

# MINNESOTA'S WILDLIFE ACTION PLAN 2025-2035

## CONSERVING HABITATS AND BIODIVERSITY

### VERNAL POOLS



**mn** DEPARTMENT OF  
NATURAL RESOURCES

NONGAME WILDLIFE PROGRAM

## Acknowledgments

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

## Funding

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



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

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Cover Photos: Vernal pool, Hill River State Forest, Spencer Rettler; Vernal pool in Nemadji State Forest, Andrew Herberg

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

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# Vernal Pools

## Habitat Description

Vernal pools are naturally occurring ephemeral wetlands generally found in depressions embedded within upland forests of the Eastern Broadleaf Forest and Laurentian Mixed Forest Province within Minnesota. Within these ecological provinces, the Western Superior Uplands, Northern Minnesota Drift and Lake Plains, and Minnesota and Northeast Iowa Morainal ecological sections host higher concentrations of vernal pools due to topographical features driven by historical glacial ice movement patterns. At a more local scale, the presence of vernal pools is strongly influenced by the surrounding forested environment including elements of topography, canopy shading, and leaf litter.

Vernal pools are typically small, shallow, fishless, confined basin wetlands less than 2.4 ac/1 ha in size. They are considered hydrologically “isolated” wetlands because there is no continuous surface water connection to permanently flooded water bodies. Pools typically receive most of their water from snow melt runoff or rain, however, in settings where pools intersect the water table, groundwater inputs may be important. Based on local topography and surrounding forest characteristics, vernal pools can also be part of larger intricate pool complexes and can be connected to other wetlands or experience overflow from other wetlands/streams, still, any flow connections to permanently flooded water bodies remain temporary.

Vernal pools are characterized by seasonal water fluctuations and temporary flooding. They experience alternating periods of flooding and drying and must go through a drying phase annually or every few years (e.g., 3 out of 5 years). Pools typically fill with water in the spring and dry down by later in the summer, however, some pools also fill again after fall or winter rains or after large precipitation events. Flood duration and timing, as well

as the frequency of flood events, can vary widely from pool basin to pool basin and even from year to year given both temporal and spatial differences in precipitation amounts. The hydroperiod, or length of time that the pool is inundated (as well as the amount of water held), has a strong effect on the type of vegetation and wildlife that occupy and utilize vernal pool habitats. Additionally, maintenance of surrounding forest conditions for canopy shading is important for minimizing effects on wetland hydrology, plant communities, nutrient cycles, and thermal regimes.



*Photo: Vernal pool, Hill River State Forest, Spencer Rettler*

These wetlands are not well captured by Minnesota’s or the national wetlands inventory and therefore not yet comprehensively mapped for the state of Minnesota. Efforts are currently underway to better understand their distribution. They are thought to be distributed mostly within Mesic Hardwood Forests and Deciduous Wet Forests (and to a lesser extent in Upland Deciduous Forest and Woodland; see those sub-chapters).

Soils are typically hydric (wet) and often covered by leaf litter. Large coarse woody debris is common and contributes to the microsite heterogeneity and complexity of vernal pools. Other variables that influence conditions within the wetland include basin

(depression) configuration and topography, light availability (canopy cover), composition of surrounding forest (and litter quality and availability), landscape setting, infiltration or drainage capacity of soil, and water inputs (which can vary spatially and temporally).

## Habitat Map

There is not currently a comprehensive map of vernal pools in Minnesota. To depict Vernal Pool habitat, we compiled spatial data from the [National Land Cover Database](#) (NLCD) and the National Wetland Inventory (for more information, see Habitat Map Methods in Chapter 3: Habitats). The map in Figure 3.18 depicts a model of where vernal pools may exist based on the parameters outlined below.

## National Wetlands Inventory

From the [National Wetland Inventory for Minnesota](#) (NWI) Layer we used the Circular 39 attribute field to include Seasonally Flooded Basins or Flat, Shrub Swamp, and Wooded Swamp that were in forested areas and 1 hectare in size or smaller.

## National Land Cover Database

From the [National Land Cover Database](#), we narrowed our search for vernal pools by including only those in Mixed or Deciduous Forest parcels that were larger than 10 hectares in size.

## Native Plant Communities

Vernal pools have not been characterized in Minnesota's Ecological Classification system, so we cannot classify them here by a particular ecological system or native plant community. At the time of this publication, the DNR is actively investigating the locations and ecological characteristics of vernal pools.

