downcutting or channel incision. During flooding, streams passing under roads may overtop and deposit sediments that fill culverts. Subsequently, as channels downcut and flows decrease, these culverts can become perched above the water level, creating barriers that impede the passage of fish and other aquatic wildlife.

The same climate models also forecast an increase in late summer drought events, underscoring the variability and unpredictability of hydrologic patterns under a changing climate (Climate Change in Minnesota). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; Climate Change in Minnesota). This seemingly counterintuitive pattern — wetter winters and springs, punctuated by hotter, drier late summers — has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:

**Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.**

**Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience**

**Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas**

**Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions**

**Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN habitat management practices to benefit SGCN**

Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Urban and Other Developed Lands

### Strategy 1. Protect, buffer, and connect high quality habitats to optimize biodiversity, SGCN, and landscape benefits, particularly across the Conservation Action Network.

| Stressor | Action |
|---|---|
| | Promote comprehensive plans that prioritize and protect open space, habitat connectivity, and higher density developments. New development projects should plan for the maintenance of urban wildlife habitat. |
| | Conservation partners can collaborate to provide landowners information regarding best management practices for green/open space in urban and suburban areas. Urban/municipal planners can focus on developing plans that will protect sites that are important to SGCN plants. Management actions might include prescribed burning, invasive species removal, population augmentation, etc. |
| | To minimize the reduction of natural lands as habitat, encourage siting of solar arrays on top of buildings and parking areas. Support the co-development of land, such as wind turbines sitting on cropland. |

| Stressor | Action |
|---|---|
| | Consider wildlife-friendly solutions such as building new lines within the same right of ways as existing lines to minimize overall effect footprint, orient transmission lines horizontally to limit transmission line heights and minimize collision potential, and/or add lighted markings or ultra-violet lighting to make transmission lines more visible to birds– which has found to lower collisions by 88% (Baasch et al., 2022). |

## Strategy 2. Restore, enhance, and maintain lands and waters to benefit SGCN, biodiversity, and ecosystem resilience

| Stressor | Action |
|---|---|
| | Encourage conversion of turfgrass to more diverse plantings that benefit butterflies, bumble bees, migrating birds, and other wildlife. Monitor SGCN use and study how effectiveness varies with size, floral composition, landscape context, and other variables. Evaluate benefits while considering threats such as window collisions, pesticides, and light pollution. |
| | Minimize outdoor use of insecticides (including those for home and garden use), especially those marketed as long-lasting treatments and those with broad spectrum (nontargeted) effects on many insects. Minimize the use of herbicides that reduce native forb abundance. |
| | Use native seed mixes to restore areas after improvement work along roadside corridors; include blooming plants to benefit pollinators, such as milkweed for monarchs (Mitchell et al., 2024; Darst et al., 2024). Pollinators and birds will benefit by managing the area to produce wildflower blooms by less frequently mowing the backside of the right-of-way. |
| | Mowing road rights-of-ways is critical to maintain sight lines for safety. Yet, beyond these zones less frequent mowing (once per summer optimally) enables better outcomes for blooming flowers to provide nectar to pollinators and for butterfly eggs and larva to survive. |
| | Broader, natural-bottomed stream crossings are a climate-smart solution when replacing culverts that have become filled with sediments or are no longer aligned with stream flows. Identify culverts where larger capacity, well-signed road crossings can provide greater resilience with future fluctuations in rainfall events and stream levels. |
| | Avoid bisecting wetland or aquatic habitats with roads without including barrier fencing to keep wildlife off roads. Wildlife mortality occurs most often where roads bisect aquatic habitats. |
| | Advocate for non-reflective coating on solar farms to reduce waterfowl collisions and insect reproductive sinks when reflective panels appear as water to passing wildlife. |
| | To minimize bird SGCN collisions into utility lines, participate in site selection to ensure wildlife collision concerns are represented, including siting away from areas where birds are accessing wetlands. Where bird strikes have occurred implement diverters. Reduce chemical vegetation control methods such as broadcast use of herbicides. |

| Stressor | Action |
|---|---|
| | Move control of vegetation, such as mowing and brush removal, to outside the bird breeding season (May-July), turtle nesting season (May-June), and migratory seasons (May/June, Sept/Oct) to minimize effects on SGCN. |
| | Provide recreational users information on potential boating disturbances to loons, waterbirds, eagles, and turtles. Suggest mitigation measures such as buoys to delineate nesting areas and no-wake or non-motorized watercraft zones. |
| | Avoid stormwater maintenance (drawdown and in-water work) in winter; these are critical winter habitats for a variety of aquatic species (turtles, frogs, fish, waterfowl). Winter maintenance work generally precludes wildlife use of these sites and may result in mortality. |
| | Design invasive or nuisance species treatment approaches with protective measures for native species and SGCN. For example: avoid drawing down aquatic habitats in the winter to temporarily reduce curly-leaf pondweed without planning for avoidance of native wildlife (turtle, fish, etc.) mortality. Reduce chemical vegetation control methods such as broadcast use of herbicides. Time control of vegetation such as mowing and brush removal to outside the bird breeding season (May-July), turtle nesting season (June) and migratory seasons (May/June, Sept/Oct) to minimize effects on SGCN. |
| | Encourage the use of lead-free fishing tackle. Fish, waterfowl, and waterbirds can consume lead tackle that can lead to impaired immunity and neurological function, bioaccumulation, and death. Support policies to reinforce the importance of adopting lead-free tackle. |
| | Suggest wildlife friendly erosion control products. Plastic erosion control blankets should specifically be avoided as they entangle and kill wildlife and introduce microplastics into the environment. See DNR Erosion Control. |
| | Support maintenance of vegetative buffers around riparian and drainage areas to reduce sedimentation and pollutants making their way into streams and lakes. |

## Strategy 3. Collaborate with conservation partners and landowners to enhance conservation delivery, particularly in the Conservation Action Network and Conservation Opportunity Areas

| Stressor | Action |
|---|---|
| | Collaborate with MnDOT, Counties, Townships, and Cities to integrate road crossings for vulnerable wildlife (such as natural-bottomed underpasses for turtles and fish). Study use patterns to determine the most effective placement, work collaboratively to write funding requests, and plan adequate timeframes for project permitting and delivery. Advocate for wildlife passage to be an integral part of building and maintaining roads and for reduced application of de-icing salts to reduce salinization of watersheds. The design and maintenance of bridges should be done with wildlife in mind (e.g. bats, cliff swallows). |
| | Engage in transportation corridor planning projects to minimize road and motorized trail building in key movement areas for wildlife such as wood turtles and American goshawks. |
| | Implement best practices for wildlife-friendly outdoor lighting, such as turning off lights when they are not needed and employing lights in the warmer part of the spectrum. For more detailed information, refer to solutions advised by Darksky International, the Xerces Society, and National Audubon's Lights Out Program. |

## Strategy 4. Monitor SGCN, native plant communities, habitats, and ecosystems for changes through time including responses to natural disturbances, conservation actions, and climatic conditions.

| Stressor | Action |
|---|---|
| | Monitor the movement of invasive plants through road, trail and utility corridors to rapidly address problem areas as needed (see EDDMaps). Research best practices regarding time of year for various maintenance activities to support native plants and reduce the spread of invasive plants. |
| | Continue research to help develop effective strategies to improve wildlife passage/ connectivity and reduce wildlife-vehicle collisions. |

## Strategy 5. Connect to develop, innovate, incentivize, and disseminate evidence-based habitat management practices to benefit SGCN

| Stressor | Action |
|---|---|
| | Advocate and disseminate information regarding the safe and healthy option of maintaining domestic animals inside the home or in controlled settings. Feral and outdoor cats have a measurable effect on some vertebrate populations (songbirds, small mammals). Existing management strategies such as trap-neuter-release have unfortunately proven unsuccessful in controlling cat populations and their effects on wildlife species. Additional steps to minimize domestic cat effects include the disbandment of cat colonies through adoption, eliminate feeding of free-ranging cats, pet cat sterilization, and public education. All pigs should remain under containment to prevent the establishment of feral swine in Minnesota. |
| | Provide materials regarding the appropriate disposal of unwanted pets and responsible pet ownership. Each year there are dozens of abandoned pet reports made with the DNR – from red-eared slider turtles dumped in state parks to pet alligators released into the Mississippi river. No unwanted pets, plants, or bait may be released into Minnesota waters. |
| | Work with developers of private and commercial properties to implement actions that address window-strike bird collisions. Increase public outreach/education on collision prevention. The American Bird Conservancy and Audubon's Bird Friendly Buildings initiative provide more details. |
| | Collaborate with counties, BSWR, NRCS, and other farm conservation organizations to share information regarding SGCN and encourage the use of rowcrop conservation measures that benefit wildlife. Valuable resources include: Science-Based Trials of Rowcrops Integrated with Prairie Strips, Minnesota Department of Agriculture Best Management Practices, TNC Guides to Prairie Restoration in Minnesota. Incentivize innovation and implementation of conservation measures. |
| | Communicate with the public, using public service announcements, educational materials, radio, and social media during seasons when turtles are most likely crossing roads, requesting motorists to slow down and be on the lookout for turtles on roads. |

| Stressor | Action |
|---|---|
| | Provide lake shore and lake owner associations with information regarding the natural systems and communities found in their water bodies and the protective management options to ensure both recreational opportunities as well as wildlife habitat on human dominated water bodies. |
| | Where people recreate, work with partners to provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's Prevent the Spread webpage details actions for different land-based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on boot brush kiosks developed by the PlayCleanGo: Stop Invasive Species in Your Tracks program. The DNR's What You Should Do webpage details actions for different water activities like kayaking and waterfowl hunting. At water accesses, share Clean in, Clean Out messaging to clean, drain, and dispose to reduce the spread of aquatic invasive species. |
| | To reduce effects of chloride, increase long-range planning, communicate more with zoning officials, facilitate enforcement of rules and ordinances, publicize best practices such as smart salting, and reducing chloride in water softeners. |

## Case Study: Optimal Bat Box Design and Placement

The DNR completed a comprehensive investigation on the optimal design and placement of bat boxes for Minnesota bats; to read the recommendations, please reference the well-illustrated Guide to Artificial Roosts for Bats.

Bat boxes are artificial roost structures that provide vertical crevices for bats to inhabit during the summer. Bat boxes typically house maternity colonies, or groups of female bats gathered to give birth and raise pups. Bat boxes help compensate for a limited supply of natural roost sites in tree cavities, bark, and crevices or to provide alternate roost sites for bats who often roost in buildings, particularly SGCN such as the little brown bat (*Myotis lucifugus*) and the big brown bat (*Eptesicus fuscus*). Bat boxes are relatively easy to build and can be deployed nearly anywhere on posts or buildings. As a result, the public has embraced bat boxes as a popular conservation tool for supporting bat conservation.

Until recently, bat box guidelines suggested installing a single bat box, painted in a dark color, placed in full sun. Occupancy rates have generally been low and highly variable, ranging from 1-48% of installations (Fontaine et al., 2021). It has been recognized that effective bat boxes need to provide appropriate microclimates (temperature and humidity) (Holroyd et al., 2023). Roost microclimate plays a critical role in bat energy budgets, reproductive fitness of mothers, and pup growth rates (Kunz and Lumsden, 2003; Tuttle, 1976). Reproductive females select roosts with suitable microclimates based on the reproductive period (pregnancy, lactation, post-lactation) to maximize energetic savings for mothers and increased growth rates for pups (Lausen & Barclay, 2003).

To improve guidelines for using bat boxes in Minnesota, the DNR Minnesota Biological Survey and Parks and Trails Division (PAT) partnered on a study to investigate what box and installation characteristics would be used most by maternity colonies. In 2021, with the help of PAT staff across 28 state parks, maternity colonies were found in 36% of 138 boxes. Analyzing box design type, color, dimensions, condition, solar aspect, entrance height, and mounting method, the study found that maternity colonies were more likely to be found in larger volume boxes with multiple roosting chambers, primarily where roost choices were provided by three or more boxes installed within sight distance. Monitoring a set of 55 boxes for three summer seasons helped to understand conditions and usage patterns. Temperatures inside the boxes were extremely variable, changing with time of day, ambient temperature, solar exposure, and structural characteristics such as box dimension and design. Bat counts fluctuated daily and group sizes shifted through the season. These findings suggest that mothers and pups switch among roosts to find suitable microclimates throughout the reproductive season, and underscore why groups of boxes with larger dimensions provide best for the array of microhabitat needs across a season.

Recommendations for using bat boxes in Minnesota are summarized in the Guide to Artificial Roosts for Bats, including links to bat box designs that were used by maternity colonies across our study. Recommendations include installing multiple boxes with large volume (>3,000 $in^3$), multi-chamber designs (providing a range of within-box temperature conditions), installed near to one another and with varying solar aspects (facing multiple directions). This allows bats to select roosts that facilitate suitable microclimates according to group size, reproductive period, and ambient conditions. These recommendations align also with Best Management Practices for Bat Houses in the U.S. and Canada (Holroyd et al., 2023). We suggest planning for the long term when installing bat boxes, as little brown bats are long-lived and will return every year to the bat boxes once colonies establish.

A major finding from this study was documentation of significant little brown bat colonies using these bat boxes. As one of the most heavily affected species by White-Nose Syndrome in Minnesota, it is good to know that artificial roosts can play an important role supporting these declining populations. Across boxes at six state parks, we found a total of at least 2,068 bats relying on these artificial roosts during the reproductive season. Ideally, with suitable habitat to support summer colonies, these bats could become common once again.

*Photo: Bat boxes at Gooseberry Falls State Park*

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# PUBLIC ENGAGEMENT

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Educators engaged in hands-on learning about insects in Monarch Joint Venture's North American Monarch Institute; Family enjoying birdwatching at the Urban Bird Festival, Grayson Smith, USFWS

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# Chapter 4: Public Engagement

## Introduction

The conservation of Minnesota's Species in Greatest Conservation Need (SGCN) requires actions by all Minnesotans. If actively engaged, the people of Minnesota can make important contributions to wildlife conservation wherever they live, from rural to urban settings. Effective engagement of our state's residents begins with an understanding of their demographics and values towards wildlife. As of 2016, 81% of Minnesota residents lived in urban areas (Minnesota Department of Transportation [MnDOT], 2022a), with over half of the state's population residing in the seven-county metro area (MnDOT, 2022b). Recent trends show that growth will steadily continue in urban areas with the highest growth rates in suburban edges (Metropolitan Council, 2024). For these residents living in more highly developed areas, connecting to rare and declining wildlife species and their habitats might pose a particularly difficult challenge. Additionally, the America's Wildlife Values Study (Dietsch et al., 2018), which sought to explore the values, attitudes, and beliefs of residents across the U.S. in relation to wildlife, found that the following breakdown of wildlife value orientations for Minnesota respondents: 37% traditionalist (believe wildlife should be used and managed for human benefit), 27% mutualist (believe people should live in harmony with wildlife), 24% pluralist (their wildlife values vary depending on the context), and 12% distanced (wildlife issues are less salient to them). While participating in the conservation of rare and declining wildlife may be most intuitive for just under a third of Minnesota's residents (the mutualists), we have the potential to engage any Minnesotan in SGCN conservation. However, our strategies will need to be varied and tailored to our residents' differing values and interests.

*Photo: Family enjoying birdwatching at Twin Cities Bird Festival, Grayson Smith, USFWS*

With a deep passion and appreciation for the outdoors, the people of Minnesota are primed to engage in conservation action, setting this plan up for success. This passion was evident in November 2024, when in remarkable agreement, over 77 percent of the state's voters approved a renewal of the Environment and Natural Resources Trust Fund. This vote assured that a portion of Minnesota state lottery monies would fund environmental projects for another 25 years.

To develop the recommendations in this chapter, the Minnesota Department of Natural Resource's Nongame Wildlife Program (NWP) utilized a participatory process. NWP staff reviewed the input of 161 conservation professionals from 28 organizations that attended a series of seven statewide SWAP workshops in 2023. To obtain further input on content specifically relevant to the SWAP's public engagement strategies, the NWP also consulted with 90 conservation educators, outreach program leaders, and communication professionals from 29 organizations across the state in two additional workshops and two working group meetings. In total, this chapter is based upon input from over 250 individuals, representing multiple DNR divisions and over 50 other agencies, organizations, and academic institutions.

Our recommendations for public engagement take a multi-faceted approach, from sparking inspiration to motivating and empowering conservation action. We seek to first connect Minnesotans to our state's SGCN and habitats by using varied educational approaches that build knowledge, relevancy and positive attitudes around these species. These approaches include information sharing, environmental education, and wildlife viewing recreation. From there, with that essential groundwork in place, we lead Minnesotans to take the following conservation actions: recreating outdoors responsibly, creating and caring for habitat, volunteering to collect wildlife data, and donating to wildlife conservation. Environmental education practices utilizing this continuum from inspiring connections to motivating and empowering action have been found to develop pro-environmental behaviors, build community capacity, support conservation action projects and contribute to long-term conservation goals (Ardoin et al., 2020).

To further increase the efficacy of these strategies for all communities in Minnesota and to address potential historical, cultural and societal barriers, our public engagement recommendations follow insights gained from a study the DNR's NWP contracted from Virginia Tech, which sought to learn how to expand Minnesota's audience for public conservation efforts (Jennings et al., 2024a). Accordingly, some themes throughout our recommended actions are meeting people where they are, working collaboratively with partners and local groups, and developing programs relevant to communities.

Our public engagement recommendations for 2025-2035 are organized into seven overarching strategies, each supported by a suite of actions, flowing from inspirational tactics to action-oriented ones. These strategies include information sharing, environmental education, wildlife viewing, responsible recreation, habitat stewardship, participatory science, and funding support.

## Public Engagement Goal

Inspire, motivate, and empower Minnesotans to engage in conservation actions that support Species in Greatest Conservation Need (SGCN) and their habitats

## Recommended Strategies for Public Engagement

1. Develop and distribute informational resources and media on SGCN, their habitats, and threats.
2. Support environmental education on SGCN and their habitats on a statewide level.
3. Provide and promote wildlife viewing opportunities and programs that inspire curiosity, caring, and connection with Minnesota's SGCN.
4. Foster responsible recreation practices that reduce recreational effects on SGCN and their habitats while allowing for safe and satisfying access to the outdoors.
5. Engage and empower communities to improve wildlife habitats where they live, work, and recreate.
6. Offer participatory science programming for Minnesotans to take part in conservation volunteerism that addresses SGCN data needs.
7. Cultivate financial support for the conservation of SGCN through the development and promotion of public funding opportunities and public-private partnerships.

## Building on the two Prior Plans

### 2005-2015 Tomorrow's Habitat for the Wild and Rare

One of the original Plan's three strategic goals was to: **Enhance people's appreciation and enjoyment of Species in Greatest Conservation Need (SGCN).** The actions associated with this goal were included within each of the profiles for Minnesota's 25 Ecological Subsections:

1. Create new information and communicate with people to enhance their appreciation of SGCN
2. Create opportunities for people to appropriately enjoy SGCN-based recreation.

### 2015-2025 Minnesota's Wildlife Action Plan

In the 10-year revision of the 2005-2015 State Wildlife Action Plan, public engagement remained one of the three primary goals, to: Enhance opportunities to enjoy Species in Greatest Conservation Need and other wildlife and to participate in conservation. The goal was revised from the 2005 Plan to emphasize creating opportunities for Minnesotans to actively participate in SGCN conservation efforts. Two objectives to reach these goals were delineated:

1. Increase the number and diversity of people participating in wildlife-related outdoor recreation.
2. Increase the number and diversity of people directly engaged in conservation of SGCN.

## Information Sharing

### Strategy 1: Develop and distribute informational resources and media on Species in Greatest Conservation Need including their habitats and threats.

A first step of inspiring and motivating people towards conservation action is raising awareness that there is a need for conservation action. The people of Minnesota cannot aid in the conservation of SGCN if they do not know these species exist in our state or are unaware of the issues affecting them. Minnesotans are passionate about conserving our state's natural heritage, so if conservation professionals provide the public more information about SGCN, their threats and their needs, we have an opportunity to foster changes in human attitudes and behaviors to benefit these species in need. To be effective, this information must be provided in easily accessed formats and in a relevant manner.

Research has shown that social media can increase pro-conservation behaviors among the public, increase conservation funding, and inspire policy change (Bergman et al., 2022). In addition, sharing information about wildlife conservation, in tandem with efforts like increasing environmental education, can help shift social norms and have a positive effect on rare wildlife species (Salazar et al., 2018).

The species groups in Minnesota that may benefit most from information campaigns include native fish, pollinating insects, mussels, amphibians, reptiles, mammals, and birds. Within these groups are Minnesota SGCN that are threatened by human behaviors such as illegal take (wanton killing/poaching), accidental take (e.g. road mortality and bird building collisions), illegal possession, pollution, climate change, and the spread of invasive species. These are also groups of wildlife that are interesting and/or relevant to Minnesotans (Sinkular et al., 2022; Duda, 2021), in which it may be easier to capture people's attention and foster behavior changes.

Sharing more information about the SGCN listed above will enable Minnesotans to make more informed decisions about their actions and interactions with nature. For example, informing Minnesotans when turtles are more likely to be crossing roads and how to help them safely cross the road may help reduce road mortality. Sharing the important role of native mussels in our water ecosystems is a gateway to discussing pollution, climate change, invasive species and how Minnesotans can make a difference for our waters.

By providing communication products that increase Minnesotans' knowledge about SGCN, the stressors they face, and what people can do to alleviate these stressors, we can foster a deeper appreciation for SGCN, the desire to help them, and motivate people towards the conservation actions outlined in Strategies 4-7.

**Stressors Addressed:** Development (e.g. bird building collisions), Roads, Trails and Railroads (e.g. road mortality), Hunting and Collecting Animals (wanton killing, poaching, illegal possession), Invasive Species (Problematic Non-Native Species), Diseases and Pathogens, Water-borne Pollution, Air-borne Pollution, Changes in Temperature related to Climate, and Changes in Precipitation and Hydrology due to Climate.

## Recommended Actions for Information Sharing:

1. **Identify specific SGCN as ambassador species (i.e. charismatic champions that represent a suite of other SGCNs or habitats) to help build a broader audience to receive wildlife information by streamlining information and making it appealing. These ambassador SGCN could be used for leveraging popular interests, communicators, communication channels, and events to reach new audiences.**

   Work with wildlife biologists to identify specific SGCN to utilize as ambassador species — charismatic champions representing a suite of other taxa (or habitats) — in which by garnering public familiarity, increasing knowledge, and leveraging support for that specific SGCN, a greater suite of species will benefit. These ambassador species can be used in a variety of ways, such as in communication campaigns around calls to action for certain stewardship practices, in an "Adopt-a-SGCN" program to engage schools and municipalities in selecting a species to represent their community, or as features in outreach products like education posters, coloring books, etc. Ambassador species could also be utilized to connect with unique, less traditional audiences, such as reaching sports fans by partnering with Minnesota sports teams that feature SGCN as their mascot (e.g. the Minnesota Lynx), artists through art contests/exhibitions themed around these species, and social media users with the use of influencers and short videos providing educational content on these species. Holding festivals to celebrate these species, serves as an attractive, fun event that also engages people in learning.

2. **Promote and support an update to the DNR's Rare Species Guide (RSG) as a means for providing an information hub on Minnesota's SGCN and their habitats and range.**

   The RSG is a valuable information resource on state listed animals and plants (see Case Study), offering an area of opportunity to present information on more SGCN. It is also in need of updates given that it launched in 2008. In 2023, a MNIT Business Value Assessment showed the RSG as having high business value and moderate to low technical health with multiple modernization efforts needed. A RSG Modernization and Enhancement IT Project has been proposed to address these needs, and a survey was implemented in 2024 to better understand how people use the RSG and how they would like to see it improved. By increasing the capacity to help with these needed technical, design, and content updates (including developing new RSG profiles for SGCN animal species that don't currently have a profile), we can deliver a modern product that will better inform Minnesotans about the needs and threats of SGCN.

## Case Study: The Rare Species Guide

The DNR's Rare Species Guide (RSG) is an online guide to Minnesota's rare animal and plant species, including State-listed endangered, threatened, and special concern species. The RSG provides information on the status, distribution, ecology, conservation, and management of our rarest animals and plants. The user can query over 600 species profiles based on name, taxonomic group, status, county, Ecological Classification System (ECS) subsection, watershed, and/or habitat.

The RSG is one way the DNR addresses the mandate in the Minnesota Environmental Protection Act to "establish and maintain information systems sufficient to gauge the environmental health of the state." The RSG is a foundational resource for State-listed and SGCN species topics and for administering State-listed species rule and law. The RSG is used by professionals and the public, receiving over 186,000 visits in 2024.

3. **Provide solutions for DNR staff, conservation organizations, and municipalities to address common wildlife questions and concerns.**

   a. Collaborate with the DNR Information Center to develop FAQs for the public that may be disseminated through communications media and materials by varied agencies and organizations. These FAQs could cover topics like keeping wild species wild, Threatened and Endangered Species poaching, and illegal take/possession penalties.

   b. Enhance internal DNR collaboration between divisions, Listed Species Program, and the Nongame Wildlife Program to increase and support knowledge and enforcement of regulations to help prevent wanton killing, illegal take, or illegal possession of protected species. Species that are protected by state and federal laws, such as Blanding's and wood turtles, migratory birds, native fish, and timber rattlesnakes, would all benefit from this action. Some examples of work to be done in this arena include, providing informational resources and trainings to DNR employees that will support their protection and public communications work for these legally protected SGCN. Trainings and resources could include summarizing protected SGCN-related rules and regulations, species identification, and locations of important populations that could be exploited.

## Example Species in Greatest Conservation Need: Black Buffalo

The black buffalo (*Ictiobus niger*) is a State Threatened, long-lived native fish species that inhabits large river systems in Minnesota including the Mississippi and Minnesota and their tributaries. Minnesota is on the Northern edge of the species' continental range and is an important area for conservation. While the black buffalo is protected from any harvest or take due to its status as a state threatened species, it is part of a group native fish including gar, buffaloes, suckers, and redhorse that have historically been classified as "rough fish" and lacked the same protections as game fish, such as legal harvest methods and bag limits. Further, confusion about native fishes' role in the ecosystem and a lack of public identification resources to help people differentiate native fish from common carp often led to unregulated overharvest. Fortunately, recent conservation and legislative efforts have resulted in these native fish being reclassified and receiving the same protections as game fish (Winter, 2024). Specific regulations for these species are relatively new and still being developed. Many people may be unaware of changing regulations and related laws regarding native fish species, and lack of resources for species identification remains an issue. Ongoing communication, education, and outreach will benefit the black buffalo and other native fish by raising awareness, reducing unintentional take, empowering conservation officers to enforce regulations, and filling gaps in scientific knowledge about native fish in Minnesota.

*Photo: Black buffalo, Konrad Schmidt*

4. **Increase understanding of misunderstood SGCN and foster tolerance for them in human spaces through informational products, trainings, and programs.**

   a. Create outreach products for SGCN that may be perceived as frightening or as a nuisance (e.g. snakes, bats, hawks, wolves, mudpuppies, northern pocket gophers and insects), so that people may learn to appreciate these interesting animals. An example of this work for snakes could include updating the DNR's "Living with Snakes" informational brochure and webpage.

   b. Create outreach products that clarify common and problematic species misidentifications and distribute/promote these to target audiences. For example, a species identification guide helps anglers understand differences among native SGCN fish, common carp, and invasive carp (Have you seen an invasive carp?; also available in Hmong and Spanish on the DNR's Invasive Carp webpage). Similarly, work with herpetologists to develop an updated field guide and/or infographics on Minnesota's snakes, so that people can learn to discern the many nonvenomous snakes in Minnesota from our one venomous snake, the state threatened timber rattlesnake.

   c. Partner with pest control companies to provide professional development on species identification and best practices (e.g. bats).

   d. Connect with Advancing Conservation though Empathy for Wildlife Network (ACE) to use and share their resources.

   e. Wildlife viewing engagement programs would also help to support tolerance and understanding (see Strategy 4) for SGCN.

## Example Species in Greatest Conservation Need: Timber rattlesnake

Timber rattlesnakes *(Crotalus horridus)* are generally docile creatures. When threatened, their initial reaction is to hide or flee. They are rarely observed, as they have a localized population in the bluffs of southeastern Minnesota. However, because they are a venomous snake, many Minnesotans fear them and regard them as dangerous. This fear is passed onto many other snake species, as there are several rattlesnake mimics in the state. While they are not venomous themselves, these mimics utilize the rattlesnake's behavior to protect themselves. Unfortunately, this perpetuates the perception that snakes are dangerous and results in wanton killings of our native snakes, which is illegal. By sharing more information about the rarity of timber rattlesnakes in our state, their status as a state threatened species, how to distinguish them from other snake species, and educating Minnesotans about their behaviors and importance to balancing our ecosystem, we can hopefully reduce the killings that they and other snakes face and begin to correct the perception and misinformation that snakes are dangerous. By simply keeping their distance, leaving snakes alone and understanding their fascinating behaviors and important role, Minnesotans can hopefully learn to tolerate and perhaps even enjoy a rare reptile sighting.

*Photo: Timber rattlesnake, Amod Zambre*

5. **Increase public knowledge on climate change as a threat to Minnesota's wildlife and their habitats.**

   a. Work with wildlife biologists to develop a resource list of iconic and unique Minnesota SGCN that are highly affected by climate change, such as moose, boreal chickadee, migratory birds, shorebirds, wood turtle, brook trout, and monarch. Feature these species in communications products, such as stories, maps and infographics, to garner public understanding of how climate change affects wildlife and natural resources.

   b. Promote and provide trainings for educators on AFWA's Project WILD module Climate and Wildlife, a curriculum guide to support integrating a wildlife lens into climate education, and Climate Generation's curriculum, Healthy Habitats: Climate Change Action for K-2.

   c. As they become available, assist in communications regarding best management practices, climate-adapted management plans, and other resources that may assist habitat managers by creating materials and holding workshops.

   d. Develop a communications plan around climate change and wildlife in Minnesota. Include crafting talking points and key messages that translate scientific information, making it more easily understood. Utilize current resources from University of Minnesota Climate Adaptation Partnership and the Midwest Climate Adaptation Science Center among others). Couple information on climate stress with action-oriented and hopeful messages to keep people motivated (e.g. stories of success in climate adaptation and actionable solutions that individuals can take to make a difference).

   e. Collaborate with biologists to develop a participatory science project that focuses on a specific phenology question and data need (such as through the National Phenology Network) to train and involve the public in documentation of seasonal changes that may be due to climate change; to help foster understanding and support for climate science.

## Example Species in Greatest Conservation Need: Moose

An iconic Minnesota species, moose (*Alces alces*) are important to the state's ecology, culture and economy. Moose are well adapted to Minnesota's traditional cold winters and the boreal forest of northern Minnesota, making them more vulnerable to changes in that climate. The moose population has experienced a 60% population decline since 2006 in northeast Minnesota, largely due to changes from the warming climate. Heat stress, increased winter ticks, and introduction of parasites carried by white-tailed deer (brainworms and liver flukes) are key effects from a changing climate (Weiskopf et al., 2019; Midwest Climate Adaptation Science Center). Minnesota has many active organizations working to better understand climate change effects on moose and find ways to adjust management actions to adapt to those changes. Moose offer an excellent opportunity to share local, relevant and compelling information about climate change effects on SGCNs and their habitats.

*Photo: Moose in winter*

6. **Apply existing social science research and conduct new research as needed to better understand Minnesotans' attitudes about wildlife and wildlife conservation and to help craft effective messaging.**

   Recent social science research, contracted by the Nongame Wildlife Program, has provided valuable insight to help guide Minnesota's public engagement efforts for SGCN (Sinkular et al., 2022; Jennings et al., 2024a; Jennings et al., 2024b) and these resources are recommended for consideration in crafting effective conservation messaging. However, it should be noted that these studies were limited to specific groups of people, such as wildlife viewers, participatory scientists, or current supporters of the Nongame Wildlife Program. To understand the perspectives of broader groups of people within Minnesota's geographic boundaries, the Minnesota results for the America's Wildlife Values study (Dietsch et al., 2018) offers an additional helpful reference. Also valuable are The Nature of Americans (Kellert, 2017) and Conservation Words That Work (Duda, 2021), however both studies' results are provided on a national scale. Consideration should be given as to whether further state-level research is needed to better understand Minnesota's unique demographics and geographic locations (e.g. Metro, suburb, rural) and their attitudes, interests, and understanding of wildlife and wildlife conservation.

## Case Study: Minnesota Bat Festival

The Minnesota Bat Festival is an annual festival organized by the U.S. Fish & Wildlife Service, held at the Minnesota Valley National Wildlife Refuge, just outside of Minneapolis. It is a good example of appealing to a broader audience in a densely populated area with a fun, well-timed event about a misunderstood, yet fascinating and ecologically valuable species. The event's goal is to educate adults and youth about bat behavior, bat research techniques, and raise awareness of the many threats bats face. Up to 15 organizations with some specialty in bat conservation and education have participated, providing live demonstrations, presentations, activities and learning opportunities appropriate for all ages. The festival takes place during International Bat Week, which is the last week of October. Also coinciding with Halloween, the event is well-timed to add additional appeal for families and adults alike seeking festive seasonal activities and draws high numbers of attendees. In 2023, 1,500 people attended. First held in 2016, many attendees have shared that the event has become a tradition in their family or that it has helped them appreciate bats more. Through this festival the Refuge has found that Minnesotans are hungry for information about bats.

*Photo: Young Bat Festival attendees learning about bat research from DNR biologist Melissa Boman*

## Environmental Education

### Strategy 2: Support environmental education on Species in Greatest Conservation Need and their habitats on a statewide level.

Environmental education builds knowledge of and connection with the natural world. It fosters awareness, skills, and agency, encouraging people to explore environmental issues, solve problems, and care for the environment. As described by the Environmental Protection Agency, "Environmental education does not advocate a particular viewpoint or course of action. Rather, environmental education teaches individuals how to weigh various sides of an issue through critical thinking and it enhances their own problem-solving and decision-making skills."

While environmental education techniques are referenced throughout this chapter to help adult audiences gain the knowledge, attitudes, and behaviors to support SGCNs and their habitats, Strategy 2 focuses on applying environmental education within the school age (K-12) realm. Studies show that environmental education for students has numerous benefits, including strengthening motivation to engage in environmentally friendly behavior, and equipping young people with "action knowledge" to have meaningful environmental impact (Van de Wetering et al., 2022).

To help implement this strategy, Minnesota has a large, established and engaged K-12 environmental education community made up of professionals and volunteers working together to increase Minnesotans' knowledge, attitudes and behaviors that support SGCNs and their habitat. Supporting environmental education as described in the recommended actions below will provide environmental educators the resources they need to teach about SGCN and habitats. Collaborating with and supporting K-12 educators is an effective way to integrate wildlife learning for youth in the short term, while building the foundation for conservationists and wildlife stewards in future generations.

*Photo: Youth participants in Empowering Pathways into Conservation (EPIC) program, Benjamin Gieseke*

Although Minnesota has a strong tradition of connecting with the outdoors and supporting conservation work, our society is still shifting to spend more time indoors (Kellert, 2017). As we do so, people are increasingly disconnected from and less knowledgeable about nature. Environmental literacy or knowledge is shown to directly foster individuals' concern, attitudes, and level of personal responsibility towards environmental protection (Teksoz et al., 2012). K-12 environmental education is essential to building environmental literacy which is key to protecting the environment and ensuring a sustainable future for generations to come (Yildirim et al., 2025).

We recommend focusing environmental education efforts on SGCN in the following species groups: mammals, birds, native fish, reptiles, pollinating insects, amphibians, and mussels. These species groups were selected to highlight based on the Minnesota Results of the National Wildlife Viewer Survey (Sinkular et al., 2022), in which our state's wildlife viewers selected these species groups (except for mussels) as those they were interested in observing. Pollinating insects make a good match for youth because supportive actions, such as native plantings and insect observation, are accessible to young people and provide an opportunity to make a meaningful impact on a threatened population. Knowing that the public places a high value on water quality (Duda, 2021), freshwater mussels are recommended for environmental education because they provide a strong opportunity to connect a community value to a less visible, yet highly valuable taxa.

## Example Species in Greatest Conservation Need: Monarch Butterfly

Equipping young people with "action knowledge" they can employ to support environmental issues they care about is one of the most profound effects of environmental education. There are many species that stand to benefit from supportive activity driven by young people. The Monarch butterfly (*Danaus plexippus*) is a profound example of this possibility and has been identified as an excellent 'ambassador species.' Charismatic, colorful, and fragile, this species captures the attention and enthusiasm of young people while also facing significant threats and a declining population. Monarchs present an ideal opportunity for young people to view a declining species and take part in its conservation. Planting milkweed and other nectar-producing plants also can help them to understand the various components of habitat. Connecting with multi-national conservation efforts with concerned residents of Canada and Mexico (e.g. through Monarch Joint Venture) further enhance the conservation learning for this inspiring migratory butterfly and allows young people to understand more about wildlife conservation.

*Photo: Monarch on blazing star, Jessica Petersen*

## Recommended Actions for Environmental Education

1. **Offer free or low-cost professional development trainings to educators (both formal and non-formal) on environmental education and on SGCN and their habitats.**

   a. Reinvigorate and support statewide coordination of reputable curriculum training programs like Project WILD and Project Learning Tree, utilizing their efficient train-the-trainer approach to expand capacity for implementation. In Minnesota, we could train facilitators to train educators, naturalists, Master Naturalists, and nature tourism professionals, who already engage with the public daily on how to implement the wildlife and habitat lessons from these valuable guides.

   b. Utilize Education Minnesota's MEA annual conference as a means for wildlife professionals to connect with educators and provide professional development sessions, and to create networking opportunities for teachers who use a given wildlife curriculum to encourage mutual support.

   c. Promote existing professional development opportunities; e.g. Monarch Joint Venture's North American Monarch Institute, Monarch NECTAR Hub and Wolf Ridge Environmental Learning Center's Teacher Training Institute.

2. **Promote existing SGCN/ habitat curricula that meet state standards in a variety of subject areas.**

   The following curricula already designed to meet state standards are recommended: 1) Association of Fish and Wildlife Agencies' suite of Project WILD curricula, which includes, Project WILD, Aquatic WILD, Growing Up WILD, Flying WILD, plus more specific modules; 2) Monarch Joint Venture's Monarchs and More; and 3) the DNR's Life on the Edge in Minnesota (a supplement to Project Learning Tree's Life on the Edge activity). It's also recommended that organizations that have existing SGCN/habitat lessons correlate these with established K-12 courses (AP Environmental Science, AP Biology, etc.) to help encourage their implementation by educators.

## Case Study: Monarch Joint Venture Education Program

Monarch Joint Venture's Education Program provides an excellent example of how an organization can integrate multiple recommended actions to support this environmental education strategy. Monarch Joint Venture offers professional development for educators (North American Monarch Institute), funding and technical support for educational gardens, curriculum (Monarchs and More Curriculum for grades K-8) aligned with the Next Generation Science Standards, educational resources for kids (Growing with Monarchs Activity Book), K-12 classroom presentations, and online courses for all ages (Monarch NECTAR Hub). The North American Monarch Institute alone has reached 126 Minnesota educators who in turn have reached 126,000 Minnesota students since 2010. These combined actions and outreach with multiple partners show how environmental education programs like Monarch Joint Venture can build support for a SGCN and its habitat.

*Photo: Educators engaged in hands-on learning about insects in Monarch Joint Venture's North American Monarch Institute*

3. **Establish or identify an existing resource hub where educational resources on SGCN could be compiled into one convenient location — sorted by grade, state standards, topic, etc.**

   a. Investigate whether the Minnesota Association of Environmental Education's EE Portal (MAEE) could serve as this hub, with SGCN resources submitted to it.

   b. Connect organizations and schools with wildlife experts by compiling a list of organizations/ programs that can be a resource and incorporate this into the Minnesota Association for Environmental Education's EE Portal.

4. **Provide funding and technical support to advance outdoor learning spaces at schools that would attract and support SGCN (e.g. native plant gardens for pollinators and birds) and enhance outdoor learning.**

   a. Develop a small grants program to provide funds to schools and local organizations conducting habitat restoration projects (e.g. Great River Greening and Metro Blooms) for development of outdoor learning spaces that provide habitat benefits.

   b. Develop a habitat education train-the-trainer program that could promote and train professional educators and established volunteer organizations (Master Gardeners, Master Naturalists, etc.) to provide technical assistance to schools (See Strategy 1, Action 2b) interested in developing or enhancing outdoor learning spaces of habitat value.

   c. Collaborate with the DNR's School Forest Program and other outdoor classroom programs to enhance habitat for SGCN through their stewardship plans and integrate other educational supports such as interpretive signs on SGCN at school forests.

5. **Provide, support the expansion of, and/ or promote grants and programs that fund field trips and transportation to natural areas for environmental education programming.**

   Some examples of existing opportunities that fund field trips and transportation for environmental education experiences include the DNR's No Child Left Inside grants and Bird by Bird and EPIC (Empowering Pathways Into Conservation) programs, as well as Hennepin County's Bus Funding for Environmental Education Field Trips.

## Case Study: University of Minnesota Bee Lab Pollinator Toolkit

The University of Minnesota Bee Lab Pollinator Education Toolkit is an example of one way in which environmental education can directly support SGCN. The toolkit comes with a variety of interactive games and activities that help recipients grow in appreciation of pollinators as well as learn strategies to support these important species. More than 200 kits have been distributed to Minnesota educators and community leaders, indicating the significant interest in both pollinator education and support. Increased public awareness of pollinator needs can lead to increases in native planting in homeowners' yards, as well as broad popular support for efforts to preserve these species.

*Photo: Educational toolkit created by pollinator experts at the University of Minnesota Bee Lab and Monarch Joint Venture*

## Wildlife Viewing

### Strategy 3: Provide and promote wildlife viewing opportunities and programs that inspire curiosity, caring, and connection with Minnesota's Species in Greatest Conservation Need.

Wildlife viewing is one of the fastest growing types of wildlife-related recreation in the U.S. and is highly popular in Minnesota, making wildlife viewers an essential audience to lead towards SGCN conservation actions. The 2022 National Survey of Hunting, Fishing, and Wildlife-Associated Recreation (National Survey of Wildlife Recreation) defines wildlife viewing as "closely observing, feeding, and photographing wildlife, visiting parks and natural areas around the home because of wildlife, and maintaining plantings and natural areas around the home for the benefit of wildlife." (U.S. Department of the Interior, U.S. Fish and Wildlife Service, 2022) In Minnesota, 3.6 million people (ages 16 and older) watch wildlife, according to the National Survey of Wildlife Recreation. For context, this number far exceeds the combined number of people (ages 16 and older) who fish and hunt in Minnesota, 1.7 million and 504,000 respectively. This same survey estimated that wildlife viewers spent $5.0 billion in our state in 2022 on wildlife watching activities and equipment (e.g. travel, purchases of camera gear and binoculars, and related expenses).

By engaging Minnesotans in wildlife viewing, an activity that fosters connections between wildlife and people's lives, we can support the conservation of SGCN, as has been demonstrated in multiple research studies (Grooms et al., 2023; Cooper et al., 2015; Hvenegaard, 2002; McKinley et al., 2017). One of the many ways that wildlife viewing engagement could support conservation is through financial support. According to a 2025 survey from Charities Aid Foundation, the leading motivation for Americans to support a cause was feeling a personal connection to it and the leading factor for their decision to donate to a charity was because it was tied to a cause they've personally experienced or care deeply about (Vogels, 2025a; Vogels, 2025b). Additionally, by supporting wildlife viewing-based tourism in Minnesota, wildlife viewers will provide income to the conservation efforts of the sites they visit, which in turn has a beneficial ripple effect to those local economies through their tourism expenditures. By communicating these economic benefits, we can garner further support for SGCN conservation from a wider variety of audiences (i.e. state and community leaders), by demonstrating how SGCN and their habitats benefit local economies.

Wildlife viewing programs that focus on birds and mammals stand to be particularly effective. These are by far the most popular species groups to view by Minnesotans. Each group was selected by 78% of respondents in the 2022 Minnesota Results of the National Wildlife Viewer Survey as the specific types of wildlife they were interested in viewing (Sinkular et al., 2022). However, it's important to note that 87% of respondents indicated they were interested in viewing more than one type of wildlife, showing potential that this strategy could support the other species groups of interest reported, which included native fish, reptiles, insects, and amphibians (listed in order of percent of people interested from highest to lowest).

Bird watchers (or birders) have been identified as a particularly key group of wildlife viewers that stand to make a positive effect on wildlife conservation. As defined in Birding in the United States (USDOI, USFWS, 2024), a birder is someone who has, "taken a trip one mile or more from home for the primary purpose of observing birds or closely observed or tried to identify birds around the home." Participation in bird watching has been found to significantly affect pro-environmental behavior (Larson et al., 2018). One study (Cooper et al., 2015) quantified that wildlife recreationists — both hunters and birdwatchers — were each 4-5 times more likely than non-recreationists to

engage in conservation behaviors, including activities such as donating to support local conservation efforts, enhancing wildlife habitat on public lands, advocating for wildlife recreation, and participating in local environmental groups. Demonstrating this behavior in Minnesota, hundreds of bird watchers of all experience levels collected data in a field survey between 2009-2013 for the Minnesota Breeding Bird Atlas, a collaborative project led by Audubon Minnesota and the University of Minnesota's Natural Resources Research Institute, that documents the distribution of every breeding bird in the state, providing a foundation for the conservation of these species.

Not only do birders demonstrate conservation behavior, but they are also a large group with significant economic might. There are 96 million birders (ages 16 and older) in the United States and birding participation rates are highest amongst those who have higher annual household incomes (USDOI, USFWS, 2024). Birders' expenditures supported $279 billion to the economy, 1.4 million jobs, and $90 billion in job income (at the local, state, and national level). By engaging Minnesotans in the recreation of wildlife viewing, we may enhance people's understanding and appreciation of wildlife and promote their likelihood of supporting conservation of SGCN through habitat stewardship, participatory science, and donations.

To ensure we effectively connect the people of Minnesota to the recreation of wildlife viewing, our recommended actions address the barriers and motivations for the activity, as identified by

Minnesota's state-level results from the National Wildlife Viewer Survey (Sinkular et al., 2022). Our recommended actions follow the survey's recommendations to provide and promote the following: (1) wildlife viewing information, including where to go and how to do it, (2) access to wildlife viewing locations, (3) around-the-home viewing opportunities, (4) social support networks for wildlife viewers, and (5) services and information that support those who are new to the activity. To sustain and increase the number of wildlife viewers in Minnesota, our recommended actions also utilize the recreational model of recruitment, retention, and reactivation (Heberlein et al., 2008; Larson et al., 2014; Quartuch et al., 2017), most often applied to the wildlife recreational activities of hunting and angling, but also applicable to wildlife viewing (Grooms et al., 2020).

