Chapter 3.
The Identification of Stressors Contributing to Population Declines of Species in Greatest Conservation Need

A stressor is a condition that directly or indirectly negatively impacts a habitat or species. Conservation actions are implemented to reduce the impact of stressors. Many of the criteria used to evaluate a species as a Species in Greatest Conservation Need also represent stressors associated with population declines. In addition to stressors, life-history traits, which were also included in the criteria for identifying SGCN, can increase a species' vulnerability to stressors. The list of SGCN and the stressors and life-history traits identified for each species can be found in Appendix C. The stressors and life-history traits were used to identify the objectives and possible conservations actions (chapter 4) that will be implemented over the next 10 years to reduce the impacts of stressors on SGCN and their habitats.

Stressors

Habitat-related stressors were considered a predominant stressor for 70 percent of SGCN (241 of 346 species), indicating that loss, degradation (including from contaminants), and fragmentation of habitats are the most serious challenges facing SGCN populations (see Table 3.1). Stressors not related to habitat also contribute to SGCN declines but do not impact as many species (see Table 3.1). However, stressors of all types may interact with each other and exert a cumulative impact on a species.

Table 3.1. Stressors affecting SGCN populations

Stressors	Percentage of SGCN for which stressor was considered a predominant factor
Habitat stressors	**70%**
Habitat degradation	38%
Habitat is rare, vulnerable, or declining	35%
Habitat loss	31%
Habitat fragmentation	23%
Depends on natural processes that are no longer within natural range of variation	10%
Contaminants	9%
Requires large home range or multiple habitats as part of their life cycle	4%
Depends on large habitat patch	4%
Other stressors: specific threats	**13%**
Invasive animal species	9%
Disease	3%
Overexploitation, collecting, bounty killing	2%
Deliberate killing	1%

Life-History Traits

Table 3.2 lists the life-history traits that were considered during the SGCN identification process. These traits may increase the vulnerability of species to stressors, including climate change, contributing to population declines.

Table 3.2. Life-history traits increasing species' vulnerability

Life-history traits	Percentage of SGCN for which this trait was identified
Highly localized or restricted distribution	32%
Needs special resources such as host species; has narrow thermal preference	24%
Aggregate their populations during some time of the year	7%
Limited ability to recover on their own due to low dispersal ability or low reproductive rate	5%

Note: Because a given species may have multiple stressors and/or life-history traits, the totals in Tables 3.1 and 3.2 do not equal 100%.

A sortable spreadsheet of stressors and life history traits identified for each Species in Greatest Conservation Need is available for online: http://files.dnr.state.mn.us/assistance/nrplanning/bigpicture/cwcs/species-stressor-spreadsheet-2015-08-27.xlsx

Addressing Stressors at the Species Level

Minnesota's Wildlife Action Plan identifies a subset of species that are being affected by specific threats or have life-history traits for which a habitat approach alone is not sufficient to maintain or increase populations. For these species, the plan identifies specific conservation actions (e.g., best management practices, restoration, and propagation) that have a high likelihood of being implemented, and conservation actions that are believed to be effective in maintaining or increasing populations (see "The Species Approach," chapter 1). These species and the associated issues to be addressed through conservation actions are listed in Table 3.3.

Table 3.3. SGCN in need of specific conservation actions.

Species	Issues
northern long-eared bat, little brown myotis, big brown bat, tri-colored bat	white-nose syndrome http://www.dnr.state.mn.us/wns/index.html
freshwater mussels	limited ability to recolonize historic sites without assistance
wood turtle	low reproductive rate, concentrated populations, and high nest predation exacerbated by habitat loss and degradation
brook trout, southeastern Minnesota heritage strain	stewardship species; limited distribution
gophersnake	deliberate killing, overexploitation, and unregulated take; requires large home range and multiple habitat types
plains hog-nosed snake	overexploitation and unregulated take exacerbated by habitat loss, degradation, and fragmentation
mudpuppy	overexploitation and unregulated take
hornyhead chub	overexploitation and unregulated take
monarch butterfly and other pollinators	pesticides, larval dependence on a host plant (milkweed), and possible climate change impacts
golden-winged warbler	stewardship species; Minnesota provides habitat for at least 40% of the global population of golden-winged warblers
four-toed salamander	low ability to disperse and is dependent on forested wetlands as breeding habitat (habitat that could be vulnerable to climate change)
Blanding's turtle	low reproductive rate and high nest predation exacerbated by habitat loss and degradation