Emerging information about the vegetation composition of vernal pools is based on survey work in the northcentral part of the state within the range of the [four-toed salamander \(\*Hemidactylium scutatum\*\)](#). In the paragraphs below we share what preliminary information has been gathered to date.

Vegetation composition of sampled vernal pools varies widely across pools and even within pools. As noted above, hydroperiod can also vary dramatically between pools (and within a pool if basin topography is complex) and has a direct influence on the vegetative response.

Vegetation in pools (or portions of pools) may be dominated by trees like black ash (*Fraxinus nigra*) or yellow birch (*Betula alleghaniensis*) or other woody species like the shrub speckled alder (*Alnus incana*). Pools may also be dominated by herbaceous vegetation or be nearly devoid of vegetation altogether. Vegetation of deeper and/or more open pools can include plants often observed in wet meadow or marsh/aquatic systems like Canada bluejoint (*Calamagrostis canadensis*), water parsnip (*Sium suave*), northern water plantain (*Alisma triviale*), and duckweed (*Lemna* spp.). Species that were encountered more regularly across a variety of pool types include: brownish sedge (*Carex brunnescens*), tuckerman's sedge (*C. tuckermanii*), bladder sedge (*C. intumescens*), spinulose woodfern (*Dryopteris carthusiana*), and marsh marigold (*Caltha palustris*). Mosses are often present in abundance, sometimes forming larger hummocks (*Sphagnum* species) and growing on leaf litter substrate (non-sphagnum species).