*Photo: Bird watching at Twin Cities Bird Festival*

## Recommended Actions for Wildlife Viewing Efforts:

1. **Develop a state Wildlife Viewing Plan for Minnesota, in collaboration with stakeholders and partners, that focuses on SGCN and addresses recommendations from the Minnesota Wildlife Viewer Survey (Sinkular et al., 2022) while tying into and promoting the state's many existing resources and programs. The following actions provide a sample of what the plan could include.**

2. **Develop and promote introductory resources, programs, and social networks to support people who are new to the activity of wildlife viewing that will help them get started.**

    a. To recruit people into the activity of wildlife viewing, provide basic information and instructional experiences. Create resources describing how to get started, (e.g. where to go to see birds and information on binoculars, field guides, and identification apps). And by promoting, providing, and supporting introductory activities and workshops, people can gain hands-on experience in a comfortable setting (e.g. guided instructional bird walks or workshops on how to find and identify birds). To help encourage wildlife viewing of other easy to observe taxa, such as butterflies and dragonflies, refer to the models created for introductory birding resources and programs.

    b. Provide introductory wildlife viewing opportunities for youth that sparks their interest and builds skills and confidence to foster continued participation in the recreation. For example, the DNR's Bird by Bird program, introduces bird watching to classrooms over the course of a school year by providing equipment, activities and lesson plans connected to state standards, a bird watching field trip, and volunteers with bird watching expertise. It also engages the students in conservation actions to support birds, such as learning how to clean bird feeders, prevent bird-window collisions and engaging in participatory science projects such as Project FeederWatch.

    c. Provide loaner equipment (e.g. a library check-out program- backpacks with binoculars and easy-to-use field guides, etc. and tips for getting started), so that people can easily try out the activity without having to make a financial investment.

    d. Create a sense of community and social support to further enhance recruitment of Minnesotans into wildlife viewing. This can be done by promoting and supporting wildlife viewing events (e.g. birding festivals or smaller scale "meet-ups") and connecting people with existing social networks, such as local Bird Alliances (former Audubon chapters) and organizations that support specific community groups like Urban Bird Collective. An important form of social support for wildlife viewers are their families (Sinkular et al., 2022), so providing and supporting programs and resources that engage families to observe wildlife together would be valuable. One example would be collaborating with DNR's Parks and Trails Division to explore development of an 'I Can Bird!' program, utilizing their successful 'I Can!' program structure.

3. **Build interest in wildlife viewing amongst broader audiences by appealing to other, related interests.**

    a. Cross-promote wildlife viewing opportunities with other popular outdoor activities taking place in natural spaces (e.g. camping, trail running, hiking, paddling, disc-golf), creating awareness of SGCN in those areas.

    b. Develop wildlife viewing games that get people outdoors observing wildlife who

are motivated by the challenge of it (e.g. birding bingo/ scavenger hunts, a SGCN observation "bucket list" or promoting/ hosting City Nature Challenges).

c. Collaborate with outdoor affinity community groups to hold introductory wildlife viewing events. Create these as an opportunity for members of the community who may be more experienced and comfortable with the activity to provide leadership and inspiration for other community members to participate.

d. Work with the Minnesota Master Gardener organization to promote planting native plant gardens for attracting butterflies, bumblebees, and birds to gardeners.

4. **Provide and promote access to wildlife viewing opportunities that enable people to observe and learn first-hand about Minnesota's SGCN.**

a. Create and promote online resources and printed materials that clearly identify and illustrate top locations to go wildlife viewing in Minnesota. A large-scale example of such a resource could be creating a statewide wildlife viewing designation system, highlighting Minnesota's top wildlife viewing destinations, including site designation signage and accompanying digital guides/ maps to those sites with descriptions of the locations describing what wildlife you can see there. Smaller scale examples of these resources could include a series of local level guides to birding in the state's popular travel destinations (e.g. birding guides to the Twin Cities, Duluth, North Shore, etc.). Partnering with Explore Minnesota and local tourism and historical societies will help expand the promotion of these resources.

## Example Species in Greatest Conservation Need: Cape May Warbler

Migratory birds, such as the Cape May warbler (*Setophaga tigrina*), face several stressors, particularly in developed areas, as they migrate between their wintering and breeding grounds each spring and fall, such as lack of suitable habitat, window collisions, light pollution, and climate change. As reported by the Minnesota Breeding Bird Atlas, cape may warblers have high mortality during migration. Loss et al (2014) found that their risk of mortality from collisions with low-rise buildings is 16.7 times more than the average risk for a bird. Cape may warblers migrate throughout Minnesota in the spring and fall to and from their breeding grounds in Northeast Minnesota and Canada. Fortunately, a high number of Minnesotans are interested in seeing birds (as described above) and birders have a particular interest in seeing warblers. By capitalizing on this existing interest in birds and especially highly attractive birds, such as cape may warbler, and engaging more folks in bird watching (a relatively easy species group to observe), an opportunity is created to increase public interest and knowledge of the birds on Minnesota's SGCN list and the stressors they face. We can leverage the relevance of migratory birds to peoples' lives and shift human behaviors towards bird-friendly conservation actions, such as those recommended in Strategy 5 on habitat stewardship.

*Photo: Cape May warbler, Terry Mortier*

b. Explore developing a small grant program to provide funding for improvements to or installation of new wildlife viewing infrastructure (e.g. platforms, trails, viewing/ photography blinds and interpretive signage) that highlight and enhance SGCN wildlife viewing opportunities at parks, nature centers, and other high visitation natural areas. Sites participating in the above-described statewide wildlife viewing system (Action 4a) could be prioritized.

c. Develop live-streaming wildlife cameras of lesser known or particularly sensitive SGCN, and couple them with interpretation, to increase public interest and knowledge about species that they may otherwise have no opportunity to observe.

d. Provide and promote guided public program opportunities that enable people to observe SGCN that are challenging for people to observe on their own. For example, the easiest entry into viewing native fish (a species group of high interest to Minnesota's wildlife viewers) is through guided experiences with professional biologists or naturalists with access to specialized equipment and identification knowledge — this could potentially include guided activities such as freshwater snorkeling, angling, microfishing, seining or electrofishing demonstrations.

## Case Study: Twin Cities Bird Festival

The Twin Cities Bird Festival, organized by the Urban Bird Conservation Partnership of the Twin Cities (a participant in the Urban Bird Treaty Program), celebrates World Migratory Bird Day (WMBD) and seeks to connect local communities with the birds around them. Hosted in 2025 by Three Rivers Park District at Mississippi Gateway Regional Park with partners providing additional bird watching experiences throughout the Twin Cities, the event provided numerous opportunities for urban residents to observe and learn about birds. The guided bird walks, presentations and exhibits were centered around the WMBD theme of creating bird-friendly cities and communities. The Twin Cities Urban Bird Festival is a great example of a partnership involving multiple conservation groups that is striving to engage folks in bird watching and connect bird watchers to conservation actions. The inaugural 2025 festival was attended by more than 500 people of all ages and birding experience levels, showing that there is demand for wildlife viewing events such as this one and holds great promise for growth. This festival addresses multiple recommended actions: creating a sense of community and social support for bird watchers, including families; opportunities to observe and learn about birds firsthand on guided bird walks; supporting those who are new to birding with guided experiences and access to equipment; and an opportunity to engage urban audiences in local bird watching without having to travel far from home.

*Photo: Twin Cities Bird Festival attendees enjoying a live raptor presentation by Three Rivers Park District, Grayson Smith, USFWS*

5. **Provide program opportunities and resources that support wildlife viewing around and near people's homes where most wildlife viewers participate.**

   Most of Minnesota's wildlife viewers participate in wildlife viewing around and near their homes (Sinkular et al., 2022). Creating and promoting community habitat stewardship engagement efforts (detailed in Strategy 5) will provide easily accessed opportunities to view wildlife. For instance, encouraging people to install native plant gardens in their home landscaping or at a local school (Strategy 2) creates easily accessed bird and butterfly viewing opportunities. Such activities could be further enriched by promoting participatory science projects (Strategy 6) that involve data collection of wildlife using these native plant gardens, educational curricula on the birds and butterflies (Strategy 2) observable in these spaces, and development of regional pocket identification guides to wildlife that people may observe in native plant gardens that includes SGCNs (see Action 6c).

6. **Create fun, engaging opportunities for wildlife viewers to directly support SGCN conservation through their participation in the activity of wildlife viewing itself.**

   a. Collaborate with partners and tourism entities to develop guided interpretive tours of charismatic Minnesota SGCNs, in which participation fees directly support SGCN conservation (e.g. supports habitat work in the area of the tour or goes into Minnesota's Nongame Wildlife Fund). These charismatic species can also work as the draw to provide interpretation on lesser known SGCN that share the same habitat. One possibility could be leveraging Blue Mounds State Park's bison buggy tours to also show and provide education about prairie SGCN observable during the tour.

   b. Hold a birding competition, wildlife photography contest, or wildlife art exhibition that supports SGCN conservation by applying a portion of the registration fees as a donation to a conservation program (e.g. the Nongame Wildlife Fund).

   c. Develop a series of pocket identification guides to Minnesota's wildlife that incorporate conservation actions and ethics. An example might be a guide to butterflies that also encourages planting of the host plants that attract them or a guide to birds that describe simple actions to help them (see Strategy 5).

   d. Recruit wildlife viewers to volunteer for participatory science opportunities (see Strategy 6) to engage them in deeper learning of the taxa they are interested in and taking conservation action for SGCN by collecting needed data.

## Case Study: DNR's EagleCam and FalconCam

For over a decade, the DNR Nongame Wildlife Program's EagleCam and FalconCam have streamed video of bald eagle and peregrine falcon pairs nesting in the Twin Cities. These cameras provide intimate looks into the lives of parent birds rearing their young, enabling their viewers to feel a connection to these species. They have created awareness of the fascinating wildlife living in our cities and in the case of the FalconCam, it's engaged people in closely observing the breeding behaviors of a SGCN and state listed Species of Special Concern.

They've also been an opportunity to draw attention to Minnesota's successful recovery efforts for these species, and the mission of the DNR's donation-supported Nongame Wildlife Program (NWP).

Both cameras have been highly successful in their efforts to engage the public in viewing wild birds, frequently attracting news media coverage. Over the last 13 years, the EagleCam has soared in popularity, streaming in over 160 countries across the world. Between 2020-2024, the EagleCam webpage was visited more than 4.1 million times with more than 795,000 users. In 2022 alone, the webpage had more than 2.2 million views with more than 350,000 users. In 2024, the FalconCam webpage had more than 72,000 views with more than 20,000 users. Many people attribute their familiarity with the NWP to the EagleCam, and numerous donors to the Nongame Wildlife Fund indicate that the EagleCam motivated their donation.

*Photo: Female peregrine falcon broods an egg and chicks on DNR's FalconCam*

## Responsible Recreation

### Strategy 4: Foster responsible recreation practices that reduce recreational effects on Species in Greatest Conservation Need and their habitats while allowing for safe and satisfying access to the outdoors.

Minnesotans benefit from abundant outdoor recreational opportunities throughout the state and outdoor recreation has been growing in popularity and importance to residents' lives (Minnesota DNR, 2017). Overall, recreational use of public lands can enhance the value of these spaces by raising awareness, increasing the importance placed on outdoor spaces by members of the public, and encouraging sustainable use and stewardship (Larson et al., 2018). Connections with nature and the outdoors also positively affect human health and wellbeing and encourage proactive conservation behaviors (Richardson et al., 2020). While outdoor enthusiasts in general want to preserve and protect the resources they value, inadvertent effects from outdoor recreation activities can be detrimental to SGCN and their habitats through lack of awareness, misunderstanding of proper etiquette and techniques, or social tolerance of destructive behaviors.

Habitat destruction, the spread of invasive species or diseases, and pollution are all stressors that can result from outdoor recreation. These effects are not mutually exclusive and may affect multiple SGCN within the same habitat simultaneously. For example, recreation that covers large distances such as canoe or OHV (off-highway vehicle) and mountain biking trails can spread invasive species, disrupt or destroy nesting habitat for turtles, salamanders, snakes, and tiger beetles, and may cause direct mortality if animals or nests/dens are run over by vehicles or bikes. Recreation on lakes can affect common loons and other waterbirds when nests and shorelines are damaged by boat wakes and pollution is introduced from lead fishing tackle. Multiple bat species can be seriously affected by recreation in caves by the spread of disease or disturbance during hibernation. Peatland habitats, such as bogs and calcareous fens, are particularly fragile ecosystems that are also sensitive to human encroachment.

Recreation can also affect SGCN by affecting their behavior. For example, some SGCN species like Canada lynx (*Lynx canadensis*) and American goshawk (*Astur atricapillus*) are particularly sensitive to human activity, such as snowmobiling for the lynx and general human disturbance for the goshawk. These sensitive species may alter their movement patterns and activity or abandon otherwise suitable nesting territories, respectively (Squires et al., 2019; Morrison et al., 2011).

This strategy offers guidance for land managers, conservation educators, outdoor program and recreation leaders, and natural resource communicators to reduce negative effects from outdoor recreation activities, encourage effective resource management, and foster positive behavioral changes through raising awareness and providing education focused on environmentally responsible recreation. Many of the actions outlined below focus on social marketing campaigns, which are a proven tool for informing and educating the public and affecting sustained behavioral change that contributes to natural resource conservation (McKenzie-Mohr & Tabanico, 2024). Successful messaging highlights the positive effects produced by individual actions and the cumulative effect on the environment or resource. Perceived impact of individual actions is a significant predictor of future behaviors (Lawhon et al., 2013) and people are more likely to act when they believe their actions make a difference. These tactics emphasize the importance of individual decisions, empower individuals to feel capable of making a meaningful difference, and encourage people to promote responsible recreational behaviors as a social norm.

**Stressors Addressed:** Recreation (e.g. accidental take and overuse of resources), Hunting and Collecting Animals (e.g. improperly discarded gut piles causing potential exposure to lead), Fishing (e.g. use of lead tackle), Invasive Species (Problematic Non-native Species), Diseases and Pathogens, and Water-borne Pollution

## Recommended Actions for Responsible Recreation Efforts

1. **Collaborate with park and natural area managers to share best practices that support responsible recreation.**
   a. Host a speaker series or symposium on topics related to creating low impact, satisfying recreational access and its benefits for sensitive wildlife and habitat. Example topics for wildlife viewing recreation include bird photography blinds, wildlife viewing platforms, and wildlife cameras. Example topics addressing all types of recreation could include effective boardwalks and interpretive/ instructional signage or public art installations that increase knowledge of the vulnerable SGCN and habitats on the property and how to reduce one's impact while visiting/ recreating to avoid inadvertent harm.

## Example Species in Greatest Conservation Need: Northern Barrens Tiger Beetle

*Photo: Northern barrens tiger beetle, Bob Dunlap*

Tiger beetles are an intriguing group of species that feed on insects including agricultural pests, but they are increasingly threatened by anthropogenic effects, with eight species listed as SGCN in Minnesota. Tiger Beetles are mostly found in open sandy habitats like beaches, dunes, savannas, riverbanks and trails. They are dependent on these habitats to mate, lay eggs, construct larval burrows and hunt for prey. Unfortunately, a substantial amount of their habitat in Minnesota has been lost to development and much of their remaining habitat is subject to negative effects from recreation. For example, the northern barrens tiger beetle (*Cicindela patruela patruela*) is native to areas in central and southern Minnesota that are also popular areas for outdoor recreation, making it particularly vulnerable. Habitat degradation can stem from recreation that occurs off designated trails or in non-approved areas, whether motorized or non-motorized. Temporary effects like soil compaction or displacement can kill adults, damage burrows, and disrupt egg-laying. Over time, repeated disturbance can render areas uninhabitable. Responsible recreational behaviors such as staying on designated trails and avoiding disturbance of other areas can lessen the negative effects on tiger beetles, but effective communication is key. Most outdoor enthusiasts are prepared to alter their behaviors if they know why the change is needed or beneficial and knowing that specific actions will benefit at-risk animals or plants while maintaining or enhancing the recreational experience can be particularly motivating (Abrams et al., 2023). Increased attention con creating specific, actionable messages is needed to create awareness around these issues and the need for behavior changes.

b. Promote and provide information to park and natural area managers on the installation of boot brush kiosks that encourage visitors to wipe mud off their boots to prevent the spread of invasive plant seeds and earthworm egg cases, which damage habitat. See the "PlayCleanGo: Stop Invasive Species in Your Tracks" program for example boot brush kiosk signage that shares consistent messaging.

2. **Develop highly positive, fun, and memorable key messages—using social science on behavior change and social marketing—that promote and create norms around specific desired behaviors that reduce human impact on SGCN and their habitat.**

   Use these key messages in social media campaigns, programs, materials, and products to promote the desired norm. Some ways to disseminate these messages are to collaborate with the DNR's Division of Parks and Trails and Division of Fish and Wildlife on incorporating these messages into their recreation education programs and materials. For example, the creation of a SGCN mascot (an ambassador species — see strategy 1a) that could help deliver the above messages similar to Smokey Bear would add to their appeal.

3. **Leverage resources from national and state initiatives to communicate established responsible recreation practices and draw the connection to how these practices benefit SGCN by reducing inadvertent human-caused threats (e.g. not transporting potential vectors of pest and disease transmission).**

   Example resources include: Tread Lightly!, Leave No Trace, PlayCleanGo, American Birding Association's Code of Birding Ethics, Partners in Amphibian and Reptile Conservation's Intro to Ethical Outdoor Practices, and Get the Lead Out

4. **Collaborate with organizations already conducting outreach on aquatic and terrestrial invasive species to incorporate information about specific SGCNs that benefit from their recommended actions.**

   The DNR has a variety of programs conducting outreach on invasive species that provide an opportunity for collaboration and inclusion of SGCN information. For example, the DNR partners with the PlayCleanGo campaign to provide an opportunity for incorporating messaging relevant for local OHV clubs, mountain bike groups, and other recreationist groups. The DNR's Invasive Species Program provides behavior change messaging about aquatic invasive species to audiences like boaters, anglers, and shoreline owners. They also provide "Prevent the Spread" messaging about terrestrial invasive to species to a wide variety of outdoor recreationists.

5. **Design and create infrastructure and materials that make it easy for people to learn and adopt responsible recreation behaviors by including specific information with "how to" style instructions.**

   Placing information regarding responsible recreation behaviors on-site at recreational areas or including it in resources that the recreationists use is a way to easily raise awareness and make adoption of the behavior more likely. One example is providing simple stations at recreation access sites such as trailheads, fishing piers, or boat launches for people to take desired actions (e.g. boot cleaning or fishing line disposal) with accompanying interpretive signage explaining the what, why, and how of the desired actions. To further reach specific recreationists, incorporate information on desired practices into materials relevant to that recreation group. For example, for wildlife viewers, incorporate information on ethical wildlife viewing practices within wildlife identification and visitation guides and other wildlife viewing materials/content.

6. **Collaborate with organizations, groups, and businesses that can help develop and deliver relevant and tailored messaging to increase awareness amongst the recreationists with which they regularly interact on SGCN that are vulnerable to harm through their recreational activities and how to avoid inadvertent injury/harm to them.**

The following entities are example organizations/ businesses that could potentially help with message development and delivery: Minnesota Outdoor Recreation Industry Partnership; specific recreational groups, such as OHV, paddling, and photography clubs; lake associations; and outdoor outfitters.

## Case Study: Clean In, Clean Out Program

The DNR's Clean In, Clean Out program is a comprehensive outreach campaign and resource to help Minnesotans avoid the spread of aquatic invasive species (AIS) throughout the state. The program is especially effective due to its positive messaging that connects people with the resources they care about, explains why AIS are an issue, empowers people to make meaningful conservation choices, and perhaps most importantly, explains exactly what actions to take based on the activity or gear involved. The main website explains that:

"Invasive plants, animals and diseases can harm lakes, rivers, streams, wetlands, water quality, and wildlife habitat. People can unintentionally spread invasive species by moving boats, gear, and equipment from one waterbody to another or releasing non-native species into the environment. No matter how you enjoy the outdoors, always take these actions to prevent the spread of aquatic invasive species (AIS)."

*Photo: Boot brush station at Interstate State Park, Laura Van Riper*

The website has information about a wide variety of common aquatic activities like boating, fishing, and paddling, as well as resources for people such as water gardeners, aquarium owners, and commercial bait harvesters. There is specific information about how AIS affect different gear and activities, what to do to minimize risk of spreading AIS, instructions to decontaminate gear, relevant laws and regulations, and links to additional resources. The message is simple and clear: We all play an important role in protecting Minnesota waters from aquatic invasive species.

## Habitat Stewardship

### Strategy 5: Engage and empower communities to improve wildlife habitats where they live, work, and recreate.

Land use change and the associated loss of habitat and habitat degradation is the number one driver of species loss and population decline for terrestrial species worldwide (Jaureguiberry et al., 2022). When lands are converted from natural landscapes to human-dominated ones, wildlife are challenged to find suitable habitat within a matrix of development and heavily modified ecological landscapes. Although many landscape scale changes in habitat cannot be reversed through small-scale actions, anyone with access to a patch of land, whether it be small urban lots or large rural acreages, can help improve habitat in their domain. Collective efforts by individuals and communities have the ability to make a difference for some SGCN, particularly those that use developed areas (see Urban and Other Developed Lands sub-chapter). This includes some migratory birds, pollinating insects, and bats seeking food sources; suitable nesting, egg laying and roosting sites; and migration stopover sites. Even the simple choice to include native plants in one's home landscaping, can provide critical benefits to wildlife (Tallamy, 2009; Tallamy et al., 2021; Tallamy & Shriver, 2021). For example, the use of native landscaping in suburban areas has been found to significantly support the abundance and diversity of birds, butterflies, and moths with one study finding that bird species of regional conservation concern were eight times more abundant and significantly more diverse on native landscaped properties than those landscaped with non-native plants (Burghardt et al., 2009). When individual actions are replicated throughout a community, these small-scale habitat improvements can make a powerful, large-scale change for wildlife in urban, suburban, and agricultural areas.

Our recommended actions for habitat stewardship primarily focus on practices beneficial to migratory birds, pollinating insects, and bats as there are simple conservation actions for these groups that can be easily and practically employed by many people in most communities. Also important, these species groups hold relevancy to Minnesotans; appealing to their wildlife viewing species interests (Sinkular et al., 2002) and in the case of bats, their interests in mosquito control to better enjoy the outdoors (Minnesota DNR, 2025) or encouraging bats to roost outdoors rather than in their homes.

In addition, when engaging members of waterfront communities, we leverage Minnesotans' passion for our state bird by highlighting the benefits to the common loon while encouraging stewardship of their lake shoreline habitats.

When engaging rural communities in habitat stewardship, we highlight practices that can support grassland birds and turtles that use upland, wetland, and stream habitats like wood turtle and Blanding's turtle — all of which would stand to benefit from habitat enhancements in these settings and may hold appeal for the landowners. Our recommended actions take a community approach (to maximize habitat benefits through collective action), create relevancy for communities by highlighting taxa of interest to wildlife viewers, and address potential societal barriers, including overcoming social norms and lack of knowledge and skill.

**Stressors Addressed:** Development, Crop Production, Timber Harvest, Tree Plantations, Air-borne Pollution, Water-borne Pollution, Light and Noise Pollution, Invasive Species (Problematic Non-native Species), and Fire Management

## Example Species in Greatest Conservation Need: Rusty Patched Bumble Bee

The rusty patched bumble bee *(Bombus affinis)* was once widespread and abundant across eastern North America including Minnesota but has disappeared from much of its historic range over the past 30 years, although still abundant in Minnesota. The cause of this decline is not fully understood, but disease, pesticides, and habitat loss have likely played roles. The bee was listed as federally endangered in 2017.

In 2019, the rusty patched bumble bee was named Minnesota's state bee to raise awareness of its conservation status and the importance of protecting pollin31ator habitat. Like many other bumble bees, rusty patched bumble bees forage on a variety of flowering plants for pollen and nectar. Bumble bees nest in cavities above or below ground and often use brush piles, leaf litter, or abandoned burrows for shelter. Rusty-patched bumble bees do not avoid developed areas, so by planting native plants that bloom throughout the growing season, reducing the use of pesticides, and leaving nesting areas alone, Minnesotans can help support our endangered state bee and other pollinator species.

*Photo: Rusty patched bumble bee, Jessica Petersen*

## Recommended Actions for Habitat Stewardship:

1. **Educate local communities, landowners, and land managers on the habitat needs of the SGCN sharing their local area, highlighting migratory birds, pollinating insects, bats, and other species relevant to the community type/geographic area, as applicable.**

2. **Provide coordination that connects communities to programs and resources for technical, financial, and organizational support, so that they can more easily implement habitat stewardship actions for SGCN. Engagement of the 11 federally recognized Tribes with Minnesota's borders is recommended as part of the process to ensure their access to these programs and resources and that this support meets their needs and interests. Specific examples of coordination are provided below.**

   a. Collaborate with conservation organizations and agencies to develop resource information hubs that compile the many existing resources on what individuals can do to improve habitat into one convenient place.

   b. Develop a train-the-trainer program for people to become Master Habitat Stewards—e.g. utilizing Soil and Water Conservation District educators, Master Gardeners and Master Naturalists—to increase capacity for habitat education, technical assistance and site visits.

   c. Promote existing stewardship programs to municipalities that empower them to engage their communities and parks departments in taking actions directly benefiting wildlife. Examples of programs to promote to municipalities include: National Wildlife Federation's Mayor's Monarch Pledge, American Bird Conservancy's Bird City, Minnesota Board of Soil and Water's Pollinator Pathways grant program, and Audubon

International's Audubon Cooperative Sanctuary Program for Golf Courses.

d. Develop a plan for the creation of local-level habitat stewardship collaboratives, involving varied stakeholders (see examples below). These groups could serve as forums for building relationships and trust, holding listening sessions, crafting relevant messaging, increasing knowledge of the SGCN and habitats in their community, and maximizing capacity for on-the-ground implementation of habitat enhancement projects.

   Example stakeholders for Urban/ suburban Communities: NGOs and agencies involved in community habitat enhancement work (e.g. watershed management organizations), Soil and Water Conservation Districts, local parks departments, transportation departments, local influential leaders (mayors and city councils), schools, libraries, and well-being centers.

   Example stakeholders for Rural Communities: Minnesota Farm Bureau, Minnesota Farmers Union, Minnesota State Cattlemen's Association, Pheasants Forever, Ducks Unlimited, Minnesota Deer Hunters Association, Minnesota Chapter of the Wildlife Society, North Shore Forest Collaborative, Forestry for the Birds Initiative, Soil and Water Conservation Districts, Natural Resource Conservation Service's Farm Bill biologists/ private lands biologists, Minnesota Corn and Soybean Growers Associations, The Nature Conservancy, U.S. Fish and Wildlife Service Wetland Management Districts, Minnesota Land Trust, Sustainable Farming Association, and Prairie Reconstruction Initiative.

   Example stakeholders for Waterfront Communities: Homeowners Associations, Watershed Organizations, Tribal governments, and researchers.

3. **Craft communication resources, campaigns, and media with messages that increase public understanding on how the health of habitats, which we share with SGCN, is directly tied to the individual choices Minnesotans make on their own properties and how collectively, our stewardship actions make a difference for both wildlife and humans.**

   a. Promote the benefits of stewardship actions for humans (e.g. well-being, cost savings, wildlife viewing opportunities) and for wildlife, celebrating habitat as a healthy space for both people and SGCN. This action could connect with actions in Strategy 3.

   b. Promote actions that have a clear connection between larger scale benefits to wildlife and humans, resulting from our individual, smaller actions. For instance, collaborate with local watershed organizations to promote connectivity messaging on how what individuals do on their property affects the health of our local lakes and rivers.

## Case Study: Minnesota Loon Restoration Project

The DNR's Minnesota Loon Restoration Project provides an example of how to engage waterfront communities. The project supports lake associations as they develop management plans that encourage loon-friendly activities and habitat restoration on the lakes, and it educates the public about loon conservation. The Minnesota DNR has recruited lake associations to participate in the "Loon Friendly Lake Registry." Through presentations at annual lake association meetings and support in the development of lake-specific management plans, the DNR has empowered owners of lake shorelines to restore and conserve shoreline habitat. There are currently 64 lake associations enrolled in the Loon Friendly Lake Registry. In 2024 alone, the Loon Restoration Project reached approximately 2,500 people in over 40 live speaking events/booths to discuss and present on loon conservation in the state.

c. Other messages could include promoting how planting a pocket of milkweed for monarchs builds habitat across the landscape, how turning "lights out" supports migrating birds and reduces light pollution, and how by landscaping with native plants, we increase food and nesting opportunities for birds.

4. **Create and distribute materials and media that promote and enhance application of everyday stewardship actions and best management practices for habitats and SGCN. To be most effective these communications should be provided in easily applied formats and translate scientific, technical information into accessible, plain language and in different languages. A list of specific actions to encourage everyday conservation actions includes:**

   a. Simplify people's ability to include native plants in their landscaping by providing and promoting information on what to plant for SGCN, where to buy the plants, and how to incorporate them into their gardens. Essential resources to develop would be lists of the top beneficial native plants for Minnesota's SGCN, organized by the state's ecoregions. These lists should include soil and sun requirements and information on which species groups are attracted to which plants (e.g. birds, butterflies, or bumble bees). Helpful partners and resources in this effort could be Minnesota's Wild Ones Chapters, Minnesota Native Plant Society and Monarch Joint Venture. To help people locate and obtain native plants, develop a database/list of native plant nurseries and seed sources in Minnesota and promote local native plant sales. And finally, to help people incorporate native plants into their landscaping, promote and connect people to resources with how-to information, such as Minnesota's Board of Water and Soil Resources' Lawns to Legumes program and Ganawenindiwag: Working with plant relatives to heal and protect Gichigami shorelines). Updating and reprinting the DNR's "Landscaping for Wildlife" and "Loonscaping" would provide additional helpful resources.

   b. Provide guidance on how people can stop the introduction and spread of invasive species. Disseminate existing products on (1) how to identify and remove common invasive plants, (2) how to avoid buying invasive plants and plant native alternatives instead, and (3) how to avoid releasing invasive plants and animals into the environment. Create new products as needed.

   c. Promote ways people can reduce threats to wildlife around homes. Guidance should include the following: (1) reducing the use of pesticides and other chemicals in yards, why it matters for wildlife, and information on alternatives that are less impactful to wildlife; 2) methods to prevent bird window collisions, highlighting available programs and resources (e.g. American Bird Conservancy); 3) the importance of snags for cavity-nesting birds, encouraging people to maintain them and/or supplement them with bird boxes; 4) keeping cats indoors for the benefit of birds by utilizing available resources (e.g. from American Bird Conservancy and the Association of Fish and Wildlife Agencies) and by working with veterinarians and Department of Public Health to help amplify these messages; and 5) turning off of exterior lights to reduce light pollution, explaining its effects on migrating birds, moths, and fireflies, and by highlighting programs such as Audubon's Lights Out Campaign and citing reports showing timed/less lights don't affect homeowner safety.

   d. Promote bat boxes, along with siting and design recommendations . Little brown bats (*Myotis lucifugus*) commonly roost in artificial structures including human residences and bat boxes (Minnesota

DNR, 2025). A statewide survey in Minnesota documented little brown bats as the primary species utilizing bat boxes, with colony sizes ranging from 20 to nearly 600 individuals. When little brown bats are excluded and displaced from a building or human structure, their preferred summer roost sites, bat boxes can provide alternative roosting habitat. They also provide a safe location for maternity colonies to raise their pups, which can support the recovery of Minnesota's little brown bat population from white-nose syndrome. (DNR, 2025) Installing bat boxes is a relatively easy way for people to support little brown bats in Minnesota, however studies have shown these structures must be properly constructed, sited, and monitored through time as these long-lived bats will rely on the bat houses to raise pups for many years. Therefore, to truly benefit the species when promoting bat boxes, it is important to provide information on best practices.

e. When working with waterfront communities, include additional information relevant to aquatic habitats: 1) promote the importance of natural shoreline for water quality, loon habitat, and other aquatic wildlife; 2) provide plant lists of native riparian vegetation that benefit loon, other waterbirds and pollinators; and 3) encourage behavior change to reduce the spread of aquatic invasive species.

f. When working with private landowners, provide information on best management practices (BMPs), applicable to larger acreages. Specific recommendations include: 1) develop easily accessed products in plain-language formats to share and promote BMPs for managing SGCN habitats, such as shorelines for loons, prairie for grassland birds and pollinating insects, and forests for birds, bats, wood turtle and other forest-dependent herpetofauna; 2) promote and distribute invasive plant BMP materials for managing large landscapes; 3) provide information on how to recognize and enhance the native plants beneficial to wildlife that are already on their lands, e.g. milkweeds; and 4) promote the importance of prescribed fire, in combination with retained areas of refuges, as a necessary habitat management tool and provide information to support capacity for conducting prescribed fire in Minnesota. University of Minnesota Extension's My Minnesota Woods and Minnesota Woodland Steward program provides resources for this work.

## Case Study: Lawns to Legumes Program

The Lawns to Legumes program by Minnesota's Board of Soil and Water Resources (BWSR) exemplifies several of these recommended actions. This stewardship program helps people to install pollinator-friendly native plantings on residential lawns. They offer workshops, coaching, planting guides, and grants to individuals. Additionally, they offer Pollinator Pathways grants, which are pollinator programs run by local governments and nonprofit organizations with support from BWSR, and a public education campaign to raise awareness about creating pollinator habitat. According to their website, in their 2024/2025 fiscal year, the Minnesota Board of Water and Soil Resources (BWSR) offered over $1.1 million in grant funding to promote and establish pollinator plantings though a residential and/or educational-based approach.

*Photo: Lawns to Legumes garden sign, Minnesota Board of Soil and Water Resources*

## Participatory Science

### Strategy 6: Offer participatory science programming for Minnesotans to take part in conservation volunteerism that addresses Species in Greatest Conservation Need data needs.

Participatory science (also known as citizen science, community science, or crowd-sourced science) engages the public in scientific projects that produce reliable data and information, often through public data collection, that may be used by scientists, decisionmakers, or the public (McKinley et al., 2017). Involving non-professional participants in wildlife research and data collection increases program capacity and fosters ongoing public involvement in conservation. One of the most significant advantages of participatory science collaborations is the ability to collect data at a scale well beyond the normal reach for many agencies and organizations (Dickinson et al., 2010), including the DNR. Participatory scientists help fill the gap by collecting data across wide geographic areas and over long periods of time. These datasets are invaluable to conservation at local, regional, and international scales (McKinley et al., 2017). A few longstanding examples are the Breeding Bird Survey, eBird, Minnesota Loon Monitoring Program, and Minnesota Statewide Frogwatch. Ongoing public participation fosters appreciation for Minnesota's unique natural resources, encouraging lifelong learning, engagement and conservation action.

Minnesota has a strong history of participatory science and conservation. Universities, state agencies, local governments and parks, nongame wildlife interest groups, and others have all contributed to wildlife conservation for many decades. Participatory science has emerged as way to empower communities to learn and invest in their local environments.

Recommended species groups for participatory science projects in Minnesota include, frogs and toads, loons and other birds, bats, butterflies, bees, and mussels. All these groups represent SGCN with data needs, while also being appropriate for volunteer researchers, thus ensuring that participatory science efforts successfully obtain useable data. These species groups are relatively easy for non-experts to identify with minimal training and simple resources and observing them requires relatively little or easily operated equipment. They are also species that can be readily identified with photographs, recordings or other simple technology. Another important consideration is that all of these recommended species groups are those that Minnesotans are interested in observing (Sinkular et al., 2022) or in the case of mussels, speak to other human conservation interests, like water quality (Duda, 2021.

Participatory science projects are reliant upon volunteers, so they must hold relevancy to people's interests. The 2025-2035 Minnesota State Wildlife Action Plan seeks to sustain and further develop the collective power of participatory science in Minnesota by supporting existing initiatives, collaborating with partners, and the developing new projects and programs. The recommended actions in this section draw upon social science research of Minnesota's participatory scientists (Jennings et al., 2024a). They are designed to contribute to a broad framework of opportunities for Minnesotans statewide to engage in participatory science that benefits SGCN and habitat and is meaningful to the interests of our residents.

**Stressors Addressed:** Participatory science does not necessarily address a specific stressor; rather, it addresses data gaps/ lack of information.

### Recommended Actions for Participatory Science:

1. **Promote existing participatory science initiatives in Minnesota to help recruit volunteers to those projects.**

   While several participatory science projects already exist in Minnesota, people need an easy way to learn about these opportunities and increased promotional efforts would

help (Jennings et al., 2024b). To help boost promotion, it is recommended to create a Minnesota-based resource hub for wildlife participatory science opportunities. This could be modeled after The Wisconsin Aquatic and Terrestrial Resources Inventory. Some examples of projects that would benefit from additional promotion and that could be part of the resource hub include: the Minnesota Bumble Bee Atlas; University of Minnesota Extension participatory science projects; Monarch Joint Venture's Integrated Monarch Monitoring Program; and the DNR's Minnesota Statewide Frogwatch, Blanchard's Cricket Frog Survey, Minnesota's Loon Surveys, and Chimney Swift Roost Monitoring Project.

2. **Collaborate with wildlife biologists and participatory science professionals to identify gaps in existing participatory science programs, identify project priorities, and to understand what specific data would be most useful and appropriate and relevant for volunteers to collect.**

   Although Minnesota has several participatory science projects, there are many areas of opportunity with other species groups, including many bird species, bats, butterflies, and other easily identified insects, and mussels – all represent SGCN with data needs and taxa relevant to Minnesotans. These should be explored further with wildlife biologists to determine specific project needs and design.

   To enhance the success of newly developed projects, partnerships and collaborations with the following organizations are recommended: 1) museums, science centers, nature centers, and zoos to identify projects of mutual interest and maximize resources for implementation; 2) The University of Minnesota Extension's Minnesota Master Naturalist Program for assistance in designing projects that are appealing and volunteer-friendly, volunteer recruitment, and engagement in train-the-trainer opportunities to maximize capacity; 3) existing conservation projects/programs to add a community science component (e.g. Lawns to Legumes to add pollinator monitoring opportunity for their grant recipients); 4) conservation agencies and organizations that have community connections (e.g. USFWS National Wildlife Refuges, Local Parks Departments, and community-based non-profit organizations); and 5) entities that may have monitoring needs (e.g. the DNR's Minnesota Biological Survey, Scientific Natural Areas, and Wildlife Management Areas; Pheasants Forever; Ducks Unlimited; and The Prairie Enthusiasts).

3. **Develop community science opportunities to collect data on SGCN occupying less developed and rural habitats through unique partnerships.**

   SGCN inhabiting less populated areas (e.g. burrowing owls and Richardson's ground squirrels), may pose challenges for volunteer recruitment, so unique partnerships should be explored. Recommendations include: 1) develop a project in partnership with rural postal offices to train mail carriers to identify SGCN of interest and 2) build relationships with educators and collaborate on project ideas, in which students and their families could participate.

4. **Engage broader groups of volunteers by providing training, meeting people where they are, and suiting their needs and interests.**

   Eliminate potential barriers to help people get started in participatory science by: 1) designing projects for variable skill levels including entry level, offering multiple trainings in varying formats, and creating opportunities requiring different levels of commitment; 2) ensuring easy to use species identification resources are available (this also relates to Strategy 1); and 3) promoting entry-level, easily accessed opportunities (e.g. eBird and iNaturalist), coupled with supportive materials or

trainings, to anyone new to participatory science and to educators to encourage youth involvement.

Create locally and personally relevant opportunities for participatory science by 1) encouraging groups to adopt-a-site (e.g. their local park) for on-going and varied community science projects, with recommendations for projects that would be a good fit for the site; 2) designing projects around community interests and needs and build the conservation effort off of that, so that it benefits the participating community as well as the organizations involved (e.g. working with a community to restore bluff habitats to help keep timber rattlesnakes out of their yards); 3) developing participatory science opportunities for collection of data around people's homes and promoting the existing opportunities (e.g. Project FeederWatch, Monarch Larva Monitoring Project, Bumble Bee Watch), which also supports Strategy 3; and 4) promoting participatory science opportunities that can be done without leaving one's home (e.g. Zooniverse and iNaturalist).

5. **Ensure that data from participatory science projects may be accessed for research conducted by conservation organizations and academic institutions.**

   Conduct outreach to relevant organizations/institutions to promote the use and application of the data. As a best practice, ensure that the need for data accessibility is balanced with the need to protect species that are most vulnerable/subject to illegal collection or disturbance (e.g. location masking for rare herpetofauna and plants).

## Example Species in Greatest Conservation Need: Blanchard's Cricket Frog

The Blanchard's cricket frog (*Acris crepitans*) is Minnesota's only endangered amphibian. Historically, they had a patchy distribution in Minnesota, with populations reported in the extreme southwestern and southeastern corners of the state. In the 1960s, their populations declined drastically for unknown reasons, and they were thought to be extirpated from the state.

In the 1990s, a group of participatory scientists found two very small populations of Blanchard's cricket frogs. For the next 20 years, these were the only known locations of Blanchard's cricket frogs in Minnesota.

In the mid-2010s, DNR biologists and partners began discovering new, small populations of Blanchard's cricket frogs throughout their historic range in Minnesota. Hope for the future of the Blanchard's cricket frog hopped back onto the scene and the Nongame Wildlife Program partnered with HerpMapper and the Amphibian and Reptile Survey of Minnesota to create a Blanchard's Cricket Frog Survey, using participatory scientists to gather more information about this rare amphibian.

*Photo: Blanchard's cricket frog, Jeff LeClere*

## Case Study: Two Minnesota Loon Participatory Science Programs

Minnesota's Loon Restoration Project includes several ways one can help with loon conservation. The Minnesota Loon Monitoring Program and Loon Watcher Survey are excellent examples of participatory science projects that provide long-term tracking of a SGCN, while offering a relevant opportunity to Minnesotans (in this case focusing on Common Loon, the state bird).

Since 1994, more than 1000 volunteers have helped the DNR survey loons with the Minnesota Loon Monitoring Program (MLMP). During a 10-day period in summer, volunteers survey 100 lakes in each of 6 different index areas in the state. The MLMP provides important data to help understand population trends in the state.

For more than 40 years, approximately 200 volunteer Loon Watchers per year have recorded their loon observations on any lake of their choosing in the state. These volunteers survey the same lake(s) repeatedly throughout the season and have provided the Minnesota DNR's Nongame Wildlife Program with data on nesting success, number of loons observed, interesting occurrences and problems that may negatively affect the loons. Data from the Loon Watchers program have been critical for identifying lakes that are relatively unproductive for loons, and candidates for conservation actions and habitat acquisition through the Minnesota Common Loon Restoration Project (as highlighted in Lakes sub-chapter).

*Photo: Loon monitoring, USGS*

## Financial Support

### Strategy 7: Cultivate financial support for the conservation of SGCN through the development and promotion of public funding opportunities and public-private partnerships.

Minnesotans care about the outdoors and the state's natural heritage and connecting to that care is imperative for supporting conservation and research for Species in Greatest Conservation Need (SGCN). By building a stronger relationship between the DNR's Nongame Wildlife Program and Minnesotans through targeted partnerships and marketing, we can leverage their support to help SGCN.

The DNR's Nongame Wildlife Program (NWP) leads the conservation of SGCN, with funding from USFWS State Wildlife Grants (SWG), donations to the Nongame Wildlife Fund, Reinvest in Minnesota (RIM) funds that are generated from purchases of Minnesota's critical habitat license plates (see Case Study below) and the Environment and Natural Resources Trust Fund (Minnesota lottery funds made available through competitive grants). The NWP does not receive any 'base funding' from the state and is reliant on this unique blend of private, state, and federal funds, none of which are guaranteed. Donations to the Nongame Wildlife Fund provide essential matching dollars required to receive both SWG and RIM funds. Donations are obtained through direct giving as well as through a 'check-off' option on Minnesota tax forms, in which tax payers can donate a portion of their tax refund.

While the amount of funds from donations has been relatively stable, the number of individual donations to the NWP have been on the decline (see Case Study below). A survey of NWP supporters (Jennings et al., 2024b) found that lack of awareness was the largest barrier for engaging with the program. They found that 52% of respondents had little to no familiarity with the NWP and 75% listed being "unaware of opportunities" as the main barrier to volunteering for participatory science programs and donating to the program. However, after receiving an introduction to the program's work, 60% of respondents were interested in volunteering and 70% were interested in donating.

In addition, wildlife viewers indicated that they were most likely to increase their contributions to the DNR if they knew their funds would be used for the conservation of rare or vulnerable wildlife species or if used to support conservation of the types of wildlife they like to view (Sinkular et al., 2022). This tracks with another finding that having a conservation impact is a primary driver of contributions for the NWP's current and potential donors (Jennings et al., 2025). Therefore, another approach the NWP can take to motivate public support will be highlighting their conservation project work and especially their success stories, instilling confidence and trust around how donations to the Nongame Wildlife Fund benefit SGCN, like the recovery of bald eagles or trumpeter swans or the improved status of peregrine falcons (see Trumpeter Swan Case Study in the Bird Sub-chapter in Chapter 2). It's important to highlight species of relevance to Minnesotans. Species groups to especially highlight include mammals and birds, which most wildlife viewers reported an interest in observing (Sinkular et al., 2022). Another species group to consider highlighting would be native mussels, given their connection to water quality, another strong human conservation value (Duda, 2021).

### Recommended Actions for Financial Support

1. **Increase public interest in donating to the Nongame Wildlife Fund with strategic marketing and promotions that expand Minnesotans' familiarity with and connection to the Nongame Wildlife Program's mission to conserve SGCN and their habitats.**

   Develop a marketing plan for the Nongame Wildlife Program that helps communicate the program's goals in a manner that

creates a sense of pride and relevancy and clearly shares how to contribute. Include the following elements within the plan: 1) materials and promotional activities that share the NWP mission, build relationships with future donors, and connect the needs of vulnerable wildlife to Minnesotan's pride in the outdoors and the state's natural heritage; 2) methods to nurture relations with current donors through regular acknowledgment and communications about the NWP; and 3) a survey of Nongame Wildlife Program donors every five years to better understand who they are and evaluate and improve outreach and engagement efforts.

2. **Reinvigorate critical habitat license plate promotions.**
   Promote how the Reinvest in Minnesota Critical Habitat License plate fund benefits the Nongame Wildlife Program and SGCN conservation. Develop updated outreach media and materials and new Critical Habitat License plates, led by the DNR. Collaborate on critical habitat license plate promotions between DNR programs/ divisions and other organizations. Increase Minnesotans' understanding about how these plates provide matching dollars to donations for the Nongame Wildlife Fund, Minnesota Biological Survey, and Minnesota's Scientific and Natural Areas, all of which support SGCN and their habitats.

3. **Promote the Nongame Wildlife Fund Tax Check Off and highlight how donating to the Nongame Wildlife Fund benefits SGCN conservation.**

   Develop information products and communication campaigns encouraging Minnesotans to donate to the Nongame Wildlife Fund during the tax season. Work with Certified Public Accountants (CPAs) and other tax professionals to promote the Nongame Wildlife Fund to their clients. Promote the Nongame tax checkoff on corporate tax forms to corporations.

## Case Study: Critical Habitat License Plate

The Minnesota Critical Habitat license plate was initiated in 1995 to provide an opportunity for citizens to contribute to conservation of Minnesota's natural resources and show their commitment and individuality with a special vehicle license plate. As of 2025, there are 9 specialty plates featuring both game and nongame wildlife and plant species. Minnesotans can obtain a critical habitat plate with a minimum $30 annual contribution added to their tab renewal. This contribution goes into the Reinvest in Minnesota (RIM) Critical Habitat Program, which provides a two-to-one match for each individual donation made to the Nongame Wildlife Program. Half of the matching funds go to the Nongame Wildlife Fund and the other half go to support the Minnesota Biological Survey and Scientific and Natural Areas, all of which benefit Species in Greatest Conservation Need. In 2024, these plate sales provided 2.3 million for the conservation of SGCN and their habitats.

*Example Critical Habitat license plate featuring a rusty patched bumble bee and monarch butterfly; artwork by Minnesota artist Timothy Turenne*

4. **Develop relationships with philanthropic organizations and individuals who have an interest in wildlife conservation.**

   Strengthen support for the Nongame Wildlife Program by corporate donors and foundations through researching conservation-inclined philanthropic organizations, relationship building, and the promotion of corporate giving. Leverage existing partnerships and connect with local businesses interested in donating portions of their sales to the Nongame Wildlife Program. Promote the Nongame Wildlife Fund to estate attorneys as an option for planned giving.

