MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

CONSERVING HABITATS AND BIODIVERSITY

TERRESTRIAL INVERTEBRATES

DEPARTMENT OF NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

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

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Terrestrial Invertebrates

Overview

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

Insects

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

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

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

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

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

Bees

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

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

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

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

Case Study: Minnesota Bumble Bee Atlas

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

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

Butterflies and Moths

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

Butterfly species richness and abundance have both declined in Minnesota. Eight species of butterflies are now considered extirpated or likely extirpated: Arogos skipper (*Atrytone arogos*), Assiniboia skipper (*Hesperia assiniboia*), Ottoe skipper (*Hesperia ottoe*), Uncas skipper (*Hesperia uncas*), Garita skipperling (*Oarisma garita*), Poweshiek skipperling (*Oarisma poweshiek*), Uhler's arctic (*Oeneis uhleri varuna*), and Karner blue (*Plebejus samuelis*). Likewise, only a single population of Dakota skippers (*Hesperia dacotae*) remains despite extensive searching of historically occupied sites. Abundance has also declined among even previously common species (Jessica Petersen, DNR, pers.comm.). Similarly, there have been range contractions for species such as the regal fritillary (*Argynnis idalia*) and dusted skipper (*Atrytonopsis hianna*). Once common species like eastern tailed-blues (*Cupido comyntas*) and pearl crescents (*Phyciodes tharos*) are less abundant than in the past. There is a conservation need for butterfly monitoring of common species in Minnesota to document changes in abundance.

Photo: Dakota skipper, Bob Dunlap

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

Beetles

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

Other Invertebrates

Spiders

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

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

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

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

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

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

Snails

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

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

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

SGCN and SNI Summary Information

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

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

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

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

Habitat Associations

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

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

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

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

Primary Stressors for Terrestrial Invertebrates

Development

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

Photo: Olympia marble pair mating, Jessica Petersen

Crop Production

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

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

Livestock Management

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

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

Mining and Quarrying

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

Roads, Trails, and Railroads

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

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

Hunting and Collecting Animals

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

Gathering Plants and Fungi

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

Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Timber harvest of mesic hardwood forests can affect fragile spring ephemerals (wildflowers) in the understory with effects on the various bee species that are specialists of spring ephemerals. For example, the spring beauty mining bee (*Andrena erigeniae*) exclusively feeds its brood pollen from spring beauty (*Claytonia sp.*), the trout lily miner bee (*Andrena erythronii*) feeds its brood pollen from trout lily (*Erythronium sp.*), *Andrena polemonii* feeds its brood pollen from Jacob's ladder (*Polemonium* *sp.*), and *Andrena uvulariae* feeds its brood pollen from bellwort (*Uvularia sp.*). Similarly, many of the bumble bee queens that emerge in the early spring use pollen and nectar from spring ephemerals to begin to build their colonies, including rusty patched bumble bee. Timber harvest in peatlands paints a mixed picture. Recent surveys of Lepidoptera in Minnesota peatlands show a diverse fauna in sparsely or semi- treed peatlands approximately 2-20 years after timber harvest. But latter successional stages have consistently had poor results, and even 70-year+ stands have been strikingly depauperate (lacking in species richness), perhaps due to denser stand structures that block more sunlight relative to their old growth counterparts. Taiga Alpine (*Erebia mancinus*) is a SGCN which has yet to be found in regenerating peatland habitats, even those with similar floral composition. More research over time is needed.

Fire Management

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

Invasive Species (Problematic Non-native Species)

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

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

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

Problematic Native Species

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

Diseases and Pathogens

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

Air-borne Pollution

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

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

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

Photo: Hairy-necked tiger beetle, Bob Dunlap

Light and Noise Pollution

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

Effects of light pollution include disrupting the behavior of amphibians whose breeding calls are delivered at night, drawing nocturnal insects to artificial lights that increase their predation risk, and disorienting birds that use environmental cues to guide their nighttime migration (DarkSky International, 2025a; 2025b). In addition, the phenology, growth rates and biomass of plants are affected (Bucher et al., 2023). Bright day and dark night cycles synchronize the internal clocks of plants and animals, and alterations to these cycles can affect hormone production, reproductive behavior, neural activity, and metabolic functions (Bumgarner & Nelson, 2021).