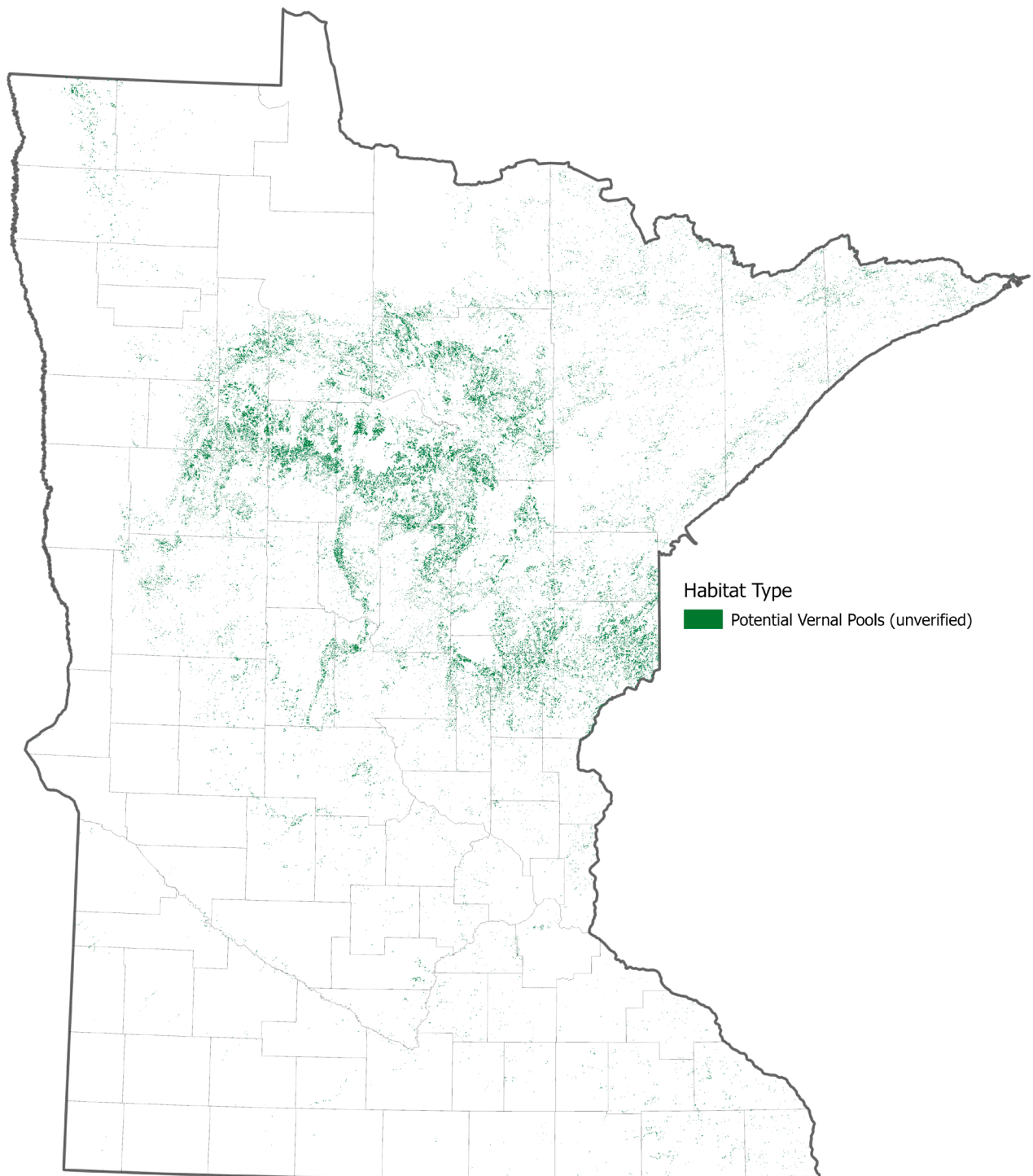


Figure 3.18. A map depicting potential (unverified) Vernal Pool habitat in Minnesota, modeled from three wetland types from the National Wetland Inventory for Minnesota, limited to those found within Mixed or Deciduous Forest parcels larger than 10 hectares in size from the National Land Cover Database. Investigations of the locations of vernal pools are ongoing.

## Conservation Overview

Vernal pools are a unique and dynamic habitat feature that many animals and plants depend upon for reproduction and survival. Due to their ephemeral nature, these wetlands act as a resource pulse that is available for only a few months of the year and often become a biodiversity hotspot during this time. Several SGCN animals and plants utilize these wetlands; therefore, there is a strong need to understand and protect these sensitive habitats.

Conversion of forested lands to development, agriculture, and other land-uses may result in the degradation and/or loss of vernal pools. Unlike wetlands that hold permanent water, vernal pools are not protected under Minnesota’s Wetland Conservation Act (WCA) and often only receive limited protection during forest management activities. Additionally, climate change presents new challenges and many unknowns for the future of vernal pools and the organisms that rely on them. These wetlands are not a readily replaceable resources on the landscape and artificial vernal pools have been met with mixed success. Thus, our primary conservation approach is the protection and enhancement of existing vernal pools.

For these reasons, vernal pools are in need of additional research and monitoring in Minnesota. Efforts are currently underway to

classify vegetation composition within these wetlands to categorize different types of vernal pools and understand their connection to the surrounding forest. Furthermore, research is being conducted to understand how vernal pools, and the SGCN that rely upon them, respond to forest disturbance and to identify strategies to minimize detrimental effects. Through these efforts, our hope is to raise awareness of these important forested wetlands, identify effectiveness techniques to protect the plants and animals using these habitats, and ensure that vernal pools continue to thrive in Minnesota.

## Species in Greatest Conservation Need

Vernal pools, despite being ephemeral, very small, and poorly documented, provide primary habitat for 9 animal Species in Greatest Conservation Need (SGCN) and secondary habitat for two others (see Table 3.18). Habitat associations for dragonflies and damselflies were not differentiated into primary and secondary habitats and are shown in the total column. Primary habitats are those that species rely on and use most consistently; loss or degradation of these habitats would have the most significant negative effect on their populations. Secondary habitats are used by the species less frequently.

**Table 3.18. Numbers of Species in Greatest Conservation Need associated with vernal pools as primary or secondary habitat.**

Species Group	Primary Habitat	Secondary Habitat	Total
Amphibians	3	0	3
Birds	0	1	1
Reptiles	0	1	1
Dragonflies and Damselflies	-	-	6
<b>Total</b>	<b>3</b>	<b>2</b>	<b>11</b>

A detailed table associating each animal SGCN with the 15 habitats identified in the 2025-2035 SWAP can be found for animals in [Appendix D](#). Plants were associated only with a single primary habitat type, based on Minnesota's native plant classification ([Appendix E](#)). Because vernal pools are not yet incorporated into that system, none were formally associated to the vernal pool type. However, some SGCN plants that may be found in vernal pools are discussed in the section below.