Summary of Climate Change Impacts on Minnesota's Habitats

Minnesota's wildlife and their habitats are impacted by a number of human activities that contribute to the stressors identified in Table 3.1, including habitat loss, fragmentation, and degradation, and the introduction of invasive species, disease, and chemicals. Because habitat is an important driver of SGCN population declines, and habitat stressors will be exacerbated by a changing climate, staff reviewed reports and journal articles to identify current or predicted climate change impacts on Minnesota's habitats. Information was also obtained from a habitat climate change vulnerability assessment exercise conducted by the DNR with habitat experts. The purpose of the exercise was to explore how changes in temperature and precipitation under a changing climate could interact with other factors to affect the health of Minnesota's terrestrial and aquatic habitats.

Introduction

The distribution, abundance, and interactions of species, along with physical elements in their environment (temperature, precipitation, moisture, soils, and topography) shape ecological communities and govern ecosystem functions. Climate change is disrupting these complex interactions; however, the scale and extent of the disruptions are unknown.

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 2013). Root and Schneider (2002) 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.

Biological diversity, the variety of living organisms and their wide range of functions and genetic variability, contributes to ecological resilience. 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. The expansion of human populations and the increased demands for natural resources are driving a loss in biological diversity. Significant changes in ecosystems could occur if climate change, along with current stressors, accelerates that loss.

Activities that fragment or degrade habitats can independently or in conjunction with invasive species reduce biological diversity. Climate change further stresses the system, creating conditions conducive for invasive species to colonize new areas or expand in existing areas. These stressors act in tandem to simplify habitats, resulting in the loss of diversity and thus resilience. For example, buckthorn and reed canary grass can rapidly expand in disturbed sites, creating large monocultures, and invasive carp can deplete essential food resources at such a rate as to severely limit the resources required by other species in the community.

Forest Ecosystems

Forests in the Laurentian Mixed Forest Province

As part of the Northwoods Climate Change Response Framework project (Handler et al. 2014), the vulnerability of forest ecosystems in the Laurentian Mixed Forest Province of Minnesota was assessed under a range of future climate scenarios. This assessment covered 85 percent of the forested area of the state. Vulnerability was considered in terms of the potential impacts to a system and its adaptive capacity. Vulnerability rankings were based on evidence and agreement among reviewers. A brief summary of those findings is provided below.

Climate change predictions for this province include warmer temperatures or drier conditions that reduce available moisture, more intense storm events, and shifts in the timing or amount of precipitation.

Fire-Dependent Forest System. This system is vulnerable to increased drought and warming that increases moisture stress. Major system stressors include fire suppression, insect pests and diseases, understory hazel competition, and deer herbivory.

Mesic Hardwood Forest System. This system is vulnerable to increased droughts that could produce moisture stress and increase the occurrence of wildfires. This system generally contains a larger number of plant species than some forest systems, which may increase its adaptive capacity. Species diversity along with warming temperatures may allow this system to expand into previously unsuitable areas. However, stands with few species and reduced structural diversity may have lower adaptive capacity. Major system stressors include earthworms, invasive plants, insect pests and diseases, freeze-thaw cycles, drought, and deer herbivory.

Floodplain Forest System. This system is vulnerable to the timing and intensity of precipitation events resulting in changes in the timing or volume of stream flows. Major system stressors include changes in flood regime, increase of invasive species (buckthorn, garlic mustard, and reed canary grass), drought, and deer herbivory.

Wet Forest System. This system is vulnerable to shifts in the timing or amount of precipitation that could disrupt system functions. Management knowledge and history are lacking for these systems; thus, less is known about how these systems function and respond to disturbance. Because these forests often exist as large complexes of a single species or few species, they have lower adaptive capacity in areas where they exist as isolated pockets on the landscape that may limit migration and gene flow. Major stressors include changes in soil moisture, ongoing ash decline, invasive species such as reed canary grass, insect pests (emerald ash borer), and drought.

