Effects of Climate Change on Midwestern Ecosystems: Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland

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Table of Contents

Foreword ... 4
  Series Overview ... 4
  Process ... 4
    Habitat Selection ... 4
    Climate Exposure ... 4
    Habitat Prioritization ... 5
    Focal Wildlife Species ... 6
    Focal Aquatic Systems ... 6
    Literature Review ... 7
    Chapter Organization ... 7
Executive Summary ... 8
  Key Climate Change Stressors ... 9
    Flooding and Inundation ... 9
    Drought ... 10
  Key Climate Change Impacts ... 13
    Habitat Structure ... 13
    Community Composition ... 15
    Invasive Species ... 16
Climate Change Impacts by Habitat ... 18
  Eastern North American Freshwater Marsh ... 18
    Overview of Climate Projections ... 20
    Key Climate Change Stressors ... 21
    Key Climate Change Impacts ... 24
    Focal Wildlife Species: Blanding's Turtles ... 27
    Focal Aquatic System: Lake Monongalia ... 28
  Midwest Wet Prairie, Wet Meadow and Shrub Swamp ... 30
    Overview of Climate Projections ... 33
    Key Climate Change Stressors ... 34
    Key Climate Change Impacts ... 37
    Focal Wildlife Species: Nelson's Sparrow ... 41
Work Cited ... 43
Appendix 1 ... 65

Foreword

Series Overview

The following is the fourth chapter of a multi-part series examining the vulnerability of natural habitats in the Midwest region to the impacts of climate change. This work was conceived as part of an inter-agency effort to facilitate the inclusion of climate change considerations into 2025 revisions of State Wildlife Action Plans (SWAPs). Although tailored to the needs of state agencies within the Midwest region, these assessments focus on habitats and species found throughout North America and are thus broadly relevant to regions and considerations beyond that of the Midwest.

This work was developed as a collaboration between the U.S. Geological Survey (USGS) Midwest Climate Adaptation Science Center (MW CASC) and natural resource agencies from Minnesota, Wisconsin, Michigan, Ohio, Indiana, Illinois, Iowa, and Missouri. During discussions on the needs and challenges of the 2025 SWAP revision process, collaborators identified habitat climate vulnerability as a key area requiring further exploration and deeper understanding.

Process

To assess the impact of climate change on habitats in the Midwest, the MW CASC developed a process comprised of the following steps: 1) potential habitat identification and delineation; 2) summarizing exposure to key climate change stressors; and 3) reviewing and synthesizing relevant scientific literature into qualitative summaries of climate change impacts to habitats.

Habitat Selection

We identified and defined habitats using the U.S. National Vegetation Classification database (USNVC, 2020), which provides a common lexicon of hierarchically classified and spatially referenced vegetation communities throughout the United States. Within this hierarchy, the Group level represents the finest resolution classification tier that is coupled with spatially referenced distributions. Hereafter, discrete "habitats" are synonymous with USNVC Groups and their corresponding lower-level community classifications (Alliance and Association). To enhance relevancy for the Midwest region, the lowest-level classifications for each group (Association) not occurring within the Midwest were excluded from this assessment.

Climate Exposure

To summarize climate exposure, we utilized a combination of Level II and Level III ecoregions (U.S. Environmental Protection Agency, 2013) to identify twelve ecologically relevant sub-regions of the Midwest that served as the spatial basis for summarizing climate exposure (Figure i).

Figure i. Distribution and names of 12 ecoregions within the larger Midwest region. Ecoregions represent a mixture of Level II and Level III EPA ecoregions (U.S. Environmental Protection Agency, 2013) and have been renamed following the Midwest Conservation Blueprint Ecoregions (Wright and others, 2022).

Habitat Prioritization

Seventy-seven natural Groups (i.e., habitats) occur in states comprising the Midwest region (Minnesota, Wisconsin, Michigan, Ohio, Indiana, Illinois, Iowa, and Missouri). To focus this assessment on a subset of these habitats, representatives from each state identified two or more habitats for each ecoregion present in their respective state. We reconciled conflicting priorities to identify two habitats per ecoregion (hereafter identified as “priority habitats”) for a total of 22 priority habitats that served as the focus of our analysis (Table i).

Table i. Priority habitats for each ecoregion. Analogous Level III EPA ecoregion numbers (U.S. Environmental Protection Agency, 2013) and U.S. National Vegetation Classification database Group numbers (USNVC, 2020) are provided for each ecoregion and priority habitat.

Ecoregion	Priority habitat
Appalachian Forest (8.4.3)	Appalachian-Central Interior Mesic Forest (G020)
	Central Appalachian-Northeast Oak Forest and Woodland (G650)
Central Irregular Plains (9.2.4)	Central Midwest Oak Openings and Barrens (G181)
	South Central-Appalachian-Northeast Floodplain Forest Group (G673)
Central Plains (8.2.1–8.2.4)	Midwest Floodplain Forest (G652)
	Central Interior-Great Lakes Flatwoods and Swamp Forest (G917)
Driftless Area (8.1.5)	North-Central Beech- Maple- Basswood Forest (G021)
	North-Central Oak- Hickory Forest and Woodland (G649)
Erie Drift Plains (8.1.1, 8.1.10)	North-Central Beech- Maple- Basswood Forest (G021)
	Appalachian-Northeast Mesic Forest (G742)
Interior Plateau (8.3.2, 8.3.3, 8.3.6, 8.5.2)	Bald-cypress- Tupelo Floodplain Forest (G033)
	Interior Low Plateau Oak Forest (G950)
Mixed Wood Plains (8.1.4)	Laurentian-Acadian Alkaline Swamp (G046)
	Eastern North American Freshwater Marsh (G125)
Northern Hardwood Forest (5.2.1, 5.2.2)	Laurentian Subboreal Mesic Balsam Fir- Spruce- Hardwood Forest (G048)
	Eastern North American Boreal-Subboreal Bog and Acidic Fen (G1172)
Northern Plains (9.2.1, 9.2.2)	Northern Tallgrass Prairie (G075)
	Midwest Wet Prairie, Wet Meadow and Shrub Swamp (G770)
Ozarks (8.4.5)	Central Interior Acidic Open Glade and Barrens (G178)
	Oak- Shortleaf Pine Ozark-Ouachita Forest Woodland and Savanna (G949)
Temperate Prairie (9.2.3)	Eastern North American Ruderal Meadow and Shrubland (G059)
	Central Tallgrass Prairie (G333)
Great Lakes Plains (8.1.6)	Midwest Prairie Alkaline Fen (G183)

Focal Wildlife Species

We include focal wildlife species to demonstrate how habitat impacts may influence wildlife responses to climate change. For each priority habitat (Table i), we review climate change impacts on one focal wildlife species, with specific attention paid to habitat considerations. We selected focal wildlife species based on consultation with state agencies, with the aim of choosing species listed by one or more state agency as a Species of Greatest Conservation Need (SGCN).

Focal Aquatic Systems

Because the USNVC is predominantly focused on terrestrial habitat types, we also include sections summarizing the impact of climate change on select focal aquatic systems. Unlike the focal wildlife species sections, which are associated with specific priority habitats (Table i), we selected one focal aquatic system for each ecoregion (Figure i). These selections were based on consultation with state agencies, with the aim of discussing a diverse set of aquatic system types. While focused on specific geographic areas, each section includes climate change impacts that are relevant to the broader aquatic system type.

Literature Review

For each priority habitat, we reviewed and synthesized available scientific literature. We used USNVC habitat descriptions and lists of dominant plant species provided for each Group and relevant sub-level to characterize each habitat and focus our literature search (Appendix 1). We searched for relevant literature related to these habitat characteristics and dominant species that either explicitly mentioned climate change or indirectly discussed climate-related topics. Lastly, to narrow our focus, we identified two particularly relevant climate-related stressors for each habitat to hone our literature search.

Chapter Organization

Each chapter in this series focuses on a subset of ecologically related priority habitats. Because climate change impacts are frequently shared between similar habitat types, we first provide an overview of climate impacts to the broader system type before summarizing climate impacts for each specific habitat. The higher-level USNVC classification that links ecologically similar habitats (typically at the Macrogroup level and hereafter referred to as “ecosystem”) determines each broader system type into which chapters are organized.

Executive Summary

The Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland is a hydrologically dynamic ecosystem highly sensitive to shifts in water availability. Across the Midwest, climate change is expected to intensify two primary stressors, flooding and drought, resulting in increased hydrologic variability that may threaten the persistence of these wetlands. Increased spring precipitation and more frequent extreme rainfall events are projected to cause deeper, longer-lasting inundation, while rising temperatures, reduced snowpack, and heightened evaporative demand are likely to increase the frequency and severity of droughts.

Changes in hydrology may significantly alter both habitat structure and community composition. Physical disturbance from scouring and erosion may intensify, while nutrient and sediment loading from surrounding land uses may lead to eutrophication and terrestrialization. Vegetation zonation is likely to become destabilized under more extreme hydrological conditions, with flood-tolerant or drought-adapted species replacing those with narrower hydrologic tolerances.

The two habitat groups within this broader ecosystem show differing vulnerabilities. The Eastern North American Freshwater Marsh, including both Great Lakes coastal and inland systems, is considered among the most hydrologically dynamic and disturbance-prone wetland types. Vegetation in these marshes is typically stratified along water depth gradients, forming distinct zones that depend on variable hydrology to persist, but deep or prolonged inundation can disrupt this zonation and reduce plant diversity. In contrast, the Midwest Wet Prairie, Wet Meadow and Shrub Swamp, generally lacks persistent surface water and relies on precipitation and snowmelt to maintain seasonal saturation. As a result, this habitat group is especially prone to drying and potentially susceptible to woody encroachment and shifts toward drier-adapted plant communities.

Across both habitat groups, invasive species are expected to gain a competitive edge under future climate conditions. Invasive wetland plants often exhibit high plasticity and can tolerate a wide range of disturbances and hydrologic conditions, allowing them to expand rapidly during both flood and drought periods. Interacting pressures underscore the growing vulnerability of the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland under future climate scenarios.

Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland

Key Climate Change Stressors

Hydrological processes, particularly the frequency, magnitude, duration, and timing of water level fluctuations, strongly influence the viability of Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland habitat throughout the Midwest (Anderson and others, 2023; Carter, 1996; Faber-Langendoen and Rocchio, 2005b; Mitsch and Gosselink, 2000; Trebitz and others, 2002; U.S. Environmental Protection Agency, 2008). This emergent wetland ecosystem exists at the boundary of terrestrial and aquatic environments, making it especially sensitive to changes in water availability (Delaney and others, 2022; Erwin, 2009; Ponzio and others, 2019; Winter, 2000). Whether situated in isolated depressions or along riparian and lake margins, these wetlands are shaped by dynamic hydrological regimes that naturally alternate between periods of inundation and drying (Carter Johnson and others, 2016). However, when these cycles shift, whether through more frequent or intense fluctuations, extended inundation or dry periods, or disrupted seasonal timing, ecological conditions may change. Climate change is likely to amplify hydrological variability, increasing the potential for shifts in distribution or a net loss in area of the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland ecosystem across the Midwest (Garris and others, 2015; Werner and others, 2013; Wuebbles and others, 2019; Xi and others, 2021; Xu and others, 2024).

