MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

CONSERVING HABITATS AND BIODIVERSITY

CLIMATE ADAPTATION

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

Acknowledgments

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.

Funding

The SWAP revision was funded through U.S. Fish and Wildlife Service State Wildlife Grants as well as matching funds from private donations to the Nongame Wildlife Fund and Reinvest in Minnesota funds. We also received funding from the Minnesota Environmental and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

U.S. FISH & WILDLIFE SERVICE — DEPARTMENT OF THE INTERIOR

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

ECOLOGICAL AND WATER RESOURCES
500 Lafayette Road
St. Paul, MN 55155-4040
888-646-6367 or 651-296-6157
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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

How to cite this document: Minnesota Department of Natural Resources. (2026). Minnesota's Wildlife Action Plan 2025-2035: Conserving Habitats and Biodiversity. Ecological and Water Resources Division.

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).

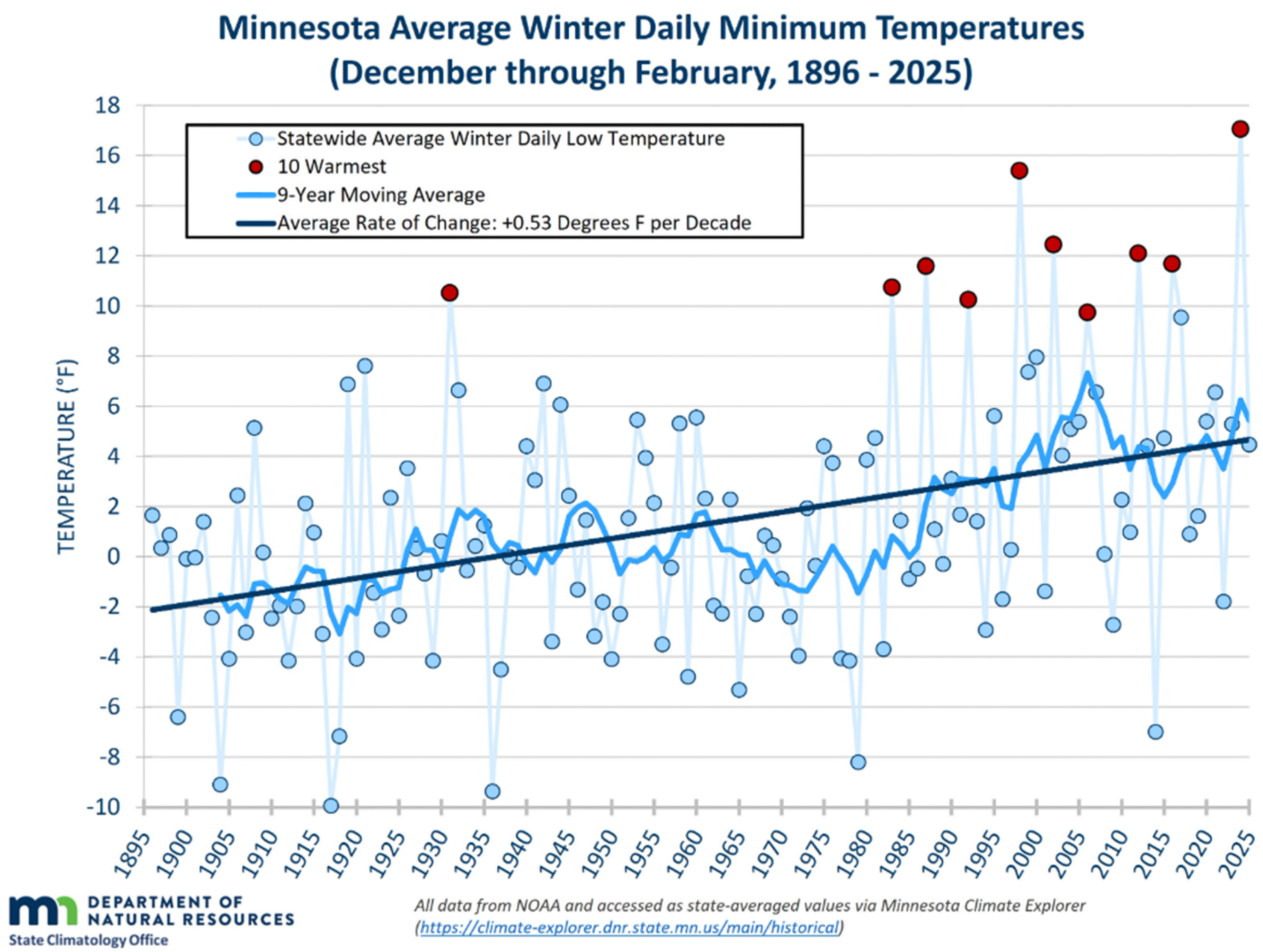

Figure 8.1. Chart depicting increases in Minnesota Average Winter Daily Minimum Temperatures (December through February 1896 – 2025). Figure produced by the DNR State Climatology Office based on data from the Minnesota Climate Explorer.

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.

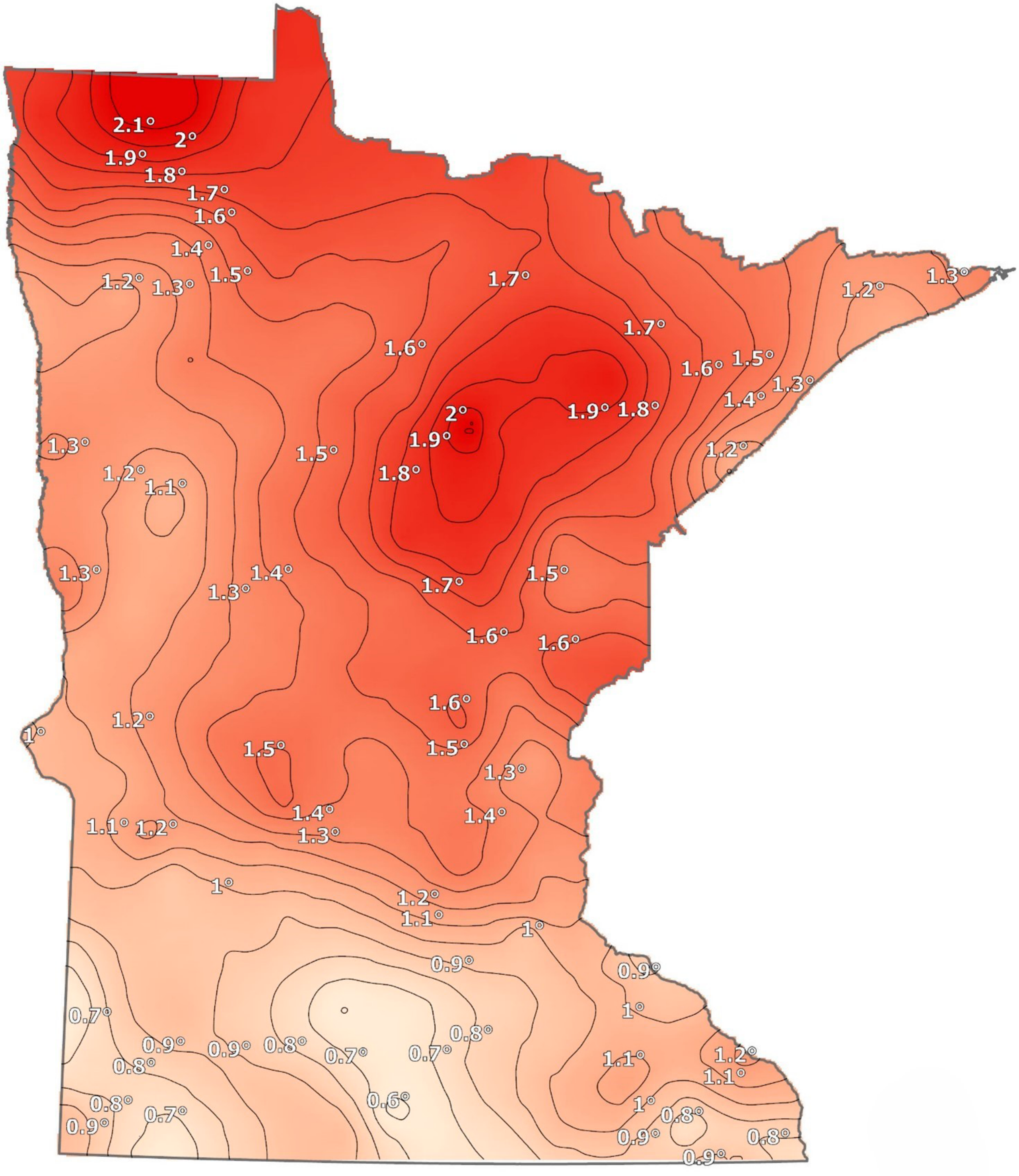

Figure 8.2. Annual average temperatures (1991-2020) deviation when compared to historical average (1895-2020) (DNR Geospatial Commons 2024). Darker red represents areas with greater deviation.