Managed Aspen System. This system is vulnerable to increased moisture stress during the growing season, which could result in greater mortality. Warmer growing-season temperatures could result in more suckering after harvests. Increased wildfires could help maintain aspen; however, frequent disturbances from herbivory, drought, and more intensive management could result in aspen becoming a less successful competitor. Major system stressors include forest tent caterpillar and gypsy moth, drought, deer herbivory, hypoxylon canker, and earthworms.

Managed Red Pine System. This system is vulnerable to seasonal shifts in precipitation patterns, which may decrease the survival of planted seedlings, particularly if the trend is for wetter springs and drier summers. Red pine plantations typically have very little genetic, structural, and species diversity, which may result in low resilience to future disturbance or changing conditions. Major stressors include armillaria fungi disease, red pine shoot blight, understory hazel competition, deer herbivory, bark beetles, and drought stress in dense stands.

Forests within the Prairie-Forest Border

It is expected that this area will experience warmer temperatures, increased evapotranspiration, and more intense storm events.

Insect damage, larger blowdown areas, droughts, and fire are expected to interact, resulting in many forests, particularly ones on marginal soils, becoming savannas. Invasive species, including earthworms, may limit the establishment and growth of native tree seedlings and other understory plants (Galatowitsch et al. 2009).

Deciduous forests within the prairie-forest border are severely fragmented by agriculture and urban/ suburban sprawl (Galatowitsch et al. 2009). Should fragmentation increase, thereby creating smaller forest patches and increasing edge habitat, the ability of some plant and animal species to adapt to climate change could become progressively limited. Reasons for this include increased predation on wildlife, the spread of invasive species, and competition from other native species that prefer forest edge.

Prairie and Surrogate Grasslands

Less than 1 percent of Minnesota's native prairie remains of what was once a diverse and extensive prairie system. These prairie communities range from the nutrient-rich southern wet prairie to the nutrient-poor northern dry prairie. Their relatively small size and isolation increase their vulnerability to climate change.

Warmer temperatures, increased evapotranspiration rates, and periods of drought interacting with invasive species, agricultural expansion, and altered hydrology (resulting in part from increased demands on groundwater resources) could result in further loss and degradation of native prairie habitats. Isolated, low-diversity mesic and wet prairie communities are the most vulnerable. Wet prairies and meadows will be reduced in extent, and some rare wet-prairie species will likely be lost (Galatowitsch et al. 2009).

Prairie communities with higher biological diversity and connectivity are expected to have a greater capacity to respond to changes in precipitation, moisture, and temperature than are lower-diversity, fragmented communities (Galatowitsch et al. 2009). Where these prairie complexes exist, the increased biological diversity and connectivity may increase their ability to reorganize while still retaining prairie species, structure, and functions. Given the fragmented nature of Minnesota prairies, protecting remaining high-diversity prairie complexes should be a priority.

In some cases intensive management, such as prescribed burns, conservation grazing with a focus on system resilience, and seeding mixtures that reflect a changing climate may be necessary to maintain existing prairies or restore prairies. In addition, the restoration of pastures and limiting agricultural drainage in the vicinity of protected wetlands and wet prairies will become increasingly important (Galatowitsch et al. 2009).

Wetland Systems

All wetland systems, with the exception of some localized areas, are expected to experience shorter hydroperiods and decreased water supply (Galatowitsch et al. 2009). These changes will most likely result in significant shifts in plant communities, either as a direct result of water-level changes or indirectly through altered soil and water chemistry, decomposition, and disturbance regimes. Reed canary grass and other invasive species are expected to further reduce biological diversity. Freshwater marshes and meadows across western Minnesota may become brackish to alkaline if evapotranspiration increases as is expected (Galatowitsch et al. 2009).

Minnesota's globally significant boreal peatland system that covers more than 2,400,000 hectares of northern Minnesota may experience the most radical changes. An important carbon sink, the drying of peatlands and the potential for increased fires would increase carbon dioxide emissions into the atmosphere.

Rich Peatland System

In the rich peatland system, higher water tables could result in a transition to open peatland systems; however, lower water levels could allow other forest types to invade as peat layers dry and decompose. Major stressors include changes to the water table, roads and beaver dams, insect pests and diseases, winter burn, drought, and deer herbivory.