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

Changes in Temperature related to Climate

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

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

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

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

Changes in Precipitation and Hydrology related to Climate

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

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

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

Photo: Regal fritillary on milkweed, Bob Dunlap

Priority Species Conservation Strategies

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

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

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

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

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

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

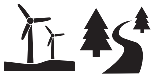
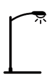
Potential Conservation Actions for Terrestrial Invertebrates

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

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

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

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

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

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

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

References

Albaseer, S. S., Jaspers, V. L. B., Orsini, L., Vlahos, P., Al-Hazmi, H. E., & Hollert, H. (2025). Beyond the field: How pesticide drift endangers biodiversity. *Environmental Pollution*, *366*, 125526. https://doi.org/10.1016/j.envpol.2024.125526

Altermatt, F. (2010). Climatic warming increases voltinism in European butterflies and moths. *Proceedings of the Royal Society B Biological Sciences*, *277*(1685), 1281–1287. https://doi.org/10.1098/rspb.2009.1910

Aubrecht, C., Jaiteh, M.S., & de Sherbinin, A. (2010). Global assessment of light pollution impact on protected areas. Center for International Earth Science Information Network, The Earth Institute at Colombia University.

Brokaw, J., Portman, Z. M., Bruninga-Socolar, B., & Cariveau, D. P. (2023). Prescribed fire increases the number of ground-nesting bee nests in tallgrass prairie remnants. *Insect Conservation and Diversity*, *16*(3), 355–367. https://doi.org/10.1111/icad.12628

Bucher, S. F., Uhde, L., Weigelt, A., Cesarz, S., Eisenhauer, N., Gebler, A., Kyba, C., Römermann, C., Shatwell, T., & Hines, J. (2023). Artificial light at night decreases plant diversity and performance in experimental grassland communities. *Philosophical Transactions of the Royal Society B Biological Sciences*, *378*(1892). https://doi.org/10.1098/rstb.2022.0358

Bumgarner, J.R. & Nelson, R. (2021). Light at night and disrupted circadian rhythms alter physiology and behavior. *Integrative and Comparative Biology*, *61*(3), 1160-1169. https://doi.org/10.1093/icb/icab017

Buxton, R. T., McKenna, M. F., Mennitt, D., Brown, E., Fristrup, K., Crooks, K. R., Angeloni, L. M., & Wittemyer, G. (2019). Anthropogenic noise in US national parks – sources and spatial extent. *Frontiers in Ecology and the Environment*, *17*(10), 559–564. https://doi.org/10.1002/fee.2112

Buxton, R.T., McKenna, M.F., Mennitt, D.J., et al. (2017). Noise pollution is pervasive in US protected areas. *Science 356*, 531–33. https://doi.org/10.1126/science.aah4783

Cameron, S. A., Lozier, J. D., Strange, J. P., Koch, J. B., Cordes, N., Solter, L. F., & Griswold, T. L. (2011). Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences*, *108*(2), 662–667. https://doi.org/10.1073/pnas.1014743108

Cardoso, P., Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Fukushima, C. S., Gaigher, R., Habel, J. C., Hallmann, C. A., Hill, M. J., Hochkirch, A., Kwak, M. L., Mammola, S., Noriega, J. A., Orfinger, A. B., Pedraza, F., Pryke, J. S., Roque, F. O., . . . Samways, M. J. (2020). Scientists' warning to humanity on insect extinctions. *Biological Conservation*, *242*, 108426. https://doi.org/10.1016/j.biocon.2020.108426

Cariveau, A. J. B., Haynes, G. A., Perish, P., Tuerk, K., Nootenboom, C., Mitchell, T., Lonsdorf, E., Oberhauser, K., & Snell-Rood, E. C. (2024). Host plants and landscape predict use of roadside habitat by breeding monarchs. *Insect Conservation and Diversity*, *17*(5), 894–909. https://doi.org/10.1111/icad.12758

Casagrande, R. A., & Dacey, J. E. (2007). Monarch butterfly oviposition on swallow-worts (*Vincetoxicum spp.*). *Environmental Entomology*, *36*(3), 631–636. https://doi.org/10.1603/0046-225x(2007)36