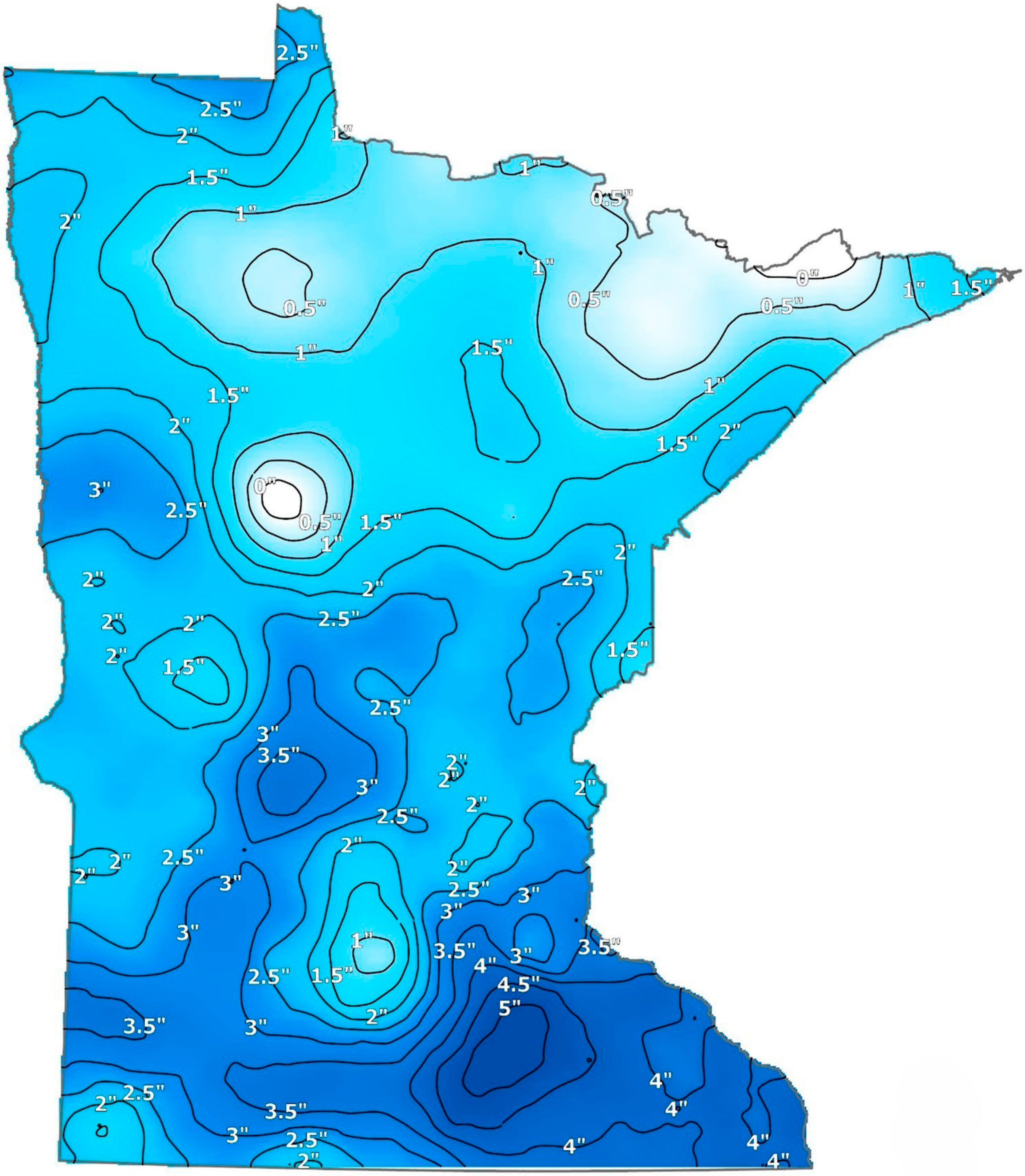

Figure 8.3. Annual average precipitation (1991-2020) deviation when compared to historical average (1895-2020) (DNR Geospatial Commons 2024). Darker blue indicates greater deviation.