Acid Peatland System

Acidic peatlands are disconnected from groundwater inputs and are reliant on precipitation. Being on the southern edge of their range in Minnesota, they may not tolerate warmer conditions. Ecosystem models show significant declines in black spruce and tamarack, which are the dominant tree species in this system. Acidic peatlands contain a suite of rare and endemic plant species, which are also presumably vulnerable to changes in the water table and peat substrate. Major stressors include changes to the water table, roads and beaver dams, insect pests and diseases, winter burn, drought, and deer herbivory (Galatowitsch et al. 2009; Handler et al. 2014).

Aquatic Systems

Aquatic systems, particularly those with altered hydrology, are vulnerable to temperature extremes and to high-intensity and high-magnitude precipitation events. Changes to hydrologic regimes are affecting stream flow and water quality (turbidity, pollutants, water temperature), which in turn affect biological diversity. Aquatic systems may be further impacted if dry periods result in increased human demands for water.

An overview of climate change impacts on Minnesota's aquatic systems can be found in the DNR's 2011 report Climate Change and Renewable Energy: Management Foundations, pp. 26–31. Information from the report is summarized here:

- Increased air temperature and/or reduced ice cover could result in warmer water temperatures, altering fish communities. Warm-water fish such as largemouth bass and bluegill are becoming more common in northern Minnesota lakes (Schneider 2010; DNR Fisheries unpublished survey data). Relative abundance of cisco has declined, and evidence suggests that climate change is a primary factor. Walleye, pike, and lake trout could also be affected, as cisco is an important food source for those species (Jacobson et. al. 2012). Effects on cool-water species are likely to be variable. Species such as walleye, yellow perch, and northern pike are expected to have good growth volume in cold northern Minnesota lakes, but competition and predation from warm-water species, such as large and smallmouth bass, may affect populations (Stefan et al. 2001; Fang et al. 2004; Fayram et al. 2005; Minns 2009).
- Warmer air temperatures, reduced ice cover and/or reduced precipitation can lower water levels in lakes and streams, resulting in oxygen depletion. Longer periods of stratification can also reduce nutrient availability and increase the risk of oxygen depletion in lakes. Lower water levels can also concentrate pollutants.
- Climate change may reduce habitat suitability for native species and open up new niches for invasive species to exploit (Walther et al. 2009).

- Warming air temperatures, reduction in groundwater inputs (as a result of higher air temperatures and evaporation), altered and more extreme precipitation patterns, increased impervious surface, agricultural drainage, and human demands on groundwater are expected to reduce the amount of available habitat for cold-water stream species such as brook trout (Ficke et al. 2007; Herb and Stefan 2010).
- Large, deep lakes with balanced food webs and relatively low levels of nutrients may have greater resilience to climate change (Stefan et al. 2001; Beisner et al. 2003; Genkai-Kato and Carpenter 2005; Jacobson et al. 2010). Streams with significant groundwater inputs, channels shaded by trees, intact floodplains and meanders, and watersheds with deep-rooted perennial vegetation will be more resilient to changes in air temperature and surface flow variability (Chu et al. 2008; Palmer et al. 2009).

Wildlife Vulnerability to Climate Change

A number of reports have identified characteristics that could increase the sensitivities of species or populations to climate change (e.g., National Fish, Wildlife and Plants Climate Adaptation Strategy [2012]; Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans [Staudinger et al. 2015], and Wisconsin Initiative on Climate Change Impacts [Wisconsin's Changing Climate: Impacts and Adaptations 2011]).

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

In another Wisconsin assessment, LeDee and Ribic (2015) categorized terrestrial vertebrate species according to traits sensitive to climate change:

- The primary trait of amphibians and reptiles was their dependence on specialized habitat and/ or microhabitat (18 of 19 amphibians assessed [94.7 percent] and 16 of 36 reptiles assessed [50 percent]). Reptiles were also sensitive because of their dependence on environmental cues.
- Of 236 avian species assessed, 72.5 percent were sensitive because narrow environmental thresholds were likely to be exceeded.

- Mammals were likely to be affected because of disease and parasitism (36 of 62 species assessed; 58.1 percent).