Chock, R. Y., Clucas, B., Peterson, E. K., Blackwell, B. F., Blumstein, D. T., Church, K., Fernández-Juricic, E., Francescoli, G., Greggor, A. L., Kemp, P., Pinho, G. M., Sanzenbacher, P. M., Schulte, B. A., & Toni, P. (2021). Evaluating potential effects of solar power facilities on wildlife from an animal behavior perspective. *Conservation Science and Practice*, *3*(2). https://doi.org/10.1111/csp2.319

Colla, S. R., Otterstatter, M. C., Gegear, R. J., & Thomson, J. D. (2006). Plight of the bumble bee: Pathogen spillover from commercial to wild populations. *Biological Conservation*, *129*(4), 461–467. https://doi.org/10.1016/j.biocon.2005.11.013

Cutler, B., & Jennings, D.T. (1992). Habitat segregation by species of *Metaphidippus* (Araneae: Salticidae) in Minnesota. *The Journal of Arachnology*, *20*(2), 88-93.

Cutler, B., Grim, L. H., & Kulman, H. M. (1975). a study in the summer phenology of dionychious spiders from northern Minnesota forests. *The Great Lakes Entomologist*, *8*(3). https://doi.org/10.22543/0090-0222.1250

DarkSky International (2025a). DarkSky International. Protecting the night skies for present and future generations. Accessed June 2025. https://darksky.org

DarkSky International (2025b). Artificial light at night: state of the science 2025. https://doi.org/10.5281/zenodo.15492393

Darst, A. L., Mitchell, T. S., Verhoeven, M. R., Evans, E., Tonsfeldt, L., Kjaer, S., & Snell-Rood, E. C. (2024). Diversity of bumble bees and butterflies in Minnesota roadsides depends on floral diversity and abundance but not floral native status. *Insect Conservation and Diversity*, *17*(4), 690–701. https://doi.org/10.1111/icad.12739

Edwards, C. B., Zipkin, E. F., Henry, E. H., Haddad, N. M., Forister, M. L., Burls, K. J., Campbell, S. P., Crone, E. E., Diffendorfer, J., Douglas, M. R., Drum, R. G., Fallon, C. E., Glassberg, J., Grames, E. M., Hatfield, R., Hershcovich, S., Black, S. H., Larsen, E. A., Leuenberger, W., . . . Schultz, C. B. (2025). Rapid butterfly declines across the United States during the 21st century. *Science*, *387*(6738), 1090–1094. https://doi.org/10.1126/science.adp4671

Ehmann, W. J. (2002). Conservation biology of special concern jumping spiders (Araneae: Salticidae) of Minnesota. Final Report submitted to the Natural Heritage and Nongame Research Program, Minnesota Department of Natural Resources. 11 pp.

Ehmann, W. J. (2011). Reconnaissance for state-listed jumping spiders (Araneae: Salticidae) in St. Louis and Lake Counties, Minnesota. Final report submitted to the Minnesota County Biological Survey, Minnesota Department of Natural Resources. 11 pp.

Ehmann, W. J., & B. E. Boyd. (1997). Surveys for proposed special concern jumping spiders of Minnesota. Final report submitted to the Minnesota Department of Natural Resources.

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, *2*(6). https://doi.org/10.1126/sciadv.1600377

Finch, D. M., Butler, J. L., Runyon, J. B., Fettig, C. J., Kilkenny, F. F., Jose, S., Frankel, S. J., Cushman, S. A., Cobb, R. C., Dukes, J. S., Hicke, J. A., & Amelon, S. K. (2021). Effects of climate change on invasive species. In T. M. Poland, T. Patel-Weynand, D. M. Finch, C. F. Miniat, D. C. Hayes, & V. M. Lopez (Eds.), *Invasive Species in Forests and Rangelands of the United States* (pp. 57–83). Springer International Publishing. https://doi.org/10.1007/978-3-030-45367-1_4

Galbraith, S. M., Cane, J. H., Moldenke, A. R., & Rivers, J. W. (2019). Wild bee diversity increases with local fire severity in a fire-prone landscape. *Ecosphere*, *10*(4). https://doi.org/10.1002/ecs2.2668

Gandhi, K.J.K., Gilmore, D.W., Ball, G.E., Holzenthal, R.W., Katovich, S.A., et al. (2005). A review of ground beetle species (Coleoptera: Carabidae) of Minnesota, United States: new records and range extensions. *Proceedings of the Entomological Society of Washington*, *107*(4), 917-940.