5. **Explore new funding mechanisms that could create new revenue streams for the Nongame Wildlife Fund.**

   Collaboration between the Nongame Wildlife Program, local businesses and corporations, and/or the DNR's legislative liaisons to develop new funding mechanisms could generate additional revenue for the Nongame Wildlife Fund.

## Case Study: Nongame Wildlife Program Boosts Tax Check-off donations

The Nongame Wildlife Fund has been present on Minnesota state tax forms since 1980. Once a strong source of funding for the Nongame Wildlife Program, donations to the tax checkoff have waned over the last decades. In 2025, the program developed new outreach initiatives for promoting the Nongame Wildlife Fund. Across all advertising platforms, messaging was overhauled to reflect Minnesotan wildlife viewers interest in supporting rare or vulnerable wildlife (Sinkular et al., 2022), coupled with images of wildlife belonging to species groups that they are interested in viewing as found in that same study. The updated and enhanced campaign was a success, resulting in an almost 100% increase in new visitors to the Nongame Wildlife Program's donation webpage and over 500 more direct donations amounting to a $30,000 increase in donations compared to the 2024 campaign period.

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# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

# MONITORING AND RESEARCH

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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This document contains maps that are available in alternative formats to individuals with disabilities by calling (651) 259-5149 or emailing the SWAP Coordinator at alison.cariveau@state.mn.us.

Cover Photos: A biologist surveys moss hummocks for four-toed salamanders, Andrew Herberg; DNR biologist conducting a broadcast survey for red-shouldered hawks, Amy Westmark

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# Chapter 5: Monitoring and Research

## Overview

The importance of monitoring wildlife populations has long been recognized as a critical component of wildlife conservation. This is not only true for species that are actively managed using harvest regulations, such as waterfowl, but also of rare species that may be at risk of extirpation or extinction if we are unaware of their declining status. Today, monitoring elements of biodiversity, from bees and salamanders to orchids and oak savannas, is recognized as one of the most important responsibilities of natural resource agencies.

For the third iteration of the Plan, this chapter focuses on the role of monitoring and research activities within Minnesota's SWAP. We provide an overview of our vision for what we want to achieve in the context of surveys, monitoring, and research for animals, plants, and habitats in Minnesota. We discuss the relevant questions we need answered and structure them into three pathways: baseline diagnostic information needs, determining positive actions and management activities that promote effective conservation and estimating.

## Building on the two Prior Plans

Monitoring rare and uncommon wildlife species began in the late 1970s with the initiation of the Nongame Wildlife Program. Initial efforts focused on common loons, bald eagles and colonial waterbird nesting sites. Soon after, the launch of the Minnesota Natural Heritage Program placed an equal emphasis on native plants and plant communities with monitoring efforts focused on rare species such as prairie bush clover (*Lespedeza leptostachya*) and western prairie fringed orchid (*Plantanthera praeclara*). The state was well-primed to address the importance of monitoring when the state wildlife action planning process began in the early 2000s.

### 2005-2015 Tomorrow's Habitat for the Wild and Rare

One of the three goals established by the 2005-2015 SWAP was to "Improve knowledge about Species in Greatest Conservation Need (SGCN)". A key strategy for implementing that goal was to "Monitor long-term changes in SGCN populations and habitats". An important statewide project funded with State Wildlife Grant dollars was the completion of a statewide survey of freshwater mussels that began in 1999 and the subsequent launch of a long-term monitoring program. Other projects included continued monitoring of American goshawks, double-crested cormorant and American white pelican nesting colonies and a small but critically important Henslow's sparrow population at Great River Bluffs State Park. Monitoring habitats that rare species depend upon for their survival is equally important. Once covering nearly one-third of Minnesota, native prairie now only covers approximately 235,000 acres. The species dependent on this rare resource are among the most endangered and threatened species in the state. It was only natural, therefore, to design and launch a long-term monitoring program (SPICE; Sustaining Prairies in a Changing Environment) to track the status and trends of this critical habitat.

### Minnesota's Wildlife Action Plan 2015-2025

In the second update of the SWAP, monitoring SGCN and their habitats, and applying the knowledge gained to design new management approaches or to adapt existing ones, was a major theme. The plan recognized the need to apply monitoring strategies at three levels: the Wildlife Action Network, in Conservation Focus Areas, and Species Monitoring. Numerous survey, monitoring and research projects were completed under this Plan.

For the third iteration of the Plan, this chapter focuses on the role of monitoring and research activities within Minnesota's SWAP. We provide an overview of our vision for what we want to achieve in the context of surveys, monitoring, and research for animals, plants, and habitats in Minnesota. We discuss the relevant questions we need answered and structure them into three pathways: baseline diagnostic information needs, determining positive actions and management activities that promote effective conservation and estimating effects from threats on species and habitats. We then follow up with a section on best practices for survey, monitoring and research design, which is subdivided into handling existing data versus collecting new data. Before diving into this discussion, we define relevant terms pertinent to the presentation of the material.

# Important Definitions

## Surveys

Wildlife and plant surveys are the primary tool used by the Minnesota Department of Natural Resources (DNR) and its partners to gather scientific data at specific locations and points in time. Surveys can be used to collect vital information on a variety of ecological metrics, including (1) population abundance or relative abundance, (2) population demography (e.g., survival, fecundity, dispersal), (3) habitat conditions and species-habitat relationships, (4) stressors or threats affecting species or habitats and (5) the geographic distribution of species across Minnesota. Even single surveys can be valuable especially when it leads to the discovery of rare species in new locations and informs conservation efforts.

## Monitoring

Monitoring is generally defined as a structured activity in a set of sites, repeated through time. These measurements can include surveys of some species (a type of structured counting effort), evaluation of habitat features (e.g., density of trees) or assessments of ecosystem health (e.g., water quality). Monitoring is distinguished from surveys by employing data collection methods and efforts that are repeated and standardized at some set of sites to detect changes (such as trends in abundance, species richness, or occupancy) through time or across space.

The temporal spacing of repeated sampling (e.g., daily, seasonally, or annually) and the spatial arrangement of sampling units such as the distance between and distribution of sampling locations are determined by the focal species or system and the specific questions being addressed. Key features of appropriately designed monitoring efforts are sampling designs built around a focal question(s) or objective(s), standardized efforts, repeatable procedures, well-curated data and recording of negative data (the absence of the target). The presence and absence of target species recorded through time permit the estimation of detection probability, either explicitly or implicitly, depending on the timing of recurrent surveys and assumptions about survival and movement in the study area. Accounting for detectability helps remove bias in metrics of interest (e.g., abundance, survival, etc.) and can improve trend estimates (Kéry & Schmidt, 2008).

**Surveillance monitoring** involves tracking trends in species, communities or habitat metrics over time to understand their status and dynamics. In contrast, **effectiveness monitoring** is structured around specific questions regarding the success of management or conservation actions intended to produce beneficial outcomes, such as habitat creation for threatened or endangered species, invasive species control or the restoration and reconstruction of native habitats or ecosystems.

## Research

Research is the process of obtaining information to answer a specific question(s), involving the collection and analysis of data to test predictions or hypotheses. While the term is frequently associated with formal experimentation, well-designed surveys and monitoring efforts can also be structured to address research questions. Research approaches vary in purpose, design and methodology, yet they are not mutually exclusive and can overlap, combining elements from multiple types. The strength and utility of research increases when questions and objectives are clearly articulated and quantitatively linked to biologically meaningful outcomes. The DNR primarily engages in the following research approaches:

- **Basic or Observational Research**, which serves to expand general knowledge and understanding of natural systems and the plants and animals that are found within them. This type of research is meant to gather information by documenting characteristics, patterns, trends or species within ecological systems and may be used to inform conservation actions. An example would be a survey to detect the presence of the plains pocket mouse (*Perognathus flavescens*) on the property of the Twin Cities Army Ammunition Plant in Ramsey County, Minnesota.

- **Applied Research** is defined by its purpose for solving practical problems or informing decision-making in natural resources. While not all applied research is experimental, many applied studies employ formal experimental designs. For example, testing whether prescribed burning or goat-grazing increases native plant and pollinator species richness in grassland habitats and measuring the magnitude of those changes compared to untreated controls constitutes applied research.

- **Experimental Research** involves intentional manipulation of variables through controlled interventions, often including randomization, replication, and pre- and post-treatment measurements.

*Photo: A biologist surveys moss hummocks for four-toed salamanders, Andrew Herberg*

While experimental research can also fit under the umbrella of being applied, some is purely theoretical. An example would be the use of a Before-After-Control-Impact (BACI) design to assess the effect of cattle grazing on composition of the native plant community or on reproductive success in prairie obligate birds.

- **Mechanistic Research** seeks to answer why patterns in nature occur, focusing on identifying underlying biological or ecological processes driving patterns that we see in nature. An example might be a study to determine the relationship between coyote abundance and snowshoe hare survival to understand how predation pressure influences their population and recruitment.

Surveys, monitoring and research are interrelated tools essential for understanding and managing ecological systems. Each plays a distinct yet complementary role in collecting and interpreting ecological data. Surveys are the primary method for gathering measurement data at specific locations and times, often used to detect the presence or absence of individual species or species groups and help define species distributions and range limits.

Monitoring builds on surveys by structuring data collection in a consistent, standardized and repeatable way across time and space. This structured approach enables the detection of trends in abundance, occupancy, species richness and habitat conditions. A critical component of monitoring and survey efforts is accounting for species detectability, which improves the accuracy of ecological assessments and trend estimates.

Research addresses specific scientific questions or objectives, often through hypothesis testing or predictive modeling, and may use data from surveys and monitoring when aligned with its objectives. Research can take various forms including observational, applied, experimental or mechanistic with each distinguished by the level of intervention and the nature of the questions asked. Together, these tools provide baseline data, reveal ecological trends and deepen system understanding to inform conservation and resource management.

Minnesota supports a wide range of terrestrial and aquatic ecosystems, which in turn provide habitat for diverse native plants and animals. These ecosystems deliver critical services, including water filtration, flood protection, carbon storage, timber production and recreational opportunities. However, they are increasingly threatened by direct and indirect stressors such as land and water use pressures, pollution, invasive species, pathogens and changes in climate and land management.

In response to these challenges, surveys, monitoring and research form the scientific foundation for biodiversity conservation and natural resource stewardship in Minnesota. Rigorous scientific approaches are critical for guiding conservation strategies, informing adaptive management, supporting technical assessments and conducting environmental reviews. Later sections of this chapter provide guidance on utilizing existing ecological data and outline recommendations for future data collection efforts.

## Baseline Information Needs

The SWAP provides a framework to guide conservation efforts, emphasizing the need for data-driven decisions to protect declining and vulnerable species. The DNR has set clear goals to sustain biodiversity, identify conservation challenges and support species viability and recovery now and for future generations of Minnesotans. By systematically tracking the distribution and abundance of wildlife, particularly species with low and declining populations, the DNR can develop targeted strategies to mitigate threats to species, populations and habitats.

In order to have a starting point for assessing species and habitat status in Minnesota, we

need baseline diagnostic information about presence/absence, spatial distribution, relative abundance and population trends. The process of assigning whether a species should be considered a Species in Greatest Conservation Need (SGCN) starts with understanding the rarity, trends and threats of an animal or plant (see Chapter 2: Species in Greatest Conservation Need). It is not enough to have survey information at one location and time because species and habitats are dynamic and their status is influenced by a multitude of factors, which can be positive or negative.

## Species

For the SWAP to be successful, a strong foundation of baseline information is essential. This includes comprehensive surveys to estimate the distributions of animal and plant species across Minnesota's diverse landscapes, and monitoring efforts designed to detect trends in species occurrence, abundance or relative abundance over time.

## Habitats

Equally critical is the collection of habitat-use data for SGCN, especially given Minnesota's ecological diversity, which spans multiple biomes and supports a wide range of species and community types. Understanding how, when and where species interact with their habitats is inherently challenging, even for common species with relatively abundant data. For rare species, these challenges are magnified due to limited detections, sparse distribution and often cryptic behaviors, making it difficult to draw reliable conclusions about habitat associations and requirements.

Nevertheless, this understanding is vital for identifying the environmental conditions necessary for the survival, reproduction and persistence of SGCN. Moreover, a focus on SGCN can yield broader conservation benefits, as their habitat needs often overlap with those of other vulnerable, under-studied and even common species, thereby supporting more inclusive, ecosystem-based conservation strategies.

*Photo: DNR biologist holding softshell turtles with transmitters that track movements and habitat use*

## Life History and Population Traits

These patterns of habitat use are closely linked to species-specific life history traits, such as reproductive strategies, dispersal capacities and habitat specialization. Such traits determine how resilient populations are to natural events (e.g., drought, fire regimes) and anthropogenic pressures (e.g., habitat fragmentation, pollution). This information helps predict population trajectories, assess extinction risks and develop science-based conservation strategies.

Additionally, data on population demographic status including survival rates, dispersal, migration and population viability are needed to assess the health and resilience of populations.

## Stressors and Actions

Coupled with detailed knowledge of stressors facing SGCN and many other species, along with management actions available to mitigate those stressors, this comprehensive baseline data enables the DNR and its partners to identify vulnerable life stages, critical habitats and priority areas for conservation, protection, or restoration.

## Surveillance Monitoring

Incorporating robust monitoring into Minnesota's SWAP is critical for sustaining wildlife and plant populations, preserving biodiversity and conserving the habitats that serve as homes for terrestrial and aquatic taxa. Surveillance monitoring establishes baseline conditions and can detect long-term trends, while effectiveness monitoring evaluates the value of conservation actions. Together, they provide the information needed to sustain biodiversity, manage habitats effectively and respond to emerging conservation challenges. In Minnesota, these monitoring approaches support the SWAP by ensuring that conservation efforts are grounded in scientific evidence and tailored to the evolving needs of wildlife and their habitats.

Surveillance monitoring focuses on understanding species, population and habitat distributions and tracking trends in various metrics through time. It provides a long-term view of ecosystem health by detecting changes in species abundance, distribution and community composition. This type of monitoring can be used to establish actionable thresholds and triggers, signaling potential ecological problems before they become critical or conditions for targeted management prescriptions (Nichols & Williams, 2006; Lindenmayer & Likens, 2010). For example, sustained declines in a SGCN could indicate habitat degradation, climate change effects or emerging threats such as disease. Surveillance monitoring also provides valuable data on habitat trends, helping natural resource managers anticipate shifts in wildlife distributions and potential barriers to conservation efforts. However, while it is useful for identifying patterns and broad-scale concerns, it does not pinpoint causal mechanisms behind observed changes in trends. In the context of trend estimation, additional limitations may include the absence of long-term, standardized data collection methods, making it crucial to establish strong roots with defensible sampling design principles incorporating sampling unit independence, replication, and stratification among diverse biomes and habitats.

### Species-level Monitoring

Surveillance monitoring may occur at the species-level across a variety of terrestrial and aquatic animal and plant taxa, ranging from common species to those that are declining, rare, or in need of further research (i.e., SNI - Species Needing Information). Of particular importance to the SWAP are SGCN, which are native animals and plants whose populations are rare, declining or at risk of decline. Also of primary focus are stewardship species, which have a stable population in Minnesota but are declining within the region. The DNR also recognizes the ecological importance of keystone species and ecosystem engineers — organisms whose roles in structuring habitats and ecosystem function make them critical for enhancing biodiversity. It is not possible for the DNR to track population status and trends of all species of animals and plants in Minnesota, so over the next 10-year cycle of the SWAP, the DNR and partners will be exploring alternative prioritization strategies for survey and monitoring efforts. Solutions may incorporate:

- Use of structured decision-making tools to guide the prioritization process (Figure 5.1)
- Stratification of species and habitats according to their conservation status (for example, as recently assessed in the s-rank process see Chapter 2: Species).
- Incorporating data emerging from parallel efforts, such as aquatic community data from the Minnesota Pollution Control Agency or participatory science programs such as the nationally known eBird (see Case Study on Participatory Science).
- Use of focal monitoring sites to sample a subset of habitat locations for a variety of animals through time, such as the Ecological Monitoring Network (see Case Study on Ecological Monitoring Network).

- Development and testing of species distribution models (Yackulic et al., 2012; Hefley & Hooten, 2016) to efficiently target potential habitat for threatened, endangered and species defined as SGCN.
- Adoption and transition from finer-scale relative abundance surveys to broader-scale occupancy designs (Mackenzie et al., 2006) to make more efficient use of limited agency resources.
- Landscape stratification with revolving spatial and temporal panels organized through time to rotate sampling and resampling efforts across all regions of Minnesota.
- Direct participatory science volunteers to monitor readily identifiable species to maximize information gain and geographic coverage given limited agency resources. It can be applied efficiently to gather broad distributional information or for targeted rare-species surveys.

Resources for conservation are chronically limited, and delays in action can push species and ecosystems toward irreversible decline. While there is debate about return-on-investment (ROI) frameworks which prioritize actions with the greatest benefit per cost (Joseph et al., 2009; Carwardine et al., 2012; Vucetich et al., 2017), there is a very strong argument made for proactive conservation (Walls 2018). This idea emphasizes conservation efforts for species and habitats before critical thresholds are met, thereby reducing extinction (or extirpation) risk and high restoration costs. Going further, Walls (2018) suggests taking actions that leverage and utilize stakeholder collaboration like participatory science initiatives and complementing time- and labor-intensive methods for long-term monitoring with alternative methodological approaches for detecting species population declines and estimating extinction risk. Although there is a large body of peer-reviewed literature on using formal decision theory and ROI approaches — often called “conservation triage” — to prioritize conservation efforts, we still need to improve existing methods and explore new strategies to make the most of limited resources.

Participatory science, community science or citizen science, refers to programs that engage members of the public in data collection and research activities — often in collaboration with or under the guidance of professional scientists. In the field of ecology, participatory science programs have become increasingly valuable for monitoring biodiversity, tracking species distributions, assessing ecosystem health and providing outreach opportunities for various user groups. These programs harness the power of widespread public engagement to gather large quantities of ecological data across broad spatial and temporal scales that would be otherwise difficult or prohibitively expensive for agencies to collect alone. DNR sponsored examples include MN PlantWatch, the Minnesota Loon Monitoring Program, the Frog and Toad Calling Survey and the Chimney Swift Survey. In addition to generating scientifically useful data, participatory science fosters environmental stewardship, increases scientific literacy and strengthens community involvement in conservation efforts. When well-designed, these programs include standardized protocols, training for participants and rigorous data validation methods, ensuring that the resulting data can inform ecological research and natural resource management decisions.

## Case Study: Ecological Monitoring Network

The DNR established the Ecological Monitoring Network (EMN) in 2017, with 544 sites across Minnesota, to track ecological change through time. The EMN provides data on the status of SGCN habitats and how those habitats are changing. This effort is being led by the Minnesota Biological Survey, in collaboration with other partners and funded by the Minnesota Environment and Natural Resources Trust Fund (ENTRF). Before EMN, there was no comprehensive statewide monitoring network to consistently measure and evaluate status and trends in native grassland, wetland, and forest habitats. This information is needed for natural resource professionals, ecologists, and policy makers to make informed land management, land use, and conservation decisions for the benefit of plant and animal SGCNs.

The EMN employs a nested plot design to sample all major habitat types across Minnesota, ensuring a statewide distribution that is independent of habitat quality or land ownership. Data collection focuses on ground layer vegetation and trees, alongside assessments of ecological factors such as deer browse, earthworms, water chemistry, prairie structure, and coarse woody debris. By 2023, 387 plots were established, including 45% in upland forests, 23% in open wetlands, 15% in forested wetlands, 12% in upland prairies and 5% in wetland prairies. Eighty-nine percent of plots are located on government owned land (20% Federal, 42% State and 17% local governments). Early findings have provided valuable insights into plant community variation across the state (see Ecological Monitoring Network, Minnesota DNR). A few notable findings are native plant communities in northern latitudes appear to be generally higher quality than their southern counterparts. Low quality (D-ranked) prairies are more abundant than high quality (A-ranked) prairies. Wet meadows are typically either high or low quality with very few examples in the middle. Acid peatlands are almost always A-ranked. This is likely due to the sensitivity of these systems, as any disturbance likely increases pH causing the system to rapidly transition toward a wet meadow, fen or marsh-like community.

The EMN will begin its first resampling cycle in 2028 to assess how SGCN habitats have changed over the past decade. It has been noted also that this framework could be expanded to include the monitoring of animals, bringing an ecological understanding of plants and animals together.

*Photo: Vegetation plot sampling, Ecological Monitoring Network*

Regardless of the approach chosen, monitoring SGCN and SNI species provides baseline data to detect population changes through time, identifying organisms that require conservation attention or those that may become SGCN in the future. This process can inform near-term conservation priorities and guide targeted management actions. The DNR and its partners are actively engaged in current and planned efforts focused on species-level surveillance in Minnesota including:

- Minnesota Frog and Toad Calling Survey (DNR)
- North American Breeding Bird Survey (U.S. Geological Survey)
- HerpMapper (a variety of biologists, University personnel, and NGOs)
- Minnesota National Forest Breeding Bird Monitoring Program (University of Minnesota Duluth Natural Resources Research Institute)
- Minnesota Statewide Mussel Survey (DNR)
- American Goshawk Nest Monitoring (DNR)
- Spongy Moth Survey (Minnesota Department of Agriculture)
- Blanding's Turtle Population Monitoring (DNR)
- Timber Rattlesnake Population Assessment (DNR)
- Common Tern Nest Monitoring (DNR)
- Wood Turtle Population Monitoring (DNR)
- Early Detection and Distribution Mapping System (EDDMapS; Center for Invasive Species and Ecosystem Health, University of Georgia)
- Dakota Skipper Monitoring (DNR)
- Bat Acoustic Monitoring (DNR, USFS and USFWS)
- Monarch Larva Monitoring Project (Monarch Joint Venture, University of Wisconsin-Madison Arboretum)
- Journey North (University of Wisconsin-Madison Arboretum)
- Integrated Monarch Monitoring Program (Monarch Joint Venture)
- Minnesota Loon Monitoring Program (DNR)
- Volunteer LoonWatcher Survey (DNR)
- MN PlantWatch (DNR; see Case Study: Minnesota PlantWatch Population Assessments in Plants Sub-chapter of Chapter 2: Species in Greatest Conservation Need))
- Federally Listed Plant Species Monitoring (DNR; see Case Study: Federally Listed Plant Monitoring in Plants Sub-chapter of Chapter 2: Species in Greatest Conservation Need)
- Minnesota Bumble Bee Atlas (University of Minnesota, Xerces Society, DNR)
- Minnesota Colonial Waterbird Survey (DNR and NRRI)
- Minnesota Breeding Trumpeter Swan Survey (DNR)
- Minnesota Waterfowl Breeding Population Survey (DNR and USFWS)
- Minnesota Amphibian & Reptile Survey (HerpMapper.org, Bell Museum of Natural History, and Minnesota Herpetological Society)
- Minnesota Cricket Frog Survey (DNR)
- Terrestrial Invasive Species Participatory Science (TIPS) projects (University of Minnesota Extension)

## Case Study: Federally Listed Plant Species Monitoring Program

*Photo: Researcher Dr. Joel Olfelt monitoring Leedy's roseroot, Derek Anderson*

The DNR has been monitoring federally listed plant species since the mid-1980s. The level and intensity of monitoring has varied for each species including the western prairie fringed orchid (*Platanthera praeclara*), prairie bush clover (*Lespedeza leptostachya*), Dwarf Trout Lily (*Erythronium propullans*) and Leedy's Roseroot (*Rhodiola integrifolia subsp. Leedyi*) and is dependent on their life history and informational needs. Basic monitoring has been done at two levels that has consisted of updating the Natural Heritage Information System (NHIS) database with more accurate locational information using GPS technology and a census count of the individuals found at a given location each year. This information has been critical in guiding conservation actions of the species, be it habitat management or environmental review projects.

Demographic monitoring has been directed toward the western prairie fringed orchid and prairie bush clover. This monitoring is more substantiative and involves returning to marked plots on the landscape and tracking individual plants from year to year as well as any new recruits that establish within the transect.

In the case of western prairie fringed orchids, we have pursued an even more intensive phenological monitoring protocol. Under this monitoring, individuals are marked multiple times within the same year to document their emergence, growth, capsule development and seed dehiscence. This combination of nested monitoring has led to the publication of several peer-reviewed papers (Biederman et al., 2018) as well as habitat management guidelines that assist land managers in making decisions that further enhance the conservation of these species.

The western prairie fringed orchid is found throughout the prairie region of Minnesota. Despite this wide geographic distribution, the DNR revisits and completes a flowering census of approximately 80% of the state's populations each season. This effort is only possible because of a collaborative effort between the DNR, The Nature Conservancy, The U.S. Fish and Wildlife Service and the National Park Service. This collaborative partnership also means that information about the species life history and management needs are shared across the entities responsible for the conservation of this rare prairie orchid.

## Habitat and Community Monitoring

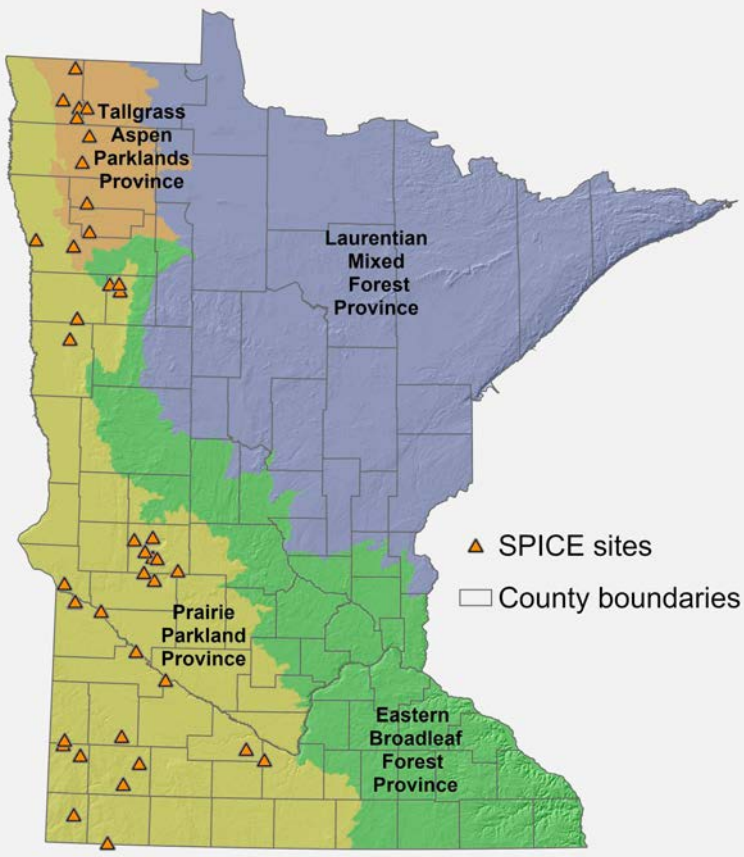
In addition to species-level surveillance monitoring, the DNR and its partners are actively engaged in ongoing and planned efforts focused on habitats in Minnesota. Habitats consist of the natural environment in which a species lives, grows and reproduces and provides essential resources like food, shelter and breeding sites. It includes all the biotic (living) and abiotic (non-living) factors that influence a species' survival, such as soil type, climate, vegetation and water availability. These factors come together to support the ecological niche for each species, which range from general to very specific. Collections of interacting species that live in the same habitat at the same time are considered ecological communities (e.g., calcareous fens and vernal pools). Not only is it important to understand status and trends of species and their habitats, but also the dynamics of how species interact as communities within habitats through processes such as predation, competition, parasitism and mutualism. The form and structuring of these kinds of interactions vary in spatial scale and shape the broader structure of ecosystems. The exact composition and diversity of a community depends on many factors such as landscape geography, resource availability, disturbance, species interactions and climate. Examples of habitat-level surveillance monitoring efforts in Minnesota led by the DNR and its partners include:

- Prairie Status and Trend Monitoring Project (SPICE: Sustaining Prairies in a Changing Environment) (DNR; see Case Study)
- Ecological Monitoring Network (DNR; see Case Study)
- Forest Health Index (DNR)
- Wetland Status and Trend Monitoring Program (DNR)
- Minnesota Wetland Hydrology Network (WHyN; DNR))
- Stream Index of Biological Integrity (IBI) Monitoring Program (MNPCA)
- Lake IBI Monitoring Program (DNR)
- Minnesota Native Plant Community monitoring by relevé sampling (DNR)
- High Conservation Value Forest Monitoring (DNR)
- Watershed Health Assessment Framework (DNR)
- Prairie Reconstruction Initiative (USFWS, USGS, DNR, and TNC)

## Case Study: Prairie Status and Trend Monitoring Project

The Sustaining Prairies in a Changing Environment (SPICE) project, led by the Minnesota Department of Natural Resources (DNR), monitors grassland structure, management, plants, birds and pollinators across 40 high-quality prairies in western Minnesota (Figure 5.6). SPICE began after the 2005 State Wildlife Action Plan identified that the highest percentage of Species in Greatest Conservation Need utilized grassland habitats, but little was known about the trends of prairie plant community condition and associated prairie SGCN populations. In 2008, SPICE was designed to evaluate long-term plant and bird community and species trends in context of two primary stressors influencing our remaining native prairies: climate change and landscape fragmentation. A pilot pollinator monitoring effort was added in 2021 and is still being tested and refined.

To address climate change, 40 sites were stratified into five geographic zones spanning a north to south latitudinal gradient across the prairie ecological provinces in western Minnesota – the Tallgrass Aspen Parklands and the Prairie Parklands (Fig. 1). To address fragmentation, sites were selected to meet the following two categories: 1) "Large-embedded" sites are greater than 20 hectares (50 acres) in size having more than 50 percent grassland within 1 km of the site boundary, and 2) "Small-isolated" sites are less than 12 hectares (30 acres) in size having less than 20% grassland within a 1 km buffer.




SPICE also partners with the Grassland Monitoring Team (GMT) – a collaborative comprised of The Nature Conservancy (TNC), the U.S. Fish and Wildlife Service (USFWS), South Dakota Dept. of Natural Resources, and the DNR divisions of Parks and Trails, Fish and Wildlife and Ecological Resources to practice adaptive management utilizing standardized vegetation monitoring protocol data and management information to inform a state-transition model that provides future management recommendations (Grassland Monitoring Team). In addition to the annual GMT management recommendations, the stratified climate and landscape design from SPICE, large span of monitoring years, and significant GMT partner involvement across many sites has informed the adaptive management process and vegetation response to management (Alhering, 2020), invasive plant species response to climate variables (Ratcliffe, 2022; Ratcliffe, 2024), and trends in bird occupancy and abundance (in prep., see Fig. 2.4). SPICE exemplifies the importance of long-term, multi-objective and multi-partner monitoring efforts to guide effective conservation.

Figure 5.1. Distribution of 40 monitoring sites of high-quality remnant prairie scattered across western Minnesota that make up the Sustaining Prairies in a Changing Environment (SPICE) project led by the DNR. See the Ecological Classification System (ECS) for province descriptions.

## Conservation Effectiveness

To evaluate whether conservation efforts are achieving their goals, effectiveness monitoring serves as a critical tool. It is a form of applied or experimental research, focused on evaluating the effect of targeted conservation actions on ecosystem attributes. This type of monitoring is essential for determining the effectiveness of management interventions such as habitat restoration, invasive species control or policy implementation, in producing desired ecological responses. Grounded in the principles of adaptive management, effectiveness monitoring enables agencies to test specific management hypotheses or learning objectives, which can then be refined based on real-world data. By systematically measuring the success of interventions, it helps identify which actions are yielding positive results and which need modification to improve outcomes for species and habitats. For example, if a restoration project intended to improve nesting success for a bird species fails to meet its objectives, effectiveness monitoring can guide refinements, such as altering vegetation structure or implementing predator control. Ultimately, this approach allows natural resource managers to respond adaptively to dynamic conditions, including climate change and human-induced habitat changes, ensuring that conservation strategies remain effective and evidence-based.

Structured decision making (SDM), from the field of decision analysis, intends to decompose natural resource problems into a structured sequence, while accounting for underlying values of all stakeholders (Runge & Bean, 2020). A common form utilizes the PrOACT cycle to lay out the decision framework, which structures the issue into problem framing, objectives, alternative actions, consequences and evaluation of trade-offs among alternatives that will lead to choosing a preferred alternative action (Figure 5.2).

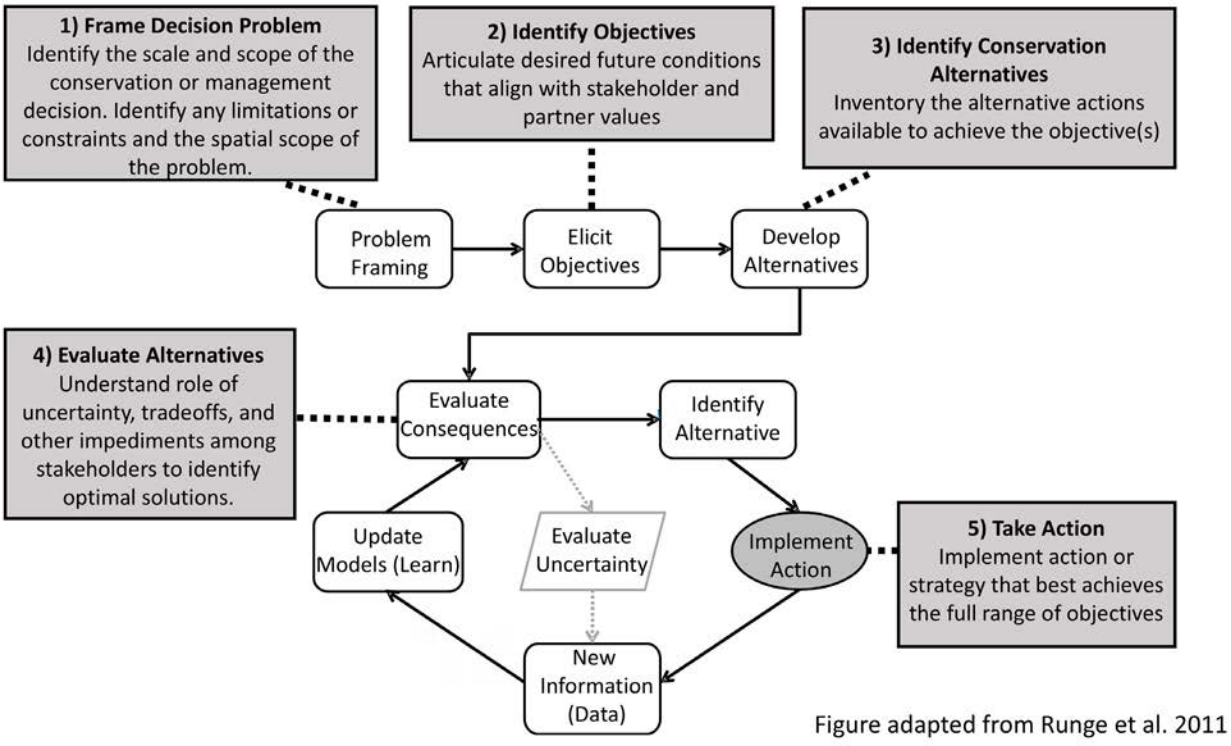



Figure 5.2. Diagram of the standard iterative steps involved with structured decision making, of which adaptive management is a sub-discipline. The figure presents a generalized form of the PrOACT cycle: Problem, Objectives, Alternatives, Consequences and Tradeoffs.

Adaptive management is a sub-discipline of structured decision making that offers a science-based, iterative approach to decision-making under uncertainty. It emphasizes the use of multiple working hypotheses, coupled with the collection of new data, to update the likelihood of outcomes predicted by those hypotheses (Williams, 2011a). Through repeated cycles of data collection and analysis, the approach seeks to identify the model, represented in each hypothesis, that best describes system dynamics (Figure 5.3).

The process, like structured decision making, involves two fluid and iterative stages: a deliberative phase and an iterative phase. In the deliberative phase, stakeholders collaboratively frame the problem, articulate objectives, identify potential management actions, predict the consequences of those actions, and design appropriate standardized monitoring protocols (Williams & Brown, 2014). In the iterative phase, monitoring data are collected and used to evaluate management effectiveness and inform the relative support for competing hypotheses. This process of confronting hypotheses with data enables technical learning about ecological systems.

Importantly, adaptive management also facilitates institutional or "double-loop" learning, wherein stakeholders can revisit and revise objectives, actions, or assumptions based on new insights (Argyris & Schön, 1978). Adaptive management can be conducted in either an active or passive form. Active adaptive management emphasizes learning about system dynamics as a primary goal, while passive adaptive management focuses on achieving specific management objectives, with learning considered a secondary benefit (Williams, 2011b). Regardless of the form, effective monitoring and iterative data collection compared against working hypotheses of system dynamics are central to the adaptive management cycle, allowing project refinement and evolving understanding.

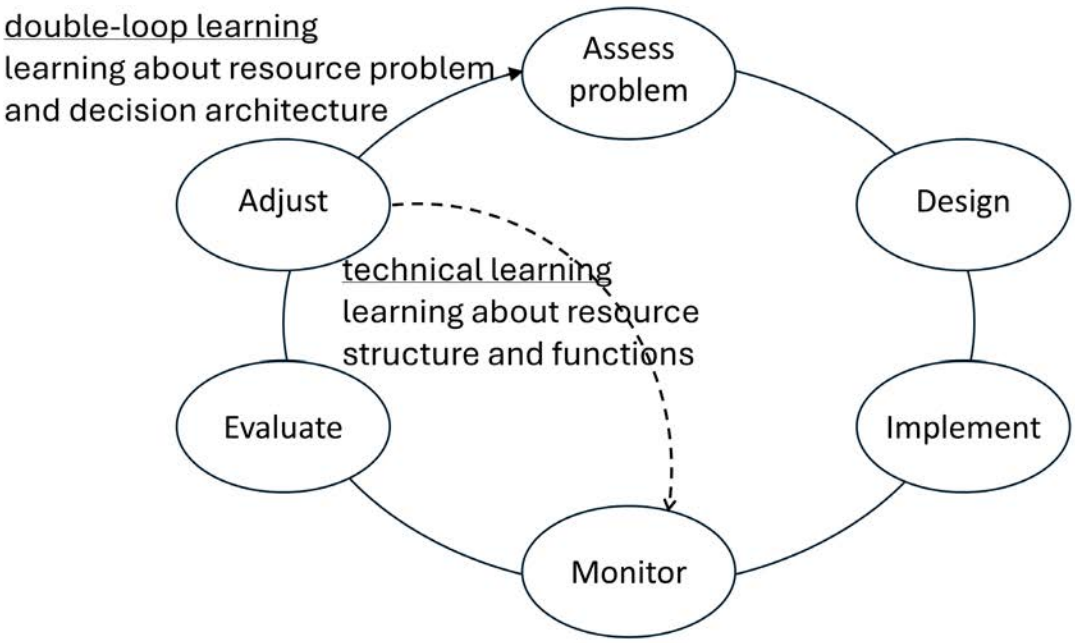



Figure 5.3. Diagram of the standard iterative steps involved with adaptive management, a sub-discipline of structured decision making. The figure presents the generalized form along with opportunities for technical and institutional learning, adapted from (Williams & Brown, 2014).

A prime example of adaptive management in action is the Grassland Monitoring Team (GMT; Grassland Monitoring Team), a collaboration among the DNR, the U.S. Fish & Wildlife Service and The Nature Conservancy. Formed in 2007, the GMT aims to improve management of native prairies in Minnesota using standardized monitoring protocols embedded within an adaptive management framework and represents a model for collaborative, evidence-based conservation across the state.

The DNR and its partners are actively engaged in current and planned efforts focused on conservation effectiveness monitoring designed with adaptive management in mind including:

- Response of American goshawks to timber management (DNR)
- Response of wood turtles to nest protection and nest site restoration (DNR)
- Response of four-toed salamanders (*Hemidactylium scutatum*) to forest management (DNR; See Case Study: Four-toed Salamanders and Forest Management in Vernal Pools Sub-chapter of Chapter 2)
- Evaluating techniques for controlling Smooth Brome in native Prairie (DNR)
- Response of red-shouldered hawks to timber management (DNR)
- Evaluation of management alternatives on bluff prairie habitat (TNC)
- Targeted control of the non-native invasive common reed (*Phragmites australis subsp. australis*) (DNR)
- Patch-burn grazing projects at Chippewa Prairie & Hole in Mountain Wildlife Management Area (DNR)
- Prairie reconstructions in the Prairie Coteau Conservation Opportunity Area and monitoring of birds, butterflies, and bumble bees (DNR)
- Conservation grazing at Hole-in-Mountain Wildlife Management Area (DNR, The Nature Conservancy, Sustainable Farming Association, private cattle producer; See Case Study on Conservation Grazing)
- Prairie reconstruction supplementation with early season forbs for pollinator communities (DNR)
- Bat artificial roost project (DNR; see Guide to Artificial Roosts for Bats)

## Estimating Effects from Stressors

Gaining a better understanding of conservation stressors and their effects on species, habitats and communities across Minnesota is an important topic for the next 10-year cycle of the SWAP. When updating our SGCN list by following the NatureServe species conservation status assessment (S-rank process; see Chapter 2: Species in Greatest Conservation Need), we found that the threats assessment component was the most challenging (Salafsky et al., 2008; Master et al., 2012; Keith et al., 2013; IUCN, 2023). Note that we have used the term "stressor" more in this Plan but that we use "threat" here to reference the NatureServe process. The conservation assessment process scores threats according to scope and severity, both measured on an ordinal scale. Scope measures how widespread a threat is in space, while severity describes how damaging a threat is to the affected portion of the population. Geographic Information System (GIS) layers representing area of species occupancy (via distribution maps, known occurrences, and modelled habitat) intersected with spatial information about where in space a given threat occurs can be used to represent scope, but such information is limited and future trends difficult to predict requiring more investment for accurate spatial representation of threats. Severity relates to how much a SGCN population is expected to decrease over some time frame (e.g., 10 years) as a result of exposure to a particular level of a specific threat. Data to inform these estimates are

very hard to find and estimates by experts and ecological analogs (effect data from similar species in similar systems) are integrated into the assessment. We emphasize the need to better understand the interactions between threats and species effects in the next 10-year SWAP cycle, not only to improve conservation status assessments, but also to help identify actions that will have the greatest impact. The area of need described here falls under the umbrella of experimental or mechanistic research, which requires well-designed studies around clear and focused questions.

## Case Study: Conservation Grazing at Hole-in-the-Mountain Prairie

In 2018, the DNR in partnership with The Nature Conservancy, U.S. Fish and Wildlife Service, The Sustainable Farming Association and a local producer launched a long-term monitoring project on a 566-acre parcel of remnant prairie at the Hole-in-the-Mountain Wildlife Management Area (WMA) to study how vegetation structure and species composition respond to a patch-burn cattle grazing approach. The project was expanded in 2021 to include evaluating a response to adaptive management grazing. The objective was to evaluate whether innovative grazing techniques can increase structural heterogeneity and species diversity in a prairie invaded by smooth brome, an invasive grass. A central aim is to improve wildlife habitat through cooperation with a local cattle operation. This project can help enhance habitat on private working lands, which is critical for slowing or reversing wildlife population declines in prairie region ecosystems. Vegetation data show that grazing is increasing overall plant species richness of both native and non-native species.

Because prairie ecosystems include more than plants, this project has evolved into an interdisciplinary monitoring approach. The DNR Nongame Wildlife Program and Minnesota Biological Survey are also monitoring responses of grassland-obligate birds, bumble bees and butterflies including several Species in Greatest Conservation Need (SGCN). Most SGCN birds show no negative effects from grazing, except bobolinks, which appear sensitive to the shorter grass structure. Some species, like the western meadowlark, are declining at both the treatment and nearby control sites —mirroring broader regional trends and suggesting no evidence of a positive grazing effect. The DNR initiated monitoring for bumble bees and butterflies in 2023.

We anticipate future data will offer clearer insights into how prairie specialist SGCN respond to these grazing techniques. Past low management grazing and subsequent lack of disturbance at the site led to smooth brome invasion and altered soil conditions, which will take time to address. This project underscores the importance of managing for resilience amid increasing variability in precipitation. Diversity and connectivity across space and time is the foundation of that resilience, and these grazing techniques may offer a viable and economically sound approach to restore prairie ecosystems.

*Photo: Hole-in-the-Mountain prairie, Lisa Gelvin-Innvaer*

## Best Practices for Survey, Monitoring, and Research Design

Resource management agencies, such as the DNR, work with two categories of ecological data: (1) data already collected and (2) data to be collected in the future. In this section we address best practices for utilizing and applying existing datasets to future conservation applications as well as how new data collection can be strategically designed to address emerging management needs and fill knowledge gaps.

Existing ecological data from past surveys, monitoring programs, and research efforts can provide critical insights for conservation planning and adaptive management. Such data have been shown to inform targeted habitat protection and protected area designation (Guisan et al., 2013; Bennett et al., 2018), support cross-scale data integration for invasive species management (Xie et al., 2022), enable integrated models for abundance, survival, and occupancy estimation (Sun et al., 2019; Doser et al., 2022) and help redefine key biodiversity metrics such as extent of occurrence, area of occupancy, and population trends (Bosso et al., 2024; Gallagher et al., 2025). In Minnesota, existing datasets have played pivotal roles in conservation decisions. For instance, when bat populations across North America began suffering from white-nose syndrome, a deadly fungal pathogen, DNR's survey and monitoring data were instrumental in informing the U.S. Fish & Wildlife Service during its deliberations to federally list several bat species.

The DNR relies heavily on living data repositories such as the Minnesota Natural Heritage Information System (NHIS), which is continuously updated and standardized as new information becomes available. NHIS is the state's most comprehensive source on rare plants, animals, native plant communities, and other significant natural features. It provides rapid, authoritative insights to guide conservation priorities and project reviews. Complementing NHIS, the Minnesota Conservation Explorer makes Natural Heritage Data more accessible by allowing authorized users to explore natural resource data, generate maps for conservation planning, and request Natural Heritage Reviews to evaluate potential project impacts on rare species and sensitive resources.

NHIS data directly inform conservation action. NHIS records help determine whether a protected species is likely to occur in a proposed project area and, if a take permit is requested, assess the potential statewide significance of that impact. They also guide proactive conservation strategies such as land protection, habitat management for threatened and endangered species, and species translocation to suitable habitats. For example, when development projects affect waterways, NHIS data are used to evaluate whether aquatic mussels should be relocated out of harm's way.

In the sections that follow, we present two complementary areas of focus. The first addresses best practices for handling, managing, and curating existing ecological data, recognizing both the value and limitations of previously collected information. The second outlines key design elements and statistical considerations for the collection of new ecological data, emphasizing actions and strategies that enhance data quality, comparability, and long-term utility for conservation decision-making. The principles to be applied retrospectively for existing data are also important to consider ahead of time prior to collecting new ecological data.

## Principles for Effective Use of Existing Data

Survey, monitoring, and research efforts are only as useful as the quality, accessibility, and interpretability of the data collected. Well-managed data ensure that years of field effort yield lasting value, providing information that remains usable for decision-making and future analyses (Michener & Jones, 2012). With intentional and consistent data management practices, datasets can be preserved in complete, well-documented, and accessible forms, maximizing their long-term impact and utility (Binley et al., 2024). Recognizing data as a core scientific product — rather than a secondary byproduct of fieldwork — ensures that the DNR will deliver long-term value for both ecological research and applied conservation.