A synthesis of four climate change vulnerability assessments that looked at resident species occurring in the U.S. Corn Belt since 2010 found species associated with freshwater ecosystems, particularly those affiliated with ephemeral wetlands, cold- or cool-water environments, and shallow streams, appear to be most vulnerable (Small-Lorenz et al. 2013). Species and their vulnerabilities include the following:

- Mollusks
  - anthropogenic and natural dispersal barriers
  - hydrologic changes: flood regimes, sediment and streambed degradation
  - climate change mitigation impacts (increased ditching, tiling, irrigation)
  - interspecific interactions: host fish required
- Amphibians and reptiles
  - anthropogenic barriers to movements (roads)
  - hydrologic changes to damp and aquatic habitats; drought
  - climate change mitigation impacts (increased ditching, tiling, irrigation)
  - restricted habitat/geology
- Fish
  - temperature changes: cool- and cold-water species
  - precipitation changes: shallow water spawners, wetland species, species intolerant of turbidity
  - water chemistry: sensitive to low dissolved oxygen
  - barriers to movement: anthropogenic, large rivers

Addressing Stressors: Minnesota's Wildlife Action Plan's Goals, Objectives, and Conservation Actions

Many of the goals, objectives, and conservation actions in Minnesota's Wildlife Action Plan were developed to (1) reduce the impacts of current stressors on habitats and species, (2) increase the resilience of species and habitats, and (3) address specific issues related to life-history characteristics that increase a species' vulnerability to stressors. Following are a few examples of how the stressors discussed in this chapter are brought forward into the goals, objectives, and conservation actions presented in chapter 4.

Habitat degradation, loss, and fragmentation are the predominant stressors impacting SGCN populations. Habitats with higher biological diversity and habitats that are less fragmented are expected to have a greater resilience in a changing climate than are systems with lower biological diversity and greater fragmentation.

Goal 1, Objective 1 focuses on maintaining and enhancing the resilience of habitats upon which SGCN and other wildlife depend. This will be accomplished by implementing conservation actions such as those identified under Objective 1.1 to "sustain and enhance species, habitat, and landscape biological diversity within the Wildlife Action Network" and Objective 1.2 to "maintain or enhance habitat in at least 6 Conservation Focus Areas." Examples of conservation actions for Objective 1 include maintaining and restoring terrestrial and aquatic habitat connectivity; expanding habitat cores; protecting and enhancing wetland, floodplain, and shoreline habitats; and acquiring from willing sellers threatened sites providing exceptional habitat or ecological value.

Changes in Minnesota's climate are already impacting habitats, and future impacts are predicted. The habitats identified by the literature review and the DNR expert-based habitat vulnerability assessment as having higher vulnerability to these climate changes, or for which management knowledge is lacking, include wet forest systems; isolated, low-diversity mesic and wet prairie communities; floodplain forests; the peatland system; and the prairie stream ecosystem with altered hydrology. Communities where maintaining complexes or forest stands with high biological diversity is important to maintain adaptive capacity include mesic hardwood forest stands, high-diversity prairie complexes, wetland complexes, and cold-water lakes and streams.

Goal 1, Objective 1.1 prioritizes these habitats for the implementation of conservation actions. In addition, a number of Conservation Focus Areas have been identified with a watershed focus for the protection, enhancement, or restoration of stream habitats (see Conservation Focus Area Overviews for more information).

Invasive species, insects, pest, disease, and deer herbivory in forested systems are important stressors interacting with climate to reduce biological diversity.

Preventing new introductions and controlling the spread of invasive plants and animals is a conservation action under Goal 1, Objective 1. Goal 1, Objective 4 addresses ensuring compliance with invasive species regulations to protect SGCN or their habitats.

Climate change is expected to affect surface and groundwater availability and flow regimes, which are important factors for maintaining biological diversity in many habitats (mesic and wet prairies; forests; wetlands; and river, stream, and lake systems).

In addition to this impact being addressed by conservation actions for Goal 1, Objectives 1 and 4, two Conservation Focus Areas (Pine Sands – South and Bonanza Valley) include DNR groundwater protection management areas (see Conservation Focus Area Overviews for more information).

An unknown variable in all habitats is how social and economic systems will respond to weather events. Natural resource managers will need to consider this uncertainty when developing and implementing habitat or species management plans. This uncertainty also highlights the importance of implementing long-term monitoring and research projects, developing demonstration management sites, and applying an adaptive management approach.