Goebel, K. M., Davros, N. M., Andersen, D. E., & Rice, P. J. (2022). Tallgrass prairie wildlife exposure to spray drift from commonly used soybean insecticides in Midwestern USA. *The Science of the Total Environment*, *818*, 151745. https://doi.org/10.1016/j.scitotenv.2021.151745

Goebel, K. M., Andersen, D. E., Rice, P. J., & Davros, N. M. (2024). Effects of insecticide spray drift on arthropod prey resources of birds in grasslands in Minnesota. *Journal of Wildlife Management*, *88*(4). https://doi.org/10.1002/jwmg.22572

Goulson, D. (2013). REVIEW: An overview of the environmental risks posed by neonicotinoid insecticides. *Journal of Applied Ecology*, *50*(4), 977–987. https://doi.org/10.1111/1365-2664.12111

Grimaldi, D., & Engel, M. S. (2005). *Evolution of the Insects*. Cambridge University Press.

Haarstad, J. 1990. The Acrididae of Minnesota. Final report submitted to the Minnesota Department of Natural Resources. 28 pp. https://www.dnr.state.mn.us/eco/nongame/projects/research_reports/abstracts/insects/haarstad1990.html

He, X., Liang, J., Zeng, G., Yuan, Y., & Li, X. (2019). The effects of interaction between climate change and land-use/cover change on biodiversity-related ecosystem services. *Global Challenges (Hoboken, NJ)*, *3*(9), 1800095. https://doi.org/10.1002/gch2.201800095

Heimer, S., Nentwig, W., & Cutler, B. (1984). The spider fauna of the Itasca State Park (Minnesota, USA). Faunistische Abhandlungen, Staatliches Museum für Tierkunde in Dresden, 11, 119-124.

Hopwood, J., Black, S. H., Lee-Mader, E., Charlap, A., Preston, R., Mozumder, K., and Fleury, S. (2015). Literature review: Pollinator habitat enhancement and best management practices in highway rights-of-way. Prepared for: The Federal Highway Administration by The Xerces Society for Invertebrate Conservation in collaboration with ICF International. https://rightofway.erc.uic.edu/wp-content/uploads/2018/05/1A11-pollinators_BMPs_in_highway_ROW-1.pdf

Horváth, G., Kriska, G., Malik, P., & Robertson, B. (2009). Polarized light pollution: a new kind of ecological photopollution. *Frontiers in Ecology and the Environment*, *7*(6), 317–325. https://doi.org/10.1890/080129

Jennings, D.T. & Cutler, B. (1996). Crab spiders (Araneae: Philodroidae, Thomisidae) of Ramsey County, Minnesota. United States Department of Agriculture, Report NC-185. 42 pp.

Kantola, T. Tracy, J.L., Baum, K. A., Quinn, M. A., & Coulson, R. N. (2019). Spatial risk assessment of eastern monarch butterfly road mortality during autumn migration within the southern corridor, Biological Conservation, Volume 231, https://doi.org/10.1016/j.biocon.2019.01.008.

Kasten, K., Stenoien, C., Caldwell, W., & Oberhauser, K. S. (2016). Can roadside habitat lead monarchs on a route to recovery? *Journal of Insect Conservation*, *20*(6), 1047–1057. https://doi.org/10.1007/s10841-016-9938-y

Keilsohn, W., Narango, D. L., & Tallamy, D. W. (2018). Roadside habitat impacts insect traffic mortality. *Journal of Insect Conservation*, *22*(2), 183–188. https://doi.org/10.1007/s10841-018-0051-2

Knight, S. M., Bleho, B. I., Grantham, M. A., Westwood, R., Koper, N., & Hamel, C. D. (2024). Management practices benefit endangered Poweshiek skipperling (*Oarisma poweshiek*) in Manitoba tall grass prairie. *FACETS*, *9*, 1–12. https://doi.org/10.1139/facets-2023-0049

Knight, S. M., Norris, D. R., Derbyshire, R., & Flockhart, D. T. T. (2019). Strategic mowing of roadside milkweeds increases monarch butterfly oviposition. *Global Ecology and Conservation*, *19*, e00678. https://doi.org/10.1016/j.gecco.2019.e00678