Comprehensive metadata is the backbone of reusable and interpretable datasets. Regardless of whether efforts were aimed at surveys, monitoring, or research, at a minimum, metadata should answer the basic questions of why, who, what, where, when, and how (Michener, 2006). For ecological data, this extends beyond objectives and methods to include observer training levels, equipment calibration, and known limitations of inference. Existing datasets must also account for potential sources of bias such as nonrandom sampling, preferential selection of higher-quality habitats, observer differences, or uneven survey effort across space and time. Such biases can limit the generalizability of results and constrain how data can be applied to broader conservation questions. Accordingly, datasets should be explicitly evaluated for representativeness, and any spatial, temporal, or methodological biases clearly documented to guide appropriate use and interpretation.

Metadata should adhere to clear or accepted standards, such as the Ecological Metadata Language (EML), and be stored alongside the data to facilitate long-term reuse (Fegraus et al., 2005). Historical or opportunistic datasets often lack this level of documentation, yet they may still be valuable if limitations are clearly articulated. When documentation is lacking, institutional knowledge becomes vital. Interviews with long-serving staff members can help fill in gaps, recover lost metadata and provide critical context.

Clear assignment of roles and responsibilities is essential for successful ecological data management. Effective projects designate not only data collectors, but also managers, curators, and end users who each play a part in ensuring data quality and accessibility (Reichman et al., 2011). Field staff and observers are responsible for accurate collection and recording, data managers and curators ensure standardization and documentation, and analysts and decision-makers interpret outputs in the context of conservation objectives. Establishing expectations for each of these roles fosters accountability and minimizes errors, ensuring data integrity throughout the project lifecycle.

Evaluating past datasets and developing future datasets in the context of robust quality control protocols helps to identify their strengths and weaknesses vital to ensuring subsequent application is accurate and reliable. Workflows should include error detection and correction steps such as cross-checking field entries, applying range checks, and using automated validation routines. For example, range rules can flag impossible values (e.g., out-of-range coordinates, dates, or biologically implausible measurements), while duplicate checks can identify repeated records (Yenni et al., 2019). Validation processes not only increase confidence in the data but also reduce the risk of propagating errors into downstream analyses or management decisions.

Survey, monitoring, and research activities generate diverse forms of data, ranging from tabular counts and environmental covariates to photographs, audio recordings, video, and geospatial (GIS) files. Each data type requires tailored management strategies. For example, image and acoustic data need metadata

describing collection equipment, settings, and conditions; geospatial datasets require attention to coordinate systems and accuracy; and tabular data require standardized variable names and units (Kelling et al., 2009). Treating each data type according to best practices ensures that datasets remain interpretable and integrable into broader ecological analyses. To the extent possible, standardization and integration ensure that data from different sources can be aligned to a common format, taxonomy, measurement unit, and coordinate system. Combining related datasets — for example, surveys for Dakota skippers (*Hesperia dacotae*) from different years and parts of Minnesota — can greatly enhance analytical utility.

Durable archiving is essential for survey and monitoring datasets that may be needed years or decades into the future. Data should not be stored only on local computers, where the risk of loss is high, but instead deposited in secure repositories with established backup systems and long-term curation support (Costello et al., 2013). This applies not only to large, high-profile monitoring programs but also to smaller-scale or project-specific datasets, which often contain valuable, fine-grained information that can be critical for future analyses, baseline comparisons, or integration with broader datasets. Such localized or narrowly focused data are particularly vulnerable to being overlooked or lost if not intentionally archived. For Minnesota, durable storage solutions include centralized systems such as the NHIS, which provides ongoing curation and accessibility for a wide range of biodiversity data.

Data management should be explicitly tied to the anticipated uses of survey and monitoring datasets, such as population trend analysis, habitat prioritization, or conservation planning. Designing management protocols with these goals in mind ensures that data remain fit for purpose and compatible with future datasets (Lindenmayer & Likens, 2010). Integration across time is especially important and projects should establish mechanisms to link existing data with new collections, facilitating long-term analyses that are critical for detecting ecological change. This forward-looking approach enhances the utility of monitoring programs and ensures that ecological data continue to inform conservation and management well beyond the life of the original project.

Modern integrated analyses increasingly rely on combining multiple datasets collected across different times, places, and projects to address shared ecological questions (Pacifici et al., 2017; Zipkin et al., 2021). While such integration can greatly enhance the scope and power of long-term monitoring, it requires careful attention to whether datasets are truly compatible. Differences in survey design, sampling effort, observer training, detection methods, and spatial or temporal coverage can introduce biases if not properly accounted for. For long-term monitoring projects in particular, where subtle changes in populations or habitats are being tracked, even small methodological inconsistencies can compromise inference. Rigorous evaluation of metadata, documentation, and data quality is therefore essential before integrating disparate datasets, ensuring that combined analyses provide meaningful and defensible insights for conservation and management.

Despite its importance, ecological data management is frequently underappreciated and underfunded. Too often, budgets prioritize field collection while neglecting data curation, archiving, and accessibility (Michener & Jones, 2012). To ensure long-term value, projects must treat data as a primary deliverable — on equal footing with reports or peer-reviewed publications — rather than a secondary output. This requires allocating resources for trained personnel, infrastructure, and ongoing stewardship. By embedding data management into project planning and funding from the outset, the DNR can safeguard the integrity and future utility of their ecological datasets.

## Principles for Effective Study Design and Collection of New Data

The following sections provide an overview of key statistical and experimental design principles to consider when developing a new project aligned within the scope of the SWAP, prior to collecting data. Whether for surveys, monitoring or research, designing an ecological study requires careful consideration of the specific goals, objectives, spatial and temporal scales, methodological approaches and logistical constraints of a given project, ensuring that the data collected are both valid and informative for the question(s) at hand. The subject is explored in depth across numerous textbooks and peer-reviewed publications, reflecting the nuanced challenges of capturing and understanding ecological patterns and processes reliably. While not exhaustive, we provide citations below to excellent resources that expand upon the ideas presented here.

### Defining Objectives

The overarching goal of SWAP-related projects is to generate data that will provide useful information about ecological system states, population trends, effectiveness of conservation actions or negative effects from stressors. To reach any of these goals requires clearly defining the objectives and question(s) and articulating precisely what metrics are to be measured or tested and why. In the context of the SWAP, the study's objectives must align with broader management or conservation goals. To be effective, objectives should be specific, defining the purpose, scope and responsible parties; measurable, by including clear metrics for evaluating ecological responses; achievable, considering time, personnel and logistical constraints; relevant, in that they address current conservation needs or priorities; and timely, with explicit benchmarks and timelines to guide implementation and assessment (Doran, 1981; but see Bjerke & Renger, 2017).

*Photo: Biologist recording data in the field*

## Defining the Target Population

An essential element of a good study design is the definition of a relevant target population and a corresponding sampling frame. The target population refers to the ecological entities or areas to which inferences will be made — such as a species across its known range or specific ecosystems like Bluff prairies in the Driftless region of Minnesota. The sampling frame, in turn, is the set of all possible units (e.g., geographic locations with a species' range, or individuals within a larger animal population) that could potentially be sampled. It is crucial that the sampling frame is explicitly defined, comprehensive and accessible, as it directly determines the validity of any statistical inference. Valuable tools for defining target populations and sampling frames spatially are GIS systems such as ArcGIS and QGIS, which are used to integrate and analyze remote sensing data from Earth-observing satellites (Landsat); Moderate Resolution Imaging Spectroradiometers (MODIS); laser imaging, detection, and ranging sensors (LiDAR); and drone imagery. A poorly defined frame increases the risk of producing biased or unrepresentative results, thereby reducing their value for informing decision-making. Sound experimental design, rooted in these principles, ensures that data collected in the field are robust, reproducible and directly informative for science-based resource management.

## Probability-based Sampling

Another critical principle is to use a probability-based sampling design for collecting data in a way that supports unbiased statistical inference by selecting sampling units that represent larger populations (Thompson, 1992). Simple random sampling is the most basic approach, where every sampling unit in the study area has an equal probability of being selected. It is easy to implement, but can lead to uneven spatial coverage, sometimes resulting in clustered sampling locations with gaps in landscape representation. This is more likely to occur in ecological studies examining patterns across space.

To account for this reality, stratified random sampling improves upon the design by dividing the study area into distinct groups or strata based on characteristics like habitat type, geographic zone or elevation. Random samples are taken within each stratum helping to ensure that important groups are represented in the sample. This increases the precision of estimates, particularly when strata are distinct, but it does not guarantee that sampling units will be evenly spaced across the landscape.

Generalized Random Tessellation Stratified (GRTS) sampling goes further by combining the value of random sampling with a spatial balancing mechanism (Stevens & Olson, 2004). It is a form of probability-based sampling within the broader framework of sampling designs where each spatial unit has a known non-zero probability of being selected. It can accommodate unequal inclusion probabilities, stratification and hierarchical designs that reduce clustering of samples by spreading them evenly across the spatial scope of inference. It is particularly useful for broad-scale environmental monitoring, where consistent coverage of diverse landscapes is important. GRTS supports flexible designs including rotating panels for long-term trend detection. The spatial balance and design flexibility make this design particularly useful for ecological applications.

In some situations, randomization may not be feasible due to logistical constraints and study areas covering large geographic expanses; in these cases, systematic sampling where samples are placed at regular intervals — can be a suitable alternative. However, care must be taken to confirm that there are no hidden spatial or temporal patterns in the sampling frame that could introduce bias into the results.

## Sampling Unit Replication

Replication is another cornerstone of effective study design. Including multiple independent sampling units, such as plots or sites, allows researchers to accurately estimate variability and capture the natural heterogeneity of a target population. Replication also strengthens

the statistical power of a study, increasing confidence in detecting real patterns or treatment effects.

## Randomization

Randomization is another key design principle that strengthens the validity of field studies. By randomly assigning management treatments and controls among experimental units — such as grazed versus ungrazed plots — one can avoid confounding effects and help ensure that observed differences in outcomes are attributable to the treatment itself rather than other uncontrolled variables. This approach enhances the internal validity of a study and supports stronger causal inference. Even in basic research applications that do not warrant control plots, randomization of sampling plots among strata within the sampling frame is essential for unbiased estimation of occupancy, abundance or relative abundance.

## Statistical Power

Prior to collection of any new data, it is important to ensure that studies are designed with sufficient sample sizes and statistical power to detect biologically meaningful effects. Also, without enough replication (and beware of pseudo-replication; Hurlbert, 1984), even well-designed studies may fail to identify important patterns or changes due to high variability or low signal-to-noise ratio. Conducting pilot studies or using simulations can help inform the number of samples needed to achieve acceptable power for detecting ecologically relevant effect sizes; prospective power analysis is key (Steidl et al., 1997). This planning step is particularly important when resources are limited, as it helps prioritize efforts and ensure that results will be informative for decision-making.

## Incorporating Controls

Equally important is the inclusion of controls units — areas or plots where no treatment or management action has occurred — which serve as a baseline for comparison. This is especially critical when evaluating the outcomes of conservation interventions or disturbances. Designs such as Before-After-Control-Impact (BACI) are particularly powerful in assessing the effects of management actions, as they compare changes over time at both treatment and control sites, helping to isolate the true impact of the intervention from natural background variability (Green, 1979).

## Temporal and Spatial Designs

A thoughtful temporal and spatial design are also important, especially in ecological studies where environmental conditions in the field can fluctuate substantially over time and space. Incorporating repeated observations through time — whether seasonal, annual or over multiple years — allows researchers to capture trends, identify cyclical patterns and reduce the effect of short-term variability that may obscure true ecological responses. In the analysis phase, it is ideal to account for temporal autocorrelation, where observations collected closer together in time are more similar than those further apart. Ignoring this structure can lead to underestimated uncertainty and overconfidence in conclusions.

Similarly, the spatial design must be carefully planned to ensure that landscape heterogeneity is properly represented. GIS and remote sensing data are readily available to help define and stratify heterogenous landscapes. The spatial distribution of sampling locations should reflect the spatial scale at which the focal species, ecological system or key processes operate, such as home range, habitat extent or the geographic scope of ecological dynamics. For instance, heterogenous habitats require spatial sampling that captures variability within and across patches. Stratified random sampling across different habitat types, elevation zones, or land-use categories can improve inference and help ensure that results are generalized beyond the sampled sites. Moreover, spatial autocorrelation — where nearby sites tend to have more similar conditions or species assemblages than distant ones — should be considered both in study design and in

statistical modeling. Failing to do so may inflate the apparent sample size and lead to spurious findings. Together, thoughtful temporal and spatial designs are essential for robust ecological inference. They increase the reliability of estimates, improve the ability to detect meaningful changes or relationships and provide critical context for understanding the dynamics of complex natural systems.

## Animal and Plant Detections

Observations of animals and plants in nature rarely reflect true population dynamics because of detection and measurement error, which can significantly bias results if unaccounted for. Many ecological field studies face challenges with imperfect detection — failing to observe a species or event when it is present. To mitigate this, personnel should design sampling protocols that incorporate methods to estimate and correct for detection probability (Otis et al., 1978). These may include repeated surveys at the same site to estimate occupancy, distance sampling to model detectability as a function of distance from the observer, time-to-detection methods, double-observer approaches or mark-recapture techniques (Williams et al., 2002). When it is not feasible to directly estimate detection probability, models should include covariates that influence detection (such as time of day, weather, or observer experience) to control for this variability implicitly. By integrating these strategies, field studies can produce more accurate and reliable inferences about the true ecological processes that are driving observed patterns.

Emerging technologies are also transforming wildlife survey methods by offering powerful tools to augment traditional survey and monitoring approaches, helping biologists and researchers detect animals more efficiently, across broader spatial and temporal scales, and with reduced bias. Tools such as environmental DNA (eDNA), Adapted-Hunt Drift Fence Technique (AHDriFT), and automated acoustic monitoring are increasingly being adopted or

*Photo: DNR biologist conducting a broadcast survey for red-shouldered hawks, Amy Westmark*

studied for their potential to improve species detection and monitoring outcomes, particularly for elusive, rare or low-density species (Lugg et al., 2018).

Technologies like eDNA allows researchers to detect species by collecting and analyzing DNA that organisms shed into the environment (e.g., water, soil, snow). This method can be highly sensitive and is particularly useful for detecting aquatic or cryptic terrestrial species without the need for direct observation or capture (Goldberg et al., 2015; Rees et al., 2014; Davis et al., 2025). Likewise, AHDriFT combines low-profile drift fences with motion-triggered cameras to document small-bodied amphibians, reptiles and mammals, offering a passive and non-invasive approach to detecting ground-dwelling species (Martin et al., 2017;

Amber et al., 2021). Of particular utility are automated acoustic monitoring systems that use programmable audio recorders to capture vocalizations such as bird songs, frog calls or bat echolocation. These recordings can be analyzed using software or expert review and have proven useful for long-term, broad-scale surveys (Sugai et al., 2019). When used in concert with conventional methods, these technologies enhance detection probability, reduce effort and observer bias and help fill key ecological knowledge gaps needed for informed conservation decisions.

## Standardized Protocols

Establishing clear and consistent data collection protocols is fundamental to ensuring data quality and enhancing the value of field studies. Standardized protocols — especially those aligned with nationally or regionally recognized methods — promote consistency in how data is collected, making it easier to compare results across studies, contribute to broader ecological databases and support meta-analyses. Calibration of equipment, consistent training for field staff, and detailed documentation of procedures all contribute to the reliability and reproducibility of findings. When protocols are widely adopted, they also support data integration efforts that can increase statistical power and expand the scope of ecological inference.

## Estimating and Communicating Uncertainty

Inferential uncertainty can arise from various sources in ecological modeling and parameter estimation, including natural variability in the underlying process(es) at work, data limitations and structural assumptions in models. Explaining the nature, sources and implications of uncertainty can be especially difficult when communicating with decision-makers, landowners or the general public. Point estimates alone can be misleading if not accompanied by measures that convey the range of plausible values, such as confidence intervals (in frequentist approaches) or credible intervals (in Bayesian frameworks). It is also essential to acknowledge and describe the sources of uncertainty in a project or study, which may include sampling error, measurement error and model-based uncertainty.

Communicating scientific and model-based uncertainty is challenging, particularly when engaging with audiences unfamiliar with the concept. Many stakeholders are accustomed to receiving definitive answers rather than probabilistic information. For example, people frequently encounter weather forecasts that express uncertainty, such as a 40% chance of rain, but may interpret such predictions in binary terms (either rain will occur or will not), highlighting the cognitive challenge of understanding probabilistic information (Gigerenzer et al., 2005). This tendency can be amplified in policy and natural resource decision-making contexts, where stakeholders may expect clear guidance or action, not ranges or degrees of confidence. Misinterpretations of uncertainty may erode trust in scientific findings or be used to justify inaction (Fischhoff & Davis, 2014). Furthermore, the language used by scientists with terms like “confidence intervals,” “model error,” or “credible intervals” can be opaque or intimidating to non-technical audiences.

Effective communication strategies include using visual aids (e.g., shaded confidence bands or probability distributions), focusing on the implications of uncertainty rather than the technical details, and framing uncertainty as a normal and informative part of the scientific process. Trust is critical; when science communicators are perceived as transparent and credible, stakeholders are more likely to accept and act on uncertain information (McInerny et al., 2014). Transparent communication of uncertainty not only strengthens scientific integrity but also supports sound decision-making by making the limits of inference clear to policymakers, managers and the public.

## Use of Statistical Models

A cornerstone of effective field study design is the use of appropriate statistical models to

address questions of interest. Depending on the study question, the type of statistical model will differ. It is suggested that models can fit into one of three applications: exploration, inference or prediction (Tredennick et al., 2021). Arguably the most prevalent use of statistical models is for exploration, where one seeks to describe patterns in the data and generate hypotheses about what drives ecological processes. On the other hand, modeling for inference formalizes sets of alternative hypotheses describing how a system functions or responds, which in turn are evaluated against empirical data. This effort comprises evaluation of model coefficients associated with hypothesized covariates of importance, which can be positive or negative, and have lesser or greater influence relative to other covariates. Modeling for prediction is likely the least utilized function by state natural resource agencies. This type of modeling simply seeks to determine which of some set of models will best predict response values for new observations of essential covariates. The use of models should align with what the work is being conducted for in the first place. Regardless of the purpose for modeling, be mindful to avoid the trap of relying on p-values within a significance testing framework to decide whether and which factors are more important for explaining variation attributable to some factor(s) (Johnson, 1999). Rather, it is good practice to consider effect sizes and biological significance of factors used in models (Johnson, 1999). The forms of these models, the paradigm of statistical thinking and model selection uncertainty are beyond the scope of this brief narrative but suffice it to say that there are many volumes dedicated to this diverse subject (McCullagh & Nelder, 1983; Gelman et al., 1995; Burnham & Anderson, 1998; Hastie et al., 2001).

## Adaptive Designs

Finally, an effective ecological study design should be adaptive and iterative, allowing for refinement as new insights emerge. Adaptive monitoring acknowledges that ecological systems are dynamic, and that initial assumptions or methods may need adjustment over time. By regularly evaluating data as it is collected, researchers can modify sampling designs, protocols or analytical approaches to improve efficiency, address emerging questions, or respond to unexpected challenges. Embedding monitoring within a broader decision framework — such as structured decision making or adaptive management — further enhances its value (Figures 5.1 and 5.2). These frameworks emphasize learning by doing, using monitoring results to inform and update management actions in a continuous feedback loop. This iterative process not only increases the relevance and responsiveness of ecological studies but also ensures that monitoring contributes directly to evidence-based conservation and resource management. Together, all these principles form the foundation of statistically sound, reproducible and management-relevant ecological field studies.

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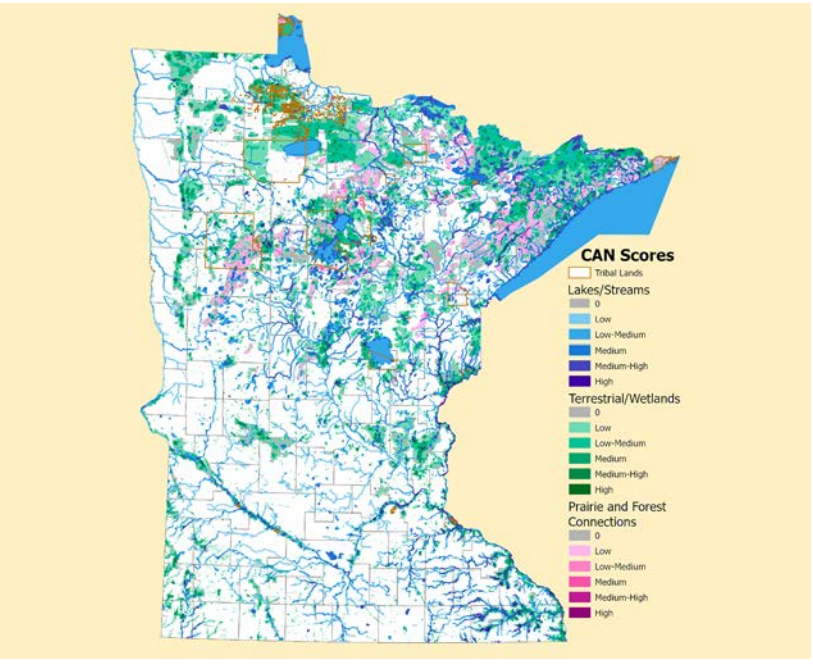
# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## CONSERVATION ACTION NETWORK



DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Conservation Action Network (CAN), depicting terrestrial and wetland cores, lake and stream cores and connectivity for forests and prairies; Workshop participants looking at maps for planning purposes, Julia Geschke

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# Chapter 6. Implementation - Conservation Action Network

Chapter 6 contains three sections, each of which are applied to guide our conservation work under this Plan. This section explains the Conservation Action Network, which represents biodiversity and high-quality habitat in our state spatially as a resource to prioritize conservation actions geographically. A second section describes Conservation Opportunity Areas, which identify locations for partners to focus on-the-ground conservation efforts that build and improve areas in and around the Conservation Action Network (see Chapter 6 Implementation – Conservation Opportunity Areas). Third, we provide foundational information regarding climate trends in Minnesota and strategies for climate adaptation that are broadly applicable throughout many types of conservation actions (see Chapter 6 Implementation – Climate Adaptation).

Of the more than 7,000 known plant and animal species in Minnesota, 1,142 have been identified as Species in Greatest Conservation Need (SGCN) following a rigorous conservation status assessment described in Chapter 2. Given the sheer number of SGCN, one of the main goals of the Plan is to prioritize and focus on conservation actions for habitats needed by SGCN (see Chapter 3: Habitats). This habitat approach can meet the needs of multiple species and emphasizes sustaining and enhancing terrestrial and aquatic habitats for SGCN in the context of both the local and larger landscape scale (including watersheds). Habitat loss and fragmentation affect biodiversity and ecosystem function, making habitat conservation and restoration central objectives in conservation planning. Evaluating landscape functional connectivity and mapping habitat networks are key steps and challenges for implementing effective actions to conserve SGCN (Duflot et al., 2018).

Goals to manage local habitat are more successful in the context of landscape-scale planning and management priorities, with the ultimate endpoint to maximize ecosystem resilience. Ecosystem resilience is an emerging concept which includes developing ways to assess functional groups (e.g., decomposers, producers, predators) and understanding the niche or redundancy of functional groups at multiple scales, while also identifying structural diversity, ecosystem services and human social/ecological connections. Resilience, as it applies to Minnesota's Wildlife Action Plan, is the capacity of an ecological system to absorb some level of disturbance and reorganize while still retaining essential functions, structures and feedbacks. Landscape prioritization provides focus for conservation actions to maintain or enhance ecosystem resilience. Examples of such actions include:

- Protecting large habitat areas from fragmentation.
- Restoring natural levels of connectivity while maintaining natural barriers.
- Reducing invasive species.
- Prioritizing habitats for biological and functional diversity (vs. single species needs).
- Minimizing pollution and impervious surfaces.
- Restoring watershed hydrology.
- Reintroducing disturbance when appropriate.

## Building on the two Prior Plans

### 2005-2015 Tomorrow's Habitat for the Wild and Rare

Minnesota's original State Wildlife Action Plan, Tomorrow's Habitat for the Wild and Rare, identified significant loss and degradation of habitat as the principal management challenge for achieving its goal to stabilize and increase SGCN populations (DNR 2005). The principal strategy for addressing this management challenge was the need to identify key SGCN habitats and focus management efforts on them. Habitat descriptions were subsequently provided for 16 key habitats in profiles of all 25 ecological subsections in Minnesota (Ecological Classification System). Each subsection profile included a matrix of SGCN use for all habitats that occurred in the subsection along with an assessment of which habitats were the most important to the greatest number of SGCN. Conservation actions to maintain and enhance the key habitats in each subsection were delineated.

### Minnesota's Wildlife Action Plan 2015-2025

Minnesota's Wildlife Action Plan 2015-2025 identified a three-pronged approach to ensuring the long-term health and viability of Minnesota's wildlife, the first and most comprehensive being the habitat approach (DNR 2015). In the 2015 Plan, the Wildlife Action Network (WAN) was developed as a tool for the implementation of a habitat-based conservation approach, resulting in a map illustrating the distribution of high-quality habitats for both terrestrial and aquatic SGCN and identifying potential movement corridors among the prioritized habitat cores. To prioritize areas for on-the-ground conservation efforts, sites within the WAN were assigned priority rankings based on five metrics, including SGCN population viability and species richness. These rankings were used in combination with a set of Conservation Focus Areas where resources, such as partners and/or funding, were available to address conservation needs through on the ground habitat restoration and management.

The 2025-2035 Plan maintains the same concept of the 2015 Wildlife Action Network (WAN), applying updated and new information to better identify and prioritize areas of high conservation value. With the addition of plants as SGCN and the availability of additional current landcover GIS layers reflecting habitat quality, the resulting WAN revision is more comprehensive and therefore called the Conservation Action Network (CAN).

The Conservation Action Network serves as the foundational prioritization tool to help accomplish the five habitat strategies laid out in Chapter 3: Habitats, which are to:

1. **Protect,** buffer and connect high quality habitats to optimize biodiversity, SGCN and landscape benefits.
2. **Restore,** enhance and maintain lands and waters to benefit SGCN, biodiversity and ecosystem resilience
3. **Collaborate** with conservation partners and landowners to enhance conservation delivery
4. **Monitor** SGCN**,** native plant communities, habitats and ecosystems for changes through time including responses to stressors, natural disturbances, conservation actions and climatic conditions.
5. **Connect** to develop**,** innovate, incentivize and disseminate evidence-based habitat management practices to benefit SGCN.

In practice the CAN is well suited to assist in large scale and multi-faceted conservation planning efforts. As climate change becomes more pronounced, its effects will be both direct and indirect. Effects from climate change in addition to those from other large-scale drivers will be synergistic; that is, multiple stressors will have an effect that is greater than what may be considered simply additive. Species are already moving in response to climate change, and it is expected that the ranges of plant and animal species will continue to shift, and habitats will change. The Conservation Action Network will facilitate planning for adaptation to these changes by identifying core areas large enough

to contain a diversity of ecotones and habitats to allow for local shifts (e.g., dry to mesic prairie) and highlighting ecological corridors to allow for species movements and the flow of energy and materials. These conditions will support the biological diversity already present in the Conservation Action Network and make it more likely that ecosystem resilience can be maintained in response to climate change and other stressors, such as invasive species and other forms of habitat degradation. The CAN may be used to prioritize areas in which to maintain and increase native biological diversity, which has also been shown generally to decrease the ability of invasive plants to become established (Yan et al., 2015; Levine and D'Antonio, 1999; Hooper et al., 2005; Fridley et al,. 2007).

While corridors are necessary for connectivity, considerations of potential negative effects and local knowledge are also important to recognize and prevent unintended consequences, such as the novel transmission of pathogens and invasive species. However, one review found little strong evidence for negative consequences of landscape corridors (Haddad et al., 2014), and others have found strong evidence of positive effects, such as increased biological diversity (Gilbert-Norton et al., 2010). Still, knowing how dynamic a system is and what the potential effects of connectivity within that system could be is important. Corridors between naturally unconnected aquatic or wetland systems might be inappropriate, for instance.

Ultimately the CAN was developed with the aim of increasing the effectiveness and efficiency of conservation actions when resources and capacity are limited. A network focus will increase efficiency by facilitating coordination of management, prioritizing outreach efforts and targeting technical assistance. Coordination of management will also increase its effectiveness. For example, coordinating activities across multiple ownerships within the network can benefit species that require large areas of habitat in particular successional stages (i.e., time since disturbance).

In essence, the Conservation Action Network is an effort to identify the best places for SGCN and Minnesota's diverse plants, animals and many other organisms to persist and adapt to a changing climate as well as physical changes to the land, water and air. The CAN identifies and scores core areas of high biodiversity, important habitats, and healthy ecosystems as well as areas of potential connectivity between the cores. The CAN intends to guide conservation partners to maximize collective outcomes and will continue to build on the utility of the 2015 WAN (see Case Study about the Wildlife Action Network in action).

The Conservation Action Network is based on a rich set of species occurrence data and biodiversity rankings from several decades of intensive survey efforts by Minnesota Biological Survey staff; surveys and public reports collected by Nongame Wildlife Program, Scientific and Natural Areas and Parks and Trails staff; intensive sampling efforts by the Minnesota Pollution Control Agency for stream Indices of Biological Integrity; and other sources of information. The CAN does not capture potentially important areas lacking survey information. Over the next 10 years, the network should be further refined to include new information on additional rare species occurrences.

## Case Study: Minnesota Land Trust's Use of the Wildlife Action Network

The Minnesota Land Trust (MLT) is a conservation non-profit organization that works with private landowners to conserve land through voluntary land conservation agreements. The Land Trust's mission is to protect and restore Minnesota's most vital natural lands to provide wildlife habitat, clean water, outdoor experiences and scenic beauty for generations to come. Since 1991, the Land Trust has partnered with hundreds of Minnesota landowners to permanently protect over 80,000 acres of natural land and 540 miles of fragile shoreline throughout the state. In addition, they have restored over 9,000 acres of critical habitat.

The MLT's conservation easement acquisition program works throughout Minnesota in a range of different "program areas" such as the Blufflands and the North Shore that largely corresponds with state grants they receive from the Outdoor Heritage Council. A main component of this work is partnering with private landowners to place permanent conservation easements on their property. MLT's focus is typically areas of high-quality natural habitat. MLT also has a restoration program to provide restoration assistance to landowners once the conservation easement is complete. All of MLT's program areas have slightly different goals and objectives, but use of the Wildlife Action Plan is consistent across all of them.

MLT uses the Wildlife Action Network from Minnesota's 2015 Wildlife Action Plan to help prioritize where our work will have the maximum conservation impact. To prioritize among a large volume of landowner applications across a given landscape, the Wildlife Action Network is a key data point in sorting through these potential parcels and identifying priorities for protection. In southeastern Minnesota, for example, MLT uses a ranking system that weighs the parcel's size, the quality of its natural resources/habitat, and its landscape context to come up with a composite ranking for prioritization. The Wildlife Action Network is an outstanding metric for use in the "natural resources/habitat" quality score because it synthesizes so many other data sets into one, easy-to-use metric.

*Photo: Workshop participants looking at maps for planning purposes, Julia Geschke*

## Developing the Conservation Action Network

The Conservation Action Network (CAN) was developed through a careful review of multiple data layers, guidance from SWAP revision core staff, and input gathered during three conservation practitioner meetings held in 2024 and 2025. A total of 18 GIS data layers were used to assemble the CAN, including 16 layers to comprise the core areas, and two layers for connectivity (Table 6.1). Also see Appendix F for more details on CAN development.

**Table 6.1. Geographical Information System (GIS) layers used to map habitat cores and corridors in the Conservation Action Network (CAN).**

| GIS layer | Scale | Description | Used in 2015 WAN? |
|---|---|---|---|
| Species in Greatest Conservation Need (SGCN) Richness Hotspots | Species | Clusters of SGCN species summed in 2 km square hexagons. See Hotspots section for more detail. | Yes – updated in 2025 |
| Mapped Endangered and Threatened Animal Populations | Species | Populations of State and Federal Endangered and Threatened Animals mapped in 2015 for the previous Wildlife Action Plan. | Yes – not updated |
| High Quality Element Occurrences of Endangered and Threatened Plants | Species | From Biotics Rare Natural Features maintained in The Natural Heritage Information System, DNR - Division of Ecological Resources (NatureServe, DNR Natural Heritage Information System). | No |
| Federal Critical Habitat designations | Species | Current Federal Critical Habitat designations for Dakota skipper, piping plover, poweshiek skipperling, and topeka shiner. | Yes |
| Bat maternity roost and hibernacula restriction buffers | Species | Selected all forest classes within buffers around known hibernacula entrances and occupied maternity roost trees that are used by northern long-eared bat (*Myotis septentrionalis*), little brown myotis (*Myotis lucifugus*), and tricolored bat (*Perimyotis subflavus*) (Lakes States Forest Management Bat Habitat Conservation Plan). | No |
| Rare Native Plant Communities | Habitat | Native Plant communities mapped by staff within the Minnesota Biological Survey (DNR) that have a state conservation rank of S1 or S2 (Minnesota's Native Plant Communities). | No |
| High Quality Wetland Native Plant Communities | Habitat | Wetland Native Plant communities mapped by staff within the Minnesota Biological Survey (Minnesota DNR) that have a condition rank of A, B or C (Minnesota's Native Plant Communities). | No |

| GIS layer | Scale | Description | Used in 2015 WAN? |
|---|---|---|---|
| Forest Management Opportunity Areas | Habitat | State forest land with management emphasis to improve forest habitat for wildlife species. The following types were included: Landscape (LAND), Old Forest Management Complexes (OFMC), White Pine/ Conifer Management Area (WPMA), Owl Management Area (OWMA), Large Block/Moose, Management Area (MMA), Open Landscape Management Area (OLMA), Forest Patch (PATCH), Deer Management Area (DMA), INT, Pilot INT MOA and Pilot UPLD MOA (Forest Resource Management Planning). | No |
| DNR Forest Inventory Old Growth and old growth Special Management Zones (SMZ) | Habitat | Currently designated or candidate old growth forest stands and old growth Special Management Zones (SMZ) - a 330-foot buffer around the Old Growth stand on lands administered by the MN Department of Natural Resources (DNR) (Old growth forests). | No |
| Forest Representative Sample Areas (RSAs) | Habitat | Ecologically viable representative samples of forest types on lands administered by the DNR designated to serve one or more of three purposes: 1) To establish and/or maintain an ecological reference condition; or 2) To create or maintain an under-represented ecological condition; or 3) To serve as a set of protected areas or refugia for species, communities and community types otherwise not captured. | No |
| High Conservation Value Forests (HCVF) | Habitat | Forest areas administered by the DNR selected by Interdisciplinary Regional Teams from a subset of sites of Biodiversity Significance identified by the Minnesota Biological Survey (MBS) that was recommended for consideration by Division of Ecological and Water Resources biologists (High conservation value forests). | Yes |
| Lakes with high Lake Health scores in the Watershed Health Assessment Framework (WHAF) | Habitat | Lakes with an overall WHAF lake health score of 75 or greater and lakes with a lower overall health score but had a biology component score of 70 or greater. (Watershed Health Assessment Framework: Lakes). | No |

| GIS layer | Scale | Description | Used in 2015 WAN? |
|---|---|---|---|
| Lakes with high bird rankings identified in the Lakes of Biological Significance layer. | Habitat | Added lakes not selected from the WHAF health scores above which ranked high or outstanding from the Lakes of Biological Significance layer with a bird rank of 1 (Outstanding) or 2 (High) (Lakes of Biological Significance). | Yes |
| High Quality Stream Reaches | Habitat | This layer includes stream reaches (WIDS) that met Exceptional Use criteria for fish and/or aquatic invertebrates based on Indices of Biological Integrity (IBI) developed and surveyed by the Minnesota Pollution Control Agency (MPCA). Adjacent reaches that met General Use criteria and all streams with an order size of 5 to 9 were also added to maintain connectivity. (MPCA Index of biological integrity). | Yes – updated since 2015 |
| Sites of Biodiversity Significance | Landscape | A biodiversity significance rank is assigned by staff within the Minnesota Biological Survey (DNR) on the basis of the number of rare species, the quality of the native plant communities, and areas' size and context within the landscape (MBS Site Biodiversity Significance Ranks). Here we include those with ranks of High and Outstanding. | Yes – updated since 2015. |
| Minnesota Prairie Conservation Plan Core Areas | Landscape | Represents landscapes with concentrations of native prairie, grasslands and other habitats identified using DNR Biological Survey, USFWS and land cover data. Where appropriate, these boundaries were adjusted to reflect watershed divides and ownership/field boundaries (Minnesota Prairie Conservation Plan). | Yes –updated in 2017 |
| TNC forest connectivity | Connectivity | Areas of high diffuse and concentrated flows selected from the forest wall-to-wall Circuitscape model developed by ecologists at The Nature Conservancy's North America Science team. | No |
| TNC prairie connectivity | Connectivity | Areas of high diffuse and concentrated flows selected from the prairie wall-to-wall Circuitscape model developed by ecologists at The Nature Conservancy's North America Science team. | No |

## Core Areas

Layers representing core areas were chosen to represent three different scales: species, habitats/communities, and landscapes. Ensuring representation of these scales has been identified as important for landscape planning under climate change (Schmitz et al., 2015). Aquatic and terrestrial cores represent areas with high concentrations of SGCN species, high-quality or rare habitats, or healthy ecosystems. Core areas of habitat are depicted in Figure 6.1.

The species scale was split into two categories: all SGCN and Endangered and Threatened species (federal and state). Five GIS data layers were used to represent the species scale, one for all SGCN species (Richness hotspots) with the other four brought together to focus on endangered and threatened species (High Quality Element Occurrences of Endangered and Threatened Plants, Mapped Endangered and Threatened Animal Populations, Federal Critical Habitat designations, and Bat maternity roost and hibernacula restriction buffers). Habitat from each of these layers was included in the CAN.

High quality and rare habitats were determined for five habitat categories: prairies, wetlands, forests, lakes and rivers/streams, based on a set of nine layers.

Healthy landscape cores were represented by two data layers: Sites of Biodiversity Significance and core areas from the Minnesota Prairie Conservation Plan.

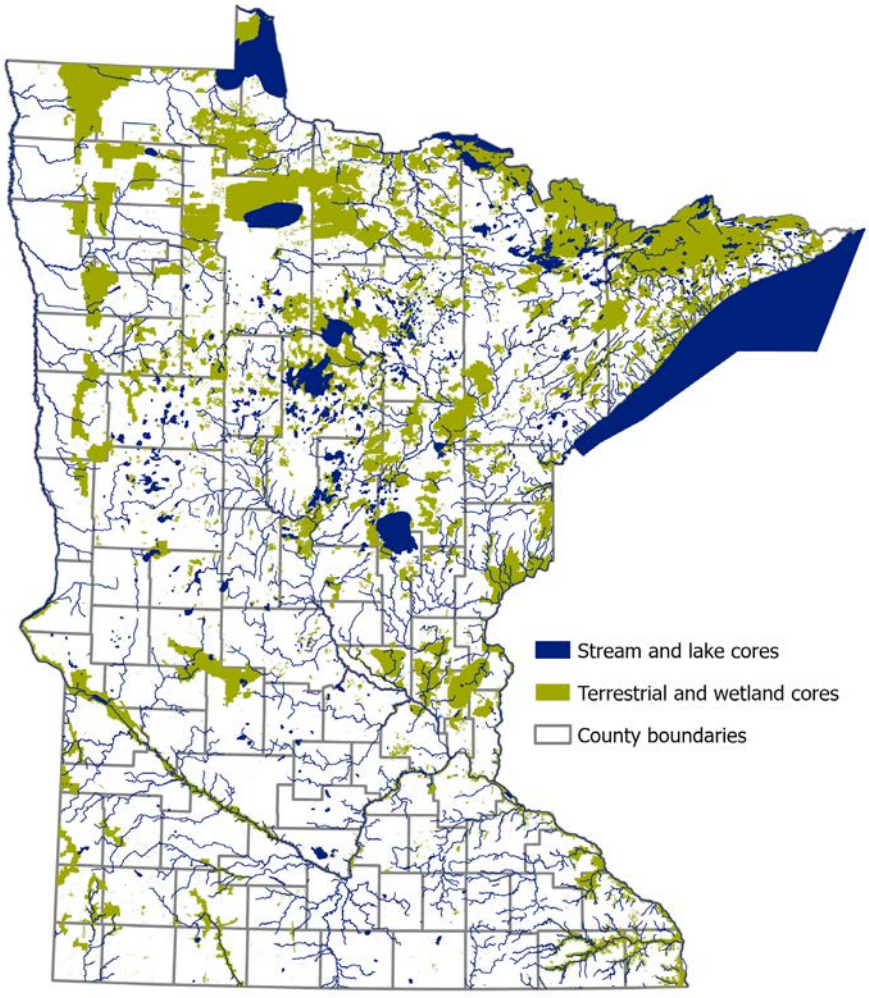


Figure 6.1. Core areas of the CAN depicting streams and lakes (blue) and terrestrial habitat and wetlands (gold).

## Connectivity

To address connectivity, we utilized separate prairie and forest connectivity maps recently created for Minnesota's, and adjacent states and provinces, landscapes by ecologists in The Nature Conservancy's North America Science team who employed a wall-to-wall Circuitscape model (Pelletier et al., 2014). These structural connectivity maps describe relative differences in how the spatial pattern of prairies and forests may support or constrain generalized animal movement and ecological processes. The methods used to create these maps follow methods described in previous work by TNC for the entire U.S. (Anderson et al. 2023), however in that work all ecosystem types were combined in a "naturalness" measure.

Circuitscape models use the mathematics of electrical circuit theory to describe how heterogeneity in land use and other factors can influence where movement is most likely, and where movement is constrained (McRae et al. 2008). The model is applied to a resistance surface comprised of landscape features, with each feature weighted by its relative resistance to movement (Dickson et al., 2019; Shah & McRae, 2008). Rather than tracking electrons, the model tracks paths of "random walkers" traveling across this resistance surface, producing a cumulative "current flow" output. In a uniform landscape, current flow spreads out evenly, but in heterogeneous landscapes this even flow pattern is disrupted as the walkers avoid areas of higher resistance and concentrate in contiguous areas with lower resistances. This pattern of variation in amount of flow in each pixel, and in diffusion and concentration, can then be used to help understand how conditions on the landscape impact species movement and the flow of ecological processes.

To update the resistance surfaces described in Anderson et al. (2023), the TNC team integrated the most up to date landcover data from the National Land Cover Database (NLCD), and then developed separate resistance weighting schemes for prairies and forest systems. Both schemes retain the same weights for roads and development, but treat either forests or prairies as lowest resistance depending on the focal system, and then reflect expert user input on how other land cover types should be weighted relative to the focal system (Table 6.2).

When the Circuitscape model is run, each cell receives a quantitative score reflecting the amount of "current" accumulated in the cell as a function of its location, context, resistance, and direction of flow. The wall-to-wall continuous grid output from Circuitscape was classified into three main flow types. Diffuse flow represents areas that are extremely intact and consequently facilitate high levels of dispersed flow that spreads out to follow many different and alternative pathways. Concentrated flow represents areas where large quantities of flow are concentrated through a narrow area. Constrained flow represents areas where little flow gets through and is consequently deflected around these features. To describe important connectivity areas at the state level, we focus on two patterns that can be categorized from the continuous current flow outputs. Areas that had high flow and a high standard deviation across neighboring pixels represent "concentrated flow", a pattern that highlights places where movement potential is predicted to be especially high due to constraints in nearby locations. Our maps also highlight areas with high to moderate flow and low standard deviations. These "diffuse" areas indicate the most intact regions, where movement processes are well supported (multiple potential movement pathways).

For both forest and prairie connectivity, areas of high diffuse or high concentrated flow were included in the CAN (Figure 6.2). The forest and prairie connectivity maps indicate areas likely to facilitate the movement of plants and animals in response to a changing climate and other stressors.

**Table 6.2. Resistance values used for connectivity runs using Circuitscape for the forest and grassland models. Lower values correspond to lower resistance.**

| Landuse | Resistance Value in Forest Model | Resistance Value in Grassland Model |
|---|---|---|
| Forests | 1 | Not included |
| Woody wetlands | 1.5 | 5 |
| Natural Barrens | 3 | 3 |
| Herbaceous wetlands | 6 | 2 |
| Shrub/Scrub | 5 | 5 |
| Undisturbed prairie/grasslands | Not included | 1 |
| Grassland/Herbaceous | 6 | 2 |
| Pasture/Hay | 8 | 2 |
| Cultivated Crop | 9 | 7 |
| Low and Medium Density Development | 10 | 10 |
| Residential Roads | 10 | 10 |
| High Density Development | 20 | 20 |
| Primary and Secondary Roads | 20 | 20 |

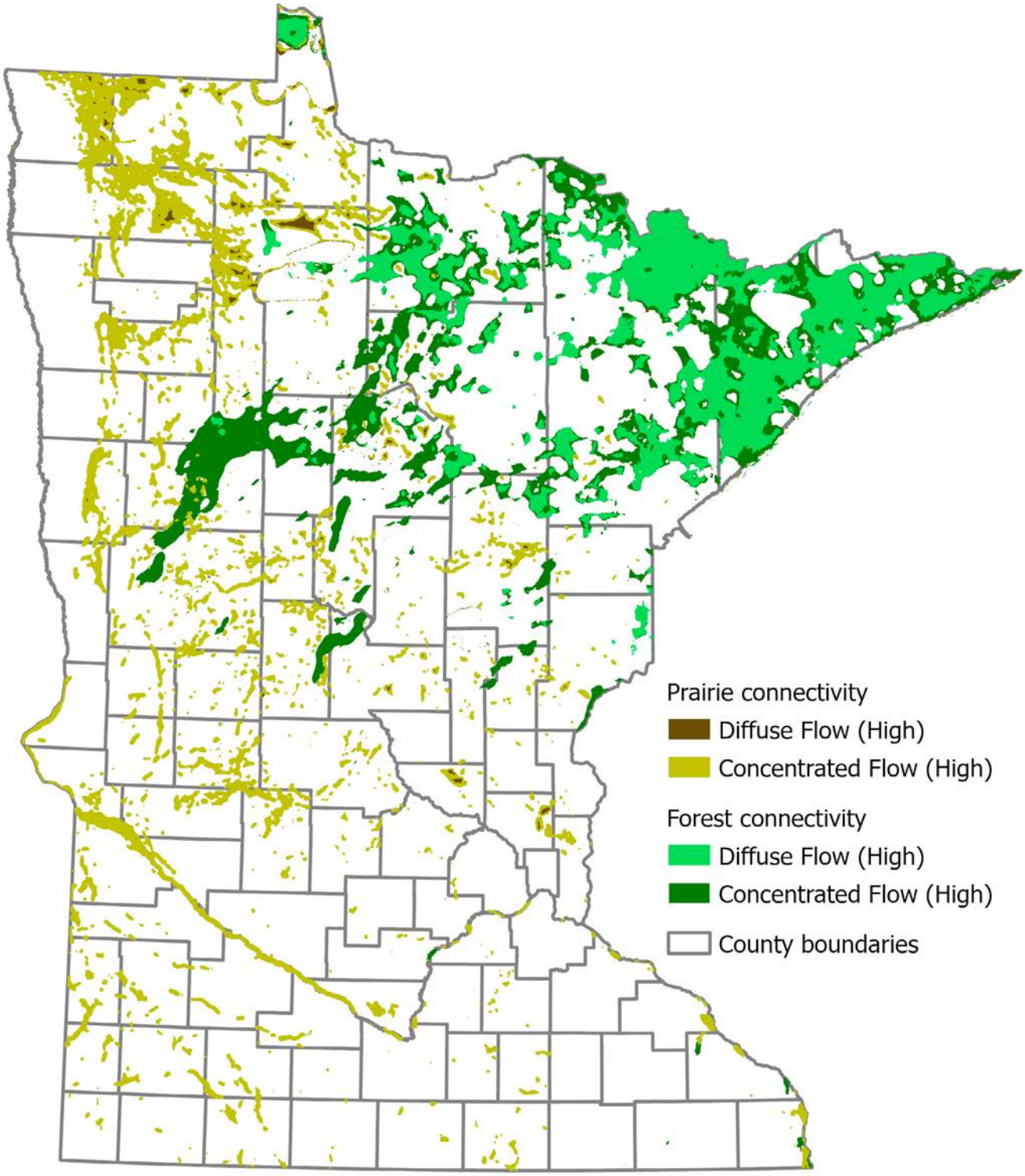


Figure 6.2. Prairie or open habitat (gold/brown) and forest (green) areas of connectivity.