Flooding and Inundation

Flooding and inundation are key natural disturbances that shape the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland across the Midwest. Seasonal inundation patterns, driven by snowmelt, heavy rainfall, and variable runoff, structure plant communities and support the ecological integrity of both Great Lakes coastal and inland wetlands (Batzer and Sharitz, 2014; Faber-Langendoen and Rocchio, 2005b; Kost and others, 2007; Wuebbles and others, 2019). The ecological impact of flooding depends on multiple factors, including frequency, timing, depth, and duration. In Great Lakes coastal wetlands, large and prolonged fluctuations in water levels contribute to a mosaic of vegetation zones and dynamic habitat conditions (Anderson and others, 2025; Gathman and others, 2005; Wilcox, 2004; Wilcox and Nichols, 2008). In inland systems, the effects of flooding vary with watershed size and local hydrology; wetlands receiving high runoff, or those found in small isolated basins, may be particularly vulnerable to extended periods of inundation (Galatowitsch, 2012; Junk, 2005; Staffen and others, 2019; Wuebbles and others, 2021).

Climate projections indicate that flooding may become more variable throughout the Midwest, leading to more frequent, intense, and prolonged periods of inundation (Figure 1) (Hirabayashi and others, 2021; Mallakpour and Villarini, 2015; Neri and others, 2020). Driven by changing magnitudes of over-lake precipitation, runoff, and over-lake evaporation, Great Lakes water levels have varied significantly in recent decades, shifting from a prolonged period of below-average levels to recent record highs (Gronewold and others, 2016; Gronewold and others, 2021; U.S. Army Corps of Engineers, 2019). Climate models project increases in the three dominant factors controlling lake levels (evaporation, runoff, and over-lake precipitation) by the end of the century, which may result in less predictable cycles, higher lake level maxima and lower minima, and higher lake levels on average (Kayastha and others, 2022; Mailhot and others, 2019; Seglenieks and Temgoua, 2022; VanDeWeghe and others, 2022). Many inland wetlands are also projected to experience greater hydrologic variability, including faster shifts between wet and dry conditions, attributed in part to increasing frequency and magnitude of extreme rainfall events (Carter Johnson and others, 2016; Delaney and others, 2022; Garris and others, 2015; Johnson and others, 2004; Johnson and others, 2005; Johnson and others, 2010; Mishra and others, 2011; Staffen and others, 2019). Additionally, warmer winters with more precipitation falling as rain, rather than snow, are likely to shift peak streamflows earlier in larger watersheds, while intense late-spring storms may lead to later peaks in smaller catchments (Byun and others, 2019; Cherkauer and others, 2021; Johnson and others, 2010; Junk, 2005; Wang and others, 2024b; Wuebbles and others, 2019; Zhou and others, 2022).

Drought

Periodic drying is also a historical component of water level fluctuations in the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland, and informs wetland classification (i.e., semi-permanent, seasonal, or temporary) (Galatowitsch, 2012; Johnson and others, 2010; Werner and others, 2013). While dry periods can play an important ecological role, they can compromise wetland integrity when their duration or intensity exceeds historical norms. Many inland wetlands in the Midwest are shallow and have a high surface-area-to-volume ratio, limiting water storage capacity (Faber-Langendoen and others, 2020; Hayashi and others, 2016; Zhang and others, 2009). These characteristics make them especially sensitive changes in precipitation changes and seasonal drying (Brotherton and Joyce, 2015; Christie and Bostwick, 2012; Johnson and others, 2010; McLean and others, 2022; Vanderhoof and others, 2024; Winter, 2000). Freshwater marshes, in particular, are considered highly sensitive to water deficits, with shallow marshes generally at greatest risk (Faber-Langendoen and Rocchio, 2005b; Mitsch and Hernandez, 2013; Short and others, 2016).

Climate projections indicate that drought frequency and severity are likely to increase in the coming decades across the Midwest, especially during the summer and fall (Figure 2). For Great Lakes wetlands, projections also suggest a higher likelihood of historically low water levels (Staffen and others, 2019; VanDeWeghe and others, 2022). In inland systems, rising temperatures, reduced snowpack, earlier snowmelt, and greater evaporative demand are expected to alter hydroperiods and reduce water availability during the growing season (Byun and others, 2019; Daniel and others, 2022; Ficklin and Novick, 2017; Rastogi and others, 2023; Xu and others, 2024). These drying trends are anticipated to be most pronounced in seasonal and depressional wetlands, where increased seasonal variability may result in wetter springs, drier summers, and reduced surface water extent (Daniel and others, 2022; Johnson and others, 2010; Shveytser and others, 2024; Vanderhoof and others, 2024).

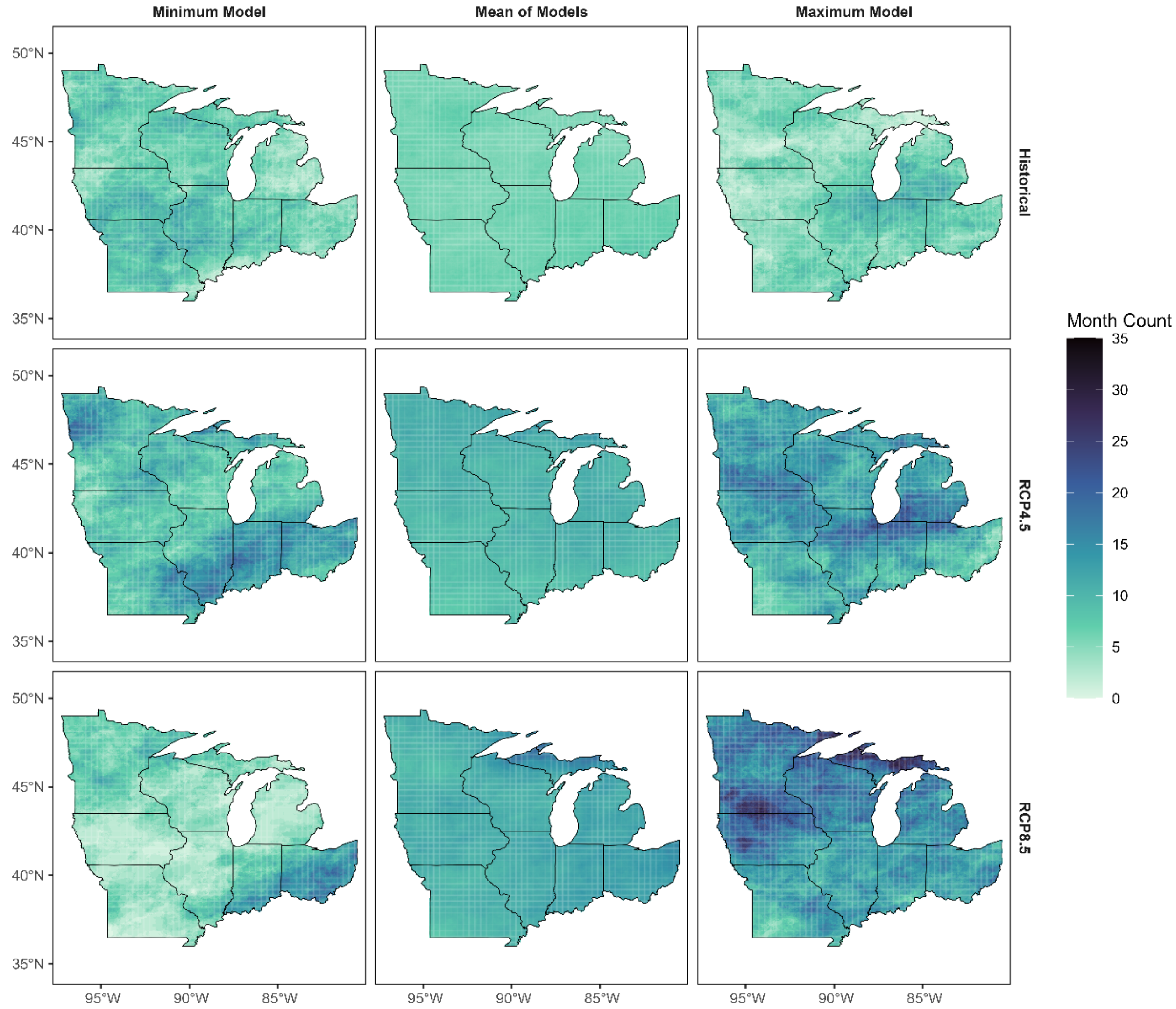

Figure 1. Projected changes in 30-year extreme wet incidence in the Midwest. Projections use gridded Standardized Precipitation-Evapotranspiration Index (SPEI) values obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme wet incidence is defined as the number of months within a 30-year period with an SPEI value of ≥ 2, corresponding to the wettest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000, top row) and projected (2070–2099) 30-year extreme wet incidence (months) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected 30-year extreme wet incidence under RCP 8.5 are presented in addition to the mean of all models (middle column).