Koch, R. L., Rider, D. A., Tinerella, P. P., & Rich, W. A. (2014). Stink bugs (Hemiptera: Heteroptera: pentatomidae) of Minnesota: an annotated checklist and new state records. *The Great Lakes Entomologist*, *47*(2). https://doi.org/10.22543/0090-0222.2305

Kok, A. C. M., Berkhout, B. W., Carlson, N. V., Evans, N. P., Khan, N., Potvin, D. A., Radford, A. N., Sebire, M., Sabet, S. S., Shannon, G., & Wascher, C. a. F. (2023). How chronic anthropogenic noise can affect wildlife communities. *Frontiers in Ecology and Evolution*, *11*. https://doi.org/10.3389/fevo.2023.1130075

Lane, I. G., Portman, Z. M., Herron-Sweet, C. R., Petersen, J. D., Bruninga-Socolar, B., & Cariveau, D. P. (2023). Higher floral richness promotes rarer bee communities across remnant and reconstructed tallgrass prairies, though remnants contain higher abundances of a threatened bumble bee (Bombus Latreille). *Biological Conservation*, *279*, 109862. https://doi.org/10.1016/j.biocon.2022.109862

Lark, T. J., Larson, B., Schelly, I., Batish, S., & Gibbs, H. K. (2018). Accelerated conversion of native prairie to cropland in Minnesota. *Environmental Conservation*, *46*(2), 155–162. https://doi.org/10.1017/s0376892918000437

LeCroy, K. A., Savoy-Burke, G., Carr, D. E., Delaney, D. A., & Roulston, T. H. (2020). Decline of six native mason bee species following the arrival of an exotic congener. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-75566-9

Liess, S., Twine, T. E., Snyder, P. K., Hutchison, W. D., Konar-Steenberg, G., Keeler, B. L., & Brauman, K. A. (2022). High-resolution climate projections over Minnesota for the 21st century. *Earth and Space Science*, *9*(3). https://doi.org/10.1029/2021ea001893

Lima, M.A.P., Cutler, G.C., Mazzeo, G. & Hrncir, M. (2022). The decline of wild bees: Causes and consequences. *Frontiers in Ecology and Evolution*, *10*. https://doi.org/10.3389/fevo.2022.1027169

Macy, R. W., & Shepard, H. H. (1941). *Butterflies: a handbook of the butterflies of the United States, complete for the region north of the Potomac and Ohio rivers and east of the Dakotas*. University of Minnesota Press.

Marquis, R. J. (2022). *Caterpillars in the middle: Tritrophic interactions in a changing world* (Vol. 642). S. Koptur (Ed.). Springer.

McKenna, D. D., McKenna, K. M., Malcom, S. B., & Bebenbaum, M. R. (2001). Mortality of Lepidoptera along roadways in central Illinois. *Journal of the Lepidopterists Society*, 55(2), 63-68.

Minnesota Department of Natural Resources (DNR) (2022). Rare Species Guide: an online encyclopedia of Minnesota's rare native plants and animals [web application]. Division of Ecological and Water Resources.

Minnesota Department of Natural Resources (DNR) (2025). DNR pollinator best management practices and habitat restoration guidelines. V2.

Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Commerce (MDOC) (2025). Greenhouse gas emissions in Minnesota 2005-2022: Biennial inventory report tracking the state's greenhouse gas emissions contributing to climate change. Report to Legislature, January 2025. Jointly submitted by the Pollution Control Agency and the Department of Commerce. https://www.pca.state.mn.us/sites/default/files/lraq-3sy25.pdf

Mitchell, T. S., Agnew, L., Meyer, R., Sikkink, K. L., Oberhauser, K. S., Borer, E. T., & Snell-Rood, E. C. (2020). Traffic influences nutritional quality of roadside plants for monarch caterpillars. *Science of The Total Environment*, *724*, 138045. https://doi.org/10.1016/j.scitotenv.2020.138045

Mitchell, T. S., Verhoeven, M. R., Darst, A. L., Patterson, C. H., & Snell-Rood, E. C. (2024). Seeding roadsides is necessary but not sufficient for restoring native floral communities. *Ecological Solutions and Evidence*, 5(3). https://doi.org/10.1002/2688-8319.12364

Müller, J., Hothorn, T., Yuan, Y., Seibold, S., Mitesser, O., Rothacher, J., Freund, J., Wild, C., Wolz, M., & Menzel, A. (2024). Weather explains the decline and rise of insect biomass over 34 years. *Nature*, *628*(8007), 349–354. https://doi.org/10.1038/s41586-023-06402-z

Nekola, J.C. (2002). Distribution and ecology of terrestrial gastropods in northwestern Minnesota. Final report to Minnesota DNR Natural Heritage and Nongame Research Program. https://files.dnr.state.mn.us/eco/nongame/projects/consgrant_reports/2002/2002_nekola.pdf.