## Scoring the Conservation Action Network

The final step scored the core and connectivity layers to provide greater prioritization within the network. Scoring employed five layers, selected for balance across the scales and types of habitats: 1) SGCN richness; 2) Endangered and Threatened species richness (and including species with s-ranks of S1 and S2); 3) Lake health or biological significance; 4) Stream Indices of Biotic Integrity; and 5) Sites of Biodiversity Significance (Table 6.3 and Figures 6.3-6.7).

We used Jenks natural breaks to classify the number of species into five categories for the SGCN richness and Endangered and Threatened species richness layers. The Jenks natural breaks classification method is a data clustering method designed to determine the best arrangement of values into different classes. This is done by seeking to minimize each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other classes. In other words, the method seeks to reduce the variance within classes and maximize the variance between classes (Jenks, 1967).

These five scoring layers were combined into a single scoring layer where the individual layer scores were first summed together and then normalized so the overall score ranged between 0 and 1. This combined scoring layer was then used to separately score 1) the terrestrial habitats (including wetlands), 2) the aquatic habitats (lakes and streams), 3) the prairie connectivity layer and 4) the forest connectivity layer. These scored layers were overlayed to create the final scored Conservation Action Network (Figure 6.8).

**Table 6.3. GIS layers used to score habitat cores and connectivity in the Conservation Action Network.**

| Layer | Scoring Parameters |
|---|---|
| Species in Greatest Conservation Need (SGCN) Richness Grids | Number of SGCN species using Jenks natural breaks: 0 = 0, 1-2 =.1, 3-7 = .3, 8-14 = .6, 15-24 = .8, 25-48 = 1 |
| Endangered, Threatened Species (and including species with s-ranks of S1 and S2) Richness Grids | Number of species using Jenks natural breaks: 0=0, 1-2 =.1, 3-5 =.3, 6-10 =.6, 11-16 =.8, 17-21 =1 |
| Lakes<br>a. WHAF Lake Health Score (LHS)<br>b. Lakes of Biological Significance | Combine a. & b. below, using b. where a. was not available. a. Lake Health Score/100 (minimum value 0.45); b. Lakes of biological significance where Outstanding = 0.8, High = 0.6 |
| Stream Indices of Biological Integrity (IBI) | [Max WID Fish IBI or Invert IBI score]/100 |
| Sites of Biodiversity Significance | Outstanding = 0.8, High = 0.6, Medium = 0.4 |

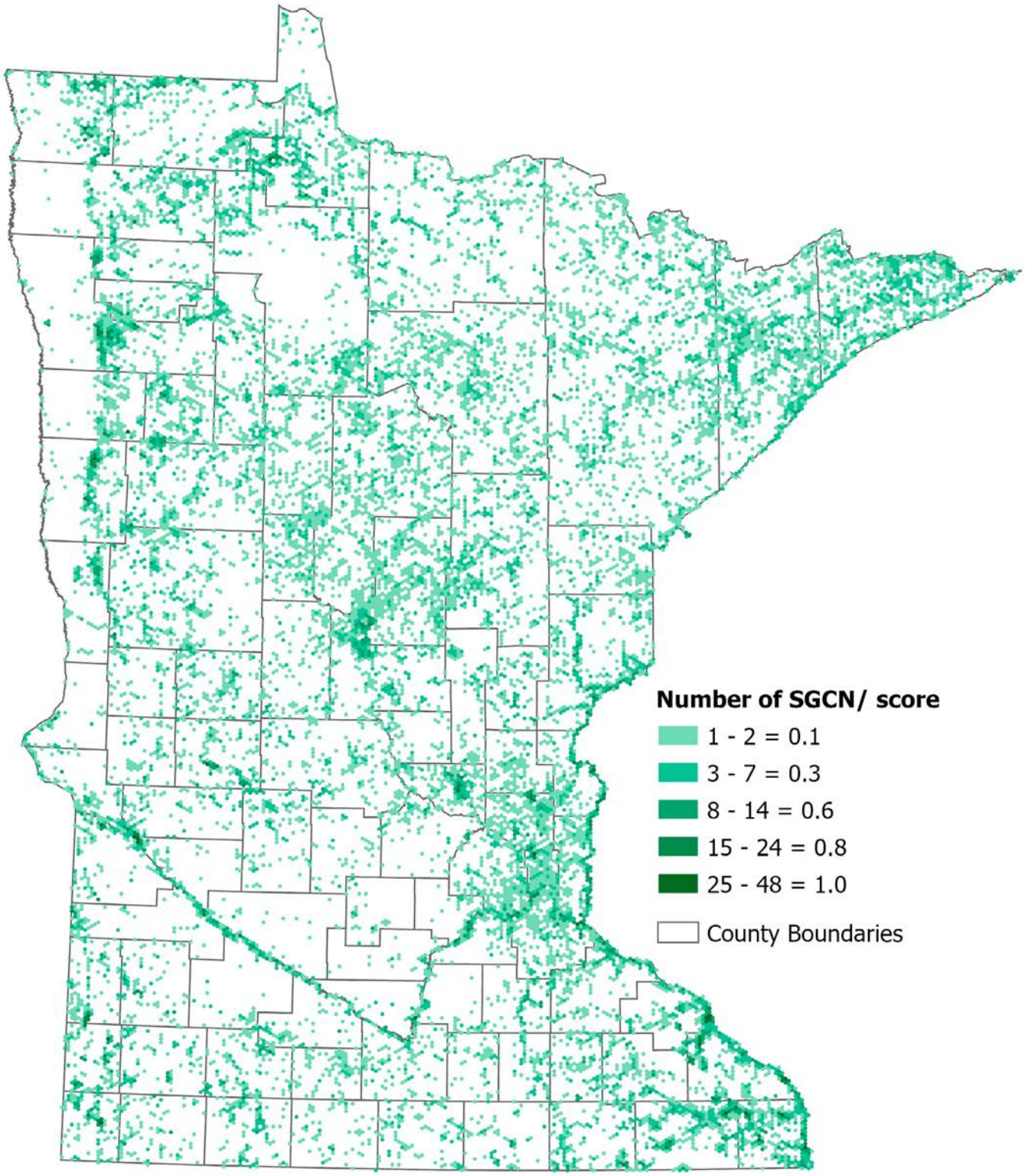


Figure 6.3. Number of all SGCN records summed within 2 $km^2$ hexagons and scored using Jenks natural breaks.

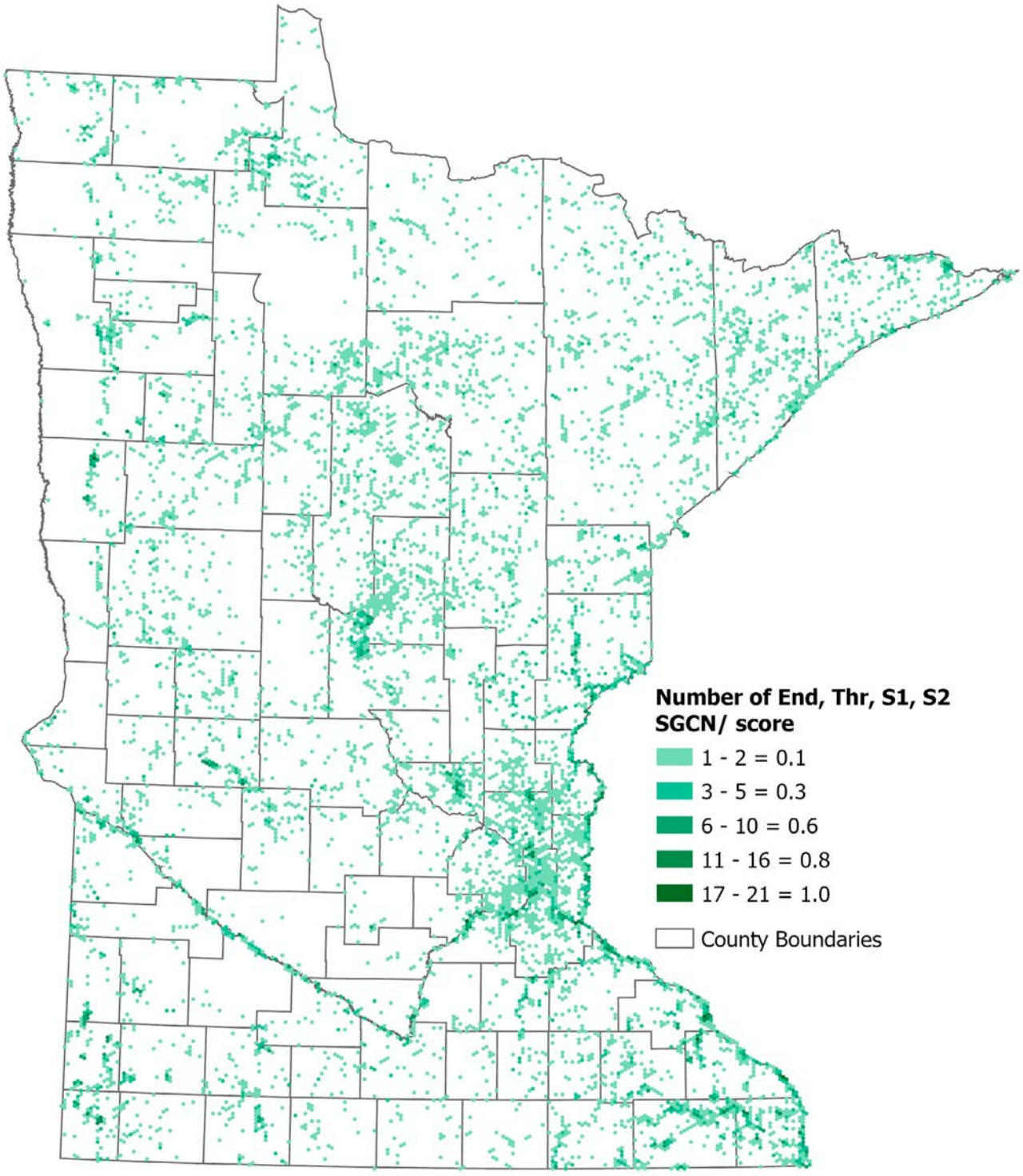


Figure 6.4. Number of Endangered and Threatened SGCN records (and including species with s-ranks of S1 and S2) summed within 2 $km^2$ hexagons and scored using Jenks natural breaks.

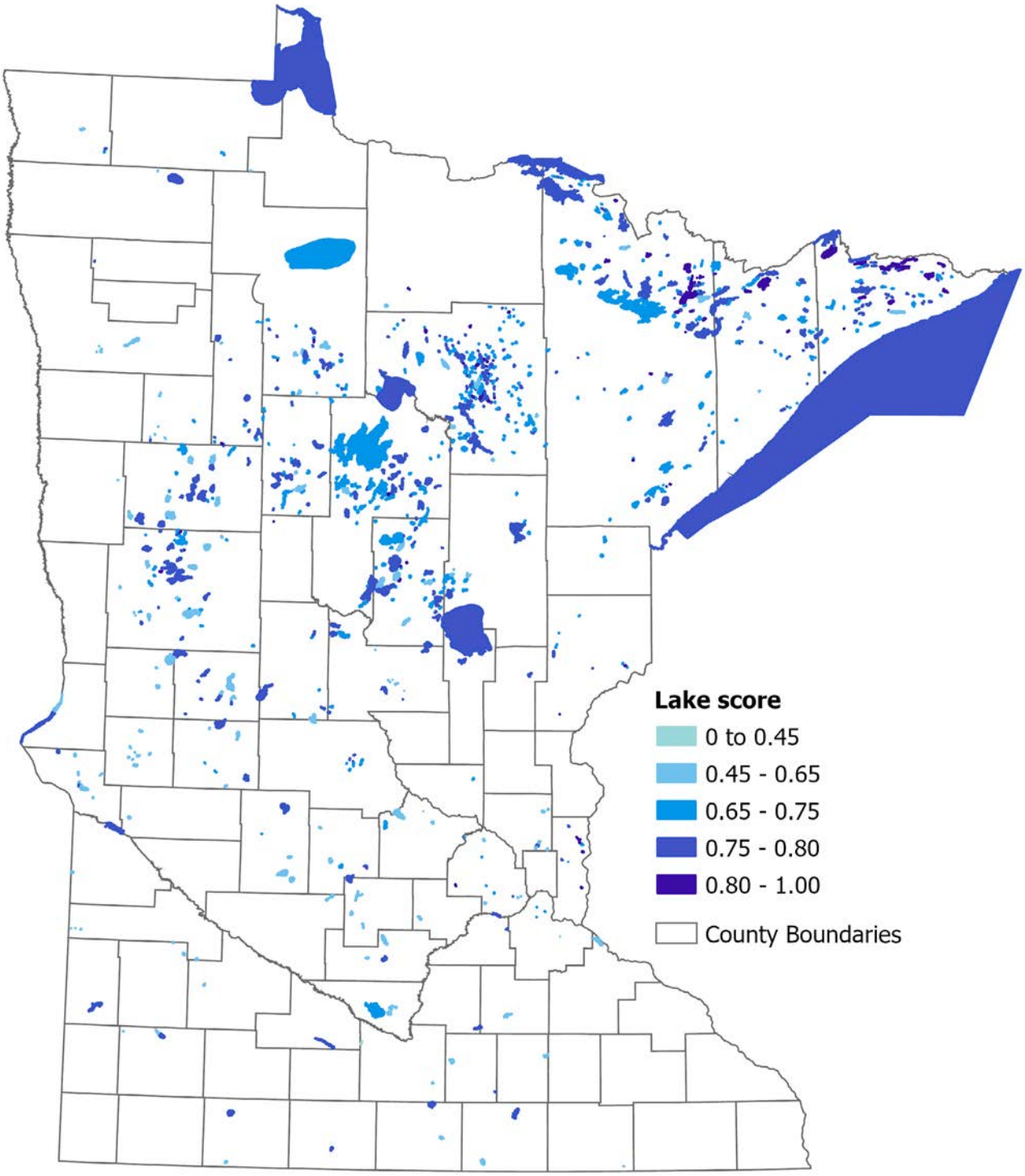


Figure 6.5. Lake scores based on Watershed Health Assessment Framework (WHAF) Lake Health Scores and Lakes of Biological Significance rankings where Lake Health Scores were not available. The area in NE Minnesota delineating part of Lake Superior represents Minnesota's managed portion of the lake.

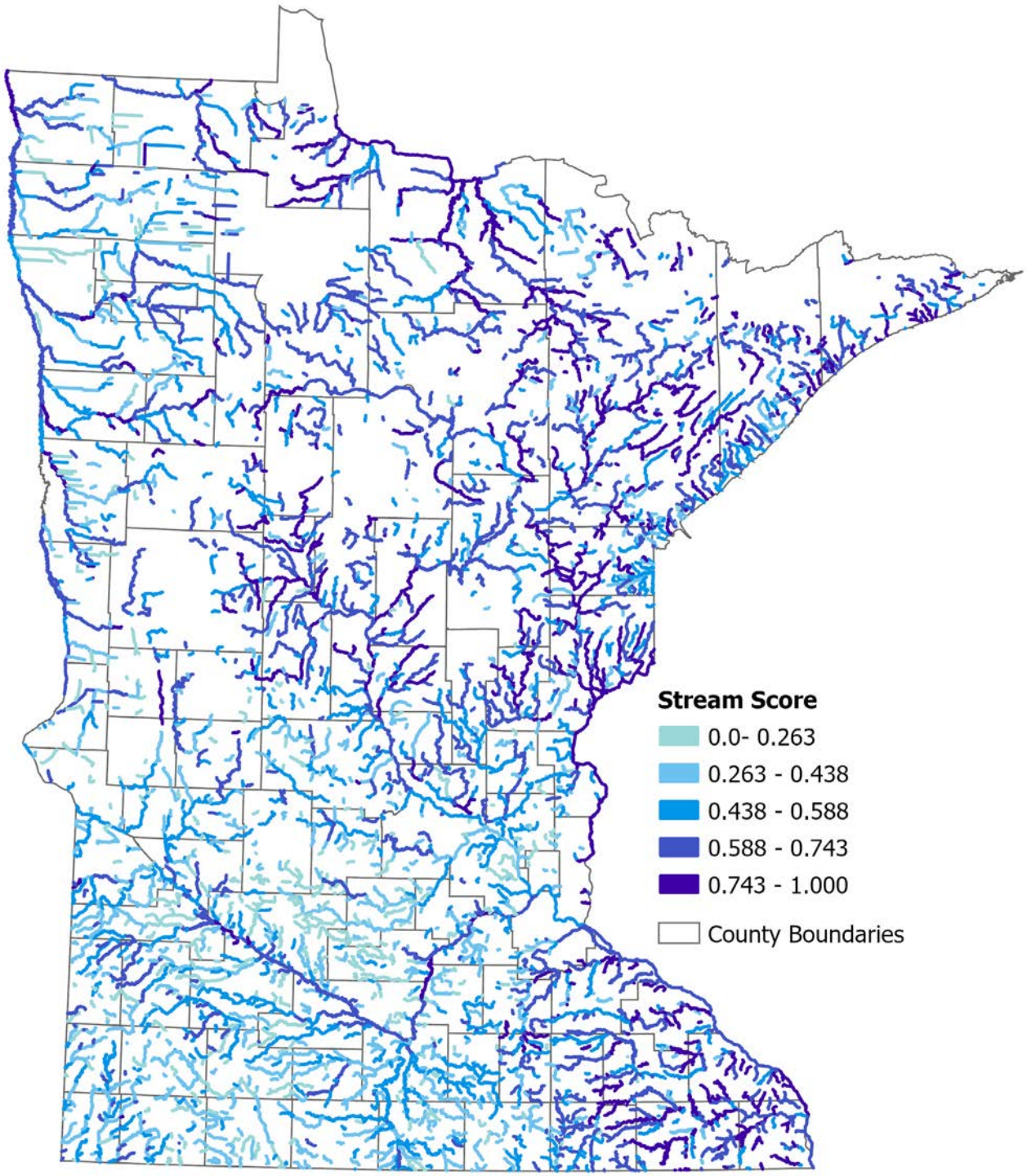


Figure 6.6. Stream score from the maximum fish or invertebrate IBI value by stream segment (WID) normalized to a range between 0 and 1.

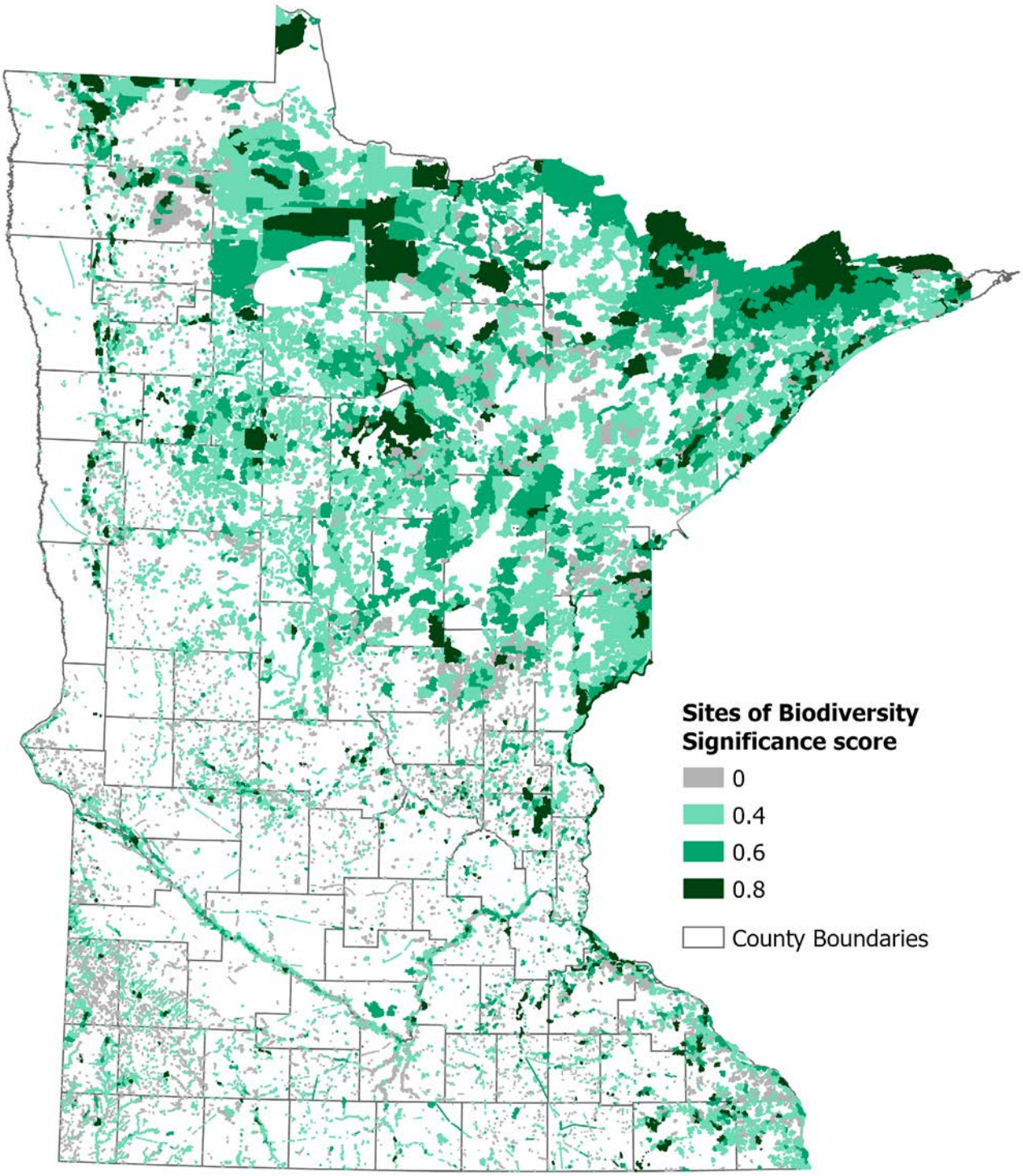


Figure 6.7. Sites of Biodiversity Significance scoring layer, with Below (gray) = 0, Medium (mint green) = 0.4, High (green) = 0.6, and Outstanding (dark green) = 0.8.

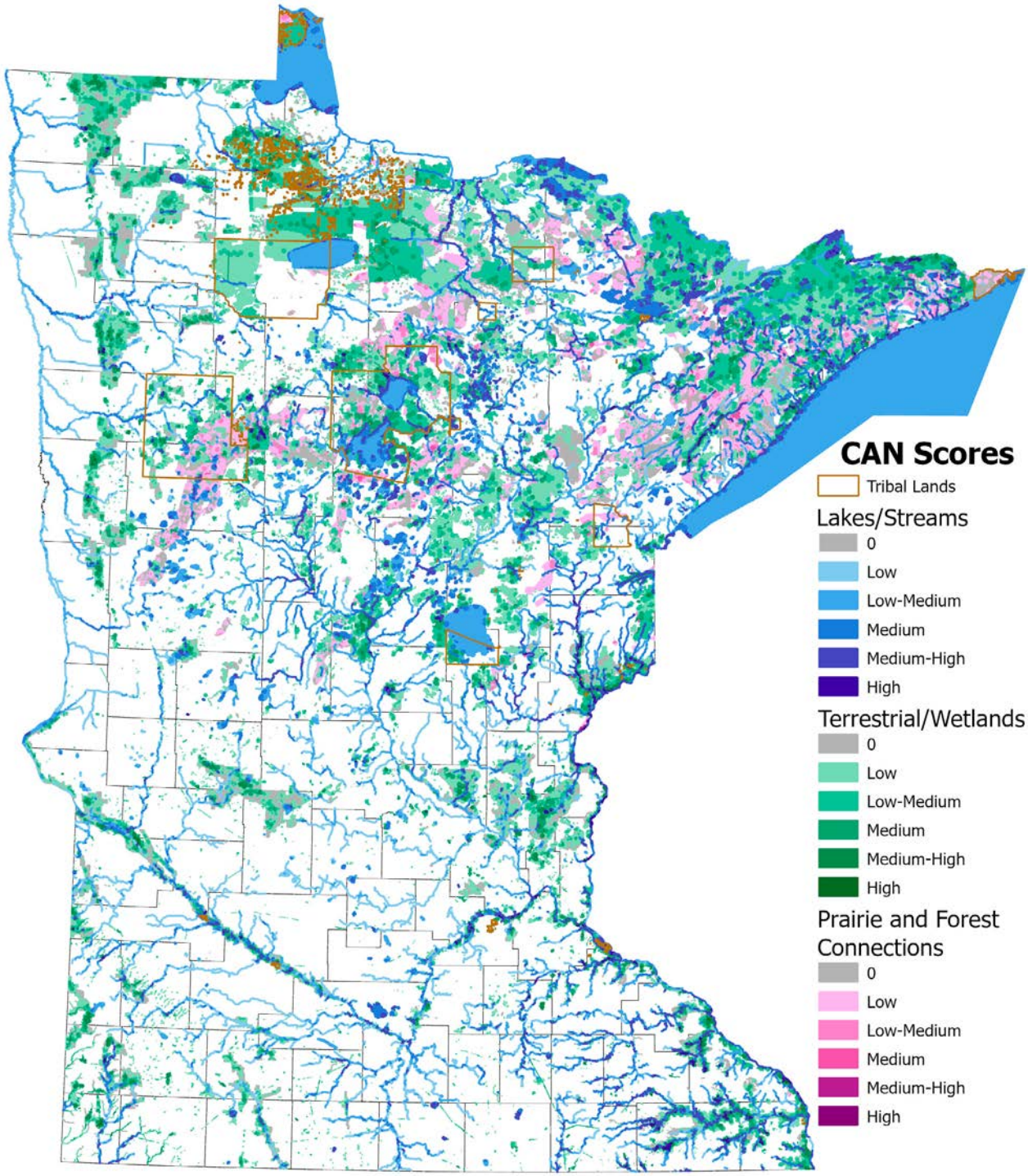


Figure 6.8. The scored Conservation Action Network (CAN), depicting terrestrial and wetland cores, lake and stream cores and connectivity for forests and prairies. Scores were applied using 5 factors.

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# Supplemental Material - Additional Detailed Methods for Developing the Conservation Action Network

## GIS data layers used for the CAN cores

### Species scale

Five GIS data layers were used to represent the species scale, one focused on all SGCN species (Richness hotspots) with the other four focused on the state and federal endangered and threatened species (High Quality Element Occurrences of Endangered and Threatened Plants, Mapped Endangered and Threatened Animal Populations, Federal Critical Habitat designations, and Bat maternity roost and hibernacula restriction buffers). Habitat from each of these layers was included in the CAN.

#### Species in Greatest Conservation Need (SGCN) Richness Hotspots

The SGCN richness hotspot analysis is a revision of the 2015 layer using new and additional data with three modifications:

1. We used a grid of 2 $km^2$ hexagons to sum the number of Species in Greatest Conservation Need (SGCN). The 2015 analysis used a grid of 2.5-km-by-2.5 km (6.25 $km^2$) square blocks.
2. We changed the hotspot selection rules to have smaller cut-off values to account for the smaller area of the 2 $km^2$ hexagons.
3. The number of SGCN increased to 1142 species in the 2025 SWAP, compared to 346 in 2015.

The first step in the process was to create a grid of 2 km2 hexagons across the entire state of Minnesota, followed by intersecting the SGCN observation points with the hexagon grid. SGCN observation data were from multiple data sources (Table 6.4) and comprised 85,782 records having a maximum locational uncertainty of 0.62 miles (1000 meters). These records represented 888 (or 75%) of the 1142 SGCN species. SGCN species not represented were mostly because locational uncertainty was not available or exceeded the 0.062 mi cut-off (generally species with very few, older records). Following the intersection of hexagons with SGCN observation records, the number of species were summed within each hexagon and then the 2025 selection rules were applied to identify SGCN richness hotspots (Figure 6.9).

2025 hotspot selection rules using 1.24 $mi^2$ (2 $kilometer^2$) hexagons:

1. A single hexagon comprising 10 or more species, or
2. A cluster of at least four contiguous hexagons each comprising four or more species, or
3. A cluster of at least six contiguous hexagons each comprising two or more species; cluster must contain hotspot already defined in 1 or 2 above

The SGCN richness hotspots were intersected with the Minnesota's 2025-2035 Wildlife Action Plan Habitat Layer (see Chapter 3, Habitat Map Methods) to remove non-habitat areas (development and agriculture) within the hexagons (Figure 6.10). This resulted in some areas, especially within the Twin Cities metropolitan area, with little natural habitat represented in the hotspots (Figure 6.11). Some observation records dated back to 1979 and habitat in these locations may have since been converted to agriculture or developed. Also, some SGCN records are in residential areas (such as rusty patched bumblebee). While residential habitat can be important for certain SGCN species, it was not mapped as a habitat given our inability to discern locations of suitable residential habitat (e.g. native plantings) from the landcover map.

**Table 6.4. Datasets used for SGCN observation records to identify richness hotspots and to score the CAN.**

| Dataset | Description |
|---|---|
| Natural Heritage Information System | Records of current federal and state listed species, and 2015 non-listed SGCN. |
| DNR releve database | Plant species occurrence data from 11,555 vegetation plots collected by the Minnesota Biological Survey Minnesota Department of Natural Resources throughout the State of Minnesota between 1986 and 2025. |
| Bell Museum Herbarium | Records of over 160,000 plant specimens collected throughout Minnesota's history. |
| MBS Aquatic Plants | Database containing aquatic plant records from approximately 2,000 of Minnesota's lakes. |
| Mayfly (Ephemeroptera) data | Minnesota mayfly records collected/curated by Luke Jacobus from Indiana University. |
| Stonefly (Plecoptera) data | Minnesota mayfly records collected/curated by Ed Dewalt from the University of Illinois. |

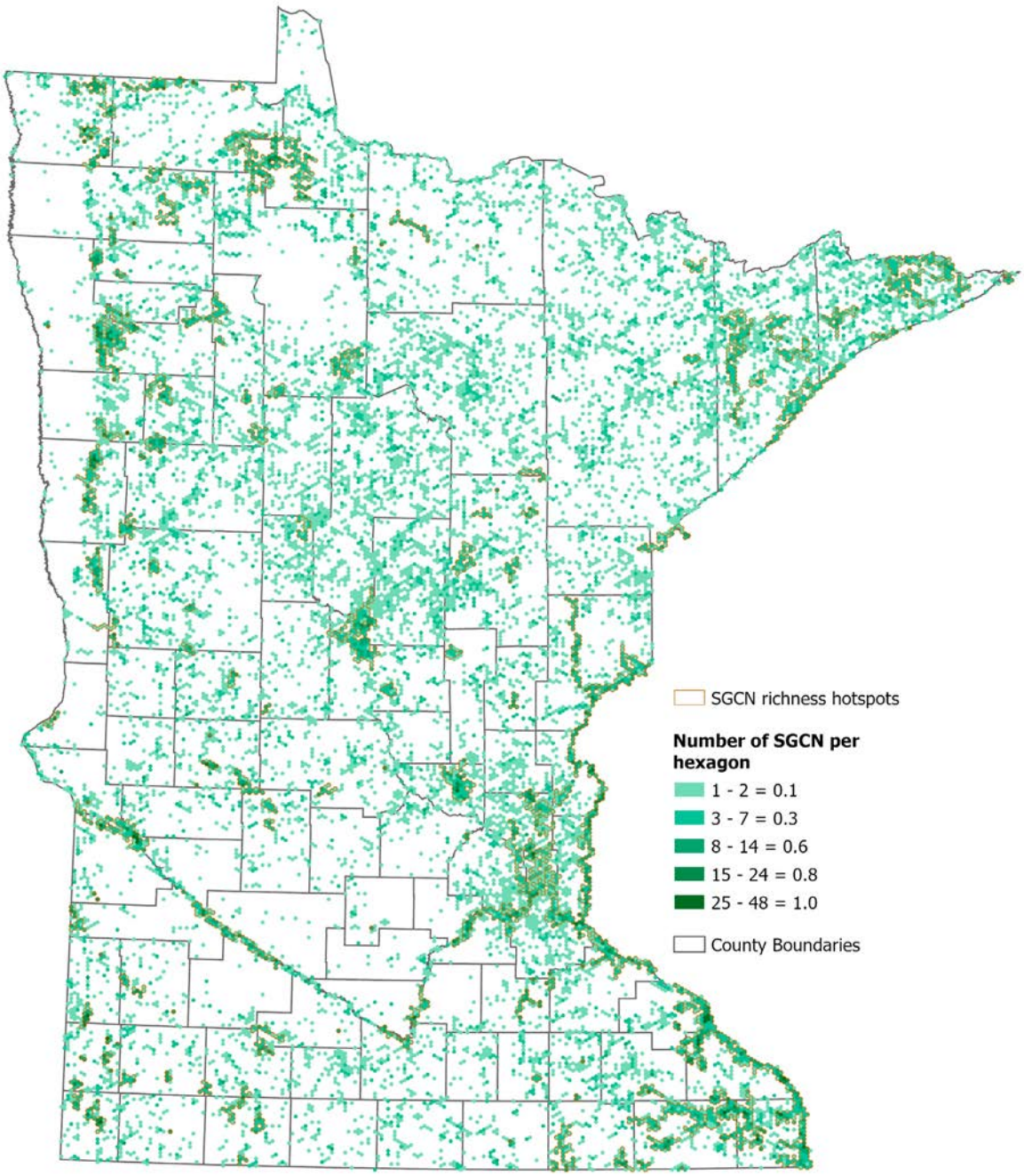


Figure 6.9. Distribution of Species of Greatest Conservation Need (SGCN) across Minnesota, shown by number of species per hexagon. Richness ranges from 1–2 species (light green) to 25–48 species (dark green). Outlined areas highlight SGCN richness hotspots.

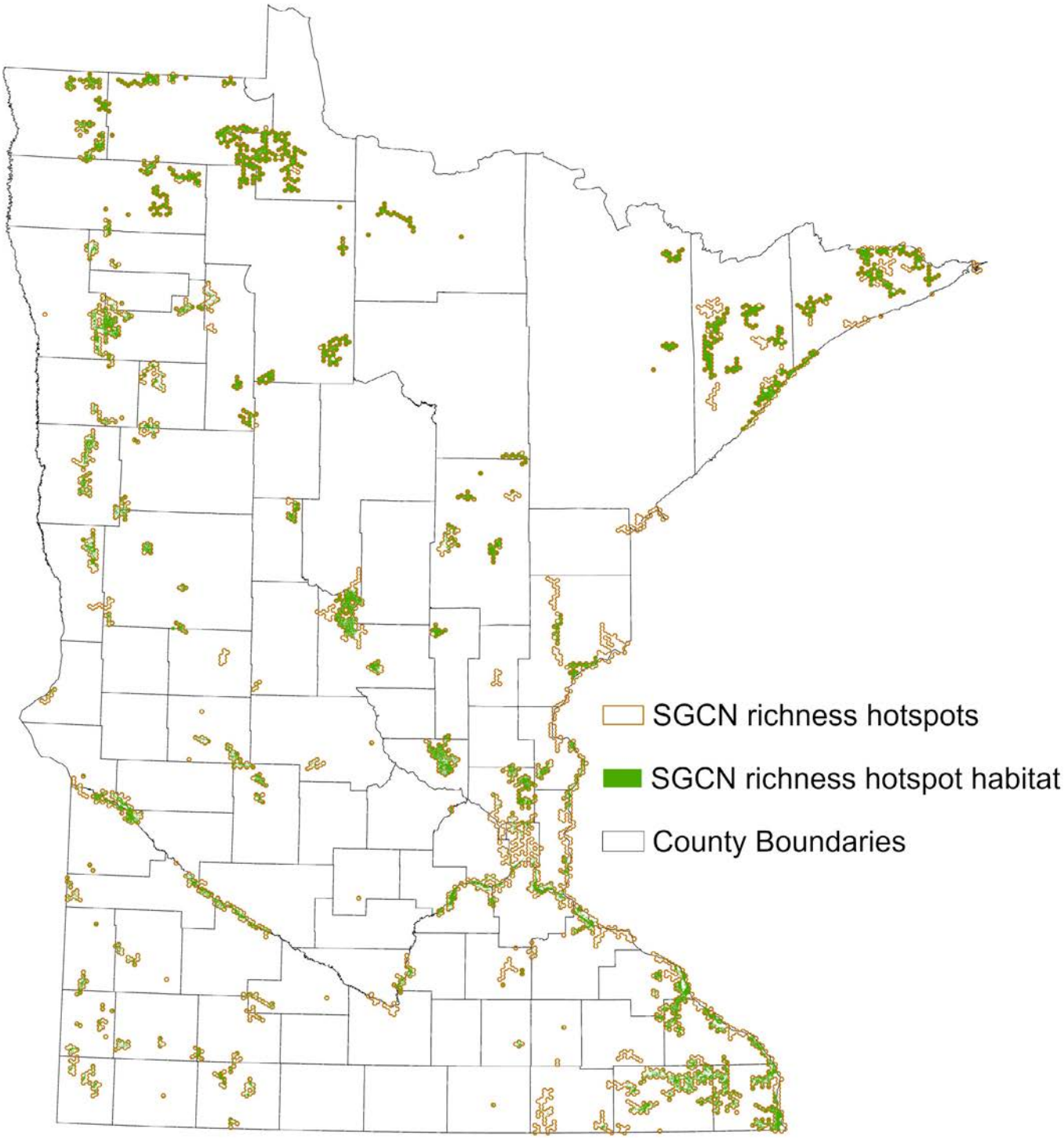


Figure 6.10. Distribution of SGCN richness hotspots across Minnesota. Outlined areas indicate hotspots, and green areas show the habitat within those hotspots.

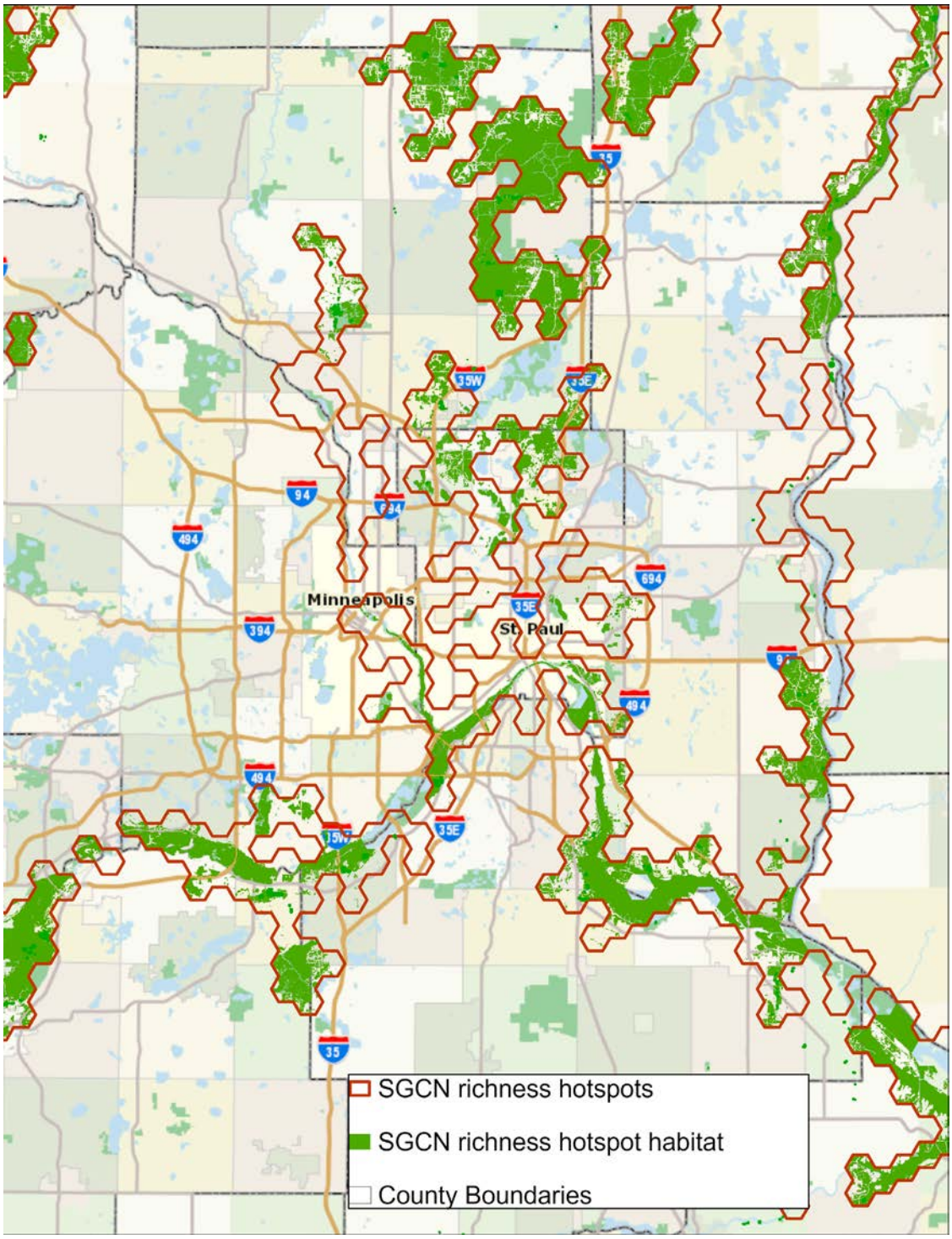


Figure 6.11. Hotspot hexagons (brown boundaries) in the Twin Cities Metropolitan area, showing remaining potential habitat (green polygons) within the mapped areas. Hotspot areas with no green habitat indicate that SGCN had been recorded there sometime in the past and are now developed or row crop agriculture. Some of this is due to records in residential areas (such as rusty patched bumblebee) and, while residential habitat is important for many species, it was not mapped as a CAN core habitat.

## High Quality Element Occurrences of Endangered and Threatened Plants

Element occurrences (EOs) of federal or state endangered and threatened plants typically represent populations that, if conserved, can contribute to the survival or persistence of the element. Rankings represent the viability of the population where an A rank = excellent viability, B rank = good viability, C rank = fair viability, and D rank = poor viability. Plant species with an A, B, or C rank were selected from the NHIS dataset resulting in 1,134 plant EOs for use in the CAN core (Figure 6.12, NatureServe, DNR Natural Heritage Information System).

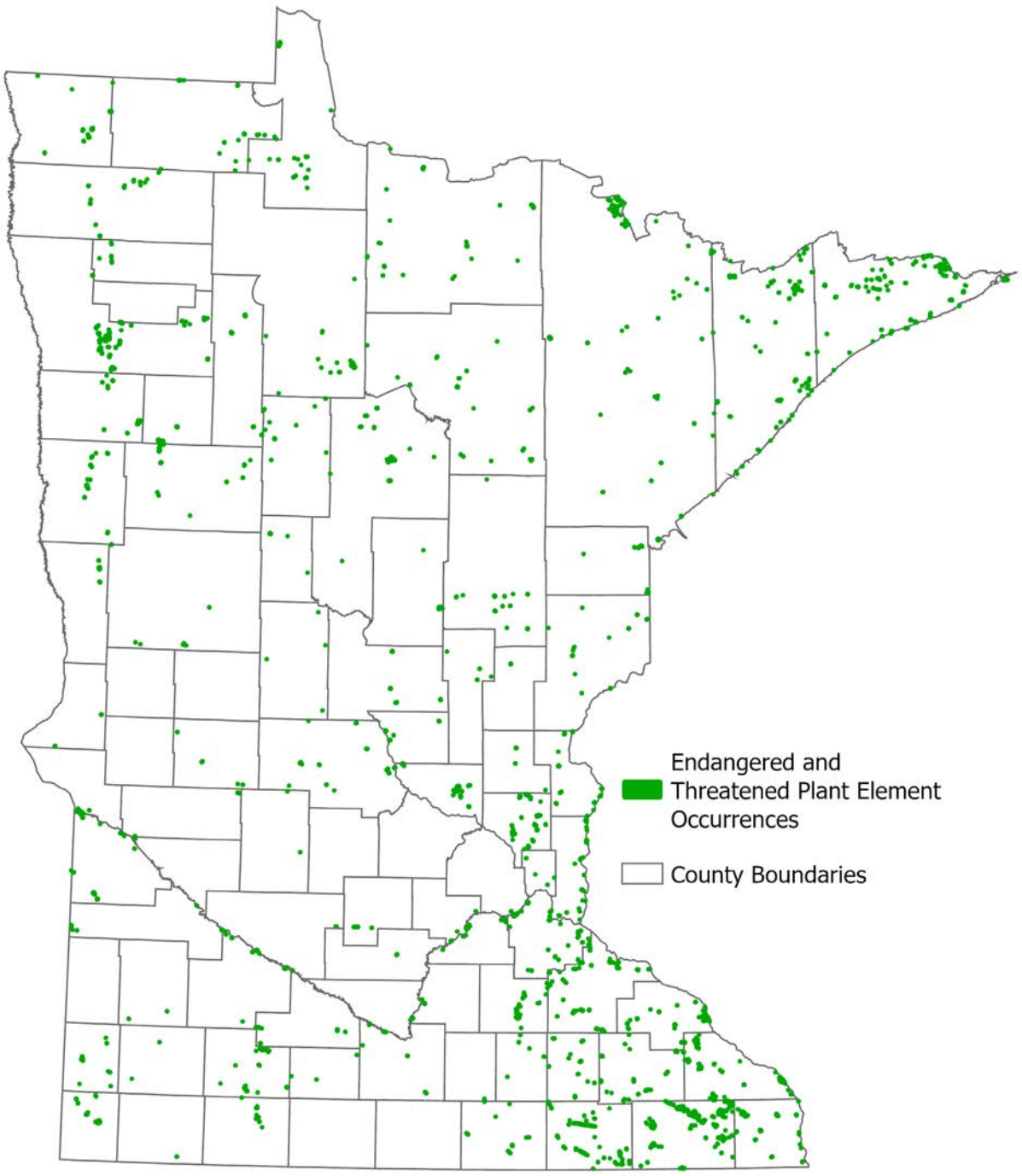


Figure 6.12. Federal or state endangered and threatened plant element occurrences (EO) with a rank of A, B, or C.

## Mapped Endangered and Threatened Animal Populations

The mapped populations of federal and state endangered and threatened animal species were developed for the 2015 MNWAP using a series of taxa expert workshops (See Appendix E in the 2015 MNWAP). This was a time intensive effort which we were not able to replicate for the 2025 revision, and efforts to automate the process were unsatisfactory.

We determined that the mapped populations of endangered and threatened species remained relevant for the 2025 revision and included them as cores (Figure 6.13). Mapped populations of other SGCN, aka the 2015 Composite Population maps, were not used as there were numerous realized or potential changes since the 2015 version. These areas are largely represented by other layers used in the CAN.