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).

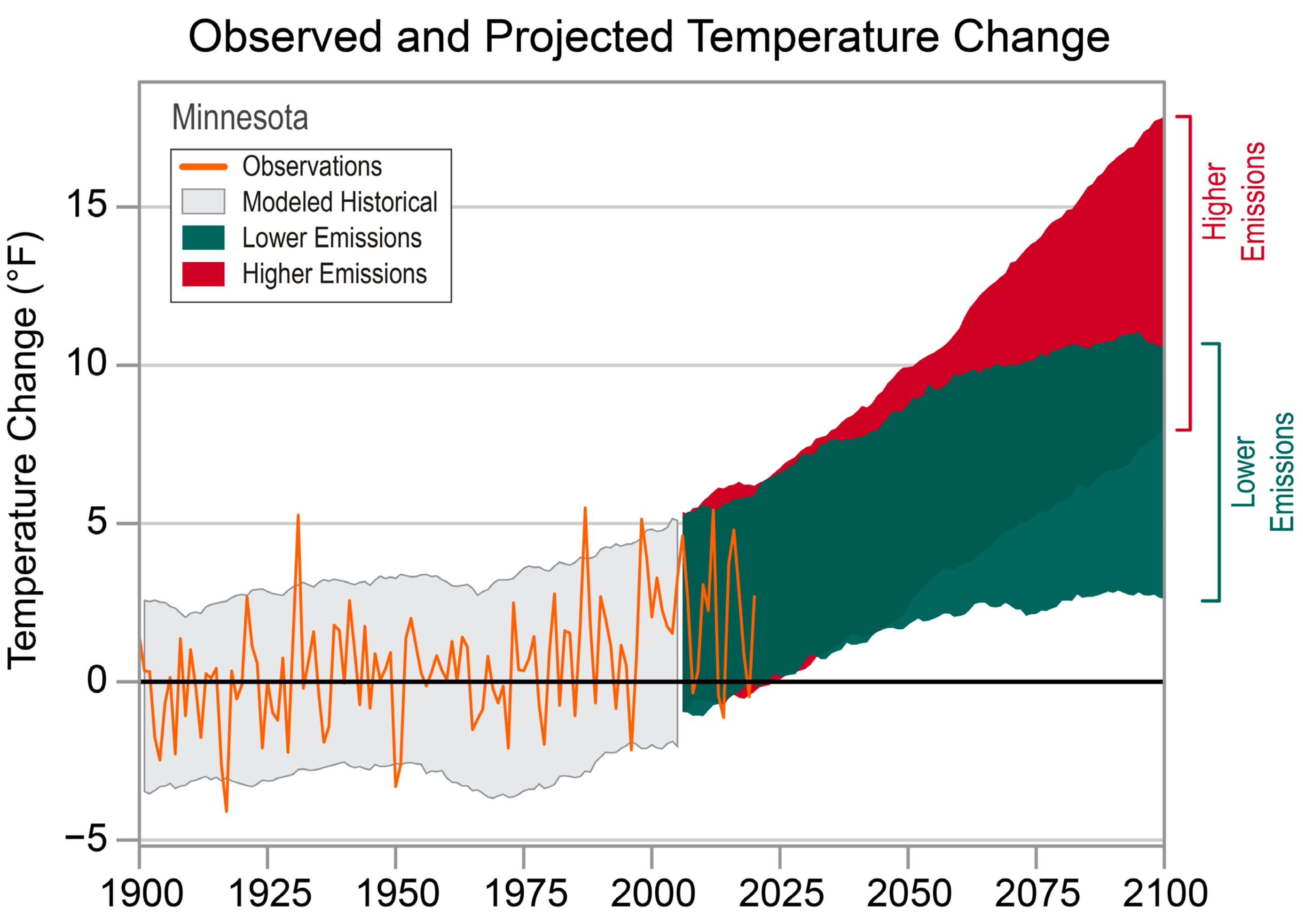

Figure 8.4. Observed and projected temperature changes in Minnesota under "lower" (teal) and "higher" (red) emissions scenarios out to 2100 compared to historical temperature observations (orange). Figure 1 reproduced from Runkle, J., et al., 2022.