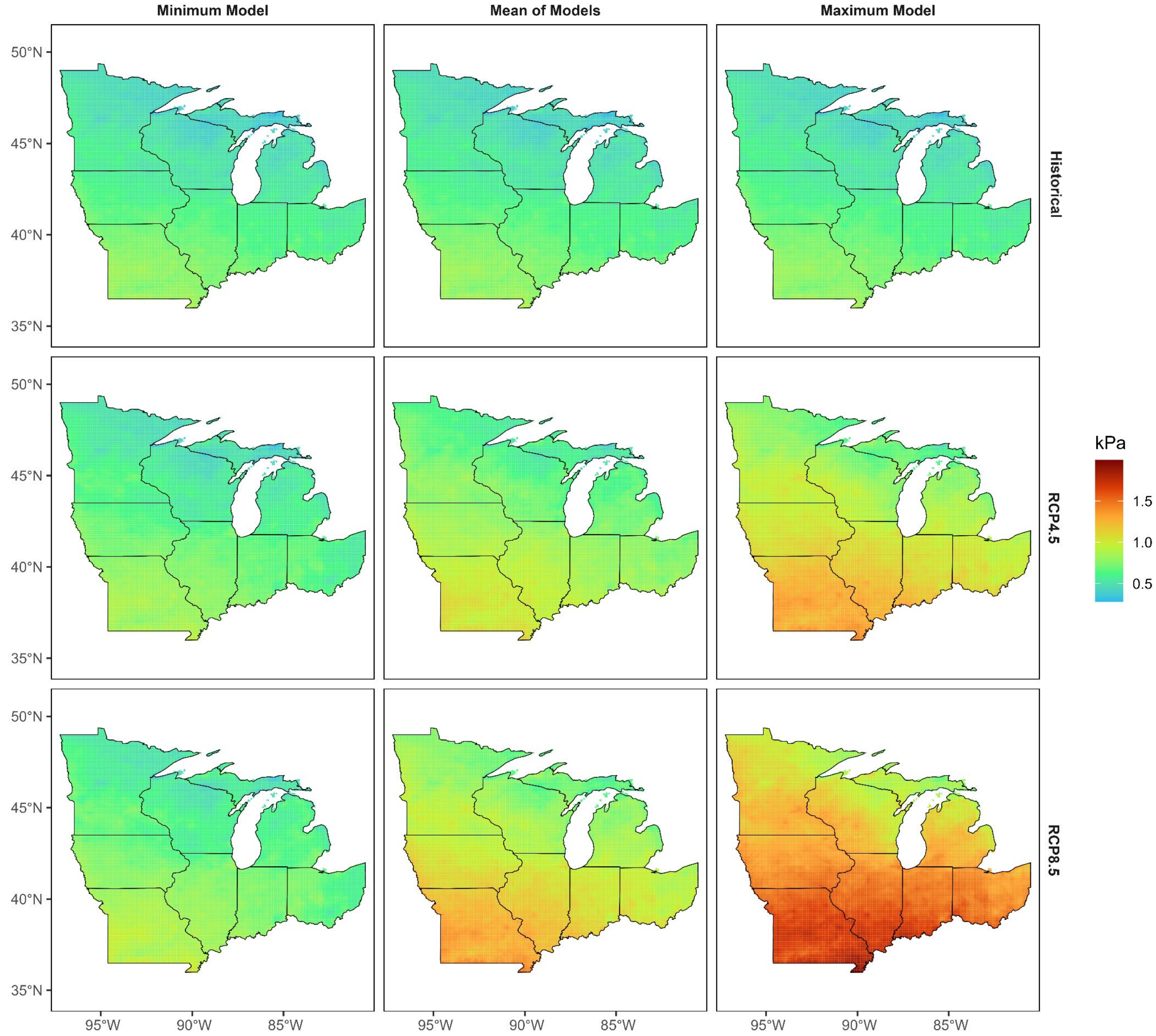

Figure 2. Projected changes in annual vapor pressure deficit in the Midwest. Projections use gridded climate data obtained via the Climate Toolbox Climate Mapper at a 4-km resolution (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000, top row) and projected (2070–2099) annual vapor pressure deficit (VPD; kilopascals) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected VPD under RCP 8.5 are presented in addition to the mean of all models (middle column).

Key Climate Change Impacts

Species in the Eastern North American Temperate Freshwater Marsh, Wet Meadow, and Shrubland are closely adapted to cyclical and dynamic hydrological regimes (Faber-Langendoen and others, 2020; Kost and others, 2007). Climate change is expected to intensify both flooding and inundation and drought, increasing hydrologic variability. These shifts may alter habitat structure, drive changes in community composition, and facilitate invasive species expansion.

Habitat Structure

Abiotic responses to flooding and inundation and droughts. Climate-driven shifts in the timing and intensity of flooding, drying, and water level fluctuations, driven by increased spring precipitation, runoff, and summer droughts, may intensify physical disturbance in Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland. In Great Lakes coastal wetlands, low winter water levels may increase sediment displacement (via increased wave energy and exposure to ice scour) and exacerbate shoreline erosion (Rutherford and others, 2022; Theuerkauf and Braun, 2021; Wilcox and others, 2007; Wilcox, 2012a). In inland systems, flooding alters wetland structure through processes such as soil scouring, plant uprooting, erosion, and sediment deposition (Amoros and others, 2000; Ma and others, 2025; Mortsch and others, 2006; Panda and others, 2024). As flood events become more intense and frequent, many wetlands, especially those near agricultural and urban areas, may receive greater inputs of sediment and nutrients, potentially accelerating nutrient enrichment and eutrophication (Amoros and others, 2000; Anteau and others, 2016; Faber-Langendoen and Rocchio, 2005b; Ma and others, 2025; Short and others, 2016; Staffen and others, 2019; Zedler and Kercher, 2004). Sediment and nutrient inputs may reduce water clarity, thereby reducing light penetration and causing loss of submerged vegetation (Lind and others, 2022; Mortsch and others, 2006). Concurrently, sediment deposition may facilitate the formation of new wetland features, such as oxbows and side channels, and promote terrestrialization (i.e., infilling of wetlands due to sediment accretion, which can be stabilized and further exacerbated by the establishment of emergent and terrestrial vegetation) (Amoros and others, 2000; Faber-Langendoen and Rocchio, 2005b).

Increasing hydrological variability can also alter biogeochemical processes. Alternating periods of inundation and drying drive transitions between anaerobic and aerobic conditions, influencing microbial activity and nutrient cycling (Faber-Langendoen and Rocchio, 2005b). When soils are inundated, limited oxygen availability slows decomposition and promotes anaerobic processes such as denitrification, sulfate reduction, and methane production (Batzer and Sharitz, 2014; Ma and others, 2025; Pezeshki, 2001; Trettin and others, 2019). These conditions can impair nutrient uptake by plants and increase toxicity (Batzer and Sharitz, 2014; Dong and others, 2024; Pezeshki, 2001). In contrast, drought and lower water tables reintroduce oxygen into the soil, stimulate microbial activity, and accelerate decomposition, releasing nutrients that had accumulated under previous wet conditions (Batzer and Sharitz, 2014; Faber-Langendoen and Rocchio, 2005b; Galatowitsch, 2012; Trettin and others, 2019).

Biotic responses to flooding and inundation. At the landscape scale, fluctuating water levels influence the overall extent of the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland. Flood frequency and amplitude define the spatial organization of vegetation zones and open water within wetlands, where plant communities are arranged along hydrologic gradients according to their flood tolerance and hydrologic niche — from submergent and floating-leaved species in permanently inundated areas to emergent and meadow species in shallower, intermittently saturated zones (Bowles and Jones, 2007; Faber-Langendoen and Rocchio, 2005b; Galatowitsch, 2012; Kantrud and others, 1989; Markham, 2019; Poiani and others, 1996; Van Der Valk and Mushet, 2016). In many wetlands, intermittent flooding acts as a periodic disturbance that limits encroachment by upland and woody vegetation and maintains early successional stages (Adapting to climate change, 2022; Foti and others, 2012; Hogenbirk and Wein, 1991; Magee and Kentula, 2005). However, more frequent, extreme, and prolonged high-water events may disrupt these successional patterns and limit vegetation recovery, particularly in low-elevation wetlands, which can lead to vegetation loss and conversion to open water (Adapting to climate change, 2022; Carter Johnson and others, 2016; Smith and others, 2021; Van Der Valk and Mushet, 2016). Such changes not only shift plant community composition but can also induce functional degradation, reducing habitat complexity and ecosystem stability (Anderson and others, 2025; Carter Johnson and others, 2016; Sun and others, 2022). Water levels that exceed historical ranges or fluctuate too rapidly may compress or eliminate upland meadow zones in systems lacking adjacent upland space for vegetation migration, resulting in a net loss of habitat area (Adapting to climate change, 2022; Anderson and others, 2025; Rutherford and others, 2022; Smith and others, 2021).

The physiological stress of inundation also plays a significant role in shaping wetland productivity. By limiting carbon fixation and reducing photosynthetic efficiency, flooding decreases plant productivity (Ormshaw, 2014; Pezeshki, 2001). Flooding limits oxygen availability in the root zone, which reduces photosynthesis, impairs nutrient uptake, and suppresses shoot growth (Batzer and Sharitz, 2014; Markham, 2019; Ormshaw, 2014; Pezeshki, 2001; Zhao and others, 2019). In deep or prolonged flood conditions, these constraints lead to declines in net biomass production (Sun and others, 2022; Werner and others, 2013). Anoxic conditions are especially harmful during the growing season and early developmental stages, affecting flood-sensitive seedlings of grasses, rushes, and sedges (Mortsch and others, 2003; Ormshaw and Duval, 2020; Panda and others, 2024; Pillsbury and McGuire, 2009). Often, the species that are able to tolerate flooding and associated increases in sediment and nutrient inputs are disturbance-tolerant invasive species like reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis* ssp. *australis*), and certain cattails (*Typha* spp.) (Larsen and Alp, 2015; Zedler and Kercher, 2004).

Biotic responses to drought. Drought can also significantly reshape the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland, with effects that often parallel those of frequent, extreme, and prolonged flooding, driving shifts in vegetation zonation that reduce ecosystem stability (Anderson and others, 2025; Faber-Langendoen and Rocchio, 2005a; Foti and others, 2012; Wernerehl and Givnish, 2025). In Great Lakes coastal wetlands, lower lake levels may allow vegetation to expand lakeward (Anderson and others, 2023; Frieswyk and Zedler, 2007; Lishawa and others, 2010; Mortsch and others, 2003), especially fast-growing invasive species (Wilcox, 2012a), leading to habitat transformations that are not easily reversed if water levels increase in the future. In shallow, inland systems, open water areas may be replaced by emergent or upland vegetation, including meadow and shrub species (Middleton and Kleinebecker, 2012; Mortsch and others, 2003; Poiani and others, 1996). In semi-permanent wetlands, extended dry periods can eliminate surface water altogether, resulting in long-term vegetation changes and potential regime shifts (Joyce and others, 2016; Poiani and others, 1996; Valk, 2005). Persistent droughts may shift wetlands to a dry state and/or facilitate encroachment by upland species (Anderson and others, 2025; Donnelly and others, 2025; Hogenbirk and Wein, 1991; Keddy and Reznicek, 1985; Lang and others, 2024; Sofaer and others, 2016; Wilcox, 2012a; Zhang and others, 2009).

The physiological stress of drought also plays a significant role in shaping wetland productivity. Reduced soil moisture can limit nutrient transport, hinder stomatal function, and increase oxidative stress, particularly for emergent species adapted to saturated conditions (Batzer and Sharitz, 2014; Cooper and Merritt, 2012; Mortsch and others, 2006; Touchette and others, 2007; Touchette and others, 2008). Without sufficient water depth, submerged aquatic plants may disappear entirely (Bornette and Puijalon, 2011; Mortsch and others, 2006; Touchette and others, 2008). Prolonged or extreme drying can also exceed the moisture tolerances of emergent species, including wild rice (*Zizania spp.*) (Desta and others, 2012; Panda and others, 2024; Varty and others, 2024). Even some shrubs and sedges may be susceptible under drought conditions (Ormshaw and Duval, 2020). The influence of drought on wetland productivity is often highly variable and non-linear. While mild drying may temporarily improve photosynthesis and water-use efficiency in emergent marshes, sustained moisture deficits tend to reduce biomass across most wetland types (Baldwin and others, 2014; Carter Johnson and others, 2016; Galatowitsch, 2012; Johnson and others, 2010; Li and others, 2024; Yu and others, 2017). Rewetting after dry periods can trigger short-lived productivity pulses, but repeated drying may impair vegetation recovery and lead to longer-term declines in productivity and community function (Carter Johnson and others, 2016; Galatowitsch, 2012; Hong and others, 2025).

Community Composition

Community responses to flooding and inundation. Natural fluctuations in water levels help support plant diversity and limit upland encroachment in the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland. However, if flooding becomes more frequent, extreme, or prolonged and inundation persists, plant diversity may decline (Altenfelder and others, 2016; Anderson and others, 2023; Batzer and Sharitz, 2014; Galatowitsch, 2012; Wright and others, 2015). Although many wetland communities exhibit some compositional resilience, repeated high-water events may exceed their adaptive capacity, accelerating species turnover, reducing evenness, and promoting dominance by disturbance-tolerant species, ultimately driving long-term shifts in community composition and vegetation zonation (Batzer and Sharitz, 2014; Čížková and others, 2013; Johnson and others, 2010; Liu and others, 2020; Magee and Kentula, 2005; Sun and others, 2022; Van Der Valk and Mushet, 2016; Wilcox, 2004).