A conservation action under Goal 1, Objective 1.1 is to assist conservation partners with the development of research, monitoring, and demonstration projects to evaluate habitat and SGCN responses to management practices to inform adaptive management. Chapter 5 in the Wildlife Action Plan addresses monitoring and adaptive management.

Life-history traits can increase a species' vulnerability to other stressors.

The Wildlife Action Network and many of the habitat conservation actions identified under Goal 1, Objective 1 are directed at reducing habitat stressors related to specific life-history traits. For example, protecting, restoring, and enhancing habitat quality may help ensure that special resources are available to species. Increasing connectivity within sites for species that have limited dispersal ability, and among sites for species that require multiple habitats throughout their life history may increase opportunities for those species to adapt to stressors, including climate change. Increasing connectivity may increase opportunities for species to connect to special resources, such as mussels to their host fish. Increasing habitat diversity may provide more specialized habitats and niches, such as thermal refugia.

Addressing Emerging Issues

Minnesota's Wildlife Action Plan will address over the plan's 10 years any emerging issues, such as new diseases, insect outbreaks, invasive species, technologies, recreational activities, and economic practices that may present potentially serious challenges to ensuring the long-term health and viability of Minnesota's wildlife as stated in Goal 1. Addressing these issues could include implementing conservation actions such as surveys, research and monitoring; participating in educational/training workshops and conferences; developing and implementing species or habitat management plans; engaging the public through education and technical guidance; and developing policy, guidance, and regulations. These actions may be undertaken as part of a state, regional, or national initiative.

References

Beisner, B. F., C. L. Dent, and S. R. Carpenter. 2003. Variability of lakes on the landscape: Roles of phosphorus, food webs, and dissolved organic carbon. Ecology 84, no. 6: 1563–75.

Chu, C, N. E. Jones, N. E. Mandrak, A. R. Piggott, and C. K. Minns. 2008. The influence of air temperature, groundwater discharge, and climate change on the thermal diversity of stream fishes in southern Ontario watersheds. Canadian Journal of Fisheries and Aquatic Sciences 65: 297–308.

Fang, X., H. G. Stefan, J. G. Eaton, J. H. McCormick, and S. R. Alam. 2004. Simulation of thermal/dissolved oxygen habitat for fishes in lakes under different climate scenarios: Part 1. Cool-water fish in the contiguous US. Ecological Modelling 172: 13-37.

Fayram, A. H., M. J. Hansen, and T. J. Ehlinger. 2005. Interactions between walleyes and four fish species with implications for walleye stocking. North American Journal of Fisheries Management 25: 1321–30.

Ficke, A. D., C. A. Myrick, and L. J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17: 581–613.

Galatowitsch, S., L. Frelich, and L. Phillips-Mao. 2009. Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America. Biological Conservation 142: 2012–22.

Genkai-Kato, M., and S. R. Carpenter. 2005. Eutrophication due to phosphorus recycling in relation to lake morphometry, temperature, and macrophytes. Ecology 86, no. 1: 210–19.

Grimm, N. B., M. D. Staudinger, A. Staudt, S. L. Carter, S. F. Chapin, P. Kareiva, M. Ruckelshaus, and B. A. Stein. 2013. Climate-change impacts on ecological systems: Introduction to a US assessment. Frontiers in Ecology and the Environment 11, no. 9: 456–64.

Handler, S., M. J. Duveneck, L. Iverson, E. Peters, R. M. Scheller, K. R. Wythers, L. Brandt, P. Butler, M. Janowiak, P. D. Shannon, C. Swanston, K. Barrett, R. Kolka, C. McQuiston, B. Palik, P. B. Reich, C. Turner, M. White, C. Adams. A. D'Amato, S. Hagell, P. Johnson, R. Johnson, M. Larson, S. Matthews, R. Montgomery, S. Olson, M. Peters, A. Prasad, J. Rajala, J. Daley, M. Davenport, M. R. Emery, D. Fehringer, C. L. Howing, G. Johnson, L. Johnson, D. Neitzel, A. Rissman, C. Rittenhouse, and R. Ziel. 2014. Minnesota forest ecosystem vulnerability assessment and synthesis: A report from the Northwoods Climate Change Response Framework project. Gen. Tech. Rep. NRS-133. Newtown Square, PA; US Department of Agriculture, Forest Service, Northern Research Station. 228 pp.