Nekola, J.C., Barthel, M., Massart, P., & North, E. (1999). Terrestrial gastropod inventory of igneous outcrops in northeastern Minnesota. Final report to Minnesota DNR Natural Heritage and Nongame Research Program. https://files.dnr.state.mn.us/eco/nongame/projects/consgrant_reports/1999/1999_nekola.pdf

Nordmeyer, C., Runquist, E., & Stapleton, S. (2021). Invasive grass negatively affects growth and survival of an imperiled butterfly. *Endangered Species Research*, *45*, 301–314. https://doi.org/10.3354/esr01136

Parmesan, C. (2006). Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology Evolution and Systematics*, *37*(1), 637–669. https://doi.org/10.1146/annurev.ecolsys.37.091305.110100

Pelton, E. (2018). Keep monarchs wild: why captive rearing isn't the way to help monarchs. Xerces Society. https://xerces.org/blog/keep-monarchs-wild. Accessed 21 Feb 2025.

Phillips, J. N., Termondt, S. E., & Francis, C. D. (2021). Long-term noise pollution affects seedling recruitment and community composition, with negative effects persisting after removal. *Proceedings of the Royal Society B Biological Sciences*, *288*(1948). https://doi.org/10.1098/rspb.2020.2906

Portman, Z. M., Gardner, J., Lane, I. G., Gerjets, N., Petersen, J. D., Ascher, J. S., Arduser, M., Evans, E. C., Boyd, C., Thomson, R., & Cariveau, D. P. (2023). A checklist of the bees (Hymenoptera: Apoidea) of Minnesota. *Zootaxa*, *5304*(1), 1–95. https://doi.org/10.11646/zootaxa.5304.1.1

Ratcliffe, H., Charton, K., Siddons, T., Lyons, M. & LeDee, O. (2025). Effects of climate change on midwestern ecosystems: temperate flooded and swamp forest. Midwest Climate Adaptation Science Center. https://mwcasc.umn.edu/node/821

Richman, D. B., & Cutler, B. (1978). A list of the jumping spiders (Araneae: Salticidae) of the United States and Canada. *Peckhamia*, *1*(5), 82-110.

Ries, L., Debinski, D.M., & Wieland, M. L. (2001). Conservation value of roadside prairie restoration to butterfly communities. Conservation Biology 15(2). https://conbio.onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.2001.015002401.x

Robinson, S. I., Mikola, J., Ovaskainen, O., & O'Gorman, E. J. (2021). Temperature effects on the temporal dynamics of a subarctic invertebrate community. *Journal of Animal Ecology*, *90*(5), 1217–1227. https://doi.org/10.1111/1365-2656.13448

Runkle, J., Kunkel, K. E., Frankson, R., Easterling, D. R., & Champion, S. M. (2022). *Minnesota State Climate Summary 2022* (NOAA Technical Report NESDIS 150-MN, p. 4 pp.). NOAA/NESDIS. https://statesummaries.ncics.org/chapter/mn/

Runquist, E., Nordmeyer, C., & Stapleton, S. (2024). Widespread annual occurrence of pesticides within designated critical habitats for endangered prairie butterflies. *Journal of Insect Conservation*, *28*(3), 539–552. https://doi.org/10.1007/s10841-024-00572-5

Samson, F., & Knopf, F. (1994). Prairie conservation in North America. *BioScience*, *44*(6), 418–421. https://doi.org/10.2307/1312365

Scott, J. A. (1979). Hibernal diapause of North American Papilionoidea and Hesperioidea. *Journal of Research on the Lepidoptera*, *18*(3), 171–200. https://doi.org/10.5962/p.266881