Persistent high-water conditions are likely to favor flood-tolerant and opportunistic species, contributing to shifts in dominance and vegetation structure. Obligate and facultative wetland species often increase in abundance under prolonged inundation, while less flood-tolerant species tend to decline (Batzer and Sharitz, 2014; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Galatowitsch, 2012; Magee and Kentula, 2005; Mortsch and others, 2006; Vervuren and others, 2003). In zones where water levels remain elevated across multiple growing seasons, submerged and floating-leaved species, such as pondweeds (*Potamogeton* spp.) and common duckweed (*Lemna minor*), may replace emergent or meadow species (Anderson and others, 2025; Galatowitsch, 2012; Magee and Kentula, 2005; van der Valk, 1981). Once established on exposed mudflats during drawdowns, many rhizomatous emergent, such as cattails (*Typha* spp.), European common reed (*Phragmites australis* ssp. *australis*), and bulrushes (*Scirpus* and *Schoenoplectus* spp.) are able to persist and dominate during subsequent high water levels (Galatowitsch, 2012; Hazelton and others, 2014; Meeker and others, 2023; Mortsch and others, 2006; Wilcox, 2012b; Wilcox and Nichols, 2008). Sedimentation associated with floodwaters may also reduce native plant productivity and create conditions that facilitate the spread of invasive species such as reed canarygrass (*Phalaris arundinacea*) (Ewing, 1996; Gleason and Euliss, 1998; Lenssen and others, 1999; Mahaney and others, 2005).

Conversely, sustained or extreme flooding can suppress or eliminate species with limited inundation tolerance. Meadow sedges and shallow emergents are particularly vulnerable to prolonged inundation, especially in low-elevation or shallow-gradient wetlands where water persists for extended periods (Budelsky and Galatowitsch, 2004; Dušek and others, 2017; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Gathman and others, 2005; Hall and Zedler, 2010; Kercher and Zedler, 2004; Smith and others, 2021). Many forbs and grasses, such as little bluestem (*Schizachyrium scoparium*), tend to decline under wetter conditions (Brotherton and others, 2019; Lenssen and others, 1999; Toogood and Joyce, 2009; Zedler and Herrick, 2023). In addition, for species that require exposed or drier soils for germination, recruitment may be restricted (Hough-Snee and others, 2015; Keddy and Ellis, 1985; Mortsch and others, 2006). Moreover, warming temperatures may interact with flooding to further reduce flood tolerance in some species, potentially amplifying the physiological stress of inundation (Sun and others, 2022).

Community responses to drought. Declines in water levels can reshape plant communities in the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland by favoring species adapted to drier conditions (Anderson and others, 2025; Faber-Langendoen and Rocchio, 2005a; Foti and others, 2012; Wernerehl and Givnish, 2025). As open water and aquatic zones contract, emergent and meadow vegetation may expand into these areas (Anderson and others, 2023; Batzer and Sharitz, 2014; Keen and others, 2024; Mortsch and others, 2006; Poiani and others, 1996). These shifts in community composition may be long-lasting, particularly when newly dominant species are tolerant of subsequent re-flooding (Didiano and others, 2018; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Lind and others, 2022; Mortsch and others, 2006; Poiani and others, 1995; Touchette and Steudler, 2009).

Drought conditions promote vegetation turnover by creating opportunities for germination in seed-reproducing shrubs and emergent species, and by favoring facultative wetland plants and long-lived perennials with deep roots and flexible reproductive strategies (Batzer and Sharitz, 2014; Garbowski and others, 2020; Hultine and others, 2020; Luo and others, 2008; Miller and Zedler, 2003; Moor and others, 2017; van der Valk, 1981; Van der Valk and Davis, 1976; Wilcox, 2012a). Invasive emergents such as cattails (*Typha* spp.) and European common reed (*Phragmites australis* ssp. *australis*) often persist or expand during dry periods, while obligate wetland species like upright sedge (*Carex stricta*), northern wild rice (*Zizania palustris*), and submersed aquatics may become confined to deep water refugia or experience significant declines (Catford and others, 2011; Mortsch and others, 2006; Varty and others, 2024; Wilcox and Nichols, 2008). As wetland substrates dry and release soil nutrients, early-colonizing annuals, opportunistic perennials like softstem bulrush (*Schoenoplectus tabernaemontani*) and cattails (*Typha* spp.), and certain graminoids can establish rapidly (Didiano and others, 2018; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Galatowitsch, 2012; Tulbure and others, 2007; van der Valk, 1981).

Invasive Species

Invasive species responses to flooding and inundation and drought. In the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland, invasive species are likely to gain a competitive edge under future climate conditions. Rising temperatures may facilitate the northward expansion of cold-limited aquatic invasives across the Midwest, including common water hyacinth (*Eichhornia crassipes*), waterthyme (*Hydrilla verticillata*), primrose-willows (*Ludwigia* spp.), and parrot feather watermilfoil (*Myriophyllum aquaticum*) (Bolpagni, 2021; Gillard and others, 2017; Hansen, 2008; Wang and others, 2019). Fluctuating water levels, driven by flooding and drought, are expected to favor invasive wetland plants (Flanagan and others, 2015; Grabas and Rokitnicki-Wojcik, 2015; Hovick and others, 2023; Magee and Kentula, 2005; Miller and Zedler, 2003; Zedler and Kercher, 2004). Invasive species often exhibit high physiological plasticity and broad hydrologic tolerance, allowing them to respond rapidly to changes in water availability (Anderson and others, 2025; Davidson and others, 2011; Herr-Turoff and Zedler, 2007; Magee and Kentula, 2005). Several of the Midwest's most problematic invaders, such as reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis* ssp. *australis*), and certain cattails (*Typha* spp.), are particularly well adapted to variable hydrologic conditions and may be less negatively affected by water level disturbances than native species (Bansal and others, 2019; Grabas and Rokitnicki-Wojcik, 2015; Kercher and Zedler, 2004; Miller and Zedler, 2003; Mortsch and others, 2006). Their ability to rapidly colonize exposed substrates and persist through extended inundation may further increase their distribution (Eggers and Reed, 2015; Tougas-Tellier and others, 2015; Tulbure and others, 2007). Through high biomass production and increased sediment accretion, they can also accelerate terrestrialization (Mitchell and others, 2011; Rooth and others, 2003).

Extended periods of flooding and drought can each create distinct opportunities for invasive species to expand, often at the expense of native wetland flora. By weakening native competitors, disrupting seed banks, and increasing nutrient availability, more frequent or prolonged inundation may promote invasive species dominance (Hannah and others, 2020; Magee and Kentula, 2005; Rutherford and others, 2022; Zedler and Kercher, 2004). For example, during prolonged moderate flooding or following more severe flood events, cattails are often favored over native sedges and forbs, especially in nutrient-enriched systems (Bansal and others, 2019; Boers and others, 2007; Hall and Zedler, 2010; Woo and Zedler, 2002; Zedler and Kercher, 2004). Conversely, droughts may expose wetland basins and promote the establishment of facultative invasive species in zones previously occupied by submergent or drought-intolerant vegetation (Anderson and others, 2025; Bansal and others, 2019; Lishawa and others, 2010; Magee and Kentula, 2005; Tulbure and Johnston, 2010). For example, reed canarygrass, European common reed, and cattails all benefit from accessing flood-deposited nutrients and sediment during dry periods and can expand into dewatered meadow zones (Anderson and others, 2025; Davidson and others, 2011; Herr-Turoff and Zedler, 2007; Magee and Kentula, 2005). In the Great Lakes coastal zone, prolonged low lake levels have facilitated the expansion of European common reed into exposed lakebeds (Tulbure and others, 2007; Wilcox, 2012a), where its tall stature and rhizomatous growth allow it to persist even as water levels rebound, resulting in long-term dominance and displacement of native vegetation.

Although many invasive species benefit from hydrologic disturbance, both flood and drought conditions can also suppress their dominance, depending on local site conditions and disturbance characteristics. For example, long-duration or high-magnitude-flooding can reduce reed canarygrass cover and facilitate re-establishment of hydrophytic native species (Charles and others, 2023; He and others, 2011; Wang and others, 2024a). Similarly, while cattails are generally tolerant of deep inundation, prolonged flooding can lead to mortality or reduced vigor and limit seedling establishment (Galatowitsch, 2012; Grace and Wetzel, 1982; Magee and Kentula, 2005; van der Valk, 1994). Alternatively, by causing excessive soil drying, droughts may hinder seed germination or the spread of invasive species (Bohnen and others, 2022; Bunbury-Blanchette and others, 2015; Varty and others, 2024; Weisner and others, 1993).

Climate Change Impacts by Habitat

Eastern North American Freshwater Marsh

The Eastern North American Freshwater Marsh includes a wide range of marsh types found across the Midwest and eastern United States, encompassing both Great Lakes coastal and inland systems (Figure 3) (USNVC, 2025). These wetlands range from shallow, seasonally flooded marshes to deepwater emergent communities and wildrice (*Zizania* spp.)-dominated systems. They occur in glacial potholes, floodplain backwaters, and along lake margins, and are typically seasonally or persistently inundated during the growing season (Drake, 2015; Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005a; Kost and others, 2007; Mitsch and Gosselink, 2015). Soils may be mineral or organic, with frequent saturation and flooding contributing to anaerobic conditions (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005a; Mitsch and Gosselink, 2015).

These marshes are highly productive and often support diverse communities, but they are also among the most hydrologically dynamic and disturbance-prone wetland types (Faber-Langendoen and Rocchio, 2005a; Mitsch and Hernandez, 2013). Surface flow, flooding, and wave action, especially in lacustrine systems, play key roles in shaping vegetation structure (Anderson and others, 2025; Faber-Langendoen and Rocchio, 2005a; Hubert, 2010; Meeker and others, 2023; Mortsch and others, 2003). Water levels in Great Lakes coastal marshes fluctuate seasonally but may undergo larger, multi-year cycles, such as the recent transition from a 15-year period of below-average lake levels to the recent multi-year stretch of record highs (Ehsanzadeh and others, 2013; Fry and others, 2020; Gronewold and others, 2016; Gronewold and others, 2021; Johnston and others, 2012; Lenters, 2001), while inland marshes often experience seasonal water level changes ranging from a few centimeters to over a meter, typically peaking in spring and declining by late summer (Faber-Langendoen and others, 2020; Park and others, 2022; Werner and others, 2013). Across all contexts, hydrologic variability is driven by fluctuations in lake and river levels, precipitation, and snowmelt, which shape marsh ecology and long-term successional trajectories (Drake, 2015; Magee and Kentula, 2005; Mitsch and Gosselink, 2015).