Herb, W., and H. Stefan. 2010. Projecting the impact of climate change on coldwater stream temperatures in Minnesota using equilibrium temperature models. St. Anthony Falls Laboratory, University of Minnesota, Project Report 546, Minneapolis.

Jacobson, P. C., T. K. Cross, J. Zandlo, B. N. Carlson, and D. L. Pereira. 2012. The effects of climate change and eutrophication on cisco Coregonus artedi abundance in Minnesota lakes. Advances in Limnology 63: 417–27.

Jacobson, P. C., H. G. Stefan, and D. L. Pereira. 2010. Coldwater fish oxythermal habitat in Minnesota lakes: Influence of total phosphorus, July air temperature, and relative depth. Canadian Journal of Fisheries and Aquatic Sciences 67, no. 12: 2002–13.

LeDee, O. E., and C. A. Ribic. 2015. Determining climate change management priorities: A case study from Wisconsin. Journal of Conservation Planning 11: 1–12.

Minnesota Department of Natural Resources. 2011. Climate Change and Renewable Energy: Management Foundations. Minnesota DNR Climate and Renewable Energy Steering Team, 79 pp.

Minns, C. K. 2009. The potential future impacts of climate warming and other human activities on the production capacity of Canada's lake fisheries: A meta-model. Aquatic Ecosystem Health and Management 12, no. 2: 152¬–67.

National Fish, Wildlife and Plants Climate Adaptation Partnership. 2012. National Fish, Wildlife and Plant Climate Adaptation Strategy. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and US Fish and Wildlife Service. Washington, DC. http://www.wildlifeadaptationstrategy.gov/pdf/NFWPCAS-Final.pdf

Palmer, M. A., D. P. Lettenmaier, N. L. Poff, S. L. Postel, B. Richter, and R. Warner. 2009. Climate change and river ecosystems: Protection and adaptation options. Environmental Management 44, no. 6: 1053–68.

Root, T. L., and S. H. Schneider. 2002. Climate change: Overview and implications for wildlife. In Wildlife Responses to Climate Change: North American Case Studies, S. H. Schneider and T. L. Root, editors, 1–56. Washington, DC: Island Press.

Schneider, K.N. 2010. Biological indicators of climate change trends in fish communities and the timing of walleye spawning runs in Minnesota. Master's Thesis, University of Minnesota, St. Paul.

Small-Lorenz, S. L., R. Schneider, and J. Walk. 2013. Climate change vulnerability of fish and wildlife in the US Corn Belt Region. Safeguarding Wildlife from Climate Change Webinar Series, US Fish and Wildlife Service, December 11, 2013. http://brightcove.vo.llnwd.net/e1/uds/pd/821753390001/821753390001_2994350606001_2013-1218-Safeguarding-final.mp4

Staudinger, M. D., T. L. Morelli, and A. M. Bryan, eds. 2015. Integrating climate change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Mass.

Stefan, H., X. Fang, and J. G. Eaton. 2001. Simulated fish habitat changed in North American lakes in response to projected climate warming. Transactions of the American Fisheries Society 130: 459–77.

Walther, G. R., A. Roques, P. E. Hulme, M. T. Sykes, P. Pysek, I. Kühn, M. Zobel, S. Bacher, Z. Botta-Dukát, H. Bugmann, B. Czúcz, J. Dauber, T. Hickler, V. Jarosík, M. Kenis, S. Klotz, D. Minchin, M. Moora, W. Nentwig, J. Ott, V. E. Panov, B. Reineking, C. Robinet, V. Semenchenko, W. Solarz, W. Thuiller, M. Vilà, K. Vohland, and J. Settele. 2009. Alien species in a warmer world: Risks and opportunities. Trends in Ecology and Evolution 24: 686–93.

Wisconsin's Changing Climate: Impacts and Adaptation. 2011. Wisconsin Initiative on Climate Change Impacts. Nelson Institute for Environmental Studies, University of Wisconsin-Madison and the Wisconsin Department of Natural Resources, Madison.