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).

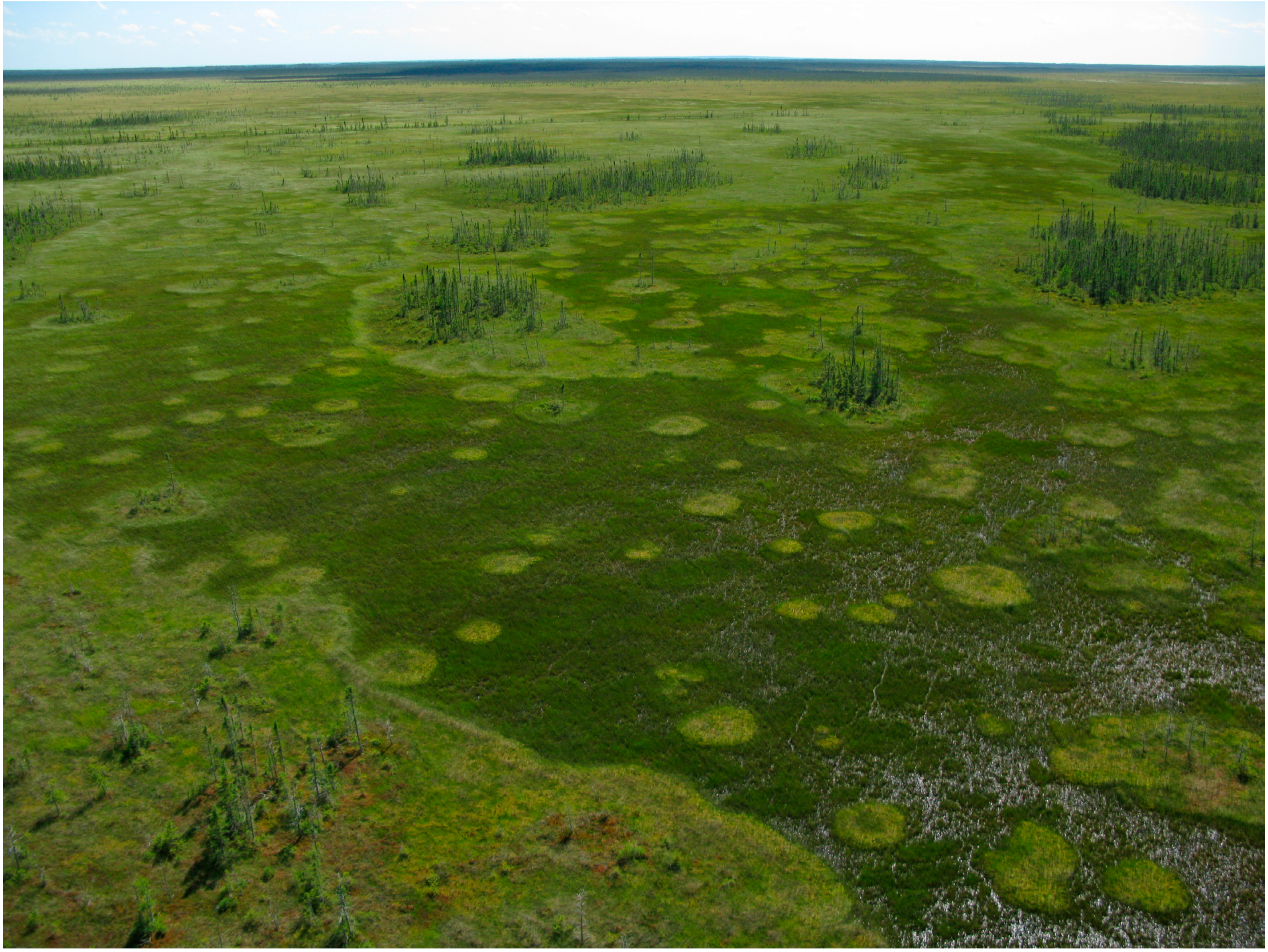

Photo: Peatlands, a habitat type vulnerable to climate change

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).