It should be noted that although the Eastern fairy shrimp (*Eubbranchipus vernalis*) is endemic to vernal pools, they are not represented in the table above because habitats were not delineated for any of the SGCN Branchiopoda (shrimp). Also, given the ephemeral nature of this habitat, some additional species mentioned in the text below, while not associated formally with the habitat, opportunistically use these pools.

Vernal pools provide critical habitat for a whole suite of animal species in Minnesota. Due to the periods of prolonged drawdown in vernal pools, permanent fish populations are not able to survive. This provides habitat for organisms that require or benefit from fishless conditions for successful reproduction. Some of these are obligate species and include organisms that use vernal pools almost exclusively for breeding and larval development. Many of the species that utilize vernal pools also rely on the integrity of the upland forest surrounding the pool for things like cover, foraging sites, and overwintering habitat.

## Amphibians

Three SGCN salamanders associate with vernal pools as their primary habitat. As a quintessential vernal pool obligate species, [spotted salamanders](#) (*Ambystoma maculatum*) depend upon these fishless, seasonal wetlands for successful reproduction. As soil and air temperatures increase and spring rains fall, adults migrate from upland forests to vernal pools to breed in late March - April (Sexton et al., 1990, Moriarty & Hall, 2014). Additionally, four-toed salamanders also use these forested wetlands for reproduction and seek out vernal

pools with abundant sphagnum moss hummocks as their preferred nesting habitat (Chalmers & Loftin, 2006; Moriarty & Hall, 2014). While adult spotted salamanders generally leave the vernal pools soon after breeding, female four-toed salamanders will continue to guard their eggs for approximately one month after oviposition (Banning et al., 2008). Larval development for both species occurs within these pools and can last until late summer. In general, these species need these pools to hold water (or ample moisture in leaf litter) until approximately mid-July for successful reproduction in Minnesota (Moriarty & Hall, 2014). In some rare cases, spotted salamander larvae may overwinter in the vernal pools and complete their development the following spring (Whitford & Vinegar, 1966). Both species eventually migrate to adjacent upland forests for the remainder of the active season. Eastern newts (*Notophthalmus viridescens*), another SGCN salamander, may also breed within vernal pools, yet they are not as dependent on these specific wetland features as the other two SGCN salamanders. Adult eastern newts will also frequent vernal pools in the spring to forage on other amphibian eggs. See also Case Study on next page.



Photo: Spotted salamander, Bob Dunlap

## Birds

Several SGCN birds breed and forage within mature upland hardwood forests with interspersed vernal pools. Wetland openings such as vernal pools are a key component of forests occupied by [Red-shouldered hawks](#) (*Buteo lineatus*), which often prey on amphibians and reptiles that inhabit vernal pools (King et al., 2011). While not formally associated with

this habitat, [Acadian flycatchers \(\*Empidonax virescens\*\)](#), and [cerulean warblers \(\*Setophaga cerulea\*\)](#) that use mature deciduous forest are often loosely associated with vernal pools. They may be responding to foraging opportunities provided by invertebrate prey linked to vernal pools, or simply the forest structural diversity associated with small canopy gaps.

## Mammals

Although not formally associated with vernal pools, several forest bat SGCN, such as [northern long-eared bat \(\*Myotis septentrionalis\*\)](#), [little brown myotis \(\*Myotis lucifugus\*\)](#), and [big brown bat \(\*Eptesicus fuscus\*\)](#), may forage in forest openings above vernal pools (Francl, 2008).

## Reptiles

[Blanding's turtles \(\*Emydoidea blandingii\*\)](#) use vernal pool habitat early in the spring for foraging, thermoregulation, and breeding opportunities (Beaudry et al., 2009). These turtles capitalize on highly abundant and concentrated food resources like amphibian eggs, tadpoles, and various invertebrates. These wetlands are also some of the first water features to ice out in the spring and provide opportunities to thermoregulate via basking and water submersion. Also, vernal pools may attract numerous individuals at once, thus providing breeding opportunities for adult turtles.

## Invertebrates

Some invertebrate species, such as the crustacean Eastern fairy shrimp, are endemic to vernal pools and live out their entire life cycle within these wetlands. Over the course of approximately three weeks, fairy shrimp larvae hatch from dormant cysts, develop into adults, reproduce, and die off (usually by mid-to late May; McCafferty et al., 2010).