Seibold, S., Gossner, M. M., Simons, N. K., Blüthgen, N., Müller, J., Ambarlı, D., Ammer, C., Bauhus, J., Fischer, M., Habel, J. C., Linsenmair, K. E., Nauss, T., Penone, C., Prati, D., Schall, P., Schulze, E., Vogt, J., Wöllauer, S., & Weisser, W. W. (2019). Arthropod decline in grasslands and forests is associated with landscape-level drivers. *Nature*, *574*(7780), 671–674. https://doi.org/10.1038/s41586-019-1684-3

Shephard, A. M., Agnew, L., Herdtle, A., Mitchell, T. S., Borer, E. T., & Snell-Rood, E. C. (2022). Traffic patterns, more than adjacent land use, influence element content of roadside forbs for insect pollinators. *Ecological Solutions and Evidence*, *3*(4), e12195. https://doi.org/10.1002/2688-8319.12195

Shirey, V. M., Lewthwaite, J. M., Gawel, A. M., & Guzman, L. M. (2025). 50 years of invertebrate conservation under the United States Endangered Species Act—history and threats to species. *Frontiers in Conservation Science*, *6*. https://doi.org/10.3389/fcosc.2025.1505451

Strazanac, J.S., Seidel, G.E., Kondo, V., Fritzler, C.J., & Butler, L. (2007). Nontarget impact of *Bacillus thuringiensis kurstaki* in central Appalachian mixed broadleaf-pine forests: long-term evaluation of arthropods. In: Gottschalk, K. W. (Ed.) *Proceedings, 17th U.S. Department of Agriculture interagency research forum on gypsy moth and other invasive species 2006*; Gen. Tech. Rep. NRS-P-10. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 94.

Swengel, A. B., & Swengel, S. R. (2007). Benefit of permanent non-fire refugia for Lepidoptera conservation in fire-managed sites. *Journal of Insect Conservation*, 11(3), 263-279.

Szabo, N. D., Colla, S. R., Wagner, D. L., Gall, L. F., & Kerr, J. T. (2012). Do pathogen spillover, pesticide use, or habitat loss explain recent North American bumblebee declines? *Conservation Letters*, 5(3), 232–239. https://doi.org/10.1111/j.1755-263x.2012.00234.x

Thogmartin, W. E., López-Hoffman, L., Rohweder, J., Diffendorfer, J., Drum, R., Semmens, D., Black, S., Caldwell, I., Cotter, D., Drobney, P., Jackson, L. L., Gale, M., Helmers, D., Hilburger, S., Howard, E., Oberhauser, K., Pleasants, J., Semmens, B., Taylor, O., … Wiederholt, R. (2017). Restoring monarch butterfly habitat in the Midwestern US: 'All hands on deck.' *Environmental Research Letters*, *12*(7), 074005. https://doi.org/10.1088/1748-9326/aa7637

Underwood, E. C., & Fisher, B. L. (2006). The role of ants in conservation monitoring: If, when, and how. *Biological Conservation*, *132*(2), 166–182. https://doi.org/10.1016/j.biocon.2006.03.022

Van Deynze, B., Swinton, S. M., Hennessy, D. A., Haddad, N. M., & Ries, L. (2024). Insecticides, more than herbicides, land use, and climate, are associated with declines in butterfly species richness and abundance in the American Midwest. *PLoS ONE*, *19*(6), e0304319. https://doi.org/10.1371/journal.pone.0304319

Van Dyck, H., Bonte, D., Puls, R., Gotthard, K., & Maes, D. (2015). The lost generation hypothesis: could climate change drive ectotherms into a developmental trap? *Oikos*, *124*(1), 54–61. https://doi.org/10.1111/oik.02066

Warren, M. S., & Bourn, N. A. (2011). Ten challenges for 2010 and beyond to conserve Lepidoptera in Europe. *Journal of Insect Conservation*, 15(1), 321-326.

Williams, P., Thorp, R., Richardson, L. & Colla, S. (2014). Bumble bees of North America: an identification guide. Princeton University Press.

Williams-Sether, T., & Sanocki, C. (2025). *Peak streamflow trends in Minnesota and their relation to changes in climate, water years 1921–2020, chap. E* (Peak Streamflow Trends and Their Relation to Changes in Climate in Illinois, Iowa, Michigan, Minnesota, Missouri, Montana, North Dakota, South Dakota, and Wisconsin: U.S. Geological Survey Scientific Investigations Report 2023–5064, p. 55) [Scientific Investigations Report]. https://pubs.usgs.gov/sir/2023/5064/e/sir20235064e.pdf