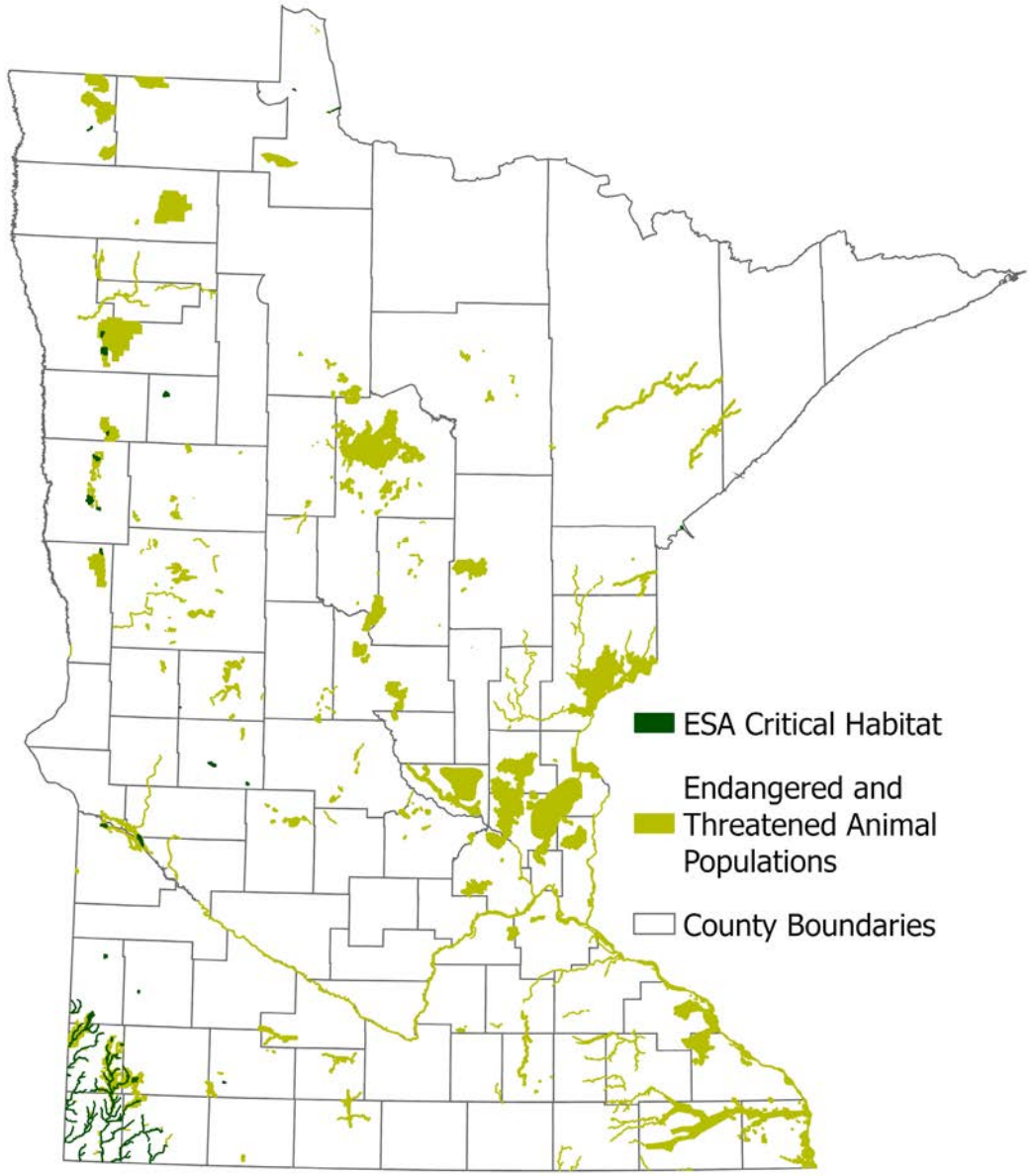


Figure 6.13. Federal or state endangered and threatened 2015 animal population map in orange and current ESA critical habitat designations in red. Critical habitat does not include Canada lynx or gray wolf as areas are too general for the prioritization mapping intent of the Conservation Action Network (CAN).

## Federal Critical Habitat designations

We also included the current Federal Critical Habitat Designations for Dakota skipper (*Hesperia dacotae*), piping plover (*Charadrius melodus*), poweshiek skipperling (*Oarisma Poweshiek*) and topeka shiner (*Notropis topeka*) which have been updated since 2015 (Figure 6.13). We did not include critical habitat designations for Canada lynx (*Lynx canadensis)* or gray wolf (*Canis lupus*) as the areas designated are too general for the prioritization mapping intent of the CAN. We also chose to not include the range maps for Northern Long-Eared Bat (*Myotis septentrionalis*) and the tricolored bat (*Perimyotis subflavus*) for the same reason. Finally, proposed critical habitats for rusty patched bumble bee (*Bombus affinis*), salamander mussel (*Simpsonaias ambigua*), spectaclecase mussel (*Cumberlandia monodonta*), snuffbox mussel (Epioblasma triquetra) and sheepnose mussel (*Plethobasus cyphyus)* were delayed for inclusion until after critical habitat statuses are finalized.

## Bat maternity roost and hibernacula restriction buffers

The MN DNR maintains an internal database of known hibernacula entrances and occupied maternity roost trees that are used by northern long-eared bat (Myotis septentrionalis), little brown bat (Myotis lucifugus) and tricolored bat (Perimyotis subflavus) with specified protection buffer distances of 150 feet for maternity roost trees, and 0.25 miles for hibernaculum restricting or limiting tree removal, road and trail maintenance and prescribed burns. There is an additional 2.5 miles buffer around hibernaculum with certain limitations for road and trail maintenance and development. For this mapping exercise, we chose the 150 ft and 2.5 mi. buffers for roost trees and hibernaculum. These data are used to implement the **Lakes States Forest Management Bat Habitat Conservation Plan.** Within these buffered areas, all forest habitat mapped in the Minnesota's 2025-2035 Wildlife Action Plan Habitat Layer were selected for inclusion in the CAN core. Map is not provided due to the sensitive nature of the data.

## Habitat scale

### Rare Native Plant Communities

All rare native plant communities, representing rare assemblages of plants in Minnesota (S1 and S2) regardless of condition rank, were included in the CAN core (Figure 6.14). Native plant communities are mapped by staff within the Minnesota Biological Survey (Minnesota DNR) using a combination of remote sensing and field verification. This layer includes prairies, wetlands, forests (Minnesota's Native Plant Communities).

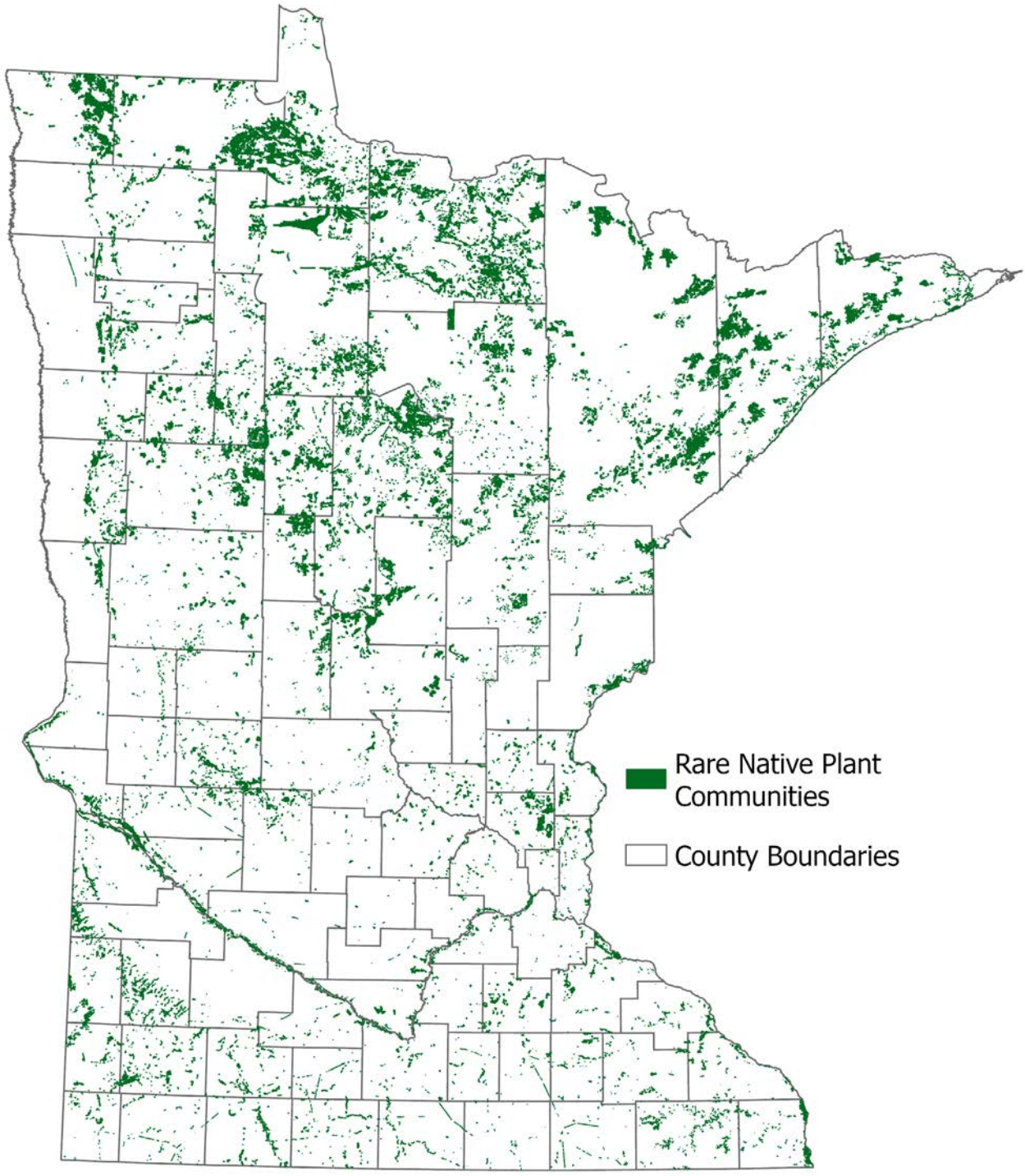


Figure 6.14. Rare Native Plant Communities defined as having a state conservation rank of S1 or S2.

## High Quality Wetland Native Plant Communities

In addition to the rare wetlands selected in the previous data layer, this layer contains all wetland native plant communities (NPC) with a condition rank of A, B, or C (Figure 6.15). This included all NPCs in the Acid Peatland, Marsh, Open Rich Peatland, Wet Meadow/Carr, and Wetland Prairie systems of the MN DNR Native Plant Community Classification (Minnesota's Native Plant Communities).

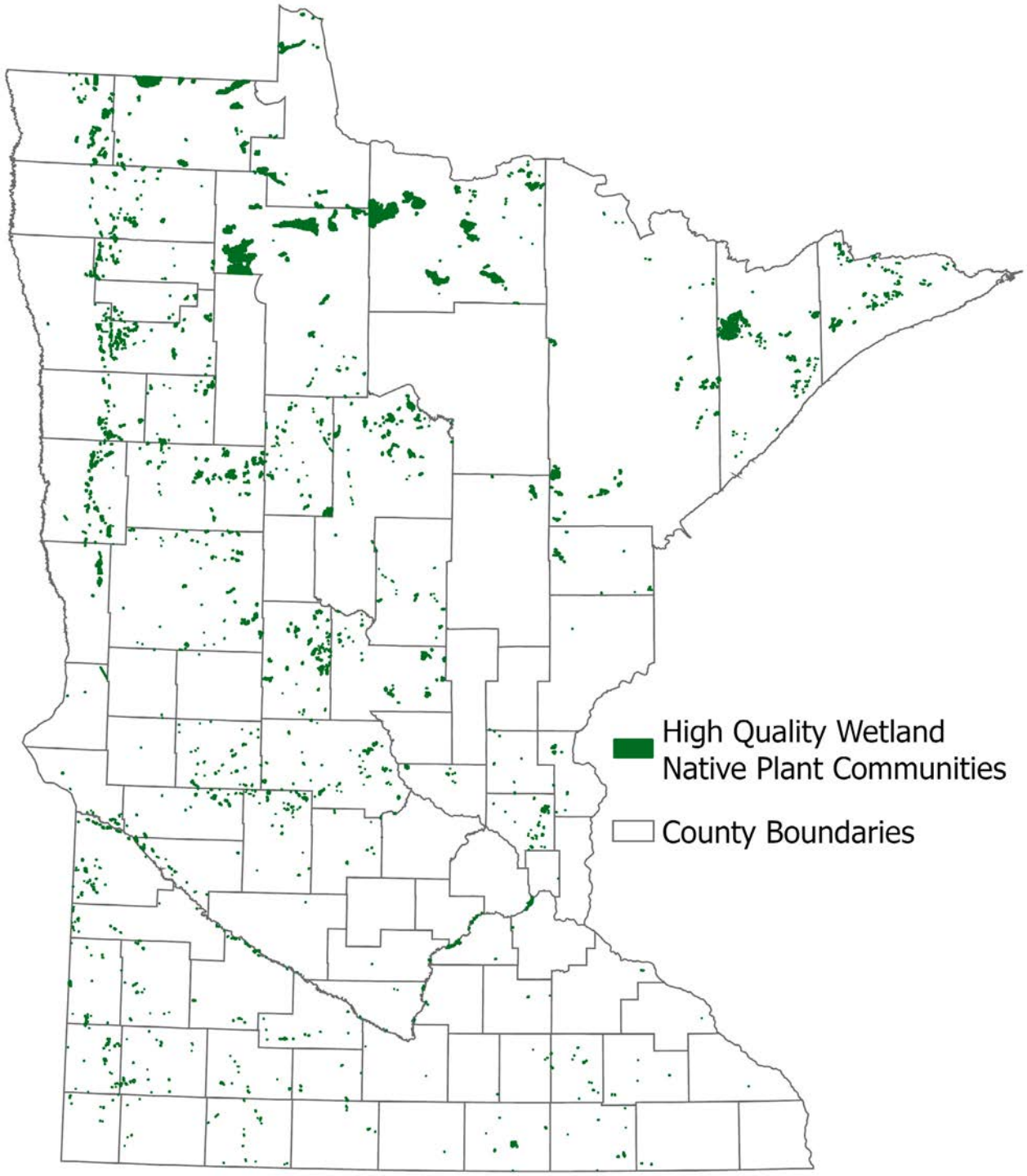


Figure 6.15. High Quality Wetland Native Plant Communities (NPCs), defined as having an NPC quality rank of A, B, or C.

## Forest Management Opportunity Areas

Forest management opportunity areas are state forest lands with management emphasis to improve forest habitat for wildlife species. The following types were included: Landscape (LAND), Old Forest Management Complexes (OFMC), White Pine/Conifer Management Area (WPMA), Owl Management Area (OWMA), Large Block/Moose, Management Area (MMA), Open Landscape Management Area (OLMA), Forest Patch (PATCH), Deer Management Area (DMA), INT, Rotating older forest within the landscape Management Area (Pilot INT MOA), and Older upland forest adjacent to younger forest for Boreal owl habitat Management Area (Pilot UPLD MOA, Figure 6.16, Forest Resource Management Planning).

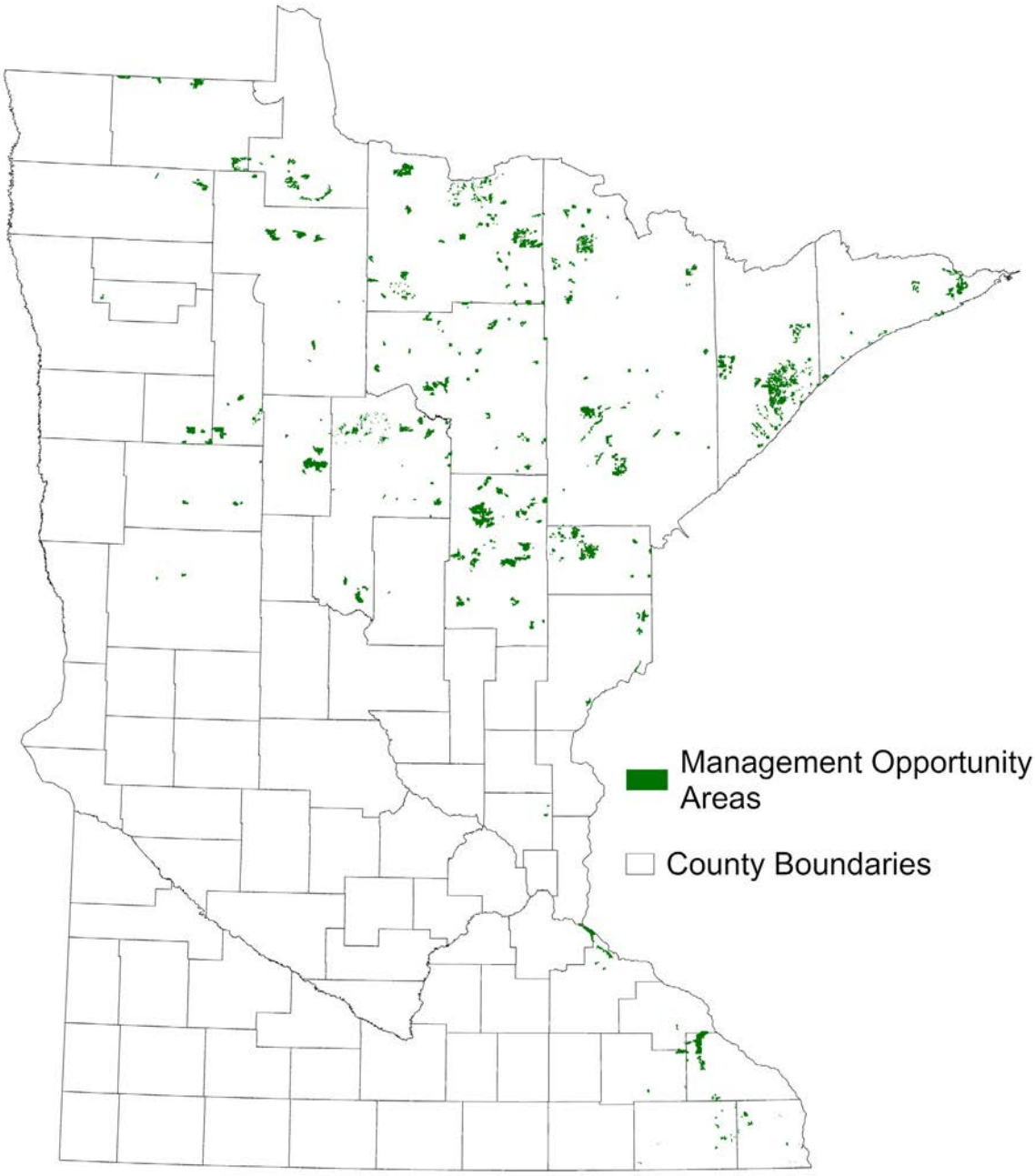


Figure 6.16. DNR forest management opportunity areas.

## Significant Forests

Three data layers are included in this group as described below. These layers represent Minnesota DNR forest land that have a focus on unique, rare, or representative characteristics that can provide habitat for certain SGCN (Figure 6.17). The layers are:

1. DNR Forest Inventory Old Growth (currently designated or candidate old growth forest stands) and Old Growth Special Management Zone (SMZ) - a 330-foot buffer around the Old Growth stand on lands administered by the DNR (Old growth forests).

2. Forest Representative Sample Areas (RSAs) are ecologically viable representative samples of forest types on lands administered by the DNR designated to serve one or more of three purposes: to establish and/or maintain an ecological reference condition; or to create or maintain an under-represented ecological condition; or to serve as a set of protected areas or refugia for species, communities and community types not captured in other criteria of this Standard.

3. High Conservation Value Forests (HCVF) are Forest areas administered by the DNR having outstanding biological or cultural significance as defined by The Forest Stewardship Council® (FSC, High conservation value forests). As part of maintaining FSC forest certification, the FSC states: "Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach."

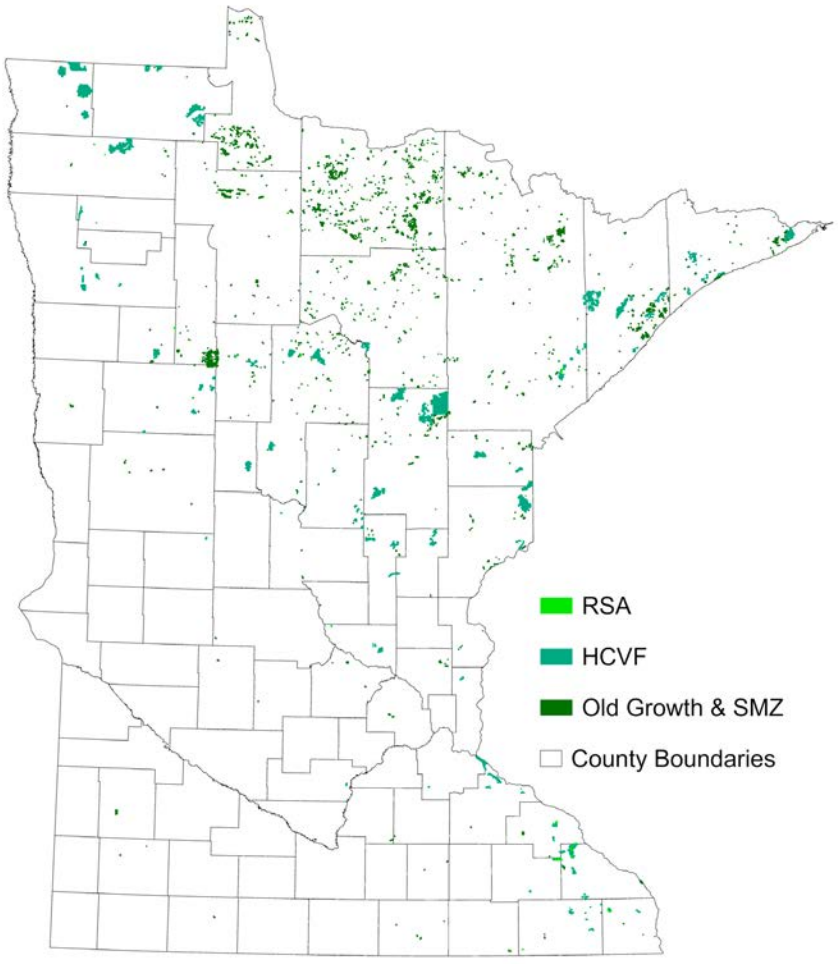


Figure 6.17. Significant Forests, including Minnesota DNR Forest Representative Sample Areas (RSA), High Conservation Value Forests (HCVF) and forest old growth and special management zones (SMZ).

## Significant Lakes

Lakes were selected with high Lake Health scores in the Watershed Health Assessment Framework (WHAF) and Lakes with high bird rankings identified in the Lakes of Biological Significance layer. First, we utilized lake health scores developed as part of the Watershed Health Assessment Framework (WHAF, Watershed Health Assessment Framework: Lakes). Lakes were selected that met either an overall lake health score of 75 or greater or lakes with a biology component score of 70 or greater. The lake health score was made up of 3 component scores: water quality, biology and hydrology to come up with an overall score ranging from 0 to 100. Given the biodiversity focus of the CAN, we included lakes with high biology scores even though they were below the 75 overall health score threshold.

Another lake evaluation layer, Lakes of Biological Significance, was used to identify additional lakes having significant SGCN bird populations given that the WHAF Lake Health Score biology component score did not include bird communities (Lakes of Biological Significance). Lakes selected from these two assessments were combined for inclusion into the CAN core (Figure 6.18).

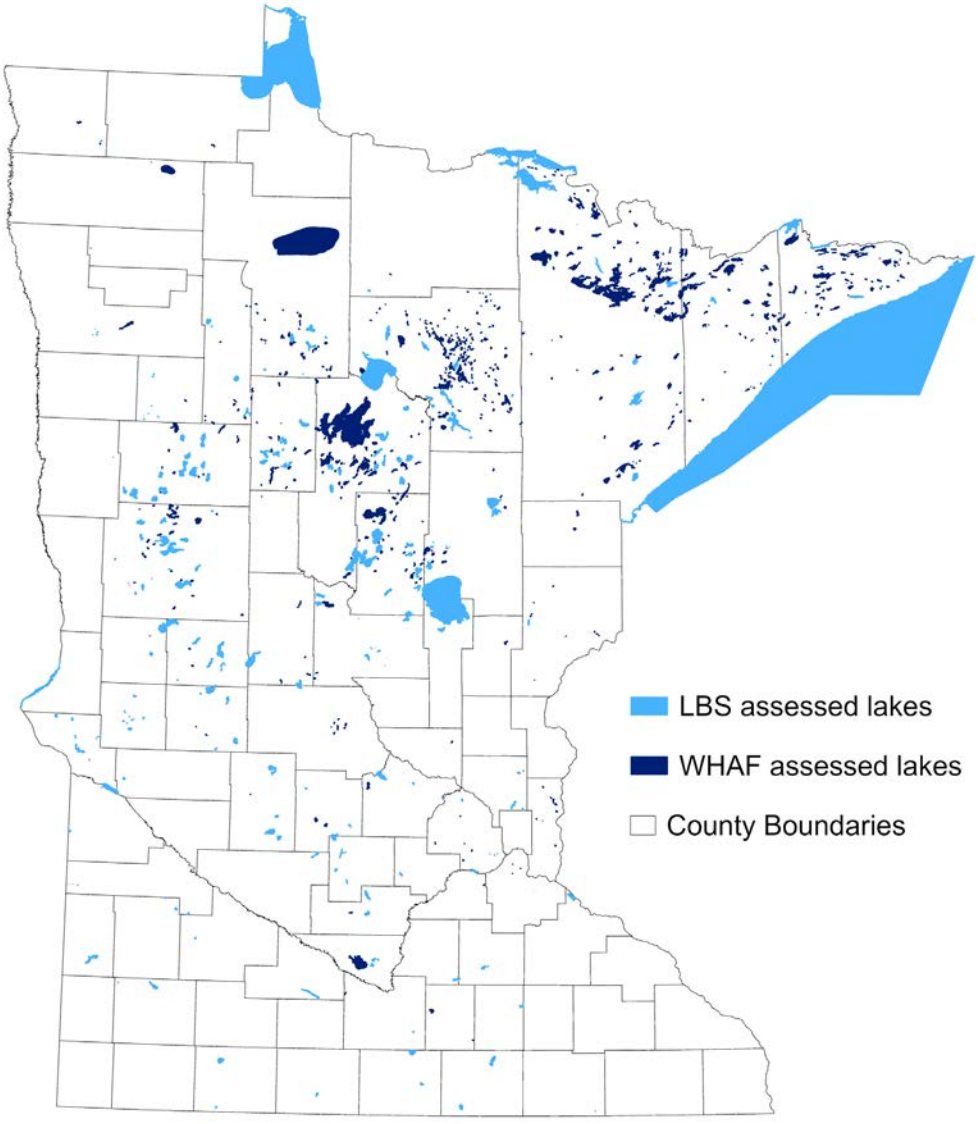


Figure 6.18. Significant Lakes selected from the Watershed Health Assessment Framework (WHAF) Lake Health assessment having overall scores of 75 or greater or biology scores of 70 or greater ("WHAF assessed lakes", dark blue) and lakes with high bird rankings from the Lakes Biological Significance (LBS) assessment ("LBS assessed lakes", light blue).

## Significant Streams

This layer includes stream reaches (WIDS) that met Exceptional Use criteria for fish and/or aquatic invertebrates based on Indices of Biological Integrity (IBI) developed and surveyed by the Minnesota Pollution Control Agency (MPCA, MPCA Index of biological integrity). To depict connectivity of streams on the map, adjacent reaches that met General Use criteria and all streams with order sizes of 5 to 9 were also added (Figure 6.19). While this approach over-represents streams by including those of lower quality, it maintains connectivity between high quality reaches. The scoring step (see below) identifies stream reaches with high IBI scores.

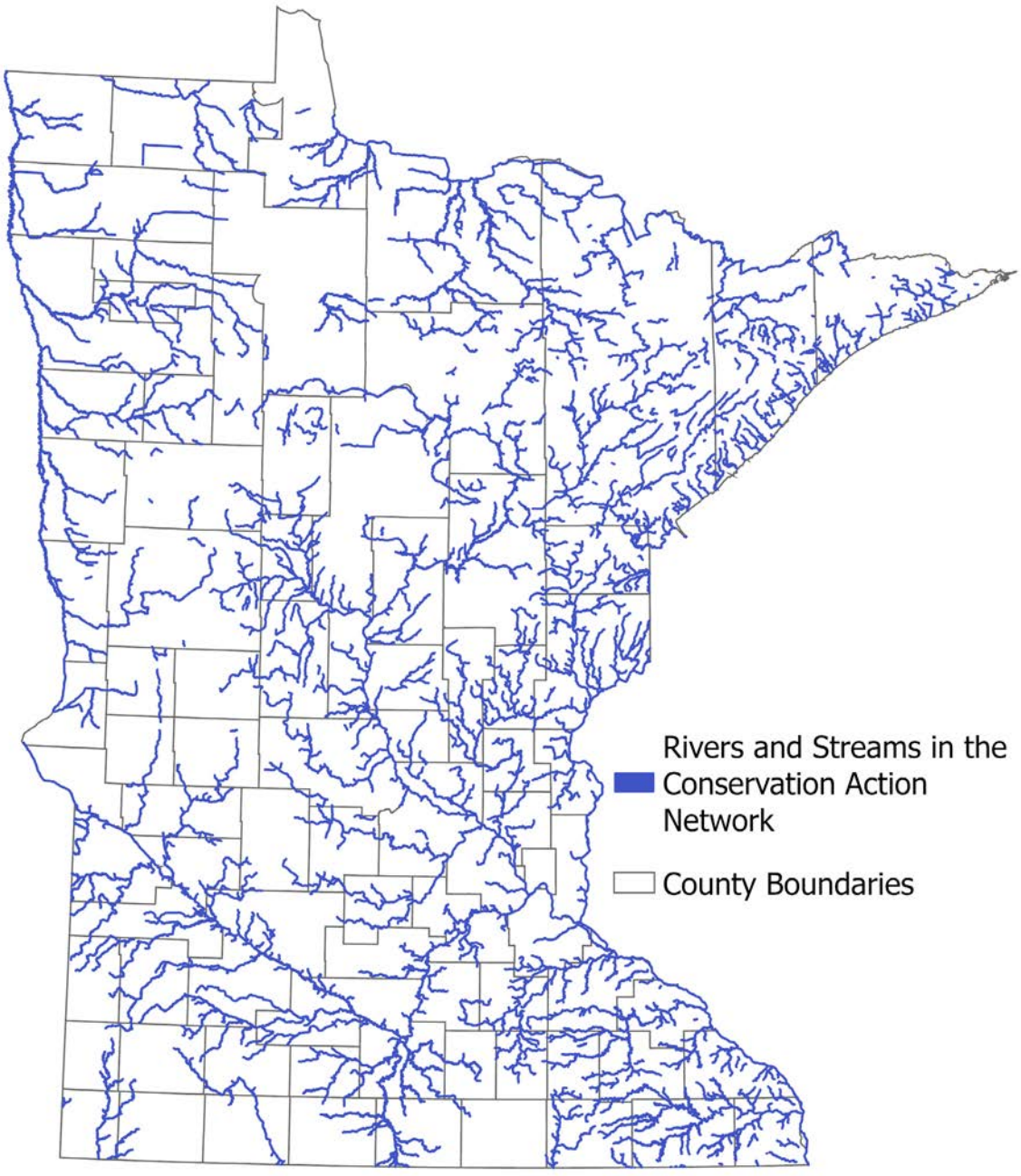


Figure 6.19. Rivers and streams included in the Conservation Action Network. Not all stream reaches depicted are of high quality, as lower quality reaches are included for connectivity. See the scoring layer (Figure 6.6) to identify higher quality streams.

## Ecosystem/Landscape Scale

### Sites of Biodiversity Significance

Sites of biodiversity significance are defined by the presence of high-quality and diverse native plant communities, along with populations of rare plant and animal species, and represent the largest and most intact natural areas within a regional context (MBS Site Biodiversity Significance Ranks). Sites were identified and delineated by staff within the Minnesota Biological Survey (Minnesota DNR) and assigned one of four ranks: poor, medium, high, and outstanding. All high and outstanding sites of biodiversity significance were selected for inclusion in the CAN core (Figure 6.20).

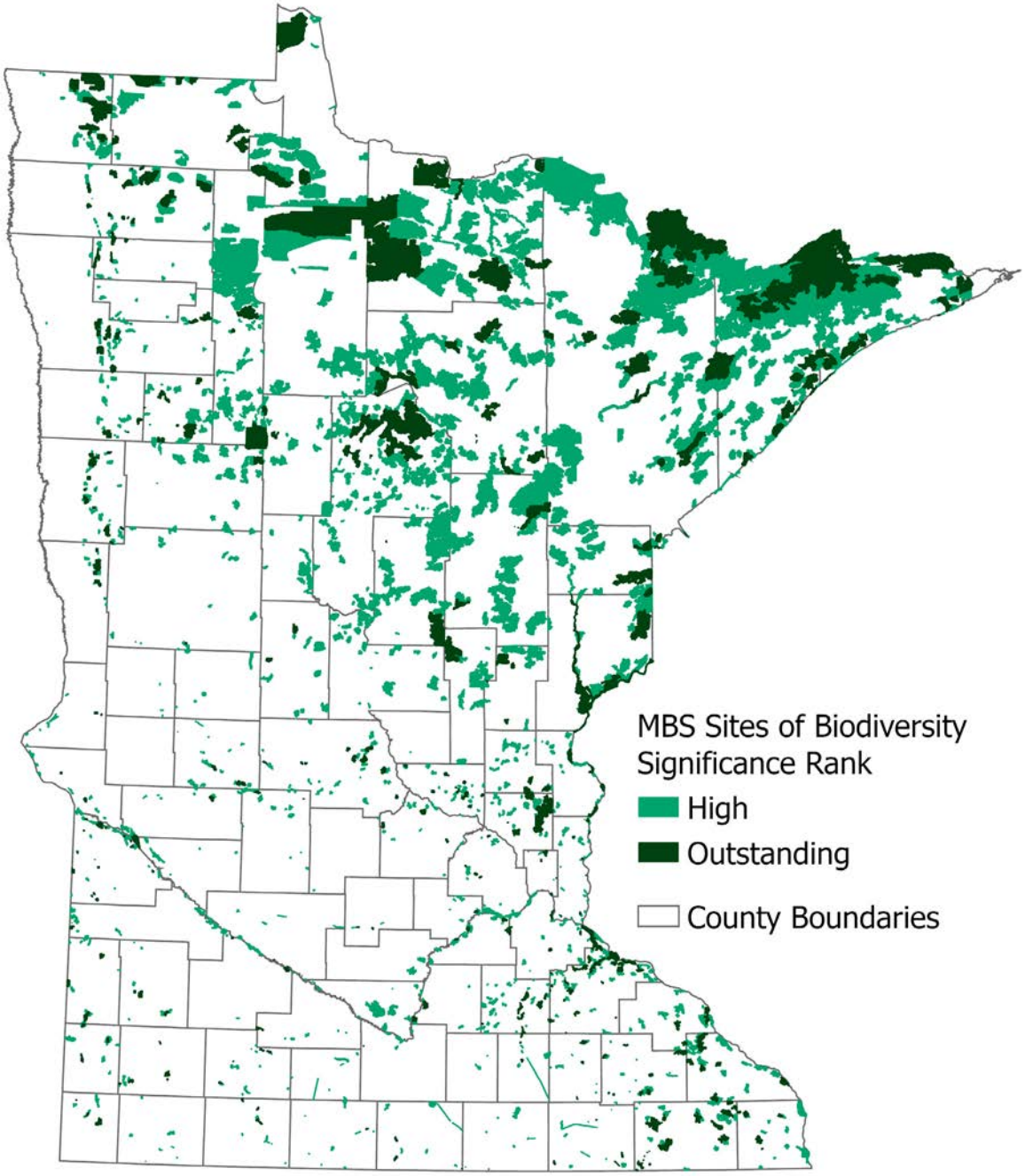


Figure 6.20. Minnesota Biological Survey Sites of Biodiversity Significance ranked high and outstanding and included as a CAN core.

## Minnesota Prairie Conservation Plan Core Areas

Minnesota Prairie Conservation Plan Core Areas represent landscapes with concentrations of native prairie, grasslands and other habitats (Figure 6.21, Minnesota Prairie Conservation Plan). The Minnesota Prairie Conservation Plans corridors and complexes were not included in the CAN, as new connectivity maps developed by TNC and partners were used instead.

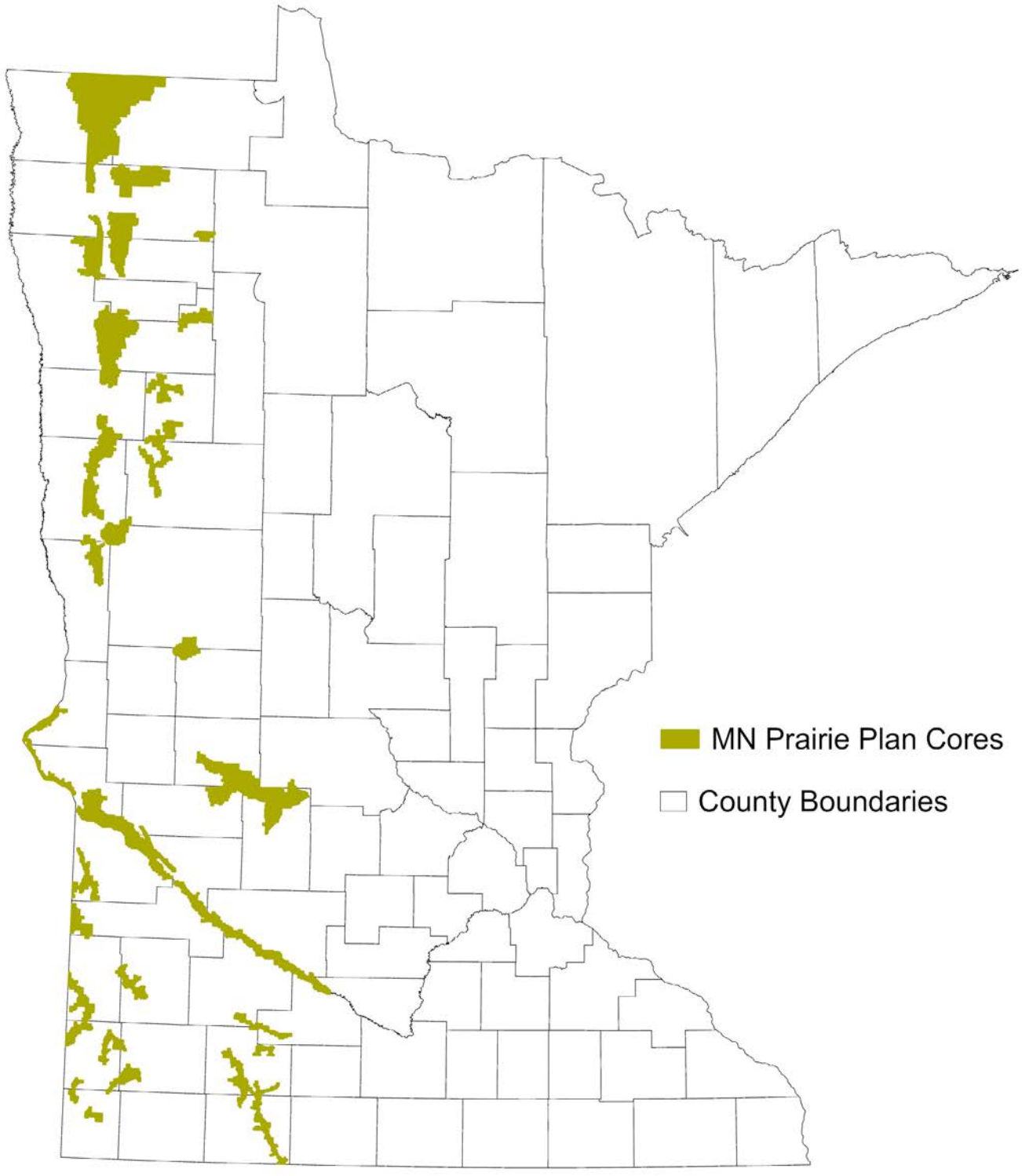


Figure 6.21. Minnesota Prairie Conservation Plan cores.

## Building the Network

The 16 vector GIS data layers (Table 6.1) representing CAN cores were combined, using the union tool in ArcGIS pro 3.3, into an aquatic core layer using the streams and lakes GIS layers (3 layers) as well as a terrestrial core layer using the species, forest, prairie, wetland and ecosystem GIS layers (13 layers). Combined, the composite aquatic and terrestrial layers comprise the base core map for the CAN (Figure 6.1 on page 8 of this chapter). The aquatic and terrestrial layers were then overlayed on top of the prairie and forest connectivity layers to create the unscored Conservation Action Network (Figure 6.22).

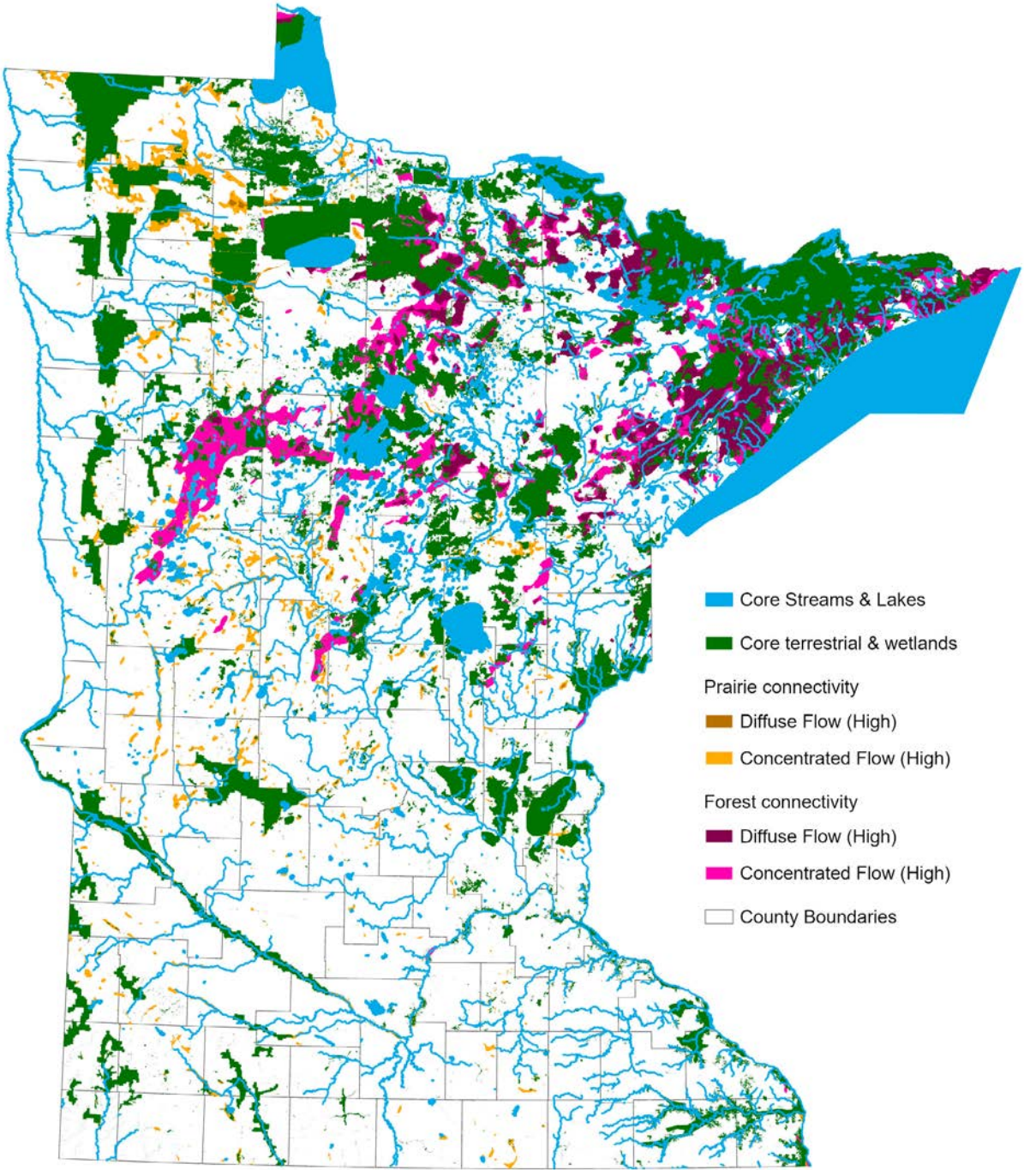


Figure 6.22. The unscored Conservation Action Network (CAN) depicting stream and lake cores (blue), core terrestrial and wetland habitats (Green), prairie connections (orange/brown) and forest connections (purple/pink). The area in Northeastern Minnesota delineating part of Lake Superior represents Minnesota's managed portion of the lake.

## Scoring the Conservation Action Network

To prioritize the information provided in the Conservation Action Network cores and corridors map, we carried out a GIS scoring exercise. The core layers of terrestrial habitat (including wetlands) and aquatic habitat (lakes and streams), and the connectivity layers of forest connectivity and prairie connectivity were each individually scored using five layers that represent the scales of species (All SGCN richness and Endangered and Threatened species richness), habitat (lake health scores/ lakes of biological significance and stream IBIs), and ecosystems/landscape (Sites of Biodiversity Significance, Table 6.2 and Figures 6.3-6.8). These layers were also selected for their statewide coverage and for having attributes that could be expressed as either continuous values (like 0 to 100) or ordinal categories (like Low, Medium, High). Values for layers with continuous variables (Stream IBI and Lake Health Score) were normalized between 0 and 1. Layers with categorical rankings (Sites of Biodiversity Significance and Lakes of Biological Significance) were linearly scaled starting at 0.4 for medium, 0.6 for high, and 0.8 for outstanding. The starting point of 0.4 for medium was used since these data already represent a prioritization, and other areas not represented in this prioritization (e.g. Sites of Biodiversity Significance areas mapped as "below", or areas not mapped at all, have a distribution of levels with a "quality" below these prioritized layers. Also, the maximum value of 0.8 was chosen to slightly reduce the weight since ranks are subjective and a maximum value cannot be determined. We used two scores for species richness – one for all SGCN and the other for Endangered, Threatened, S1 and S2 SGCN. We used this two-pronged approach to add weight for species rarity. Given the highly skewed distribution of the number of species per hexagon (there were many more hexagons with one or 2 species than the hexagons with a high number of species), we used Jenks natural breaks to classify the number of SGCN species in richness hexagons into five categories.

The five scoring layers were intersected individually with each of these layers: terrestrial core, aquatic core, forest connectivity, and prairie connectivity. Each of the five component scores were then summed into an overall score with a possible range of 0 to 4 for any unique polygon. The maximum possible score was 4 despite that there were five scoring layers because the lake and stream scoring layers were spatially distinct and did not overlap. Calculated maximum scores ranged from 3.2 for the prairie connectivity layer to 3.5 for the terrestrial, lake and streams and forest connectivity layers. Composite scores were normalized to the maximum value resulting in the scores ranging from 0 to 1. Since the distributions of scores were skewed to lower values, Jenks natural breaks were applied to derive the six CAN score categories (Table 6.5). Higher scores indicate areas where multiple layers with high values overlap, representing locations with greater SGCN diversity as well as elevated community and ecosystem values. The scored layers were overlayed to create the final scored Conservation Action Network map (Figure 6.8 on page 17 of this chapter).