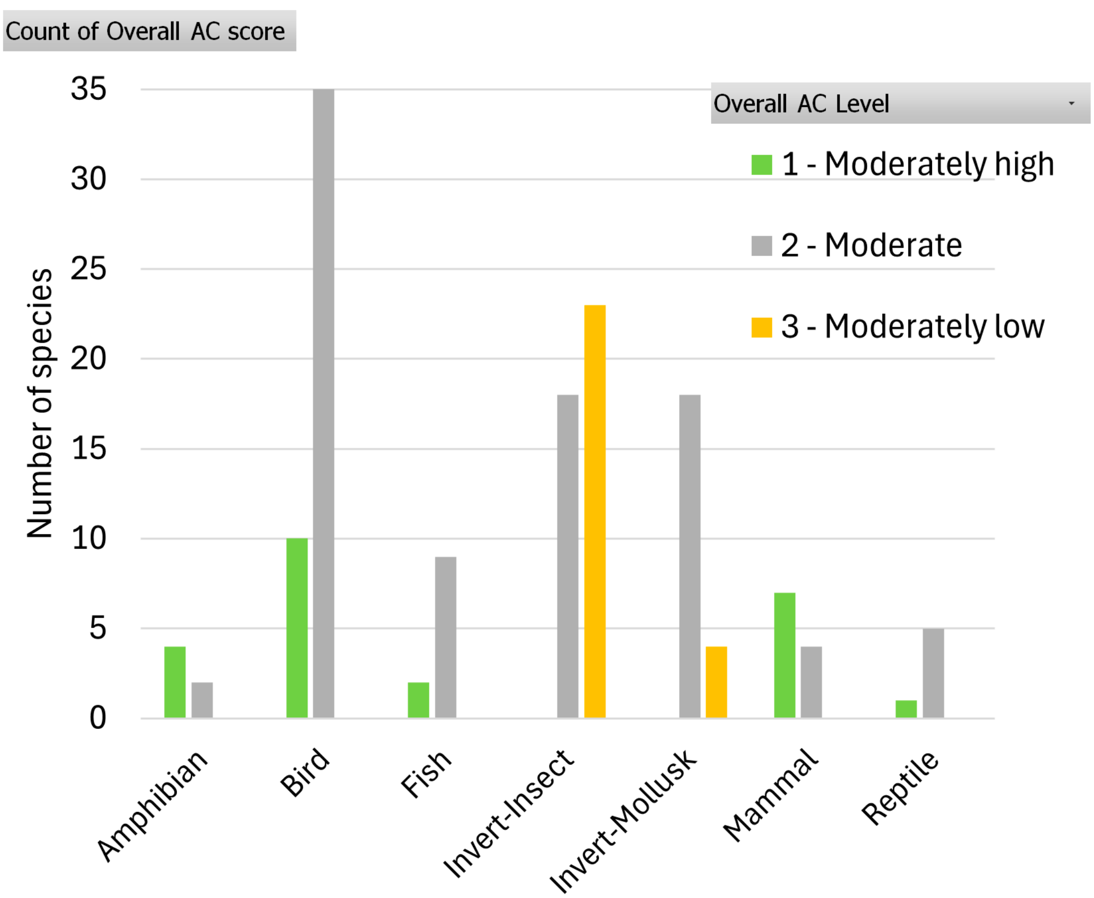

Figure 8.5. Graph indicating the overall adaptive capacity assessment scores for Minnesota SGCN evaluated in the Michigan-led adaptive capacity assessment study (based on supplemental materials from Earl, D., et al., 2024).

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).