Other aquatic invertebrates that utilize vernal pools to forage, reproduce, and undergo larval development include numerous insect species such as caddisflies (Trichoptera), dragonflies and damselflies (Odonata), water bugs (Hemiptera),

midges (Chaoboridae and Chironomidae), beetles (Coleoptera), as well as some mollusk species like snails (Lymnaeidae, Physidae, and Planorbidae), and clams (Sphaeriidae) (Colburn, 2004; Batzer et al., 2004; Bischof et al., 2013). Dragonflies SGCN associated with vernal pools include the following six species: springwater dancer (*Argia funebris*); arrowhead spiketail (*Zoraena obliqua*), azure bluet (*Enallagma aspersum*), elfin skimmer (*Nannothemis bella*), [ocellated darner \(\*Boyeria grafiana\*\)](#), and [Quebec emerald \(\*Somatochlora brevicincta\*\)](#).



Photo: Arrowhead spiketail, Jeff Fischer

## Plants

The intersection of vernal pools and the upland forest that surrounds them can provide a key habitat for many SGCN plant species. When the transition zone or ecotone is gradual and rich and mesic or wet-mesic in nature, it can provide habitat conditions that support some of Minnesota's most rare interior forest species of moonworts (*Botrychium*) and grapeferns (*Sceptridium*) as well as the mycorrhizal fungi associates that they rely upon. This includes SGCN species such as [narrow triangle moonwort \(\*Botrychium angustisegmentum\*\)](#), swamp moonwort (*B. tenebrosum*), and [blunt-lobed grapefern \(\*Sceptridium oneidense\*\)](#).

Shallow, sparsely vegetated vernal pools with shorter hydroperiods also provide key habitats for grape ferns, including blunt-lobed grapefern, a SGCN species with a state conservation status of imperiled (S2).

## Primary Stressors in this Habitat

Throughout Minnesota, habitats have been lost and degraded due to pressures associated with human settlement, subsistence, livelihoods, and recreation. Indeed, habitat loss or alteration remains the primary threat to most, if not all, SGCN. In this section, we identify key “stressors” that may continue to contribute to habitat degradation and loss. The list is adapted from a globally recognized threats lexicon developed by the International Union for the Conservation of Nature (Salafsky et al., 2024). For additional details, see the “Stressors” section in Chapter 1: Species in Greatest Conservation Need.

It is important to note that some of the factors listed as “stressors” can also be used to advance conservation goals. Broad terms such as “fire management” reflect the dual nature of these factors as they may function as stressors in some contexts while serving as valuable conservation tools in others. For example, an intense wildfire following prolonged fire suppression may cause significant stress for the habitat and species affected, while prescribed fire, when planned appropriately, can enhance ecosystem health and resilience.

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



### Development

Conversion of forests to developed landscapes can result in the direct loss of vernal pools, degradation of vernal pools and their surrounding terrestrial habitat, increased road mortality of vernal pool wildlife, inhibited animal movement due to impervious surfaces, as well as reduced gene flow between wetlands (Windmiller & Calhoun, 2007; Hamer & McDonnell, 2008; Beaudry & deMaynadier, 2009; Evans et al., 2017).



### Crop Production

Forest conversion to agriculture may result in the loss and degradation of vernal pools. Additionally, proximity to agricultural lands can increase the likelihood of herbicide and pesticide introductions into vernal pools, which can have profound effects on plant and invertebrate communities (Battaglin et al., 2009).



### Roads, Trails, and Railroads

Roads and trails can produce hazardous run-off (such as salt, fertilizer, and pesticide/herbicide) that may alter water quality and chemistry within vernal pools. For example, salinization of these freshwater pools may occur from road deicers found in spring snowmelt. This has been shown to negatively affect zooplankton and cyanobacteria communities, as well as a reduction of dissolved organic matter, creating unsuitable conditions for various invertebrates and amphibians (Eakin et al., 2019; Vigil & Schuler, 2024). Additionally, roads may act as a movement barrier and/or source of mortality (via car strikes) as herpetofauna migrate to and from vernal pools (Colino-Rabanal & Lizana 2012).



### Timber Harvest

Timber harvest is a forest management tool that can affect wildlife habitat by changing forest and woodland structural and compositional diversity. Forest management decisions, including inaction, typically have positive effects for some species and negative effects for others. Forest management can alter forest composition and cover (shade), thereby affecting water levels and temperature, litter source, quality, and quantity, vegetation composition within pools, and seasonal food availability with an overall effect on pool food webs. This can affect both plant and animal

SGCNs that utilize the pools directly as habitat for at least part of their life history as well as species utilizing the transition zone of the pools and the surrounding upland forest with close proximity to pools.