Vegetation structure and species composition vary with water depth and disturbance regime but are generally characterized by 16 common species (Table 1). Shallow marshes often support shorter emergents and hydrophytic forbs, while deeper systems are typically dominated by tall monocots such as bulrushes (*Schoenoplectus* spp.), cattails (*Typha* spp.), and wildrice (*Zizania* spp.) (Drake, 2015; Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005a; USNVC, 2025). These species occur alongside floating-leaved and submerged aquatics in open-water zones or intermixed in a dynamic mosaic (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005a). Marshes typically exhibit distinct zonation patterns, with emergent to submerged vegetation bands shaped by microtopography and hydrology (Faber-Langendoen and Rocchio, 2005a; Foti and others, 2012; Wilcox, 2012a).

Marshes are sensitive to long-term changes in climate, hydrologic regulation, sedimentation, and nutrient loading. Historically, many marshes across the Midwest have been degraded or lost due to agricultural drainage, which disrupted natural hydrology and contributed to increased sediment and nutrient loading (Ballut-Dajud and others, 2022; Brinson and Malvárez, 2002; Mitsch and Hernandez, 2013; Mortsch and others, 2003; Rice, 2023; Wilcox, 2012a). Invasive species further threaten habitat structure and function, including flowering rush (*Butomus umbellatus*), barnyardgrass (*Echinochloa crus-*

galli), Canadian waterweed (*Elodea canadensis*), purple loosestrife (*Lythrum salicaria*), Eurasian watermilfoil (*Myriophyllum spicatum*), reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis* ssp. *australis*), curly pondweed (*Potamogeton crispus*), and certain cattails (*Typha* spp.) (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005a; Kost and others, 2007; Trebitz and Taylor, 2007).

Table 1. Plant species common to the Eastern North American Freshwater Marsh. Asterisks (*) denote species introduced to the region. Taxonomic authority, common name, growth habit, and native status are determined according to the PLANTS Database (USDA, NRCS, 2025).

Species	Common name	Growth habit
Alisma subcordatum Raf.	American water plantain	Forb/herb
Alisma triviale Pursh	Northern water plantain	Forb/herb
Bacopa rotundifolia (Michx.) Wettst.	Disk waterhyssop	Forb/herb
Bolboschoenus fluviatilis (Torr.) Soják	River bulrush	Graminoid
Heteranthera limosa (Sw.) Willd.	Blue mudplantain	Forb/herb
Leersia oryzoides (L.) Sw.	Rice cutgrass	Graminoid
Pontederia cordata L.	Pickerelweed	Forb/herb
Sagittaria latifolia Willd.	Broadleaf arrowhead	Forb/herb
Schoenoplectus acutus (Muhl. ex Bigelow) Á. Löve & D. Löve	Hardstem bulrush	Graminoid
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	Softstem bulrush	Graminoid
Sparganium eurycarpum Engelm.	Broadfruit bur-reed	Forb/herb
**Typha angustifolia* L.	Narrowleaf cattail	Forb/herb
Typha latifolia L.	Broadleaf cattail	Forb/herb
Typha × glauca (pro sp.) [angustifolia or domingensis × latifolia]	Hybrid cattail	Forb/herb
Zizania aquatica L.	Annual wildrice	Graminoid
Zizania palustris L.	Northern wildrice	Graminoid

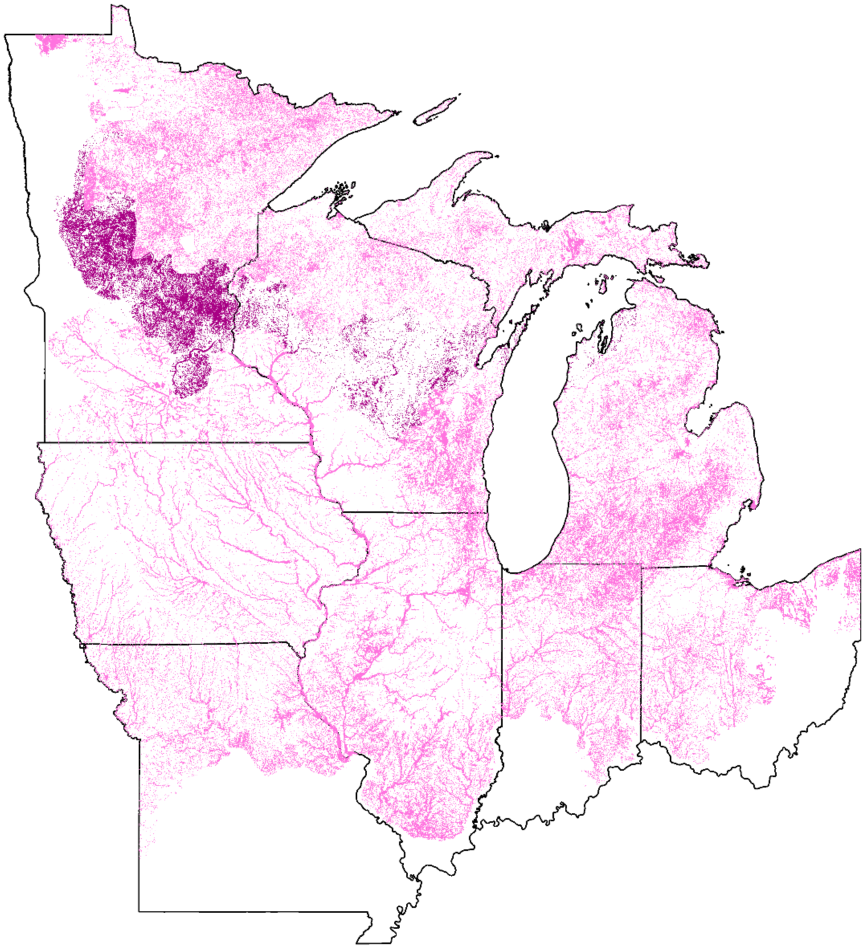

Figure 3. Eastern North American Freshwater Marsh distribution. Geographic distribution of the Eastern North American Freshwater Marsh (Group Code: G652) in the Midwest (USNVC, 2020). Purple areas indicate Eastern North American Freshwater Marsh habitat in the Mixed Wood Plains ecoregion, while light pink areas mark additional locations throughout the Midwest. Polygon boundaries have been enlarged to enhance visibility and do not reflect true proportions.

Overview of Climate Projections

The Eastern North American Freshwater Marsh habitat is a priority within the Mixed Wood Plains ecoregion. Both average and extreme temperatures are expected to rise throughout the coming century (RCP 8.5; Table 2) (Clarke and others, 2022; Marvel and others, 2023; Masson-Delmotte and others, 2021; Polasky and others, 2022; Xue and others, 2022). Most climate models also project an increase in precipitation, although some indicate a slight decrease (Table 3) (Marvel and others, 2023). Additionally, precipitation patterns are anticipated to shift towards more extreme events and greater seasonal variability, with notably wetter springs (Chen and Ford, 2023; Dollan and others, 2022; Marvel and others, 2023; Na and Najafi, 2024; Zhao and others, 2023).

Table 2. Projected changes in annual temperature in the Mixed Wood Plains. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000) and projected annual mean temperature (°F) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected temperature under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	43.7 °F	46.4 °F (6%)	47.4 °F (8%)	47.3 °F (8%)	50.1 °F (15%)
Mean of models	43.7 °F	48.9 °F (12%)	50.5 °F (16%)	50.0 °F (14%)	54.6 °F (25%)
Maximum model	43.9 °F	51.9 °F (18%)	53.4 °F (22%)	53.6 °F (22%)	59.1 °F (35%)

Table 3. Projected changes in annual precipitation in the Mixed Wood Plains. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000) and projected annual precipitation (inches) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected precipitation under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	30.3 in	30.7 in (1%)	29.7 in (-2%)	32.2 in (6%)	28.8 in (-5%)
Mean of models	30.1 in	32.0 in (6%)	32.1 in (7%)	31.9 in (6%)	32.7 in (9%)
Maximum model	30.2 in	33.7 in (11%)	33.5 in (11%)	33.1 in (9%)	36.0 in (19%)

Key Climate Change Stressors

Flooding and inundation and drought. Across the Mixed Wood Plains ecoregion, spring precipitation is projected to rise by approximately 25% compared to historical conditions by the end of the century (Table 4). These trends will be particularly pronounced in southeastern Minnesota, central to south-central Wisconsin, and along the upper Lake Michigan shoreline of Michigan, where spring precipitation may total more than a foot (Figure 4). Thirty-year extreme drought incidence is also projected to increase by approximately 917%, with 35.4 months of extreme drought expected within a 30-year period (Table 5). This trend remains relatively consistent throughout the region (Figure 5). The rise in extreme drought frequency, combined with increased spring precipitation, may drive substantial hydrological fluctuations, intensifying both inundation and drought stress and disrupting hydrological processes.

Table 4. Projected changes spring precipitation in the Mixed Wood Plains. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000) and projected spring (March–May) precipitation (inches) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected spring precipitation under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	7.3 in	8.0 in (10%)	8.2 in (13%)	8.9 in (22%)	8.1 in (11%)
Mean of models	7.7 in	8.6 in (12%)	9.0 in (16%)	8.8 in (14%)	9.7 in (25%)
Maximum model	7.7 in	9.7 in (26%)	9.2 in (20%)	9.4 in (22%)	11.3 in (47%)

Table 5. Projected changes in 30-year extreme drought incidence in the Mixed Wood Plains. Projections use Standardized Precipitation-Evapotranspiration Index (SPEI) data obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme drought incidence is defined as the number of months within a 30-year period with an SPEI value of ≤-2, corresponding to the driest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000) and projected 30-year extreme drought incidence (months) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected 30-year extreme drought incidence under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	3.2	7.8 (143%)	8.9 (179%)	8.0 (150%)	11.2 (250%)
Mean of models	3.5	13.9 (300%)	19.0 (445%)	18.1 (421%)	35.4 (917%)
Maximum model	6	16.1 (170%)	18.6 (211%)	36.8 (517%)	65.2 (991%)