**Table 6.5. CAN score category and corresponding ranges of score values.**

| CAN score category | Score value range |
|---|---|
| No score | 0.0 |
| Low | 0.01 to 0.30 |
| Low-medium | 0.31 to 0.37 |
| Medium | 0.38 to 0.44 |
| Medium-high | 0.45 to 0.56 |
| High | 0.57 to 1.00 |

# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

## CONSERVATION OPPORTUNITY AREAS

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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Cover Photos: Goats are being utilized to combat regrowth of common buckthorn on dry bluff prairies and surrounding woodlands following removal of eastern red cedar, TJ Boettcher; Field Tour hosted by the Prairie Coteau Conservation Opportunity Area showcasing a grazing collaboration between a producer and Hole in the Mountain Wildlife Management Area

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# Chapter 6. Implementation - Conservation Opportunity Areas

Chapter 6 contains three sections, each of which are applied to guide our conservation work under this Plan. The first, the Conservation Action Network, represents biodiversity and high-quality habitat in our state spatially as a resource to prioritize conservation actions geographically (see Chapter 6 Implementation – Conservation Action Network). Here we describe Conservation Opportunity Areas, which identify locations for partners to focus on-the-ground conservation efforts that build and improve areas in and around the Conservation Action Network. Third, we provide foundational information regarding climate trends in Minnesota and strategies for climate adaptation that are broadly applicable throughout many types of conservation actions (see Chapter 6 Implementation – Climate Adaptation).

## What are Conservation Opportunity Areas?

Conservation Opportunity Areas (COAs) are designated geographic areas where high biodiversity and active partnerships overlap and where on-the-ground actions are focused to directly benefit Species in Greatest Conservation Need (SGCN) and their associated habitats. This network of partnerships provides a non-regulatory approach to help focus and prioritize statewide conservation actions to prevent future Federal or state listing of species and to promote the recovery of species that have already been listed. Partners may include private landowners and non-government organizations as well as federal, state, and local government agencies collaborating to identify, design, and implement coordinated on-the-ground conservation actions that not only benefit SGCNs but help partners reach their specific conservation goals.

## Conservation Opportunity Area Delineation

Locations of COAs are based on core areas of high biodiversity, SGCN, high-quality habitats, and buffers and corridors identified in the Conservation Action Network (CAN). However, not all important areas identified in the CAN have an associated COA, and COA boundaries can also go beyond the CAN. COAs must also include resources such as active and interested partners, and/or funding available to address conservation needs. As a result, many of the COAs expand beyond those priority areas identified in the CAN to incorporate areas where established partnerships are actively collaborating to deliver habitat management projects that can benefit SGCN. These partnership efforts present unique opportunities to capitalize on established working relationships and shared conservation goals to achieve the goals of Minnesota's Wildlife Action Plan (MNWAP).

*Photo: Field Tour hosted by the Prairie Coteau Conservation Opportunity Area showcasing a grazing collaboration between a producer and Hole in the Mountain Wildlife Management Area*

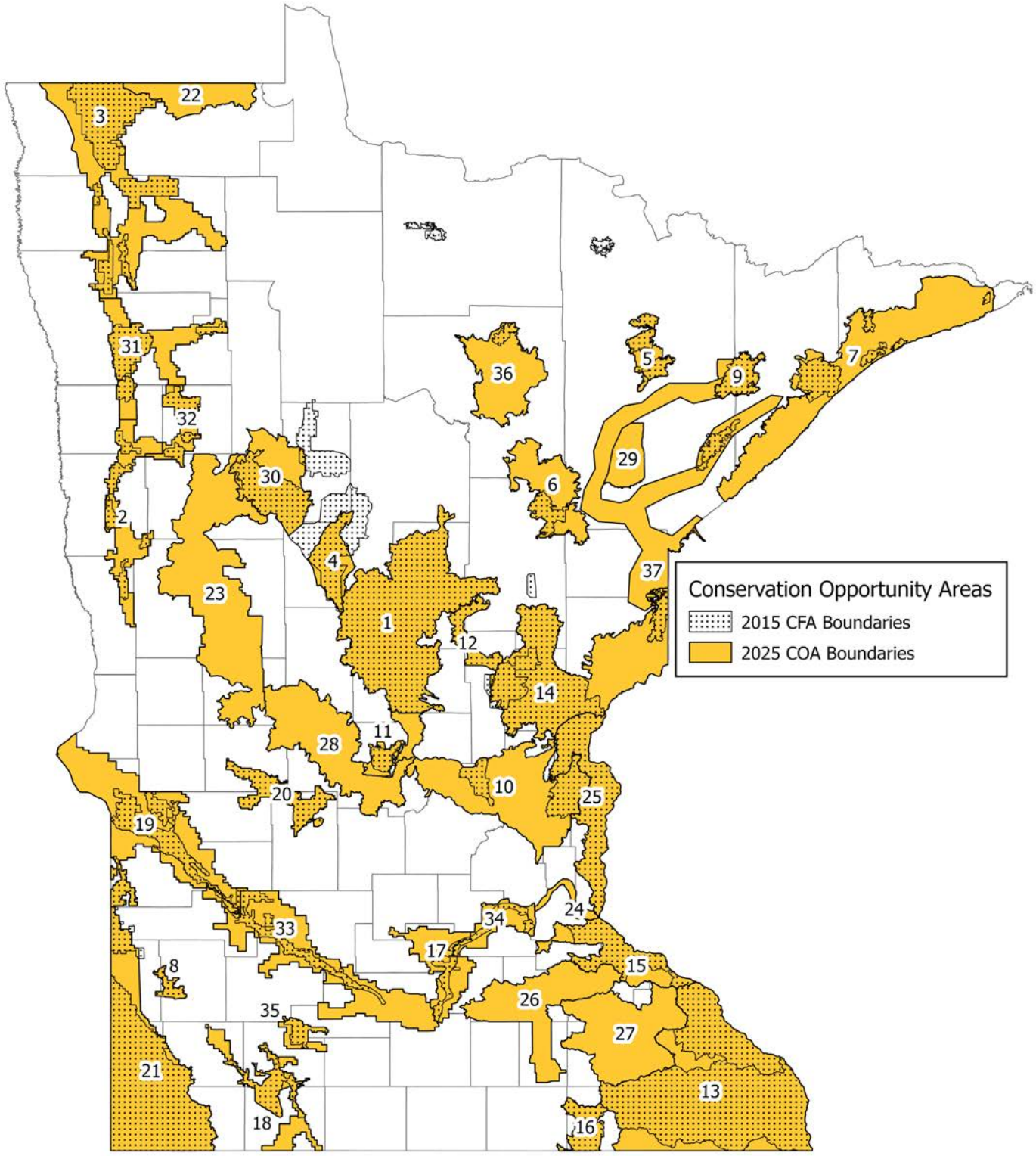


Figure 7. Map of Conservation Opportunity Areas (COAs) for 2025-2035, developed with input from internal and external partners to revise the 2015-2025 Conservation Focus Areas. After some COA's were added, some were merged, some were split, and some were removed altogether, the number of COA's remained at 37. Two additional COAs proposed in north central Minnesota require further consultation with Tribes for delineation and were not depicted on this map.

The 2025 version of Minnesota's Wildlife Action Plan designates 37 COAs, as listed below and depicted in Figure 7.

1. Brainerd Lakes
2. Agassiz Beach Ridges
3. Aspen Parklands
4. Pine Sands-South
5. Big Rice- Lost Lake-Pike Range
6. Cornish Hardwoods
7. North Shore Resilient Forests
8. Altamont Moraine
9. Sand Lake
10. Anoka Sandplain
11. Avon Hills
12. Mille Lacs Morraine
13. Lower Driftless
14. St. Croix River Watersheds-North
15. Vermillion River Watershed
16. Cedar River
17. Lower MN River Valley
18. Des Moines River Valley
19. Lac qui Parle
20. Glacial Lakes
21. Prairie Coteau
22. Roseau River
23. Pothole Lakes
24. Gray Cloud
25. St. Croix River Watersheds-South
26. Cannon River
27. Zumbro River
28. Sauk River
29. Saz-Zim Bog
30. Pine Sands-North
31. Glacial Ridge
32. Mahnomen
33. Upper Minnesota River Valley
34. Metro Big Rivers
35. Cottonwood River-Red Rock Ridge
36. Coon Creek
37. St. Louis-Cloquet Rivers

In addition, two additional COAs were proposed in northern Minnesota: a Northern Minnesota Peatlands COA primarily in Beltrami, Koochiching, and Lake of the Woods Counties, and Sand Plain Pine primarily located in Cass, Beltrami, and Itasca Counties. We did not designate COAs in these two areas due to the proximity to the Red Lake Band of Chippewa and Leech Lake Band of Ojibwe Tribal lands. Further consultation will be needed with the Tribes to determine if a COA would be desirable in these locations. Over the next ten years an increased focus on developing Tribal relationships within the COA framework is an important goal. Understanding Tribal priorities and working to adapt habitat management efforts to help address those priorities is an important part of addressing the habitat needs of SGCN statewide.

## COAs and the CAN Focus Habitat Management Efforts

The footprint of many of the COAs have been expanded since 2015 to incorporate areas where established partnerships are actively collaborating. To focus habitat management efforts within critical areas designated by the CAN, the COAs will prioritize State Wildlife Grant project funding based on the location of the project in relation to the priority areas designated by the CAN. Focusing habitat management, restoration, and protection for SGCN within the CAN will enhance core areas of habitat and connections between habitats. This approach will also allow land managers/ owners to use existing partnerships while focusing their efforts on priority areas.

## Building Relationships, Capitalizing on Opportunities, and Working in Partnership

Since the first SWAP was established in 2005, broad-based collaborative partnerships have proven to be a very successful way to implement natural resource-based projects nationwide. By sharing resources

and working collaboratively to overcome roadblocks, partnerships between federal, state, and local government entities, private landowners, non-government organizations and local stakeholder groups have been able to implement large-scale watershed level projects that cross jurisdictional boundaries as well as smaller site-based projects. Since the COA coordinator position was created 7 years ago, the partnership approach and the relationships built through the local COAs have increased the capacity of the DNR Nongame Wildlife Program to implement effective habitat management, restoration, and improvement projects by facilitating the coordination of management, prioritizing outreach efforts, and targeting technical assistance.

## What Makes a COA Effective?

Effective COAs typically hold partnership meetings at least twice a year. These meetings generally occur in the late winter to plan for the upcoming field season and in fall to evaluate and discuss how much progress was made on various efforts. Besides being an opportunity to conservation projects, the meetings often accomplish the following:

- Develop/update dynamic planning documents to guide partnership efforts.
- Provide opportunities to coordinate the implementation of on-the-ground habitat conservation projects to meet the conservation goals of partner organizations while addressing Wildlife Action Plan objectives.

## Case Study: Build Biodiversity or Bus(t): Grazing, Wildlife, Cover Crops

A field tour was an identified action item by partners of the Prairie Coteau Conservation Opportunity Area in southwest Minnesota. Many of the SGCN are imperiled due to conservation issues related to prairie/grassland loss and fragmentation, stream sedimentation and contamination, channelization, and impoundments which this tour hoped to address. The goal of this field tour was to showcase good examples of management, especially for grazing and cover crops, and to emphasize how these practices can directly or indirectly improve wildlife habitat. The target audience was private landowners and agency personnel. Around forty people attended the tour which started at Southwest Minnesota State University in Marshall, Minnesota and travelled to a local farm that showcased regenerative grazing and cover crops. Breakout sessions at this farm included Grazing for Soil Health, Small Ruminant Economics, Water and Stream Quality, and Bird Use of Cover Crops. The bus then travelled to Hole in the Mountain Wildlife Management Area to showcase a patch-burn grazing operation in partnership with a local agricultural producer. Breakout groups included Effects of Grazing on Nongame Species, and a discussion on forage differences between warm and cool season grasses and goal-oriented grazing.

Funding for this field tour was provided by a USFWS State Wildlife Grant. Partners who were involved in the planning, advertisement, and implementation of the field day included the Minnesota Grazing Lands Conservation Association, the DNR Nongame Wildlife Program, Sustainable Farming Association, Pheasants Forever, Natural Resources Conservation Service, Pipestone Soil and Water Conservation District, and the Minnesota Pollution Control Agency.

*Photo: A producer describes his strip grazing system to a group of attendees at the "Build Biodiversity or Bus(t)-Grazing, Wildlife, and Cover Crops Farm Tour, TJ Boettcher*

- Identify and prioritize potential future projects to be implemented. This could include assessing available resources needed to implement projects, reviewing new information on species and habitats that has become available, defining project effectiveness, and implementing monitoring to evaluate and report on effectiveness.
- Address opportunities for watershed/landscape project planning within the COA and the Conservation Action Network (CAN). This can include considering how management objectives and actions at the site level can be coordinated across sites to sustain or enhance landscape-scale biological diversity and improve the ecological functionality of the habitat types involved.

## Improving Habitat for SGCN While Meeting Shared Objectives

Minnesota has an abundance of habitat management and restoration work being accomplished by state, federal, and local government entities as well as non-government organizations and private landowners.

Conservation Opportunity Areas often contain multiple partnership groups that are actively collaborating on project implementation. Each of these groups may have a slightly different approach to their efforts and/or a slightly different set of habitat types in which they work. While there may be different goals associated with each partner's involvement, each partner is able to bring resources to the table to address those goals while enhancing the overall effectiveness of a project. In most cases, managing habitat for the benefit of SGCN incorporates many of the same land management practices as managing for non-SGCN wildlife. Often just changing the timing of implementation, leaving patches of a specific habitat type untouched, or the implementation of follow-up practices such as reseeding, grazing, burning or mowing can address the needs of SGCN within a project site. Working with partners to coordinate project planning can incorporate these types of practices within the existing framework of the project. In this way, all the partners involved can achieve their intended goals while benefitting a wider range of wildlife species.

Approximately 75% of the land in Minnesota is privately owned. In order to increase connectivity between and improve habitat within the areas delineated by the CAN, an increased capacity to implement conservation work on private lands will need to be developed. The partnership approach that COAs foster has been able to facilitate the implementation of SGCN related conservation work on private lands to date (see the Case Study below). However, to increase that impact over the next ten years, greater capacity for promoting SGCN related conservation on private lands will need to be developed. This could include identifying funding sources, allocating staff, and developing procedures to facilitate the flow of funding to partners and landowners for SGCN conservation work on private lands that emphasizes native biodiversity.

## Conservation Opportunity Areas in Your Area are a Great Starting Place to Direct Conservation Efforts

- Local governments can work together on referencing COAs in land use planning and capitalize on opportunities for conservation within those areas
- Work with property owners whose lands host significant natural features and share and discuss voluntary conservation options ranging from habitat management actions to permanent land conservation
- Become familiar with the rare plants, animals, and habitats that occur within the COA and learn how to better manage their habitats for long-term conservation
- Educate landowners and the public about significant natural areas within the COA and create support for local conservation initiatives to conserve them
- Collaborate with state agencies for funding support

## Case Study: Partnering with Private Landowners for Driftless Habitiat

Many projects are completed on public properties within COAs; however, many agencies and NGO's work with private landowners to implement conservation work on private properties. One private land steward started their conservation journey in 1987 when they bought their first parcel of property in Houston County. The property consisted of agricultural fields, old pastures, and degraded native plant communities. Conservation work began when the land steward received a copy of the Minnesota Conservation Volunteer magazine. In it, they read an article about reforestation and decided they would like to convert one of the old fields to forest, so they partnered with a DNR forester and planted a combination of red and white pine. This was a start, but conversion of the agricultural fields didn't stop there. Many more were enrolled in the Conservation Reserve Program and were planted to a diverse mixture of native grasses and forbs. With many of the fields retired, the land steward began to make a concerted effort to restore the native plant communities on the property. These consisted of oak-hickory forest and woodlands, savanna, and remnant bluff prairie, which were all suffering from non-native species pressure from plants such as honeysuckle and common buckthorn as well as native eastern red cedar on the savanna and bluff prairie. The land steward partnered with several agencies including the NRCS and their Environmental Quality Incentive Program as well as the DNR's Nongame Wildlife Program. Together, efforts were made to first remove the eastern red cedar on the south facing slope of the bluff, and since then, a variety of follow-up treatments including forestry mowing, drone seeding, prescribed fire, and goat grazing have been utilized in an effort to control the woody invasives. These habitats are important for a variety of species near the property including timber rattlesnakes (*Crotalus horridus*) and brown snakes (*Storeria dekayi*). Partnering with private landowners will be crucial for the survival of these species in a landscape where most land is privately owned.

*Photo: Goats are being utilized to combat regrowth of common buckthorn on dry bluff prairies and surrounding woodlands following removal of eastern red cedar, TJ Boettcher*

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Cover Photos: Flooding at Gooseberry Falls State Park; Fish and wildlife friendly and climate-adapted road crossing, Hockamin Creek, Jeff Jasperson, Minnesota Pollution Control Agency

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# Chapter 6. Implementation - Climate Adaptation

Chapter 6 contains three sections, each of which are applied to guide our conservation work under this Plan. The first section explains the Conservation Action Network, which represents biodiversity and high-quality habitat in our state spatially as a resource to prioritize conservation actions geographically. A second section describes Conservation Opportunity Areas, which identify locations for partners to focus on-the-ground conservation efforts that build and improve areas in and around the Conservation Action Network (see Chapter 6 Implementation – Conservation Opportunity Areas). This Climate Adaptation section provides foundational information regarding climate trends in Minnesota and strategies for climate adaptation that are broadly applicable throughout many types of conservation actions.

## Overview

Climate change is a pervasive stressor that influences every habitat and species in Minnesota. As such, integrating climate adaptation strategies into conservation planning is not optional — it is necessary. This plan addresses climate change throughout, with climate-related stressors and actions incorporated into the chapters on Species of Greatest Conservation Need (SGCN), various habitat sub-chapters, and identified as a priority within the public engagement chapter.

This section provides a concise overview of current and projected climate patterns in Minnesota, introduces climate-smart strategies, and includes references to additional resources. Scientific data, concepts, and strategies are presented to support conservation practitioners in adapting their work in a changing climate. Climate was prominently featured in the 2015 Plan, and the trends identified then, such as rising temperature and shifting precipitation patterns, have continued and are clearly depicted in updated charts and statistics.

Increasing temperatures, altered precipitation patterns, more frequent flooding, and changes in winter duration and growing seasons are driving stress across all ecosystems and are addressed in the habitat sub-chapters.

*Photo: Flooding at Gooseberry Falls State Park*

These climate-induced changes are further compounded by other stressors, including invasive non-native species, disease, and challenges related to fire management. These interactions amplify effects on both wildlife and their habitats.

Minnesota's wildlife already faces significant threats from habitat loss, invasive species, fragmentation, and degradation, as well as exposure to pollutants and pathogens. Climate change exacerbates these threats by altering habitat suitability, increasing prevalence of disease and invasive species, and introducing new physiological challenges to SGCN, such as heat stress or phenological mismatches. For example, shifts in seasonal timing can cause key life stages of one species to fall out of sync with those of its food sources or mutualistic partners.

The following content is intended to equip conservation professionals with foundational knowledge, practical strategies, and illustrative examples to help them plan and act effectively in the face of climate change.

Changes in Minnesota's climate are easily detected through historical records and are projected to continue into the future. Climate remains a topic of great interest, with a growing body of scientific literature exploring its effects. In this Plan, we present climate information from global trends to localized profiles for Minnesota's nine sub-regions. We also include references and links to current research efforts aimed to understanding how climate change may affect the state's vulnerable wildlife and habitats. To support the implementation of conservation actions outlined in this SWAP, we will provide climate data as part of our online spatial layers. These will depict seasonal temperature and precipitation patterns across the state, along with deviations from both the 30-year baseline and the full period of record.

In this chapter, we present strategies that can assist in making our conservation work more 'climate-smart' following seven principles from the document, "Voluntary Guidance for States to Incorporate Climate Adaptation into State Wildlife Actions Plans and other Management Plans" (Association of Fish and Wildlife Agencies 2022). These principles include:

1. Fully integrate climate change into SWAPs — ensuring climate adaptation is embedded throughout planning, rather than treated as a standalone section.
2. Adopt forward-looking goals — setting conservation objectives based on projected future conditions instead of only historic baselines.
3. Explicitly link actions to climate vulnerabilities — directly tying conservation actions to identified climate risks and vulnerabilities in species and habitats.
4. Manage for change, not just persistence — planning for ecological transitions and adaptive responses rather than aiming to maintain current conditions forever.
5. Consider broader landscapes and longer timeframes — expanding our planning beyond immediate areas with short time horizons to account for greater-scale shifts.
6. Address uncertainty by considering future scenarios and use of adaptive management — incorporating scenario planning and iterative monitoring to navigate uncertainty in climate projections.
7. Engage diverse partners with climate experience and expertise — collaborating with individuals and organizations that bring climate-specific knowledge and capabilities.

## Building on the two Prior Plans

### 2005-2015 Tomorrow's Habitat for the Wild and Rare

The first SWAP focused generally on habitat loss and degradation but did not focus specifically on climate change.

### Minnesota's Wildlife Action Plan 2015-2025

Climate was identified as a stressor in Minnesota's Wildlife Action Plan 2015-2025, which outlined a range of projected effects on the state's wildlife and their habitats. To inform the Plan, staff reviewed scientific literature and technical reports, and the DNR conducted a climate change vulnerability assessment with habitat experts. This assessment helped identify the habitats most at risk from climate change. The Plan incorporated goals, objectives, and conservation actions aimed at: (1) reducing the effects of current stressors on habitats and species, (2) increasing the resilience of species and habitats, and (3) addressing species-specific vulnerabilities related to life-history traits that heighten sensitivity to stressors.

## Global and National Context

Globally, average temperature has risen approximately 2 degrees Fahrenheit (between 1.7 and 2.2 degrees F° F; 0.95 and 1.20 degrees Celsius) since 1850-1900; these changes are related to the production of greenhouse gasses by human activities that warm the earth's surface and atmosphere (Intergovernmental Panel on Climate Change (IPCC) 2023; Marvel et al. 2023). The sources of those gasses are primarily the burning of fossil fuels for transportation and energy generation, followed by industrial processes, deforestation, and agricultural practices (Canadell et al. 2021). These higher temperatures have already driven sea level rise and caused more frequent natural disasters (IPCC 2023). Currently, up to 3.6 billion people globally live in highly vulnerable climate contexts (IPCC 2023).

In the United States, temperatures have increased more than the global average, as higher latitudes are warming more rapidly than lower ones. Since 1970, average temperatures in the contiguous U.S. have risen by 2.5°F, compared to a global increase of approximately 1.7°F during the same period (Marvel et al. 2023). Winter temperatures in many northern states are rising nearly twice as fast as those in summer (Marvel et al. 2023). Precipitation has also increased, with annual totals across much of the Midwest rising by 5%–15% from 1992 to 2021, relative to the 1901–1960 average (Wilson et al. 2023).

These climatic shifts have contributed to more frequent and intense extreme events, including hurricanes, floods, droughts, and catastrophic wildfires. Such conditions increasingly affect human health and safety, with extreme heat alone linked to over 700 deaths per year nationwide between 2004 and 2018 (Vaidyanathan et al. 2020). Additionally, major disasters are occurring more frequently and causing greater economic and infrastructural damage (National Centers for Environmental Information 2022).

*Photo: Summer storm over calcareous fen on Burke Wildlife Management Area, Megan Benage*

Disaster risk is not evenly distributed, and geographic, socioeconomic and demographic factors all influence vulnerability to extreme events. Some populations face significantly higher risks; for example, older adults and Black Americans are more than twice as likely to die from heat-related illnesses compared to younger individuals or the general population, respectively (Environmental Protection Agency 2022). Discriminatory urban zoning policies have contributed to environmental inequities, with some low-income neighborhoods experiencing temperatures up to 12°F higher during heatwaves than wealthier areas within the same city (Hoffman et al. 2020). These communities also face a substantially greater risk of flooding (Wing et al. 2022).

Rising temperatures, along with corresponding shifts in precipitation patterns, place increasing stress on both natural and built environments affecting people, wildlife, and plant communities. The magnitude of future climate change will depend largely on global greenhouse gas emissions, which could range from aggressive reductions to more likely scenarios based on current policies. These projections estimate an increase in global temperatures of approximately 3.6 to 6.7 ° F (2 to 3.7 ° C) by 2100 (Marvel et al. 2023). Even if emissions were reduced to net zero, residual climate effects would persist due to changes already set in motion, such as elevated ocean surface temperatures, rising sea levels, and diminishing sea ice extent (IPCC 2023).

## Climate Context for Minnesota

Between 1895 and 2020, average temperatures in Minnesota increased by 3.0 °F, while annual precipitation rose by an average of 3.4 inches (Climate Trends). The most significant changes have occurred in recent decades. Compared to 20th-century average, nearly every year since 1970 has been warmer, wetter, or both, and all the top ten warmest and wettest years on record occurred between 1998 and 2020 (Climate Trends).

Winter warming in Minnesota is especially pronounced (see Figure 8.1). In fact, Minnesota has experienced the most significant winter temperature increases of any contiguous U.S. state (Climate Change in Minnesota citing Liess et al. 2022). Since 1895, average temperatures during winter (December through February) have risen two to three times faster than those in summer (June through August) (Climate Trends). The pace of winter warming has accelerated in recent decades. Between 1970 and 2021, average daily winter low temperatures increased more than 15 times faster than average daily summer high temperatures. Since 1985, Minnesota's average winter temperatures have risen by 5.4°F, with average winter low temperatures increasing by 6.8°F (Climate Change in Minnesota). These changes have led to a shorter season of snow cover across the region (Contosta et al. 2020). And Minnesota has lost approximately 10-14 days of lake ice over the past 50 years (MPCA and MDOC 2025).

Heavy rainfall events in Minnesota have become more common and intense than at any point on record. Since 2000, the state has experienced a significant increase in large-scale, extreme rainstorms. Rainfall events that once fell in the 98th percentile (historically among the largest 2% annually) are now occurring more regularly (Climate Trends). The number of very heavy rain events, defined as six inches or more in a single day, has been two to three times greater since 2000 compared to 20th century (Runkle et al. 2022; NOAA National Centers for Environmental Information State Climate Summaries 2022: Minnesota). In addition, a range of extreme weather events including extreme droughts, summer heat waves, severe storms, flooding, and tornadoes caused more than $4 billion in property damage between 2000 and 2012 (Runkle et al. 2022).

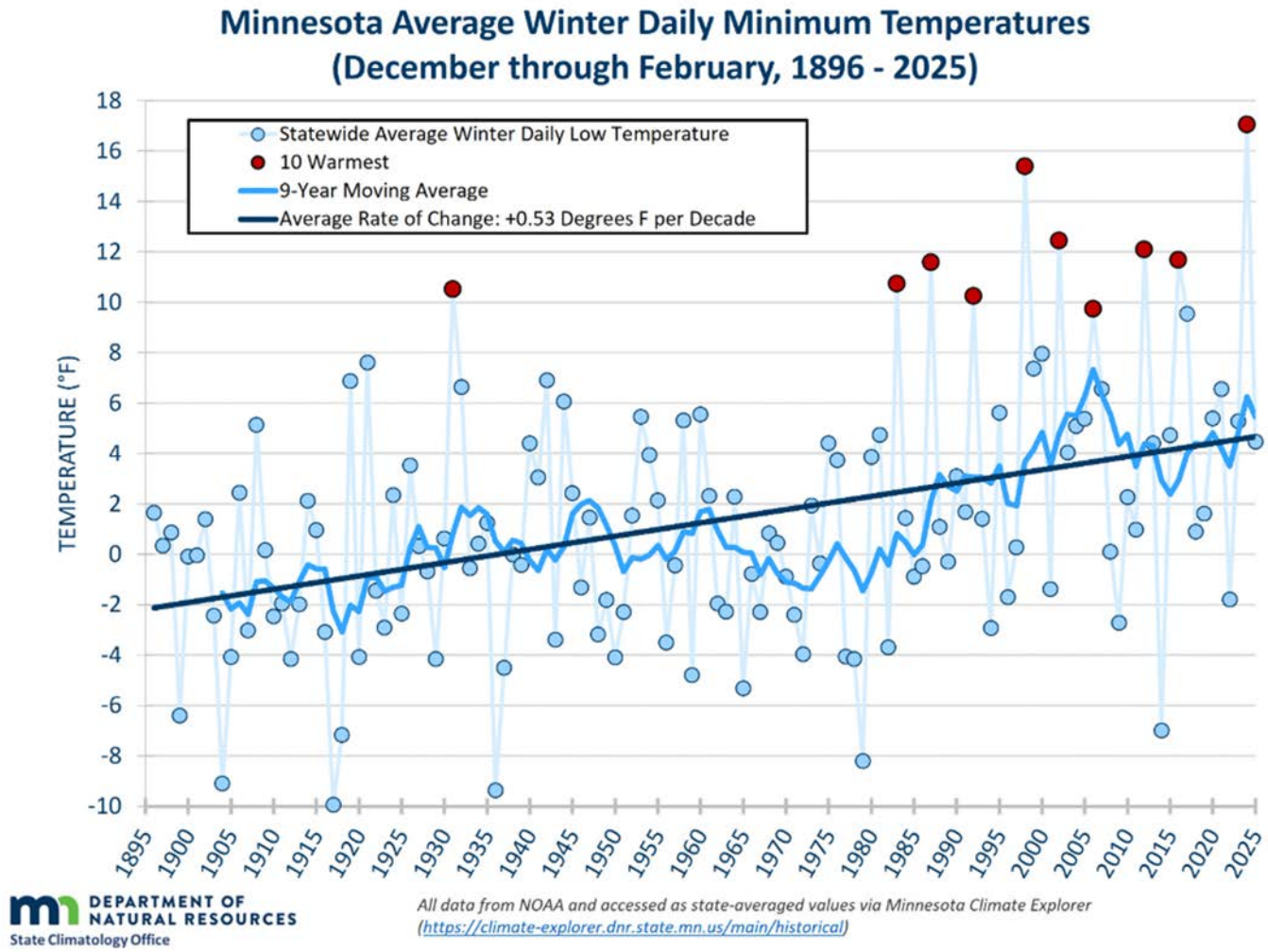


Figure 8.1. Chart depicting increases in Minnesota Average Winter Daily Minimum Temperatures (December through February 1896 – 2025). Figure produced by the DNR State Climatology Office based on data from the Minnesota Climate Explorer.

The DNR recently developed a set of geospatial layers illustrating climatic conditions across the state over the past 30 years (1991 – 2020), known as Minnesota Climate Normal, 1991-2020. These layers are publicly available through the Minnesota Geospatial Commons, a website that provides free and open access to Minnesota spatial data. The layers include annual and seasonal climate summaries, as well as comparisons between the most recent 30-year period and the historical record (1895 – 2020). Figures 8.2 and 8.3 present maps of average annual temperature and precipitation during 1991-2020, in comparison to the long-term historical averages, based on this dataset.

Information about Minnesota's goals and trends regarding greenhouse gas emissions are reported biannually (Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Commerce (MDOC) 2025). Data visualization for the information in that report is provided in a set of graphics online in the Minnesota Greenhouse Gas Inventory.

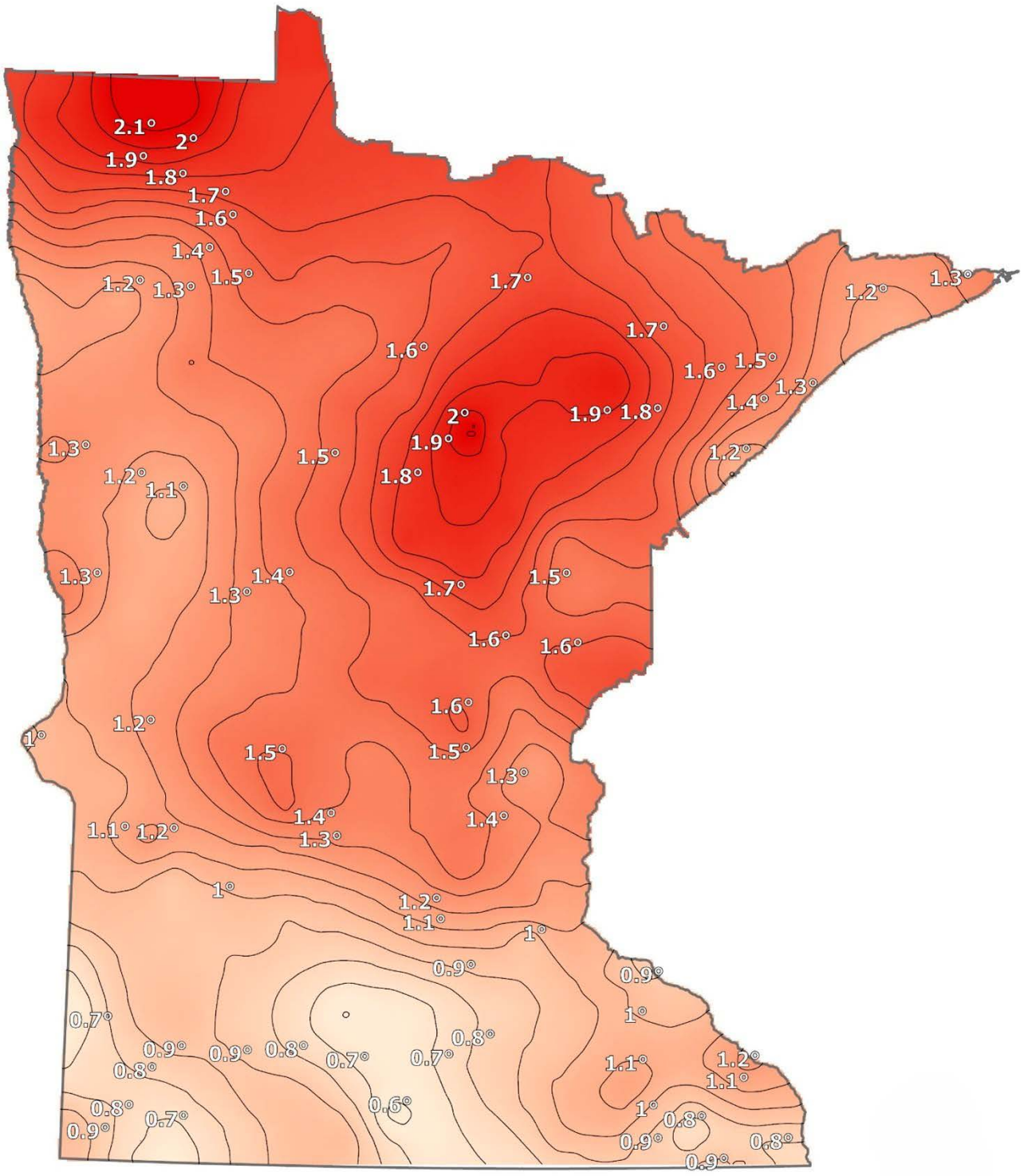


Figure 8.2. Annual average temperatures (1991-2020) deviation when compared to historical average (1895-2020) (DNR Geospatial Commons 2024). Darker red represents areas with greater deviation.

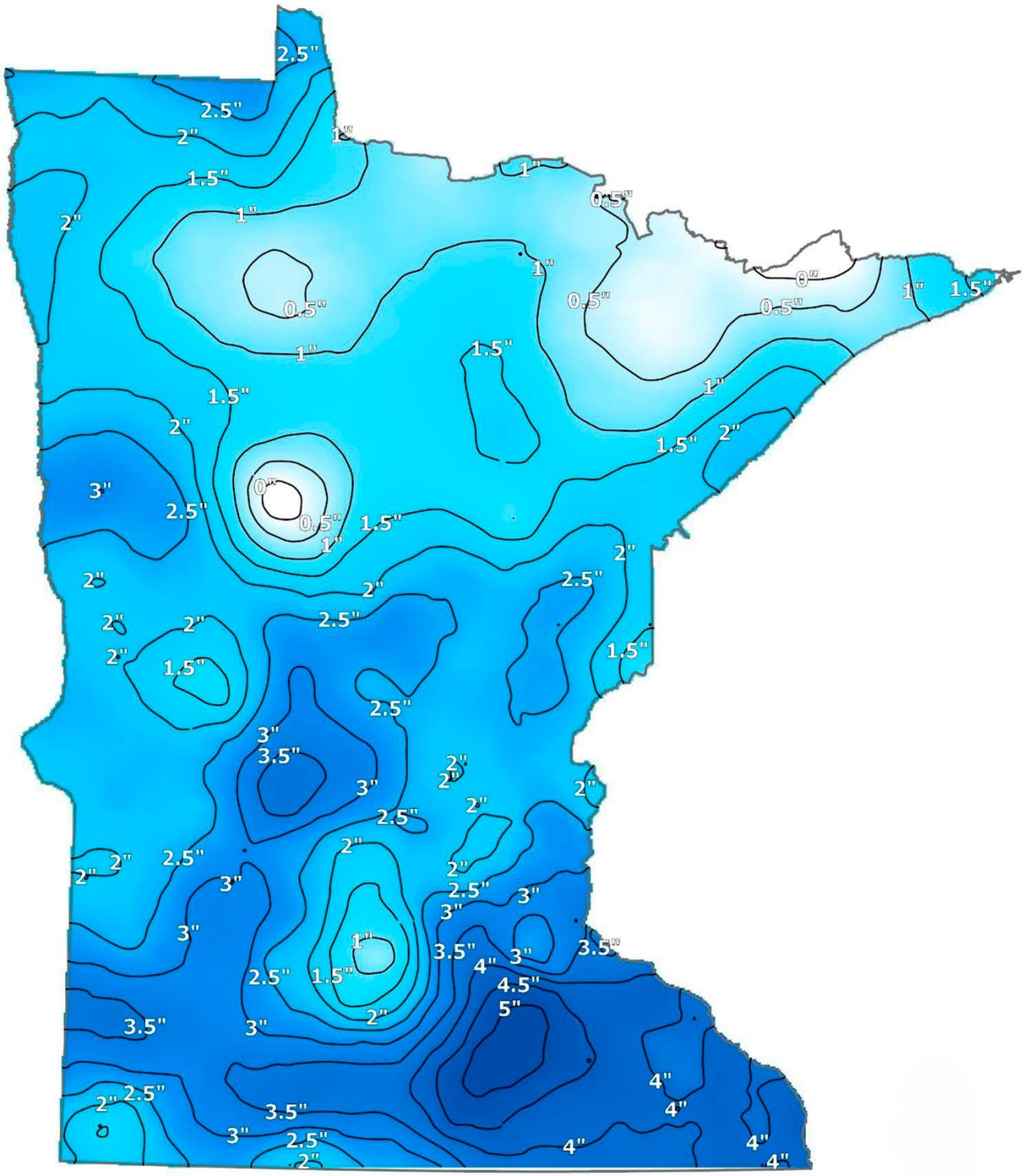


Figure 8.3. Annual average precipitation (1991-2020) deviation when compared to historical average (1895-2020) (DNR Geospatial Commons 2024). Darker blue indicates greater deviation.

## Future Climate Projections for Minnesota

Trends for warmer and wetter conditions are projected to continue into the future (see Figure 8.4). By mid-century (2040-2059), average annual temperatures in Minnesota are projected to increase by 3.8 - 4.5 °F (depending on future emissions scenarios) and average annual precipitation is projected to increase by up to 1.2 inches, depending on the emissions scenario (Coffman et al. 2024; Climate Change in Minnesota). When looking toward the end of century, both temperature and precipitation are projected to continue increasing.

Another valuable source of projected rainfall and temperature data for Minnesota comes from reports developed by the U.S. Geological Survey (USGS) Midwest Climate Adaptation Science Center, prepared in support of State Wildlife Action Planning in the Midwest. These reports include tables that allow users to explore climate projections under different models and greenhouse gas emissions scenarios. They offer comparisons to historical baseline conditions (1971-2000) for both mid-century (2040 -2069) and late-century (2070-2089) timeframes. For example, Table 6.3 presents projected annual temperature changes for the Mixed Wood Plains Ecoregion, which extends through central Minnesota, Wisconsin, and into Michigan (Ratcliffe et al. 2025).

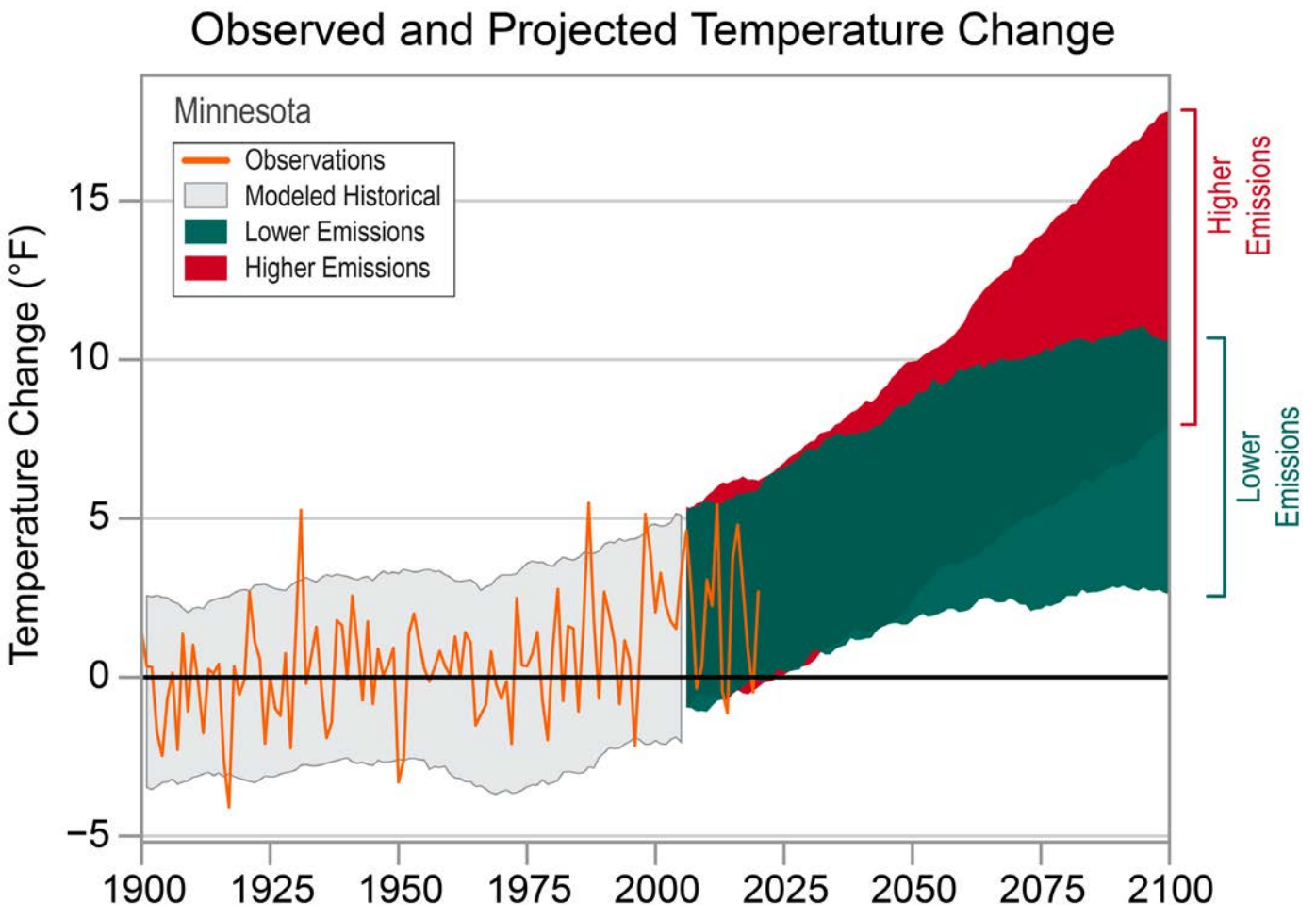


Figure 8.4. Observed and projected temperature changes in Minnesota under "lower" (teal) and "higher" (red) emissions scenarios out to 2100 compared to historical temperature observations (orange). Figure 1 reproduced from Runkle, J., et al., 2022.

**Table 6.3. Reproduced from Ratcliffe et al. 2025. Table 30. Projected changes in annual temperature in the Mixed Wood Plains. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971-2000) and projected annual mean temperature (°F) by mid- (2040-2069) and end of the century (2070-2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected temperature under RCP 8.5 are presented in addition to the mean of all models.**

| Type of model | 1971-2000 Historical | 2049-2069 RCP 4.5 | 2049-2069 RCP 8.5 | 2070-2099 RCP 4.5 | 2070-2099 RCP 8.5 |
|---|---|---|---|---|---|
| Minimum model | 43.7 °F | 46.4 °F (6%) | 47.4 °F (8%) | 47.3 °F (8%) | 50.1 °F (15%) |
| Mean of models | 43.7 °F | 48.9 °F (12%) | 50.5 °F (16%) | 50 °F (14%) | 54.6 °F (25%) |
| Maximum model | 43.9 °F | 51.9 °F (18%) | 53.4°F (22%) | 53.6 °F (22%) | 59.1 °F (35%) |

The timing and intensity of precipitation is also expected to shift, with wetter springs, drier summers, shorter snow seasons, heavier rainfall events, and longer dry periods without measurable precipitation (Climate Change in Minnesota). While weather and climate conditions vary from year to year, long-term trends indicate that overall precipitation increases are expected to continue throughout this century (Climate Trends). An increase in the frequency of severe storms poses challenges for the people of Minnesota, their communities, economies and ecosystems. These effects extend across a wide range of sectors, including water and soil resources, agriculture, stormwater and wastewater infrastructure, public health and safety, waste management, and emergency response systems.

Despite these overall increases in precipitation, it may seem counter-intuitive, but future droughts are likely to become more frequent due to rising temperatures, which accelerate soil moisture loss (Runkle et al. 2022).

For more detailed projections of various climate factors such as temperature, precipitation, humidity, and snow under different future climate scenarios, please refer to the Minnesota CliMAT (Climate Mapping and Analysis Tool). This interactive tool displays modeled climate data across a statewide map and allows users to explore changes over multiple time horizons, helping to visualize how conditions may vary both spatially and temporally.

## Climate Projections by Region within Minnesota

In 2024, the Minnesota Climate Adaptation Partnership released a set of regional climate summaries for each of the state's nine regions. These detailed accounts explain observed changes in summer and winter temperatures and precipitation patterns over the past century (since 1895), along with projected changes for coming decades. Each summary also highlights key climate-related effects on water resources, human health, tribal lifeways, agriculture, and tourism and recreation. Use the links below to access the climate profile for your region of the state.