Runoff from timber harvest sites may introduce sediments into wetlands such as vernal pools, particularly if buffer areas are not scaled appropriately. Several studies have examined the effects of forest management on hydrology, plant and animal communities of vernal pools. One study suggested that buffers around vernal pools help maintain similar hydrology to those of undisturbed sites, whereas thinning or clearcutting up to the pool boundary resulted in greater water depths and took several years to return to pre-harvest water depths (Kolka et al., 2011). Palik and Kastendick (2010) determined that harvesting up to the margins of the vernal pool resulted in significant changes in plant communities in the ground layer and shrub/tree regeneration within the wetland. Furthermore, this study demonstrated that a 15.25-m (50 ft) uncut buffer around the vernal pool helped mitigate changes in the plant community. The utilization of buffers around vernal pools generated mixed results when attempting to mitigate effects on invertebrate communities (Batzer et al., 2004, Bischof et al., 2013). More specifically, some species (such as Eastern fairy shrimp) appear to be more sensitive to changes in the surrounding forests and the subsequent alterations to hydrology and sediment load (Hanson et al., 2010). Another study examined the long-term effects that timber harvest had on vernal pool obligate species that also utilize the adjacent upland forests: spotted salamanders and wood frogs (*Lithobates sylvaticus*). Within vernal pools that experienced timber harvests, researchers found that occupancy of breeding adults and egg mass abundance significantly decreased over time for both species, with wood frogs experiencing a more drastic decline (Wiewel et al., 2023). Furthermore, it was also noted that many of the vernal pools within harvested forests were smaller in size and held less water than those in unharvested forests. While these results contradict Kolka et al.'s (2011)

assessment that timber harvests resulted in greater water depths, it should be noted that there are many other habitat factors that influence vernal pool depth and size such as precipitation frequency and amount, previous winter's snow depth and surrounding topography.



## Recreation

Recreation (OHV, mountain biking, horseback riding, etc.) within a vernal pool may significantly degrade sensitive features, especially with repeated disturbance. The bottoms of these pools are often mucky and soft; therefore, human activity within the wetland may affect the topography and alter how water is distributed within the pool. Additionally, if recreation activity occurs during a sensitive period, such a breeding and larval development of amphibians, this can result in mortality of breeding individuals and loss of reproductive potential. Finally, recreational traffic may act as a vector for disease and invasive species if care is not taken to disinfect and clean equipment.



## Invasive Species (Problematic Non-native Species)

Increasing density and species diversity of invasive European earthworms can drastically alter the leaf litter/humus, as well as soil horizon composition, within the adjacent forest around a vernal pool (Hale et al., 2005). In turn, this affects soil nutrient availability and ultimately plant species composition (Alexander et al. 2022). Areas with high earthworm invasion may result in a loss of SGCN plants (such as rare ferns of *Botrychium* and *Sceptridium*; Gundale, 2002; Alexander et al., 2022), as well as a loss of vital cover for forest-floor dwelling animals.

Emerald ash borer (*Agrilus planipennis*) poses a risk to vernal pools since black ash is a common species within vernal pools. The mortality of ash within these wetlands may affect the hydrology, canopy cover, wetland depth, and plant species

composition. This may result in the vernal pool becoming unsuitable for various species. Grinde et al. (2022) conducted experimental manipulations of black ash wetlands to mimic EAB damage and examined the response of bird, amphibian, and small mammal communities. While there was an initial increase in species richness attributed to the change in forest structure, researchers suggested that there would be a shift from forest-dependent wildlife to more open-canopy, wetland-associated species within these wetlands.

One study found that a metabolite released by the invasive plant species common buckthorn (*Rhamnus cathartica*) contributed to significant embryo mortality and malformation in frog species. The more buckthorn present around a vernal pool, the higher the concentration of the metabolite, which could lead to amphibian population declines in the long-term (Sacerdote & King, 2014).