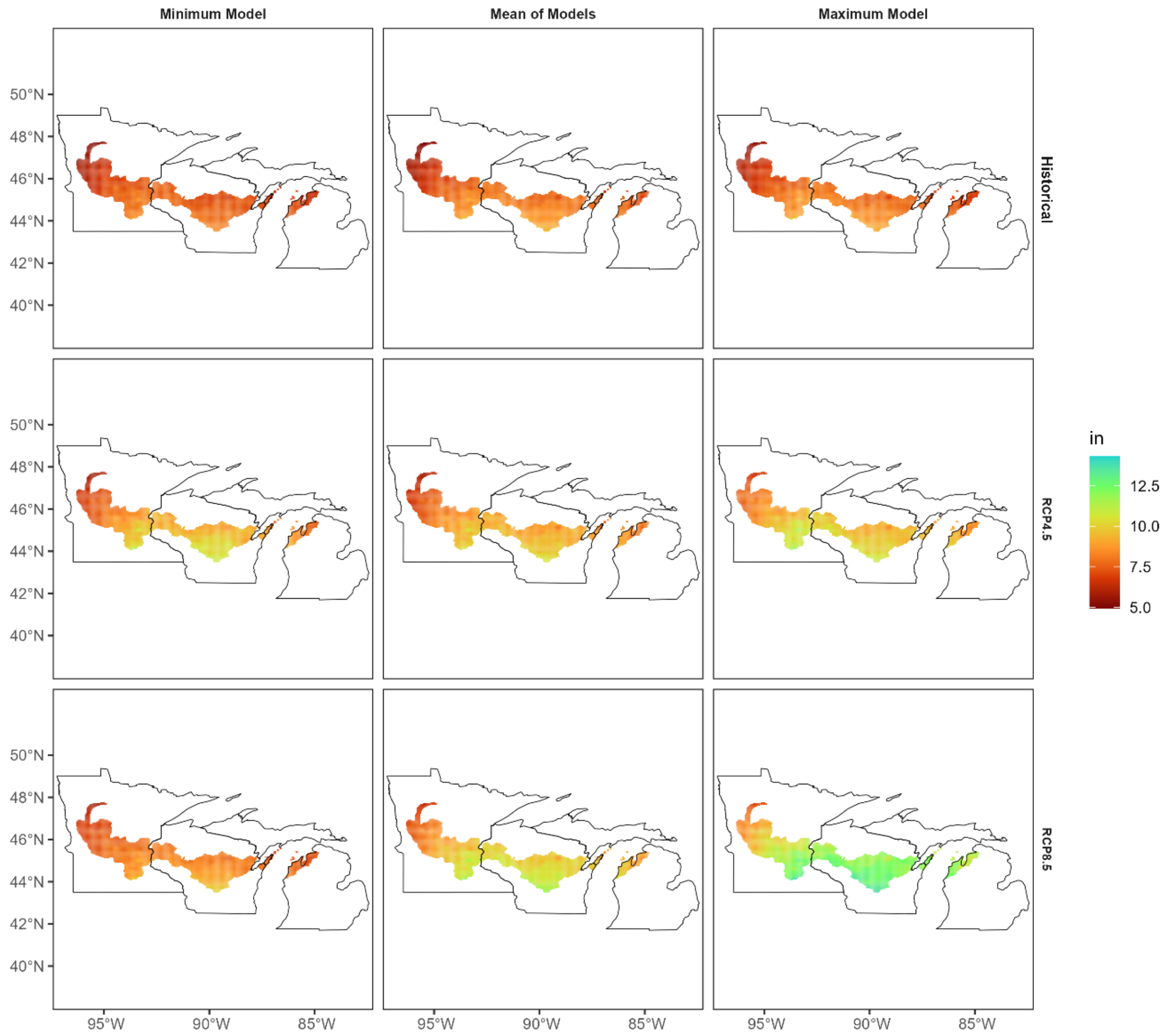

Figure 4. Projected changes in spring precipitation in the Mixed Wood Plains. Projections use gridded climate data obtained via the Climate Toolbox Climate Mapper at a 4-km resolution (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000, top row) and projected (2070–2099) spring (March–May) precipitation (inches) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected spring precipitation under RCP 8.5 are presented in addition to the mean of all models (middle column).

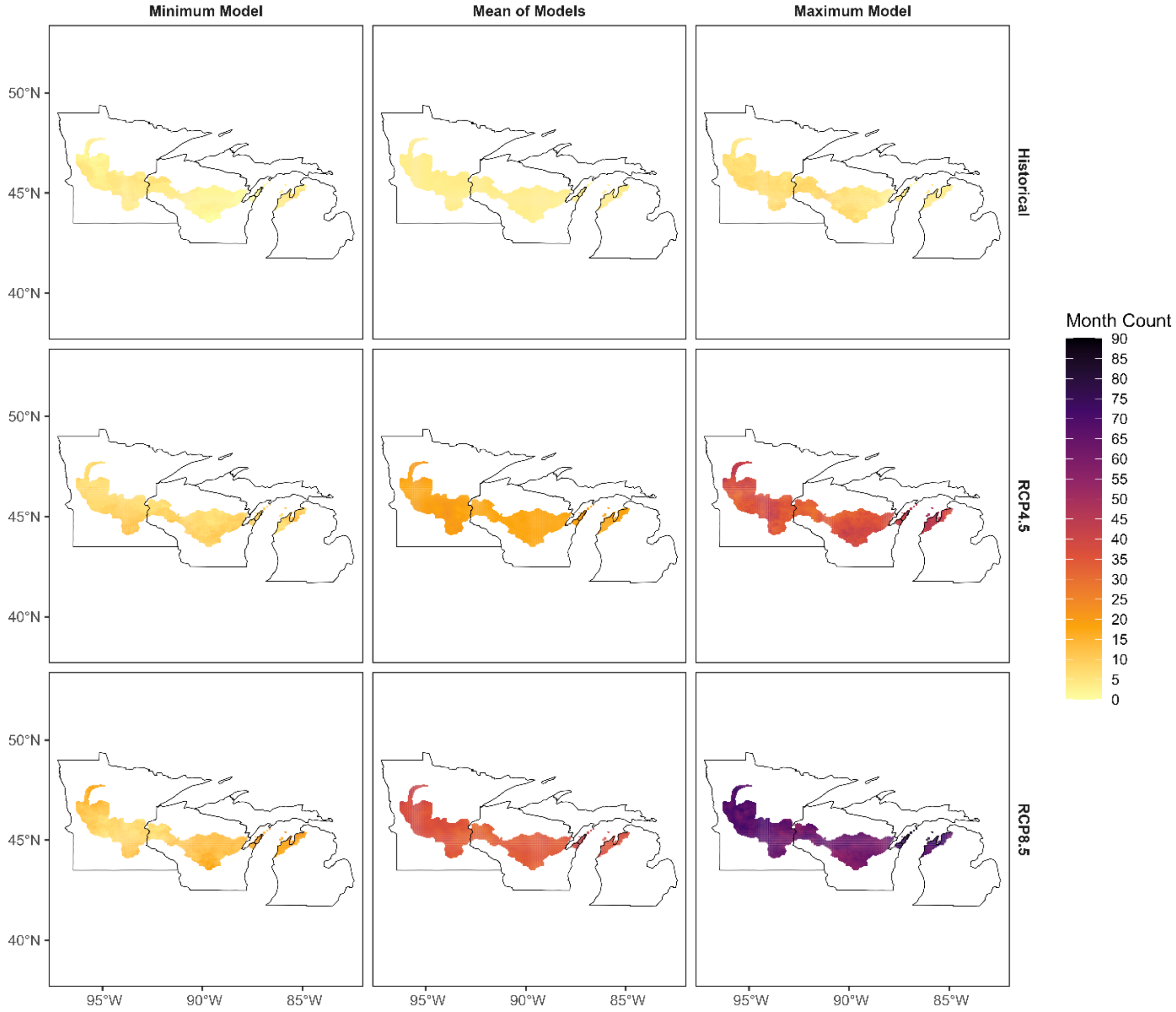

Figure 5. Projected changes in 30-year extreme drought incidence in the Mixed Wood Plains. Projections use gridded Standardized Precipitation-Evapotranspiration Index (SPEI) values obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme drought incidence is defined as the number of months within a 30-year period with an SPEI value of ≤-2, corresponding to the driest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000, top row) and projected (2070–2099) 30-year extreme drought incidence (months) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected 30-year extreme drought incidence under RCP 8.5 are presented in addition to the mean of all models (middle column).

Key Climate Change Impacts

This section summarizes how climate change is impacting the Eastern North American Freshwater Marsh. It covers the specific effects of flooding and inundation and drought on key species (Table 6). The bullet points below provide a concise overview of these impacts on habitat structure, community composition, and invasive species.

Habitat structure:

- Flooding may alter habitat structure through scouring, sediment deposition, and localized landscape transformation, potentially increasing vulnerability to degradation from turbidity, wave energy, and erosion (Amoros and others, 2000; Lind and others, 2022; Ma and others, 2025; Mortsch and others, 2006; Rutherford and others, 2022; Theuerkauf and Braun, 2021; Wilcox and others, 2007).
- Flooding may increase nutrient and sediment inputs from adjacent agricultural and urban areas, promoting eutrophication, invasive species, and terrestrialization in shallow basins (Anteau and others, 2016; Magee and others, 2021; Short and others, 2016; Staffen and others, 2019; WICCI Great Lakes Working Group, 2021; Zedler and Kercher, 2004).
- Intensified cycling between inundation and drought may shift soils between aerobic and anaerobic states, slowing decomposition, denitrification, and plant nutrient uptake during saturation and accelerating decomposition, carbon dioxide release, and mineralization during dry periods (Batzer and Sharitz, 2014; Faber-Langendoen and Rocchio, 2005a; Ma and others, 2025; Pezeshki, 2001; Trettin and others, 2019).

Community composition:

- Climate change may reduce the range of species like broadleaf cattail (*Typha latifolia*) while decreasing populations of vulnerable or low-adaptive capacity species such as northern wildrice (*Zizania* palustris) and pickerelweed (*Pontederia cordata*) (GLIFWC Climate Change Team, 2023; Inter-Tribal Council of Michigan, Inc, 2016; Mortsch and others, 2006; Xu and others, 2013).
- More frequent, prolonged, and severe flooding may destabilize plant communities by displacing dominant species, accelerating turnover, and compressing or eliminating vegetation zones, leading to more homogenous assemblages as specialist species with narrow hydrological niches are lost (Table 6) (Anderson and others, 2025; Batzer and Sharitz, 2014; Foti and others, 2012; Magee and others, 2021; Smith and others, 2021; Wilcox, 2004; Wilcox and Nichols, 2008).
- Flood-tolerant facultative and obligate species may expand or become more dominant under wetter conditions, while species less tolerant of inundation, including many forbs and grasses, decline or shift to higher elevation vegetation zones (Table 6) (Anderson and others, 2025; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Gathman and others, 2005; Lind and others, 2022; Magee and Kentula, 2005; Meeker and others, 2023; Rutherford and others, 2022; Smith and others, 2021).
- Repeated drawdowns during drought, including those driven by prolonged lake level declines, may facilitate rapid colonization of exposed substrates by annuals and rhizomatous species, potentially driving long-term shifts in community composition (Mortsch and others, 2006; Rose and others, 2023; Rupasinghe and Chow-Fraser, 2024; Tulbure and others, 2007; Wilcox and others, 2022).
- More frequent, prolonged, and severe drought may favor perennials with deep root systems and facultative over obligate wetland species (Table 6) (Anderson and others, 2023; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Garbowski and others, 2020; Hultine and others, 2020; Moor and others, 2017; Wilcox and others, 2022).
- Lower water levels during drought may promote encroachment of meadow and shrub species, shifting composition toward drier-adapted communities (Brotherton and Joyce, 2015; Keddy and

Reznicek, 1985; Mortsch and others, 2006; Rose and others, 2023; Rutherford and others, 2022; Wilcox, 2012a).

- Wildrice (*Zizania* spp.) marshes are particularly vulnerable to hydrological change, as these annuals require shallow, stable water and soft organic substrates for germination and growth, and are easily uprooted during flooding or outcompeted under both flooding and drought (Panda and others, 2024; Pillsbury and McGuire, 2009; Varty and others, 2024).