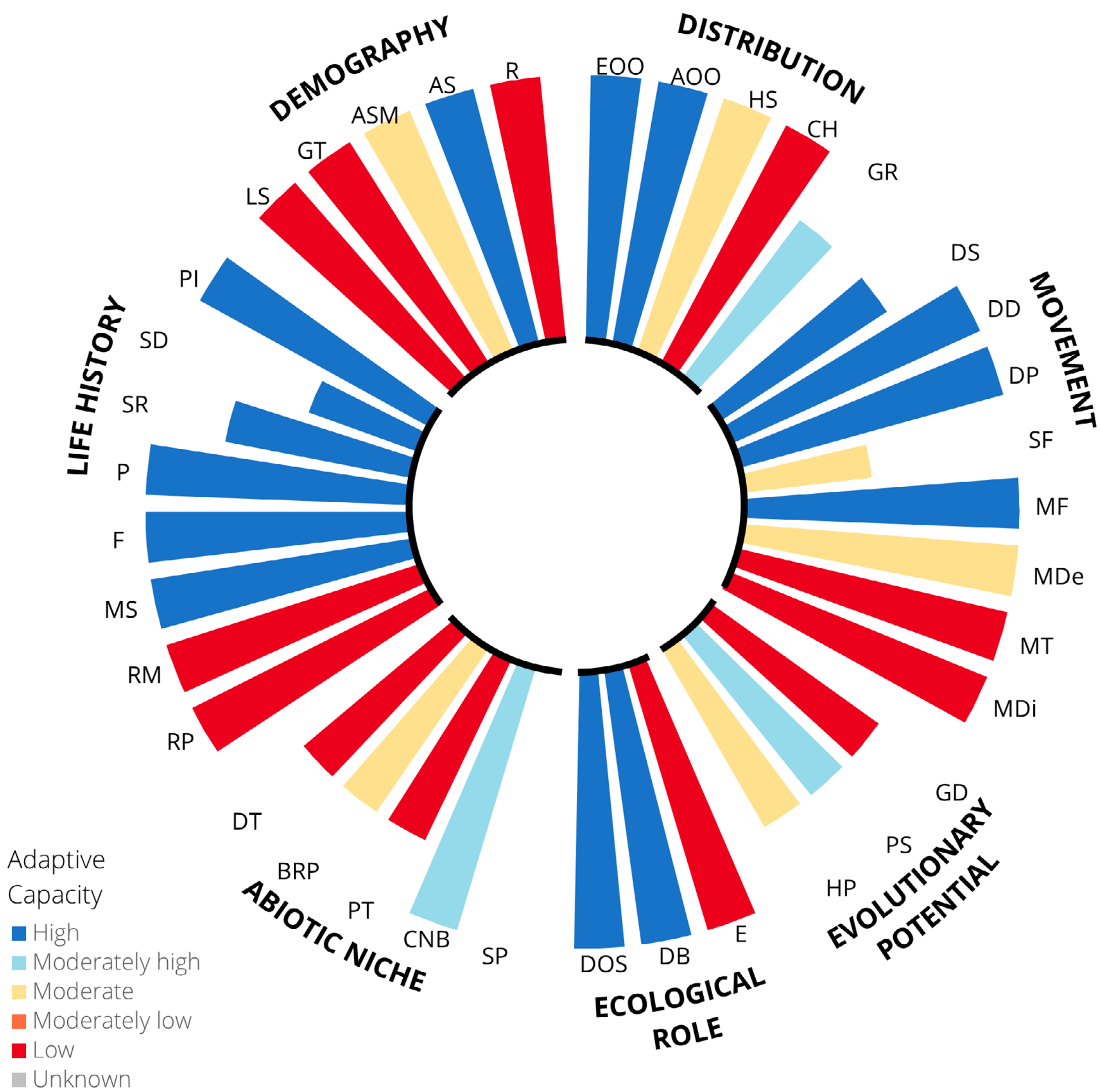

Figure 8.6. An example of a Summary of Adaptive Capacity for lake sturgeon, which comes out with an average score of 0.5 Moderate (from supplemental materials, Earl, D., et al., 2024).

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).