### Changes in Temperature related to Climate

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

This warming trend is expected to continue. By mid-century (2040-2059), Minnesota's average annual temperature is projected to rise by an additional 3.8 - 4.5 °F, depending on future greenhouse gas emissions scenarios (Liess et al., 2022; [Climate Change in Minnesota](#)). Warmer temperatures may result in shorter hydroperiods and create challenges for larval development of some animals that require water availability (Montrone et al., 2019). However, amphibian eggs and larva may develop faster under warmer water conditions, thus, some animals may be able to adapt better than others. Climate change does not act in isolation, interacting with invasive species dynamics, land-use change, and shifts in water quality and quantity, compounding ecological effects (He et al., 2019; Finch et al., 2021). For additional context and resources, refer to the Climate Adaptation section in Chapter 6: Implementation.



### Changes in Precipitation and Hydrology related to Climate

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

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

[Change in Minnesota](#)). By mid-century (2040-2059), average annual precipitation is projected to increase by up to 1.2 inches, depending on emissions scenario (Liess et al. 2022; [Climate Change in Minnesota](#)). This seemingly counterintuitive pattern – wetter winters and springs, punctuated by hotter, drier late summers – has profound implications for water availability, wetland health, soil stability, and species dependent on seasonal hydrologic cycles (Runkle et al., 2022). For more information and resources for climate-adapted management strategies, see the Climate Adaptation Section in Chapter 6: Implementation.

More specifically for vernal pools, increased frequency, duration, and intensity of droughts may drastically reduce hydroperiods. In some extreme cases, this may result in water shortages for an entire season, which may inhibit some animals' ability to successfully reproduce (Wiewel et al., 2023). Alternatively, large increases in precipitation will increase the hydroperiod, but may also flood previously suitable habitat. For example, sphagnum moss hummocks used for nesting by four-toed salamanders may become inundated with water after extreme rainfall events, which may affect the viability of deposited egg masses.



*Photo: Vernal pool in Nemadji State Forest, Andrew Herberg*

## Priority Habitat Conservation Strategies

To implement the Habitat Goal of this Plan, to protect and enhance the resilience, function, and ability of habitats to support biodiversity, especially for SGCN, five strategies were identified:



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



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



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



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





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



Examples of conservation actions are grouped below under these five strategies and tagged with icons for the stressor(s) that they address. Some of these actions are widely in place as best practices while others may be more novel. Some actions will combine multiple strategies, in which case we present it under the one it fits best. Also note that some strategies, such as Strategy 3, collaborating with partners, could truly be applied to all actions to most broadly and effectively implement them. Other actions, such as those related to monitoring, might be difficult to relate to a specific stressor, in which case they are marked as not applicable (NA).

## Potential Conservation Actions for Vernal Pools








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

Stressor	Action
	<p>A minimum of a 50 ft “no impact” buffer should be maintained year-round around the whole perimeter of the vernal pool. This includes no removal of overstory and understory vegetation, as well as no use of heavy equipment.</p>
	<p>If habitat disturbance surrounding a vernal pool is unavoidable, plan work from October 1 through March 15 and conduct work under frozen soil conditions only.</p>

Stressor	Action
	<p>Maintain habitat corridors between adjacent vernal pools (especially those within 300 ft of each other) to enable wildlife movement and promote genetic diversity.</p>
	<p>Avoid development of roads or trails in proximity to vernal pools to minimize an alteration of hydrology. For existing or new roads/trails, ensure run-off cannot enter the vernal pool.</p>




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

Stressor	Action
	<p>Avoid herbicide/pesticide application within forested habitat surrounding vernal pools.</p>
	<p>Avoid or minimize soil compaction and rutting if operating heavy equipment in proximity to vernal pool.</p>
	<p>In the case of forest management, ensure the slash is distributed evenly and not piled into or surrounding a vernal pool.</p>
	<p>Avoid ditching or draining of vernal pools during any land conversion process.</p>
	<p>Follow proper disinfecting protocols if traveling between isolated vernal pools to prevent the movement of invasive species or diseases that may affect amphibians (see Amphibian sub-chapter).</p>




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

Stressor	Action
	<p>Work with land managers, including private landowners, to implement habitat conservation practices that support the habitat needs of rare forest species that rely upon vernal pools.</p>







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

Stressor	Action
	Prior to any work in forested habitat that may contain vernal pools, locate and assess the condition of these wetland features in the spring/early summer to ensure proper delineation of vernal pool boundary.
NA	Given that this habitat is not yet well-mapped and understood in Minnesota, continue studies to identify and map the habitat and learn more about the plant communities and animals reliant on the habitat. Continue building and sharing knowledge about managing for healthy vernal pool systems.