Invasive species:

- Rising temperatures may facilitate the northward expansion of cold-limited aquatic invaders such as waterthyme (*Hydrilla verticillata*), primrose-willows (*Ludwigia* spp.), and parrot feather watermilfoil (*Myriophyllum aquaticum*) (Bolpagni, 2021; Gillard and others, 2017; Wang and others, 2019).
- Prolonged flooding and fluctuating water levels may weaken native competitors and favor invasive species adapted to a wide hydrologic range, such as reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis* ssp. *australis*), and cattails (*Typha* spp.), especially in nutrient-rich systems (Table 6) (Bansal and others, 2019; Grabas and Rokitnicki-Wojcik, 2015; Magee and Kentula, 2005; Miller and Zedler, 2003; Zedler and Kercher, 2004; Hall and Zedler, 2010b; Woo and Zedler, 2002).
- Elevated nutrient and sediment inputs from flooding and runoff may reinforce invasive dominance, particularly in already disturbed systems with reduced native diversity (Ma and others, 2025; Short and others, 2016; Zedler and Kercher, 2004).
- Drought and water drawdowns may promote invasive establishment in formerly aquatic or saturated zones, accelerating spread into exposed basins (Anderson and others, 2025; Lishawa and others, 2010b; Magee and Kentula, 2005; Tulbure and Johnston, 2010).

Table 6. Summary of impacts from key climate change stressors on Eastern North American Freshwater Marsh species. Asterisks (*) denote species introduced to the region, while daggers (†) denote some species within the genus may be introduced to the region, though most are native. Some species appear in contradictory columns (e.g., showing both negative and positive drought impacts), reflecting conflicting findings in the literature

Stressor	Impact	Affected species
Drought	When tolerance of water deficits is low, potential for reduced growth rates and abundance	*Leersia oryzoides*[1] **Phalaris arundinacea*[1] *Phleum pratense[1] **Phragmites* australis ssp. *australis* [1] *Sagittaria latifolia*[1] *Schoenoplectus tabernaemontani*[1,2] *Sparganium eurycarpum*[3] **Typha angustifolia*[1] *Typha latifolia*[1,4] †*Typha* spp.[5] *Zizania aquatica*[1,6]
		**Cirsium arvense*[7]

Stressor	Impact	Affected species
	When tolerance of water deficits is high, potential for competitive advantage and increased abundance	*Leersia oryzoides*[5] **Phalaris arundinacea*[5,8–10] **Phragmites* australis ssp. *australis* [2,11] *Schoenoplectus acutus*[1] *Schoenoplectus tabernaemontani*[5] **Typha angustifolia*[12,13] †*Typha* spp.[9,11,14] *Typha × glauca*[12]
Flooding/Inundation	When flooding/inundation tolerance is low, potential for reduced growth rates, mortality, or abundance	*Leersia oryzoides*[15] **Phalaris arundinacea*[10,16,17] *Schoenoplectus tabernaemontani*[18] *Zizania aquatica*[6] *Zizania palustris*[19] *Zizania* spp.[20]
	When flooding/inundation tolerance is high, potential for competitive advantage and increased abundance	*Bolboschoenus fluviatilis*[18] *Leersia oryzoides*[15,21,22] **Phalaris arundinacea*[9,23,24] *Schoenoplectus tabernaemontani*[25] *Sparganium eurycarpum*[3] *Typha latifolia*[9] †*Typha* spp.[25–27] *Typha × glauca*[24,28]

[1]USDA, NRCS (2025); [2]Mortsch and others (2006); [3]Chapman and others (2013); [4]Sueltenfuss and others (2020); [5]Wilcox and others (2022); [6]Tucker and others (2011); [7]Hogenbirk and Wein (1991); [8]He and others (2011); [9]Kercher and Zedler (2004); [10]Rutherford and others (2022); [11]Anderson and others (2025); [12]Lishawa and others (2010); [13]Wilcox and Nichols (2008); [14]Tulbure and others (2007); [15] Darris and Bartow (2004); [16]Charles and others (2023); [17]Miller and Zedler (2003); [18]Chapman and others (2013); [19]Arneson (2020); [20]Hansen (2008); [21]Koont and Pezeshki (2011); [22]Pierce and others (2007); [23]Waggy (2010) ; [24]Zedler and Kercher (2010); [25]Mortsch and others (2003); [26]Bansal and others (2019); [27]Boers and Zedler (2008); [28]Bunbury-Blanchette and others (2015); [29]Boers and others (2007)

Focal Wildlife Species: Blanding’s Turtles

Blanding’s turtles (*Emydoidea blandingii*) are long-lived, semiaquatic freshwater turtles found across the northern and eastern United States and southern Canada. In the Midwest, their reliance on a variety of aquatic and upland habitats during their annual activity cycle, combined with low thermal tolerance, make them potentially vulnerable to both the direct and indirect impacts of climate change (Lyons and others, 2023, p. 202). Of all North American freshwater turtles, Blanding’s turtles have the lowest critical thermal threshold, and summer maximum temperatures are increasingly likely to exceed this threshold, reducing foraging time (Lyons and others, 2023). Warmer winters and increasingly variable freeze-thaw conditions may also increase mid-winter movements, raising energy demands during a time when food is scarce (Newton and Herman, 2009). Additionally, temperature fluctuations may prompt premature emergence from overwintering sites (Markle and Chow-Fraser, 2014).

Climate change also poses risks to Blanding's turtle reproduction. Higher temperatures during incubation are likely to skew hatchling sex ratios toward females if not compensated by selecting cooler, shaded nest sites or nesting earlier in the season (Gutzke and Packard, 1987). More frequent extreme precipitation events may increase nest failure due to flooding, while drought may hinder nest construction, cause nest collapse, or increase embryo and hatchling mortality through desiccation (Congdon and others, 2000).

Blanding's turtles depend on freshwater ponds, bogs, and marshes for overwintering and foraging and upland, well-drained sites with sparse vegetation for nesting. In the Midwest, these aquatic habitats are likely to face growing impacts from more frequent and intense cycles of drought and deluge. Prolonged summer dry periods may reduce foraging habitat, leading to food shortages and increased movement in search of suitable conditions (Hall and Cuthbert, 2000). These movements during low water periods may increase mortality risk due to road collisions (Ruane and others, 2008) and heightened exposure to predators (Gasbarrini and others, 2021). While some degree of behavioral plasticity, such as earlier nesting or shorter incubation periods, may buffer against these risks, additional adaptive management strategies will likely be necessary, including the installation of turtle road crossings and the implementation of head-starting programs, which raise hatchlings in captivity through their most vulnerable early stages before releasing them into the wild.

Focal Aquatic System: Lake Monongalia

Lake Monongalia, located in the Middle Fork Crow River Watershed in central Minnesota, spans 2,255 acres and reaches a maximum depth of just 14 feet, and is classified as entirely littoral and polymictic (MFCRWD, 2007). As a shallow lake, it is highly sensitive to changes in water quality and temperature, with frequent mixing throughout the water column. Like many shallow lakes, Lake Monongalia is prone to abrupt regime shifts from clear to turbid water states, often triggered by nutrient overloading and altered hydrology (Scheffer and van Nes, 2007).

The watershed surrounding Lake Monongalia, marked by extensive agriculture and growing urban development, faces significant climate-related challenges that may intensify existing environmental pressures (Johnson and others, 2023). Increased precipitation and rising temperatures intensify runoff and lead to more frequent and severe flooding, which can contribute to nutrient loading and sedimentation (Jeppesen and others, 2014; Perleberg and others, 2023). Such changes can increase the likelihood of regime shifts from clear to turbid conditions (Jeppesen and others, 2014; Perleberg and others, 2023).

As a polymictic lake, Lake Monongalia does not form stable thermal layers and instead mixes multiple times per year. Combined with its limited water volume and broad surface area exposed to the atmosphere, this frequent mixing makes Lake Monongalia highly responsive to short-term climate variability, particularly shifts in wind and air temperature, compared to deeper, stratified lakes (Magee and Wu, 2017; Winslow and others, 2017). These changes can significantly influence biological processes, such as the timing of phytoplankton blooms, and alter the lake's overall productivity (Winslow and others, 2017).

Submerged aquatic vegetation, which plays a crucial role in maintaining water clarity by anchoring sediments and competing with algae for nutrients, is under threat as the lake trends towards a eutrophic state (Jeppesen and others, 2014). This shift could undermine the ability of macrophytes to maintain water clarity, accelerating the transition to a turbid state and degrading overall lake health. The resulting decline in macrophyte populations would reduce habitat quality for aquatic and terrestrial wildlife and weaken the lake's natural resilience to future environmental change.

Midwest Wet Prairie, Wet Meadow and Shrub Swamp

The Midwest Wet Prairie, Wet Meadow and Shrub Swamp encompasses a diverse group of seasonally saturated and intermittently flooded wetlands distributed across the Midwest (Figure 6) and parts of Canada (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005b; USNVC, 2025). This habitat group includes graminoid-dominated systems such as wet prairies and sedge meadows, as well as shrub-dominated communities like wet shrublands and buttonbush (*Cephalanthus* spp.) thickets (Curtis, 1959; Faber-Langendoen and others, 2020; Minnesota Natural Heritage Program (MNNHP), 1993). These wetlands occur across a variety of glacial and alluvial landscapes, including lakeplains, outwash plains, floodplain terraces, and upland depressions, often forming part of broader wetland mosaics at the margins of mesic prairie or forested habitats (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005b; Gibson and others, 2023; Kost and others, 2007). Soils are typically mineral, although mucky and organic substrates occur in areas with prolonged saturation (Curtis, 1959; Faber-Langendoen and Rocchio, 2005b; Gibson and others, 2023; Kost and others, 2007).

Unlike marshes or fens, these wetlands generally lack persistent standing water and do not accumulate deep peat (Cowardin and others, 1979; Faber-Langendoen and Rocchio, 2005b; Kost and others, 2007). Water tables are typically shallow in spring and early summer, with periodic saturation or flooding followed by drawdowns later in the growing season (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005b; Hollands, 1988; Kantrud and others, 1989; Valk, 2005). Their shallow basin topography and reliance on precipitation and snowmelt inputs make wet prairies and meadows especially vulnerable to drying (Galatowitsch, 2012; Johnson and others, 2005; Johnson and others, 2010; Joyce and others, 2016; van der Kamp and Hayashi, 2009). Evaporation is the primary driver of water loss, as these systems are largely disconnected from larger hydrological networks except during heavy precipitation events (Galatowitsch, 2012; Hayashi and others, 2016; Poiani and others, 1996). Extensive historical drainage and conversion to agriculture have led to widespread habitat loss, particularly in productive, moisture-rich areas such as the Prairie Pothole Region of western Minnesota and Iowa (Anteau and others, 2016; Dahl and Allord, 1997; Johnson and others, 2010; Oslund and others, 2010).