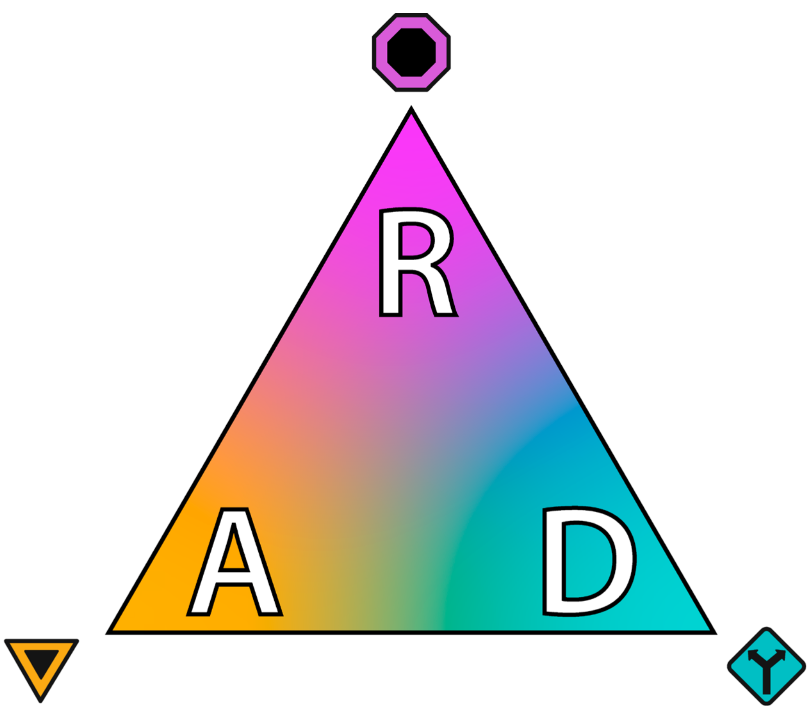

Figure 8.7. The Resist-Accept-Direct (RAD) Framework lays out three approaches for making management decisions for systems undergoing ecosystem transformation: 1) Resist, where managers work to maintain or restore ecosystem composition, structure, processes, or function on the basis of historical or 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.

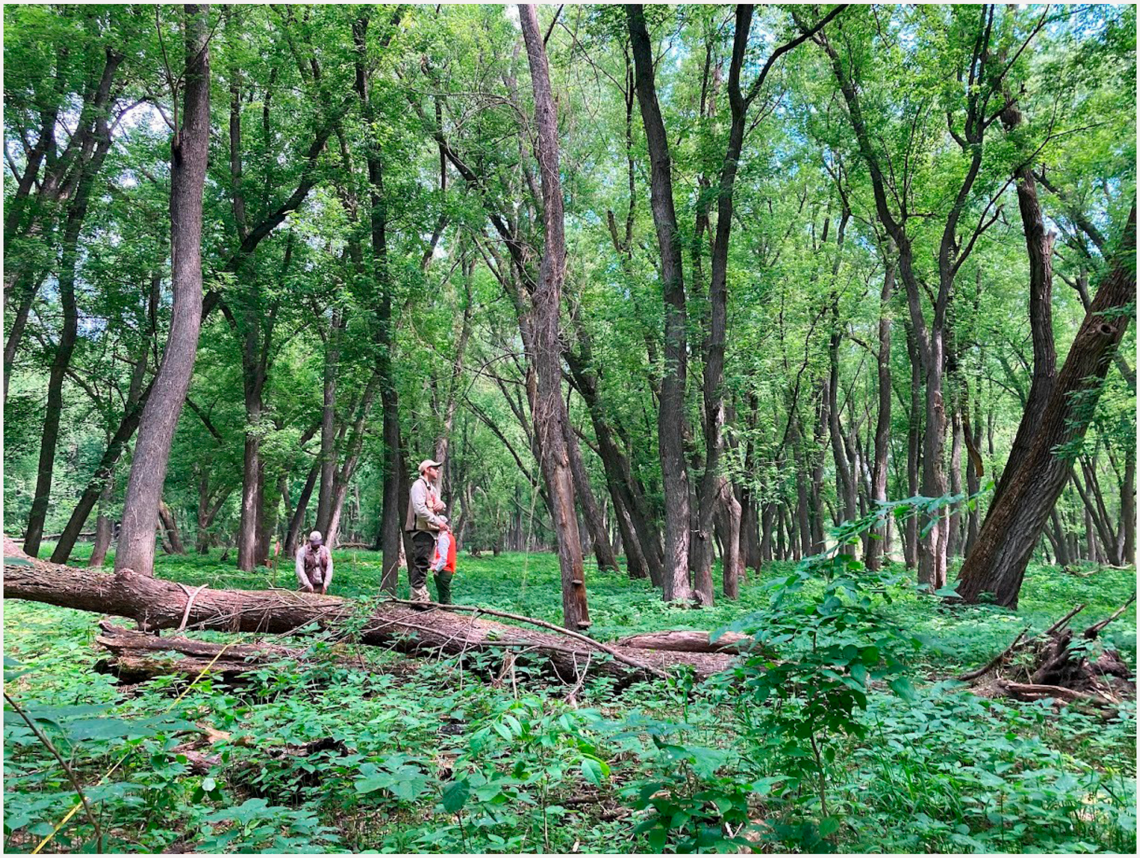

Photo: Surveyors in Floodplain Forest, Mississippi River

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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