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

Stressor	Action
	Promote and consider further development of tax incentives that enable landowners and farmers to gain value for maintaining conservation values on their properties. Provide increased levels of incentive payments for woodland owners to help protect woodlands and forests from further reduction due to development pressure.
	Support and promote education and technical assistance to maintain or restore forest habitat.
	Research and communicate alternative management techniques (i.e., variable density thinning, natural seeding), reference to natural disturbance intervals, natural regeneration methods, and to increase habitat quality for SGCN.
	Where people recreate, provide outreach and education on cleaning gear and equipment to reduce the introduction and spread of invasive species. The DNR's <a href="#">Prevent the Spread</a> webpage includes specific actions for different land based activities like biking, hiking and off-highway vehicle riding. At trailheads, add invasive species prevention messages, such as those on the boot brush kiosks developed by the <a href="#">PlayCleanGo: Stop Invasive Species in Your Tracks</a> program. Prioritize high recreation use areas where invasive species have not yet established.

## Case Study: Four-toed Salamanders and Forest Management

Understanding how a species and their habitat responds to forest management is a vital piece to conserving rare forest-dependent wildlife. Initiated in 2022, the DNR Nongame Wildlife Program began a study to explore how four-toed salamander populations respond to forest management activities in proximity to their preferred nesting habitat: vernal pools. This study utilizes a Before-After-Control-Impact (BACI) study design to tease apart natural annual variation in salamander abundance from the effect that forest management may have on these populations. Within the range of four-toed salamander in Minnesota, 45 vernal pools were identified for long-term monitoring with approximately half of these vernal pools scheduled for forest management activities within 350 meters of the pool boundary (i.e., treatment vernal pools). The other half of the survey pools were identified as controls and not planned for forest management. Survey pools were selected based on historical and recent observations of four-toed salamanders or pools that consisted of suitable nesting habitat. Survey work involves conducting nesting surveys that consist of 30 minutes of "active" search time or until all suitable nesting habitat within a vernal pool has been searched, whichever comes first. "Active" search time is defined as any time spent searching suitable nesting habitat (moss hummocks, woody debris, sedges clumps, etc.) within the highwater mark of a vernal pool for female four-toed salamanders and/or eggs. Relative abundance is determined by counting the occurrence of nesting activity (i.e., presence of salamander guarding eggs, gravid female salamanders, or unattended egg masses) within each wetland. All wetlands are surveyed at least once during the nesting season (May 1 – June 15).

Started in 2024, vegetation surveys and trail cameras deployment occurred within several survey pools (both treatments and controls) to better understand vegetation composition and hydroperiod of vernal pools, respectively. Vegetation surveys were conducted in August after the drying period within these vernal pools to allow for ample growing season and to minimize effects on salamander larval development. These surveys employed a relevé sampling structure and documented species abundance, diversity, and other vernal pool characteristics. The goals of these surveys are to document vegetation composition/ diversity within vernal pools and to develop a



*Photo: Four-toed salamander with eggs, Andrew Herberg*

classification structure for this understudied wetland type. Additionally, these data establish a baseline of vegetation composition and provide the opportunity to examine changes in vegetation after forest management has occurred. The objectives of the trail camera deployment are to record spatial and temporal variation in hydroperiod across most of the study vernal pools, and to determine whether hydroperiod significantly changed after forest management operations. These cameras are programmed to record timelapse photos of the wetlands and identify how many days standing water was present/visible. The deepest location of the wetlands was located during nesting surveys and a measuring post and camera was installed to monitor this location.

As of 2024, four-toed salamanders were detected in approximately 90% of the study vernal pools. Over 500 nests have been detected with over 290 female four-toed salamanders observed during nesting surveys. The mean egg mass size is 39.5 eggs (StDev: 53.2). The majority of vernal pool depths ranged from 24 – 35 cm at the time of nesting surveys. With May 1 as the start day for hydroperiod monitoring, most vernal pools held water for 74 to 152 day (July 14 and September 30, respectively) with a mean hydroperiod of 103 days (August 12). To date, few vernal pools have experienced the planned forest management activities; thus, not enough data exists to make any inference on the effects of forest management on four-toed salamander abundance. As this study continues for the next several years, additional data will yield valuable information on how best to protect these sensitive vernal pools and the species that rely on them.

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