1. Northwest — Kittson, Roseau, Marshall, Polk, Pennington, Clearwater, Red Lake, Norman, Mahnomen, Clay, and Becker counties
2. North Central — Lake of the Woods, Beltrami, Koochiching, Itasca, Cass, and Hubbard counties
3. Northeast — St. Louis, Lake, and Cook counties
4. West Central — Otter Tail, Wilkin, Grant, Douglas, Traverse, Stevens, Pope, Big Stone, Swift, Lac qui Parle, Chippewa, and Yellow Medicine counties
5. Central — Wadena, Todd, Morrison, Benton, Stearns, Sherburne, Kandiyohi, Wright, Meeker, McLeod, Carver, Renville, Scott and Sibley counties
6. East Central — Aitkin, Crow Wing, Carlton, Pine, Mille Lacs, Kanabec, Isanti, Chisago, Anoka, Washington, Hennepin, and Ramsey counties
7. Southwest — Redwood, Lincoln, Lyon, Pipestone, Murray, Cottonwood, Rock, Nobles, and Jackson counties
8. South Central — Le Sueur, Rice, Brown, Nicollet, Blue Earth, Waseca, Steele, Watonwan, Martin, Faribault, Freeborn counties
9. Southeast — Dakota, Goodhue, Wabasha, Dodge, Olmsted, Winona, Mower, Fillmore and Houston counties

## Climate and Species in Greatest Conservation Need

A number of reports have identified characteristics that can increase the sensitivities of species or populations to climate change (e.g., National Fish, Wildlife, and Plants Climate Adaptation Partnership [Pellicciotto et al. 2012]; Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans [Staudinger et al. 2015]; Persist in place or shift in space? Evaluating the adaptive capacity of species to climate change [Thurman 2022]; and Wisconsin Initiative on Climate Change Impacts [Wisconsin's Changing Climate: Impacts and Solutions for a Warming Climate 2021]).

*Photo: Moose, a Species in Greatest Conservation Need stressed by a warming climate*

Such characteristics include the following:

- Highly specialized habitat requirements.
- Dependencies on interspecific interactions (host plants or animals).
- Temperature limits or having narrow environmental tolerances.
- Isolated, rare, or declining populations with poor dispersal abilities.
- Long generation times, low fecundity, or reproductive potential.
- Narrow or restricted distribution.
- Special sensitivity to pathogens.
- Sensitivity to human disturbance.

An assessment of wildlife vulnerability to climate change in Wisconsin identified several key patterns (LeDee and Ribic 2015). Amphibians and reptiles were found to be most vulnerable, primarily due to their dependence on specialized habitats microhabitats, and environmental cues. Among birds, approximately two-thirds of the 236 species assessed were considered climate-sensitive, as many have narrow environmental tolerances that are likely to be exceeded under future conditions. Mammals were projected to be affected largely due to increased risks from disease and parasitism (LeDee and Ribic 2015).

## Birds

Studies have documented that some bird species are arriving earlier at their breeding grounds across the northern U.S., a trend linked to climate change (Butler 2003; Wilson 2013). For migratory species, phenological mismatches — when the availability of resources such as food are no longer aligned with species' migratory or breeding cues — are a growing concern. The scarlet tanager (*Piranga olivacea*), for example, has been identified as vulnerable to shifting seasonal patterns and the mistiming of spring conditions (Zumeta & Holmes 1978).

While some species are negatively affected, others may benefit from a warming climate. In New Hampshire, black-throated blue warblers (*Setophaga caerulescens*) were observed initiating breeding earlier during warmer springs. Early breeders were more likely to produce a second brood, resulting in higher overall reproductive success (Townsend et al. 20fe13). et

Conversely, species such as the Canada warbler (*Cardellina canadensis*) are projected to shift their range northward in tandem with the retreat of the boreal and northern hardwood forests they depend on. Under the most severe climate projections, this species could face complete extirpation from the northeastern U.S. (Rodenhouse et al. 2008). Similar declines are anticipated for other bird species that inhabit montane spruce-fir forests at the southern edge of their range in the Midwest and Northeast. These include spruce grouse (*Alcipennis canadensis*), three-toed woodpecker (*Picoides tridactylus*), black-backed woodpecker (*P. arcticus*), yellow-bellied flycatcher (*Empidonax flaviventris*), gray jay (*Perisoreus canadensis*), boreal chickadee (*Poecile hudsonica*), ruby-crowned kinglet (*Corthylio calendula*), blackpoll warbler (*Setophaga striata*), and white-winged crossbill (*Loxia leucoptera*) (Rodenhouse et al. 2008).

A study by Culp et al. (2017) completed a detailed climate change vulnerability assessment for 46 migratory birds of the Great Lakes and Upper Midwest region, including a variety of types from waterbirds to warblers. Their analysis explicitly considered the full annual life cycle for these migratory species. They classified 10 (20%) of the species as vulnerable to climate change, including six of Minnesota's SGCN: red-necked grebe, common tern, Forster's tern, black tern, eastern whip-poor-will, and black-throated blue warbler. In most cases the breeding season appeared to be when birds were faced with the greatest vulnerability to climate change; however, in some cases including the migratory and wintering habitat exposure increased species' overall vulnerability. Two species,

the black tern and Forster's tern, faced high vulnerability on both the winter and breeding grounds. They also distinguished species which had background risk that increased their vulnerability from those that were more specifically more sensitive to climate changes.

*Photo: Spruce grouse, Red Lake Wildlife Management Area, Beau Liddel*

In 2019, National Audubon Society conducted an assessment of climate change and anticipated effects on North American birds entitled Survival by Degrees: 389 Bird Species on the Brink. Using more than 70 data sources, 140 million bird records, and information on vegetative cover, land use, and climate, the researchers modeled distributional changes to birds under three global warming scenarios based on the 2014 Intergovernmental Panel on Climate Change. They include a 1.5°C warming above preindustrial levels (which is considered imminent between 2030 and 2052 if no climate change mitigation measures are taken); a 2° C warming (which could happen as soon as 2050); and a 3°C warming scenario (which could occur by 2080). Distribution maps for each species for each of the three warming scenarios are available and can be used to assess effects at the national, regional and state level.

Pfannmuller et al. (2024) assessed the predicted results for Minnesota species. They designated a species as extirpated at a given warming scenario when the NAS models portrayed the absence of any current or newly available "thermal breeding range" for the species in Minnesota. At the lowest warming scenario (1.5°C), the models predicted the extirpation of 27 breeding birds from Minnesota. The vast majority of these species are dependent on the northern boreal forests of the Laurentian Mixed Forest Province. They include such SGCN as the spruce grouse (*Canachites canadensis*), great gray owl, olive-sided flycatcher (*Contopus cooperi*), and Cape May warbler. At the 2°C warming scenario Minnesota may lose a total of 41 breeding birds including the SGCN American goshawk, evening grosbeak, and LeConte's sparrow and a total of 66 species at the 3°C warming scenario including the SGCN lesser scaup (*Aythya affinis*), red-necked grebe (*Podiceps grisegena*), and Franklin's Gull (*Leucophaeus pipixcan*).

## Turtles

Studies of the Blanding's turtle (*Emydoidea blandingii*) have shown that rising temperatures are correlated with declines in habitat suitability, though these effects may be either mitigated or intensified by human land-use decisions (Millar & Blouin-Demers 2012). Similarly, research on wood turtles (*Glyptemys insculpta*) in Massachusetts found that annual flooding displaced nearly half of a subpopulation, increased mortality rates, and reduced reproductive success. With flood events projected to become more frequent and intense, the situation may be further exacerbated by impervious surfaces and the hardening of upstream riverbanks (Jones & Sievert 2009).

Another important consideration for turtles is temperature-dependent sex determination. As nest temperature plays a key role in determining the sex of hatchlings, there is growing concern that climate change could skew sex ratios toward either females or males, depending on the species' specific thermal thresholds. However, for some species such as the eastern box turtle (*Terrapene carolina carolina*), the degree of atmospheric warming required to significantly alter nest temperatures and affect sex ratios is not anticipated until later in the century (Savva et al. 2010).

A recent assessment of Adaptive Capacity of Midwest SGCN completed by the University of Michigan in association with other states is described under Principle Number Three below.

Species shifting ranges in response to changing climate norms has already been seen and is continuing. Corridors for dispersal and connectivity of habitats is essential for supporting these movements. This is a fundamental function of the Conservation Action Network, to facilitate landscape-scale ecological connectivity. Species movements in response to climate change are already apparent. There is evidence that major changes in species composition and ecological system structure and functions (primary productivity and nutrient cycling) are occurring as a result of plant and animal range shifts (Grimm et al. 2013). Mastrandrea et al. (2010) summarized evidence from 45 studies that indicated significant changes in the timing of life-cycle events for a wide range of plant and animal species. These changes could result in the unavailability of essential food resources during critical life-history stages. The unavailability of a resource during peak migration periods, for example, could reduce the size of the population over time and potentially contribute to its extinction.

When available, we integrate information regarding potential climate effects on Minnesota SGCN into the SGCN species group sub-chapters and recommend climate-smart conservation actions.

## Climate Assessments for Minnesota's Habitats

Each of the habitat sub-chapters in this Plan addresses the context of a changing climate. Where available, we incorporate climate assessments developed through the State Wildlife Action planning in the Midwest project, conducted by the USGS Midwest Climate Adaptation Science Center (MWCASC). This project was specifically designed to support State Wildlife Action Plans in the Midwest by providing climate-relevant information for major habitats, along with climate change profiles for selected SGCN. The assessments offer provide a comprehensive overview of climate stressors, trends, and projected changes across multiple scenarios for each ecoregion and its associated major natural habitat types. Each includes a literature review/ synthesis of direct and indirect climate change effects on habitats and their key or dominant species, a literature-based review of ecological vulnerabilities, and a detailed overview of recommended climate adaptation strategies relevant to each habitat and the threats they face.

The climate assessments are being prepared for seven ecosystem types, listed below, the first four of which are available at the time of this publication and the remaining ones to be incorporated when available:

1. Temperate Flooded & Swamp Forest
2. Appalachian Interior Northeast Mesic Forest
3. North American Bog & Fen
4. Eastern North American Temperate Freshwater Marsh, Wet Meadow & Shrubland
5. Central and Eastern North American Grassland & Shrubland
6. Central Interior Oak Forest, Woodland, and Savanna
7. Laurentian-Acadian Northern Hardwood – Conifer Forest

We integrated findings from these ecoregional assessments into our corresponding habitat chapters where available. Please note that not all assessments were complete as of July 2025).

Another analysis of projected climate change effects on Minnesota's grassland and wetland habitats was conducted by MWCASC-affiliated researchers at the University of Wisconsin. A summary of that analysis is presented in the Prairie and Other Grasslands sub-chapter.

There are several great resources regarding our climate change in our forests, including Climate Change and Minnesota's Forests prepared by the Minnesota Forest Resources Council, which includes sections on recommended management actions management to increase climate adaptability and resilience in our forests. There is work on increasing the adaptive capacity of conifer forests in Minnesota (White et al., 2020).

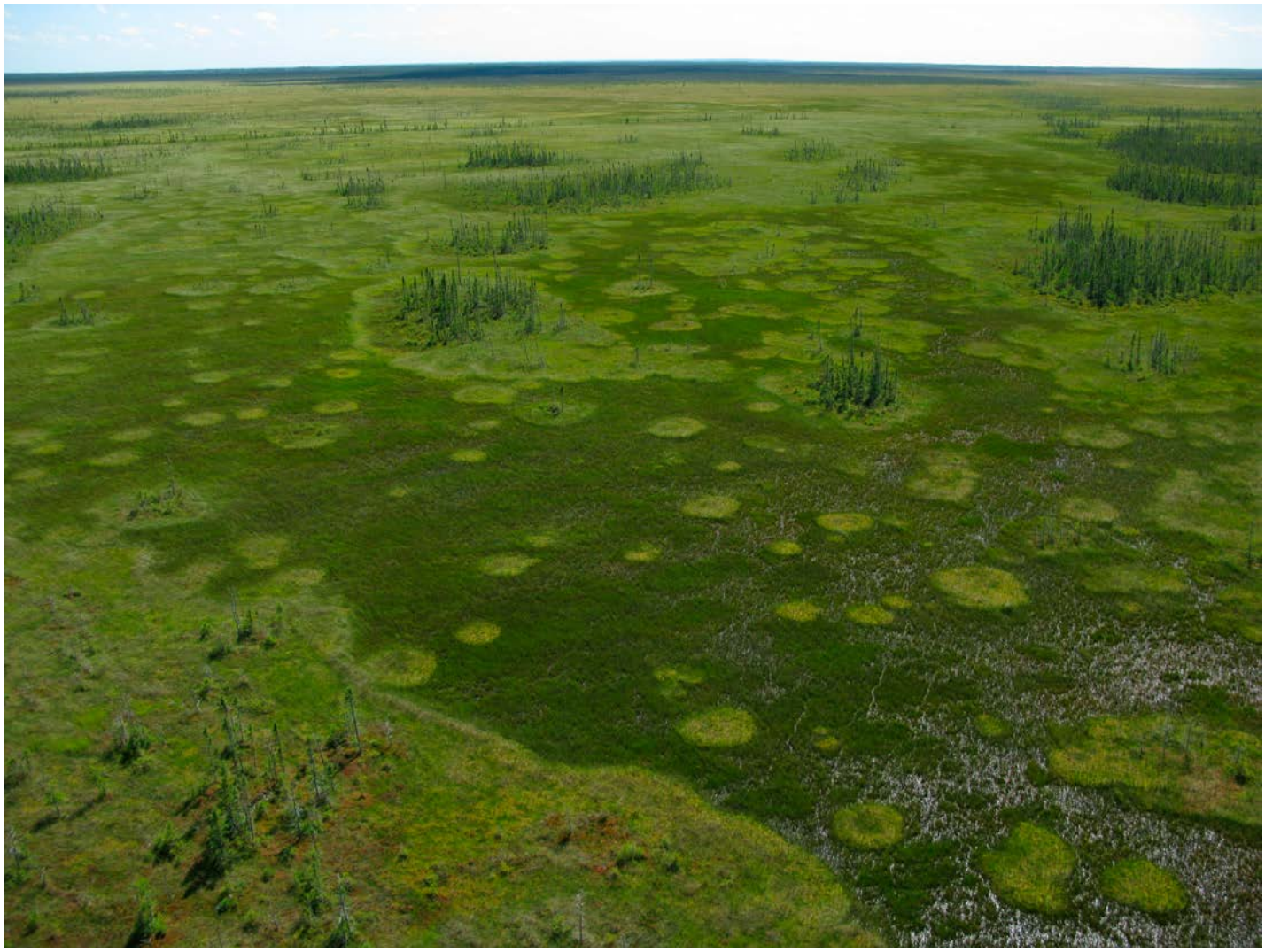

*Photo: Peatlands, a habitat type vulnerable to climate change*

## Climate-smart Strategies and Actions

In this section, we reference the document, "Voluntary Guidance for States to Incorporate Climate Adaptation into State Wildlife Actions Plans and other Management Plans" (Association of Fish and Wildlife Agencies 2022). These are the six Principles highlighted in the guidance document:

1. Fully integrate climate change into SWAPs.
2. Adopt forward-looking goals.
3. Explicitly link actions to climate vulnerabilities.
4. Manage for change, not just persistence.
5. Consider broader landscapes and longer timeframes.
6. Address uncertainty by considering future scenarios and use of adaptive management.
7. Engage diverse partners with climate experience and expertise.

### 1. Fully Integrate Climate Change into SWAPs

As outlined in the sections above, climate change considerations are integrated throughout the SWAP. For Species in Greatest Conservation Need (SGCN), climate change effects were considered as part of the conservation status assessment (S-rank) process and are also reflected in the list of stressors discussed within each SGCN species group sub-chapter. Within the habitat sub-chapters, projected changes in temperature, precipitation, and hydrology are considered within the standard list of ecological stressors. Climate education and outreach are discussed in Chapter 4: Public Engagement, highlighting the importance of building public awareness and capacity for climate resilience. In Chapter 5: Monitoring, we identify opportunities to better integrate climate considerations into survey, monitoring, and research efforts, supporting a more adaptive and climate-informed approach to conservation.

### 2. Adopt Forward looking Goals

A key theme in climate-informed ecological conservation is the importance of managing habitats and ecosystems for resilience — the capacity to remain diverse and functionally robust under a wide range of future conditions. Given the projected magnitude of changes in temperature, seasonality, and precipitation, managing for pre-contact or historical conditions may be feasible in some cases, but not universally achievable.

As a result, there is a growing shift in perspective from aiming to restore pre-settlement conditions, toward defining new conservation goals that prioritize biodiversity, ecosystem function, and the delivery of ecosystem services, even when these outcomes yet may deviate from historic baselines. This adaptive approach acknowledges the dynamic nature of ecosystems in a changing climate and supports more flexible, forward looking management strategies.

### 3. Explicitly Link Actions to Climate Vulnerabilities

Linking conservation actions to the specific climate vulnerabilities of SGCN, habitats, or ecosystems is a powerful effective way to prioritize efforts where they are likely to have the greatest impact. Climate change vulnerability assessments consider three key components: exposure (the magnitude and rate of climate change a species or habitat is likely to experience), sensitivity (the degree to which it is affected by those changes), and adaptive capacity (ability to cope with, persist through, or adjust to those changes) (Glick et al. 2010; Thurman et al., 2020, see also NatureServe's Climate Change Vulnerability Index: Species). A more detailed framework for evaluating adaptive capacity was developed by Thurman et al. (2022), who categorized species traits into two adaptive pathways: the capacity to 'persist in place' and the capacity to 'shift in space.'

A major regional effort to assess climate vulnerability and adaptive capacity was conducted by the Michigan Natural Features Inventory in partnership with the Michigan Department of Natural Resources, Nebraska Game and Parks Commission, and the U.S. Geological Survey, with Minnesota DNR serving in an advisory capacity. Funded by a Competitive State Wildlife Grant from the U.S. Fish and Wildlife Service, the project evaluated assessed climate vulnerability and adaptive capacity of 400 Midwest SGCN using a rapid assessment tool focused on 37 life-history traits related to climate vulnerability and resilience (Earl et al., 2024). Of the total, 142 Minnesota of Minnesota's SGCN were included: 6 amphibians, 45 birds, 11 fish, 41 insects, 11 mammals, 22 mollusks, and 6 reptiles. The species groups with the lowest average adaptive capacity scores were invertebrates, with insects scoring lowest, followed by mollusks. Among Minnesota's SGCN, 91 species were ranked as having moderate adaptive capacity, 24 as moderately high, 27 as moderately low, and none were ranked as having low or high adaptive capacity. Notably, a greater number of invertebrates were rated as moderately low in adaptive capacity, while amphibians, birds, and mammals tended to fall into the moderately high category (see Figure 8.5).

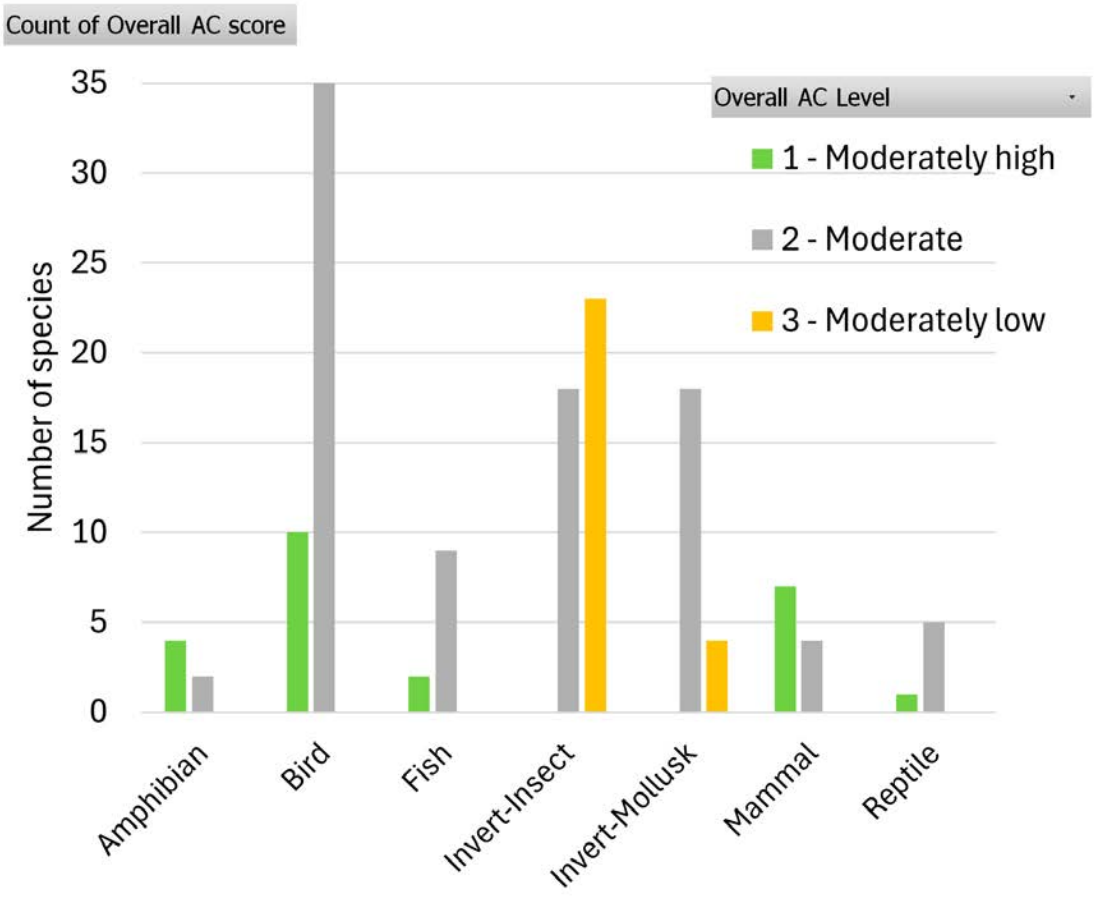


Figure 8.5. Graph indicating the overall adaptive capacity assessment scores for Minnesota SGCN evaluated in the Michigan-led adaptive capacity assessment study (based on supplemental materials from Earl, D., et al., 2024).

The 37 life-history traits considered in the adaptive capacity assessment are organized into seven thematic groups: life history, demography, distribution, movement, evolutionary potential, ecological role, and abiotic niche. The traits within each group are evaluated to produce a sub-score for that category, which together inform an overall assessment of a species' adaptive capacity. For example, traits related to distribution and movement reflect a species' ability to shift its range in response to changing climate conditions (i.e., shift in space), whereas attributes within life history and demography often indicate a species' ability to persist in place despite climate stressors (Thurman et al., 2020). The adaptive capacity assessment tool generates visualizations of these trait groupings in a circular graphic format, offering a clear depiction of how different attributes contribute to a species' adaptive capacity (see Figure 8.6).

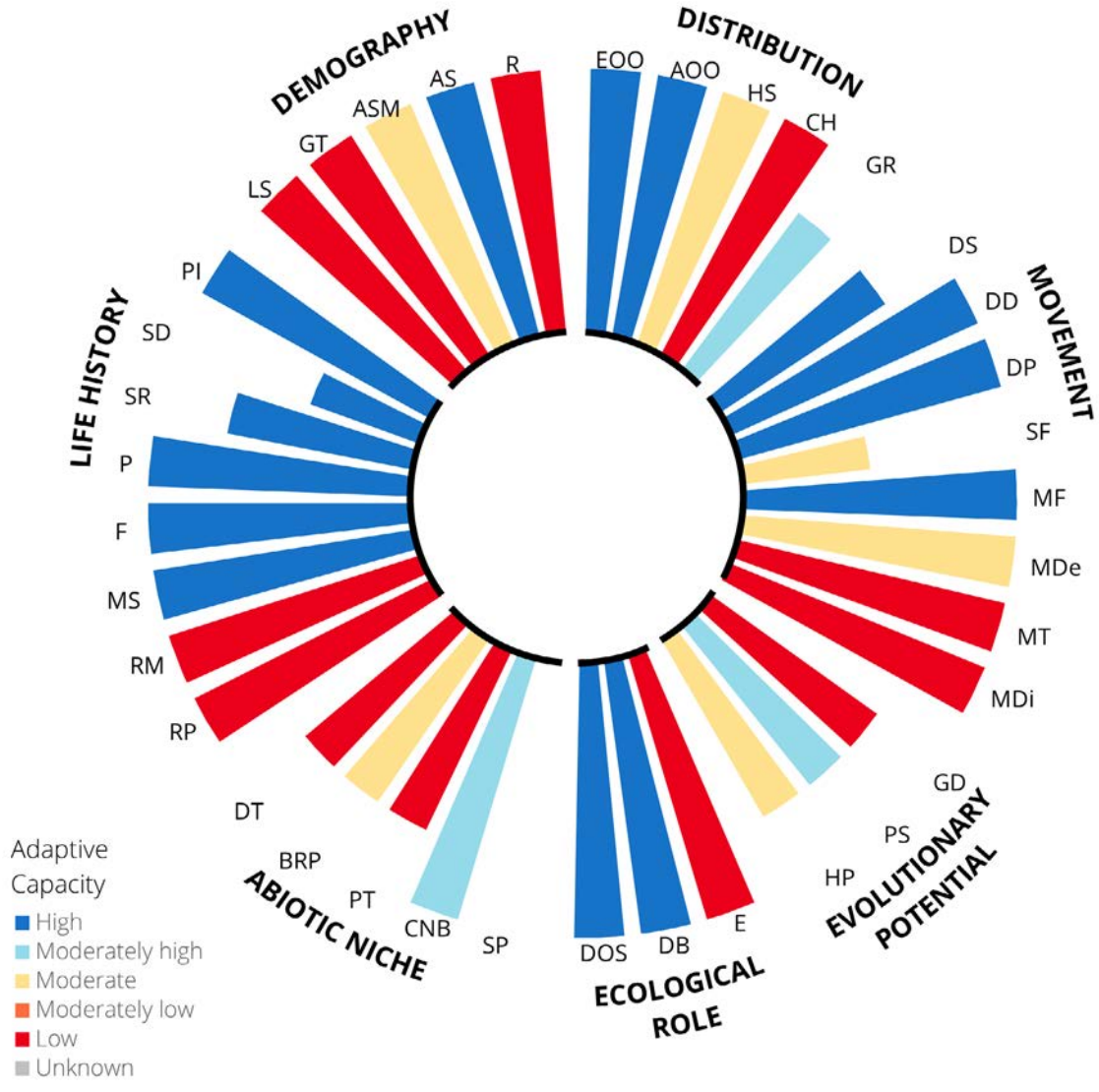


Figure 8.6. An example of a Summary of Adaptive Capacity for lake sturgeon, which comes out with an average score of 0.5 Moderate (from supplemental materials, Earl, D., et al., 2024).

Patterns in adaptive capacity traits across the seven attribute groups can help managers tailor strategies and actions to address the specific factors limiting a species' ability to adapt to climate change. For instance, if a species exhibits greater capacity to shift in space, then actions that that enhance habitat connectivity and movement corridors may be most effective. Conversely, for species with limited evolutionary potential, efforts to increase population sizes and promote gene flow may be more effective.

Several high-quality online resources are available to guide conservation actions for wildlife facing stress from climate change. One such tool is the Wildlife Adaptation Menu, developed by the Climate Change Response Framework, which provides adaptation options for wildlife managers. The menu organizes strategies into three categories — resistance, resilience, and transition — and provides specific actions within each. Another valuable resource for climate adaptation strategies is the Great Lakes Indian Fish and Wildlife Commission's (GLIFWC) Tribal Climate Adaptation Menu. This tool offers guidance on incorporating indigenous and traditional knowledge into climate adaptation planning, fostering more holistic and culturally informed conservation approaches.

Another resource is the Climate Change Bird Atlas hosted by the Northern Research Station of the United States Department of Agriculture Forest Service (USFS).

In the realm of managing habitats, there are several tools that help one to understand how to tailor management actions to various species traits. One tool is the USFS Tree Atlas that details models habitat suitability and climate adaptability in terms of reproduction and survival for individual tree species. The Northern Forests Climate Hub provides in-depth vulnerability assessments for various forest types and tree species, as well as adaptation workbooks for managers. A newer addition is the climate adaptation menu for North American grasslands (Bernath-Plaisted et al., 2025), which includes eight overarching strategies that frame 145 specific management actions for implementing climate adaptation in grassland ecosystems.

## 4. Manage for Change, Not Just Persistence

Traditional restoration and habitat management efforts have focused on recreating ecosystem conditions believed to have existed prior to European settlement. However, the magnitude of climate change interacting with other human-caused stressors is increasingly challenging managers to decide when it is appropriate to manage for the persistence of current or historical conditions, and when it is more effective to manage for ecological change.

The Resist-Accept-Direct (R-A-D) framework was developed in response to the growing mismatch between the scale of ecological change and traditional tools available to address it (Schuurman et al. 2020, Lynch et al. 2021). R-A-D offers a structured approach to identifying practical, forward-looking mitigation strategies that prioritize desirable future conditions for both ecosystems and human societies.

The framework provides agencies with: (1) a long-term view of the provisioning of ecosystem services which recognizes agency limitations to manage sources of ecosystem change, (2) a structure to prioritize actions that efficiently achieve management goals, (3) a foundation to re-evaluate current management given new information and resources, and (4) a closer alignment between stakeholder expectations and what an agency is likely to achieve. This last point is key because procedural fairness, a component of good governance (Decker et al. 2016), builds trust in agency policies (Riley et al. 2018, Ford et al. 2020).

The three R-A-D strategies are Resist, Accept, and Direct (Schuurman et al. 2020; Figure 8.7). The Resist strategy is intended to arrest system change and maintain (or restore) ecosystems to current (or historic) conditions. An Accept strategy recognizes that directional change is unavoidable and allows ecosystems to respond

without direct intervention on forces that drive that change. A Direct strategy recognizes that directional change is unavoidable and aims to steer the ecosystem toward desired novel future conditions while reducing undesired effects on system processes, functions, or composition. An important distinction between Resist and Direct is that the Resist strategy strives to maintain current or historical conditions, whereas the Direct strategy strives to promote desired novel ecosystem conditions, often when resisting change is not feasible. In combination, R-A-D strategies are intended to cover the full range of policy choices that agencies can evaluate in managing large scale drivers of ecological change. R-A-D may best be thought of as a brainstorming tool, often most beneficial when applied at the beginning of a decision-making process, alongside identification of plausible future conditions for the system (Wise et al. 2014; Magness et al. 2022; Bouska et al. 2025). Selecting among R-A-D strategies can be done within existing decision-making processes, such as structured-decision making (Runge 2011).

The R-A-D framework can be a valuable tool for guiding conservation planning and action in the face of climate change. Resist strategies are often best suited to areas of climate refuges, where the pace of climate change is relatively slow or in landscapes that have experienced minimal degradation, allowing current conditions to be maintained. Accept strategies involve allowing ecological change to occur while adapting management practices accordingly; examples include diversifying seed mixes, modifying the timing of prescribed fire or grazing, and adjusting to newly emerging conditions. Direct strategies take a more proactive approach by intentionally guiding ecological transitions. These may include species translocation, assisted migration, or restoring ecosystems to support habitat types that are anticipated in the future, even if they differ from historical or current conditions. An applied example of the R-A-D framework was recently applied to guiding conservation strategies along different reaches of the Mississippi River (Ward et al. 2023).

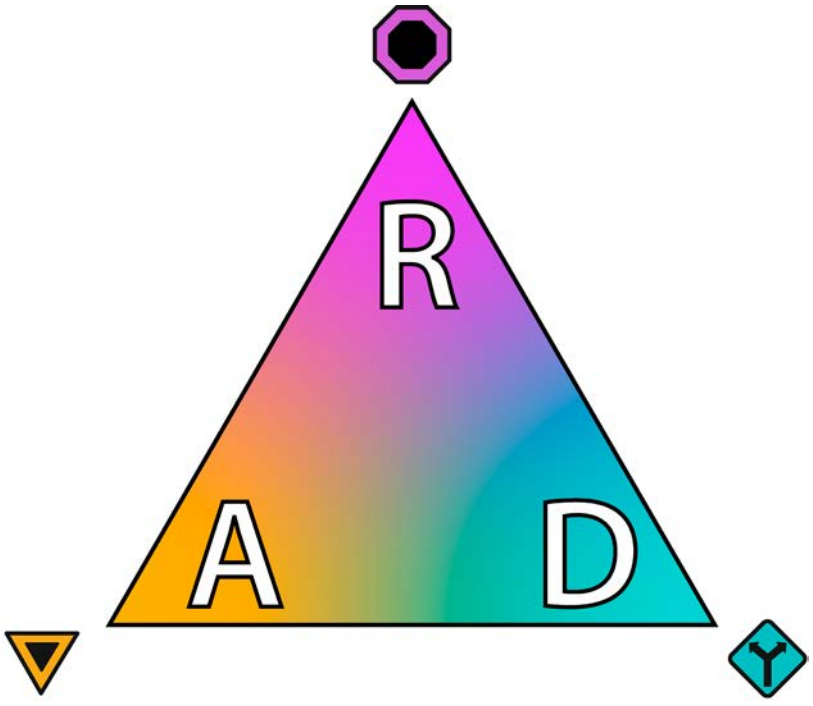


Figure 8.7. The Resist-Accept-Direct (RAD) Framework lays out three approaches for making management decisions for systems undergoing ecosystem transformation: 1) Resist, where managers work to maintain or restore ecosystem composition, structure, processes, or function on the basis of historical or acceptable current conditions, 2) Accept, where managers allow ecosystem composition, structure, process, or function to change autonomously, and 3) Direct, where managers actively shape change in ecosystem composition, structure, processes, or function toward preferred new conditions (public domain image, USGS, 2025).

## Case Study: Adapting Bottomland Hardwood Forests to Changing Climate

Adaptive Silviculture for Climate Change (ASCC) is a collaborative network of experimental forest management trials to evaluate management options under climate change across a variety of forest types throughout North America. Site-specific treatments are developed for local conditions and tailored to meet site-specific management objectives, while still aligning with a common framework for answering questions about how different forest types will respond to future climate. Trials feature three adaptation options (resistance, resilience, and transition), as well as a 'no action' treatment where no management is applied. Monitoring includes overstory, mid-story, and understory forest composition and health and productivity evaluations before and after treatment at 3, 5, and 10 years, providing timely and specific feedback for managers.

One example site in this network is a floodplain ecosystem dominated by ash-elm mixed lowland hardwoods in the Mississippi National River and Recreation Area (MNRRA) in the Minneapolis - St. Paul urban area. This floodplain forest is experiencing warming temperatures, increased frequency of severe storms, and prolonged floods, all projected to increase with climate change. The warming climate has favored the invasive emerald ash borer and resulted in nearly 100% mortality of ash trees. Increasing temperatures and drought stress are projected to reduce suitability for many of the resident tree species while favoring others. Experimental forestry treatments are resistance, which restores native floodplain species resistant to current pests and pathogens; resilience, which incorporates a wider diversity of flood-tolerant species native to Minnesota; and transition, which incorporates species and genotypes from warmer, southern locations. The project features a strong outreach component, engaging community volunteers in tree planting and monitoring to multiply the effects of the study. Major partners include Mississippi Park Connection, University of Minnesota, Colorado State University, City of St. Paul Parks and Recreation, MNRRA, Northern Institute of Applied Climate Science, and the U.S. Forest Service. The project has received funding from the Wildlife Conservation Society's Climate Adaptation Fund, as well as the National Park Foundation, Mississippi Park Connection, Minnesota Pollution Control Agency, the Minneapolis-St. Paul National Science Foundation Long-term Ecological Research Program, and 3M.

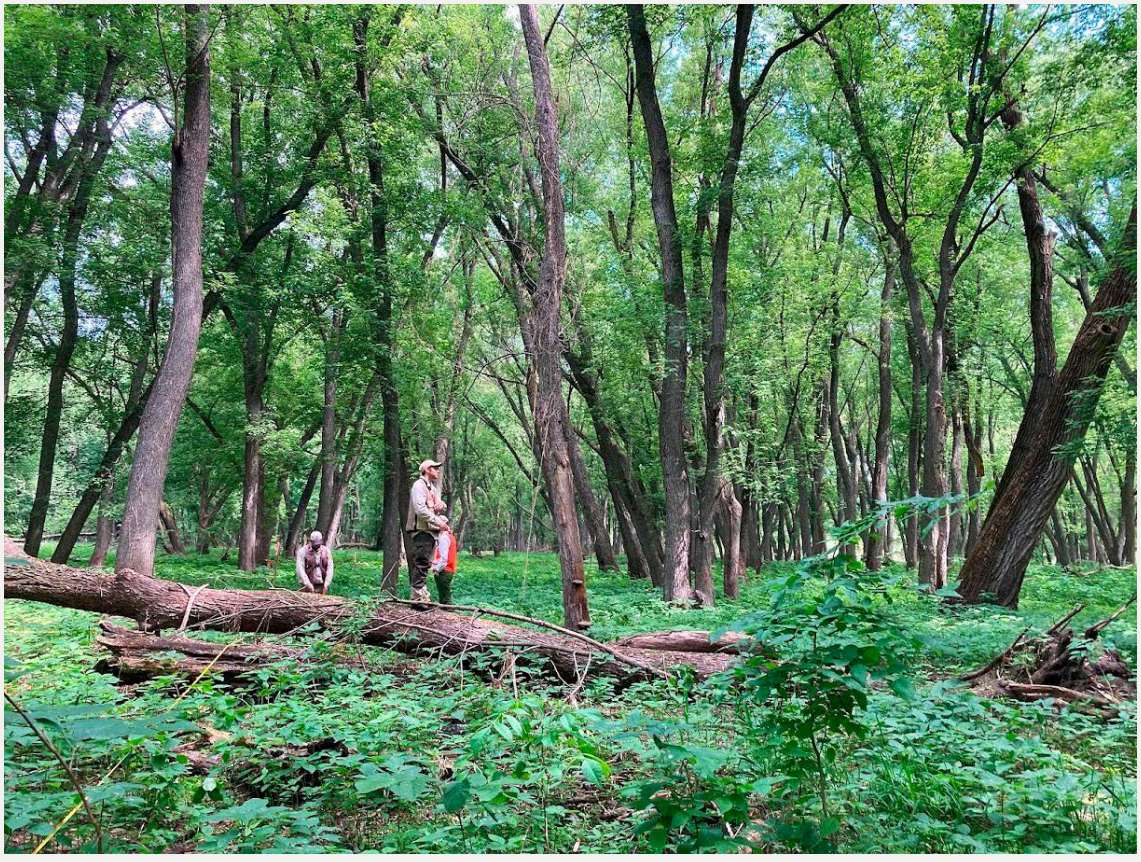

*Photo: Surveyors in Floodplain Forest, Mississippi River*

## 5. Consider Broader Landscapes and Longer Timeframes

Providing a place for animals and plants to move, even if very slowly over the course of the next century or more, is an essential part of planning for a resilient landscape. Buffering or expanding protected areas for high-quality habitats may be needed to enable biodiversity to persist by shifting to adapt to changing conditions. Corridors that enable organisms to move among high conservation value areas, such as delineated in the Conservation Action Network, are also likely to play a significant role in enabling plants and animals to adapt to a changing climate.

Climate change over the past 30 years is easily detected and depicted (see Minnesota DNR's Climate Trends). Projections of future climate track the same warming trajectory into the future. Minnesota's climate is projected to continue changing directionally over the course of the century (see University of Minnesota's Minnesota CliMAT Climate Mapping and Analysis Tool). Even if all increases in carbon emissions were immediately halted there would be significant residual increases in temperature. Although State Wildlife Plans are revised every ten years, climate-smart planning for biodiversity conservation must reference a much longer planning horizon to plan for climatic changes across the scale of the century.

## 6. Address Uncertainty by Considering Future Scenarios and Use of Adaptive Management

Uncertainties associated with climate change stem from four main sources: 1) uncertainty of how much the climate will change, 2) uncertainty in how wildlife, fish, and habitats will react to the change, 3) uncertainty in what management actions to take to address changes, and 4) uncertainty in how people will respond to climate change, both in terms of adaptation as well as mitigation (AFWA 2022).

In the face of this uncertainty, planning and management approaches that enable one to envision multiple potential outcomes such as adaptive management and scenario-based planning are essential. Adaptive management is a strong approach for climate-smart ecological conservation because it allows for the incorporation of uncertainty and the ability to select actions as new conditions unfold over time. The 'Resist-Accept-Direct' decision framework, described above, guides one into thinking about pushing a system towards past conditions, supporting it in whatever transitions it might or might not take, or actively managing it toward different future conditions. 'Scenario management' allows for planning to include multiple outcomes, which might not be able to be selected immediately due to the dependence on future events that cannot be precisely projected (e.g., drought, wildfire, series of warm winters).

Adaptive management is a structured decision-making approach (see also Chapter 5: Monitoring) that centers on iterative learning and adjusting management decisions on that that learning: "plan, do, monitor, and learn;" it has been described in the climate realm as the 'climate-smart conservation cycle' (Stein et al. 2014).

Monitoring is a key part of the adaptive management cycle, that is particularly worth emphasis in the climate-smart conservation realm. It is essential that we continue to collect information about the interaction between climate and SGCN and habitats, as well as invest in robust means to evaluate monitoring and effectiveness of climate-informed conservation (Oakes et al. 2022). As we get a better understanding of how our climate is changing, it becomes evident that we lack information about how species are responding to the changes. We need to build important questions about changes in climate into many of our surveillance studies and consider how climate may interact with our studies of the effectiveness of conservation actions as well. When we design wildlife monitoring studies, we should integrate hypotheses and predictions about how wildlife may be interacting with

heat, flooding, drought, or other climatic variables. Adding monitoring components such as microhabitat conditions, such as by using data loggers, may assist in relating behavioral and habitat use profiles to climatic data.

There are several descriptions of adaptive management that explicitly considers a changing climate.

1. Investigate climate by integrating into ongoing monitoring programs and projects, such as by including abiotic micro-scale monitoring to provide feedback on models about climate change effects.
2. Create ways to test models and make them better.
3. Monitor changes in ecosystem composition, structure, and function relative to climate predictions.
4. Apply an experimental approach to restoration projects testing hypotheses about which seed sources or practices are most successful.

Scenario-Based Climate Change Adaptation is a strategy for planners to incorporate climate change and its significant effects to habitats when knowing their exact timing and nature of future effects is difficult. Scenario-Based Climate Change Adaptation is a strategy that helps planners work with the wide array of future possibles that climate change may bring (See Figure 8.8). This process uses a small set of possible scenarios that cover a wide range of problems in hope of gaining understanding and practice with these problems, in preparation for when they become a reality. The information in this section is based off of the National Parks Service's Scenario-Based Climate Change Adaptation Showcase. To do this process, a set of scenarios must be identified. Good scenarios are plausible, relevant, divergent (covers a range of future possibilities), and challenging. Scenarios that meet these conditions can help planners understand how current practices will fair in the future, identify important holes in understanding (i.e., places for new research) and define future goals. Characterizing and integrating the uncertainty of possible ecological futures is critical to enhance the robustness of scenario planning. The appropriate process to achieve this could combine quantitative modeling with expert elicitation techniques to describe narrative descriptions of possible alternatives (Lawrence et al., 2021; Rangwala et al., 2021).

Figure 8.8. National Park Service (NPS) figure that illustrates the difference between forecast or traditional planning (left) for a single future condition and scenario-based adaptation planning (right) that works with a set of plausible futures that capture a broad range of conditions, providing a framework to support decisions under conditions that are uncertain and uncontrollable (NPS, 2025).

Examples of scenario-based climate change adaptation planning in the NPS:

Apostle Islands National Park, 2015. An Apostle Islands scenario-based climate change adaptation planning workshop used regional climate science to craft local scenarios for the park and the surrounding lake (Lake Superior, one of the fastest-warming lakes in the world), to inform both resource management and infrastructure (dock) development.

Isle Royale National Park, 2013. Isle Royale National Park and partners used scenarios to explore the range of ways in which climate, species interactions, ecosystem processes, and lake conditions might change and ultimately inform a decision to supplement a dwindling population of the island's first known wolf population, which had inhabited the island since the 1940s.

Workshops may be an effective way to assist land and natural resource managers in climate-smart planning and resource management. As experts, they know their landscape and ecosystems best and are the ones to design any future planning for management. Local workshops are an effective way for managers and stakeholders to learn about local climate changes, think through likely vulnerabilities, imagine alternative scenarios, and sketch out effective strategies to meet the changing nature of their resource area. Examples include the riparian workshop with the beaver from Wyoming (Voluntary Guidance p. 22) and a series of workshops at U.S. Fish and Wildlife Refuges (Bouska et al. 2025). Similar workshops may be helpful for local managers across the state of Minnesota.

## Case Study: Pigs Eye Lake Climate Resilient Vegetation Experimentation

The U.S. Army Corps of Engineers and Ramsey County are partnering on an aquatic and terrestrial habitat project in Pigs Eye Lake of the Mississippi River. One of the project goals is to restore lost floodplain forest areas. However, the Mississippi River is experiencing more frequent and longer duration flood conditions. Thus, the project is experimenting with different mixes of tree species, including some that are more flood tolerant. It is too early on in the project to know the outcomes, but the project provides an example of how experimentation may be worked in to habitat restoration projects and inform future work.

*Photo: Willows planted in the Pigs Eye Lake restoration project, Army Corps of Engineers*

Engage diverse partners with climate experience and expertise

Climate science is complex, and it is essential to engage with experts to interpret the data, particularly when working with climate projection models that are globally derived and downscaled to regional and local applications. Depictions of data through graphs, figures, and statistics, are vital toward understanding, applying, and communicating about climate. Sources for climate information are numerous and may change over time, but here are a few prominent ones to note:

- The Minnesota State Climatology Office is the state's primary source for current, well-explained climate data.
- The Minnesota Climate Adaptation Partnership (MCAP) conducts research and offers resources, tools, and training for organizations, individuals, and communities to respond to and plan for changing climate conditions. They offer climate adaptation training programs, host the Minnesota CliMAT tool, and keep an up-to-date set of applied well-interpreted resources for those who want to learn more about practicing climate adaptation in their work.
- The Midwest Climate Adaptation Science Center (MWCASC) is a regional group of university, Tribal, non-profit, and United States Geological Survey (USGS) scientists within the national USGS Climate Adaptation Science Center network. Scientists team up with natural and cultural resource managers to conduct applied research and develop resources and tools to help people, wildlife, fish, water, and land adapt to a changing climate.
- The Great Lakes Indian Fish and Wildlife Commission has been a leader in climate change investigation, documentation, and production of adaptation resources, including the Dibaginjigaadeg Anishinaabe Ezhitwaad: A Tribal Climate Adaptation Menu (2019) and the Aanji-bimaadiziimagak o'ow aki Climate Change Vulnerability Assessment Version 2 (2023). Seek their information and consider working more closely together with them on projects.
- The Northern Forests Climate Hub hosted by the United States Department of Agriculture provides in-depth vulnerability assessments for various forest types and tree species, as well as adaptation workbooks for managers.
- The Northern Research Station of the United States Department of Agriculture Forest Service provides a number of resources that pertain to management of sustainable and healthy forests. There is a Tree Atlas that details modeled habitat suitability and climate adaptability in terms of reproduction and survival for individual tree species, as well as a Climate Change Bird Atlas.

## Case Study: Climate-informed Fish Passage in North Shore Streams

Climate is a factor in trout stream health, as warming temperatures and more frequent higher floods put strain on coldwater stream riparian systems. Extremely high floods as have happened in recent years are also putting strain on infrastructure, particularly at stream-road crossings. From flooding events, culverts become less functional due to sedimentation and downcutting and then these become impediments to aquatic habitat connectivity and fish passage. The Division of Fisheries in Minnesota Department of Natural Resources mapped the coldwater stream network on the north shore of Lake Superior and in the St Louis River watershed to prioritize the replacement of culverts in locations to that would optimize aquatic connectivity of streams with good groundwater sources. Connectivity to cold groundwater can help maintain coldwater streams as climate refuges. In these prioritized locations, culverts are replaced with road crossings that are designed to hold up under much larger floods. Also designed with gentle gradients and natural bottoms these provide for superior fish passage at lower water levels that can come with projected late summer droughts. The natural bottoms also provide access for terrestrial species moving along stream corridors as well.

*Photo: Fish and wildlife friendly and climate-adapted road crossing, Hockamin Creek, Jeff Jasperson, Minnesota Pollution Control Agency*

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