Vegetation varies along a moisture gradient, with structure and composition shaped by hydrology and disturbance. Graminoid-dominated wet prairies and meadows typically occur in drier, temporarily flooded basins, while shrub swamps develop in more saturated depressions or backwaters with longer hydroperiods and limited fire exposure (Faber-Langendoen and others, 2020; Faber-Langendoen and Rocchio, 2005b; Nelson and Anderson, 1983; Prince, 2008). Shallow basin topography and dependence on precipitation and snowmelt inputs make wet prairies and meadows especially vulnerable to drying (Galatowitsch, 2012; Johnson and others, 2005; Johnson and others, 2010; Joyce and others, 2016; van der Kamp and Hayashi, 2009). Evaporation drives water loss in these systems, which are generally disconnected from larger hydrological systems except during periods of heavy precipitation (Galatowitsch, 2012; Hayashi and others, 2016; Poiani and others, 1996). Extensive historical drainage and agricultural conversion have resulted in widespread loss of wet prairie, wet meadow, and shrub swamp habitats, particularly in more productive and moisture-rich regions such as part of the Prairie Pothole Region in western Minnesota and Iowa (Anteau and others, 2016; Dahl and Allord, 1997; Johnson and others, 2010; Oslund and others, 2010). These habitats are typically characterized by a group of 61 common species (Table 7), but they are also highly susceptible to invasion by both native and non-native species, including Canada thistle (*Cirsium arvense*), marsh thistle (*Cirsium palustre*), purple loosestrife (*Lythrum salicaria*), reed canarygrass (*Phalaris arundinacea*), timothy (*Phleum* *pratense*), European common reed (*Phragmites australis* ssp. *australis*), Kentucky bluegrass (*Poa pratensis*), and certain cattails (*Typha* spp.) (Faber-Langendoen and Rocchio, 2005b; Kost and others, 2007; Rutherford and Fawcett, 2024).

Table 7. Plant species common to the Midwest Wet Prairie, Wet Meadow and Shrub Swamp. Asterisks (*) denote species introduced to the region, while daggers (†) denote some species within the genus may be introduced to the region, though most are native. Taxonomic authority, common name, growth habit, and native status are determined according to the PLANTS Database (USDA, NRCS, 2025).

Species	Common name	Growth habit
Aronia × prunifolia (Marshall) Rehder, (pro sp.) [*arbutifolia × melanocarpa*]	Purple chokeberry	Shrub
Cephalanthus occidentalis L.	Common buttonbush	Shrub, tree
Cornus sericea L.	Redosier dogwood	Shrub, tree
Gaylussacia baccata (Wangenh.) K. Koch	Black huckleberry	Shrub
Rubus hispidus L.	Bristly dewberry	Shrub
Salix bebbiana Sarg.	Bebb willow	Shrub, tree
Salix discolor Muhl.	Pussy willow	Shrub, tree
**Salix fragilis* L.	Crack willow	Tree
Salix humilis Marshall	Prairie willow	Shrub
Salix petiolaris Sm.	Meadow willow	Shrub, tree
†*Salix* L.	Willow	Shrub, tree
Spiraea alba Du Roi	White meadowsweet	Shrub
Spiraea tomentosa L.	Steeplebush	Shrub
Vaccinium angustifolium Aiton	Lowbush blueberry	Shrub
**Agrostis stolonifera*	Creeping bentgrass	Graminoid
Andropogon gerardii Vitman	Big bluestem	Graminoid
Arnoglossum plantagineum Raf.	Groovestem Indian plantain	Forb/herb
Bartonia virginica (L.) Britton, Sterns & Poggenb.	Yellow screwstem	Forb/herb
Boltonia asteroids (L.) L'Hér.	White doll's daisy	Forb/herb
Calamagrostis canadensis (Michx.) P. Beauv.	Bluejoint	Graminoid
Calamagrostis stricta (Timm) Koeler	Slimstem reedgrass	Graminoid
†*Carex* L.	Sedge	Graminoid
Carex aquatilis Wahlenb.	Water sedge	Graminoid
Carex bicknellii Britton	Bicknell's sedge	Graminoid
Carex buxbaumii Wahlenb.	Buxbaum's sedge	Graminoid
Carex cristatella Britton	Crested sedge	Graminoid
Carex lacustris Willd.	Hairy sedge	Graminoid
Carex molesta Mack. ex Bright	Troublesome sedge	Graminoid
Carex pellita Muhl. ex Willd.	Woolly sedge	Graminoid
Carex praegracilis W. Boott	Clustered field sedge	Graminoid

Species	Common name	Growth habit
Carex rostrata Stokes	Beaked sedge	Graminoid
Carex sartwellii Dewey	Sartwell's sedge	Graminoid
Carex scoparia Schkuhr ex Willd.	Broom sedge	Graminoid
Carex sterilis Willd.	Dioecious sedge	Graminoid
Carex stipata Muhl. ex Willd.	Awlfruit sedge	Graminoid
Carex stricta Lam.	Upright sedge	Graminoid
Carex tribuloides Wahlenb.	Blunt broom sedge	Graminoid
Clinopodium arkansanum (Nutt.) House	Limestone calamint	Forb/herb
Deschampsia cespitosa (L.) P. Beauv.	Tufted hairgrass	Graminoid
Juncus arcticus Willd. ssp. *Littoralis* (Engelm.) Hultén	Mountain rush	Graminoid
Lemna minor L.	Common duckweed	Forb/herb
**Lythrum salicaria* L.	Purple loosestrife	Forb/herb
Muhlenbergia richardsonis (Trin.) Rydb.	Mat muhly	Graminoid
Nuphar advena (L.) Sm.	Yellow pond-lily	Forb/herb
Oligoneuron ohioense (Frank ex Riddell) G.N. Jones	Ohio goldenrod	Forb/herb
Osmunda regalis L.	Royal fern	Forb/herb
Panicum virgatum L.	Switchgrass	Graminoid
Parthenium integrifolium Britton	Wild quinine	Forb/herb
Pedicularis canadensis L.	Canadian lousewort	Forb/herb
Plantago eriopoda Torr.	Redwool plantain	Forb/herb
**Poa compressa* L.	Canada bluegrass	Graminoid
Poa palustris L.	Fowl bluegrass	Graminoid
**Poa pratensis* L.	Kentucky bluegrass	Graminoid
†*Sagittaria* L.	Arrowhead	Forb/herb
Schizachyrium scoparium (Michx.) Nash	Little bluestem	Graminoid
Sorghastrum nutans (L.) Nash	Indiangrass	Graminoid
Spartina pectinata Bosc ex Link	Prairie cordgrass	Graminoid
Symphyotrichum lanceolatum (Willd.) G.L. Nesom	White panicle aster	Forb/herb
**Typha angustifolia* L.	Narrowleaf cattail	Forb/herb
Typha latifolia L.	Broadleaf cattail	Forb/herb
Viola lanceolata L.	Bog white violet	Forb/herb

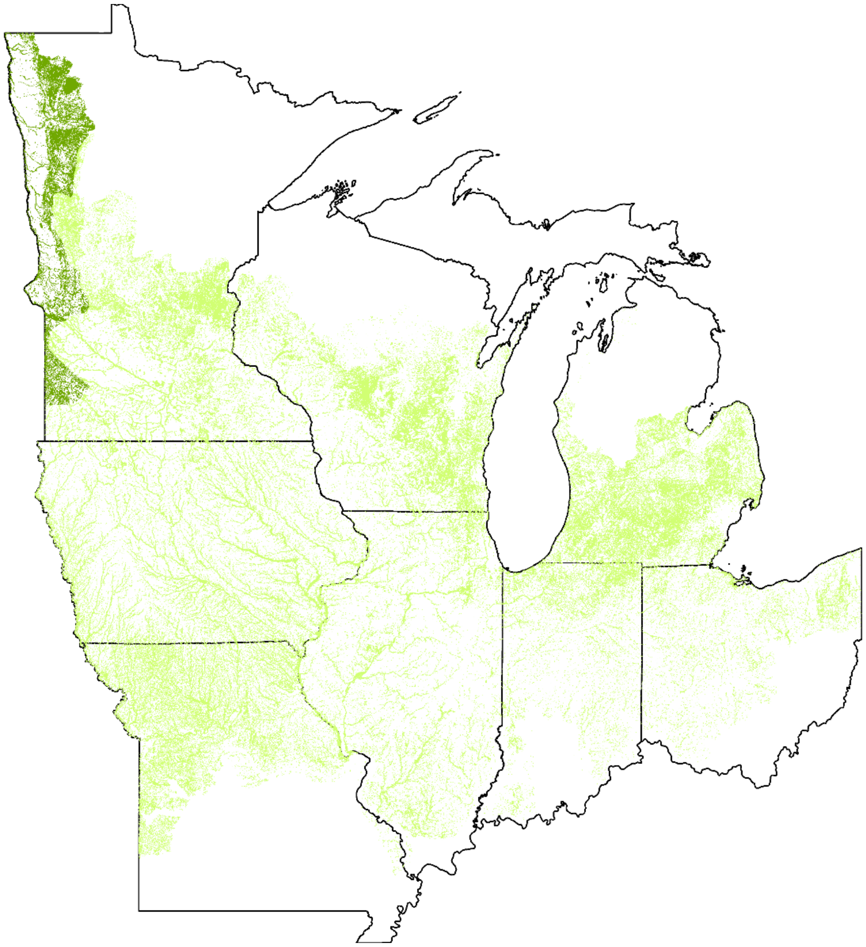

Figure 6. Midwest Wet Prairie, Wet Meadow and Shrub Swamp distribution. Geographic distribution of the Midwest Wet Prairie, Wet Meadow and Shrub Swamp (Group Code: G673) in the Midwest (USNVC, 2020). Dark green areas indicate Midwest Wet Prairie, Wet Meadow and Shrub Swamp habitat in the Northern Plains ecoregion, while light green areas mark additional locations throughout the Midwest. Polygon boundaries have been enlarged to enhance visibility and do not reflect true proportions.

Overview of Climate Projections

The Midwest Wet Prairie, Wet Meadow and Shrub Swamp habitat is a priority within the Northern Plains ecoregion. Both average and extreme temperatures are expected to rise throughout the coming century (RCP 8.5; Table 8) (Clarke and others, 2022; Marvel and others, 2023; Masson-Delmotte and others, 2021). Most climate models also project an increase in precipitation, although some indicate a slight decrease (Table 9) (NCA 5 Chapter 2). Additionally, precipitation patterns are anticipated to shift towards more extreme events and greater seasonal variability, with notably wetter springs (Dollan and others, 2022; Marvel and others, 2023).

Table 8. Projected changes in annual temperature in the Northern Plains. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000) and projected annual mean temperature (°F) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected temperature under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	41.6 °F	43.6 °F (5%)	45.4 °F (9%)	44.3 °F (7%)	47.6 °F (14%)
Mean of models	41.4 °F	46.7 °F (13%)	48.3 °F (17%)	47.8 °F (15%)	52.5 °F (27%)
Maximum model	41.5 °F	48.3 °F (17%)	50.6 °F (22%)	50.1 °F (21%)	57.0 °F (38%)

Table 9. Projected changes in annual precipitation in the Northern Plains. Projections use data obtained via the Climate Toolbox Climate Mapper (Hegewisch and Abatzoglou, 2024) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Values show average historical (1971–2000) and projected annual precipitation (inches) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected precipitation under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	22.6 in	22.8 in (1%)	24.2 in (7%)	23.5 in (4%)	22.7 in (0%)
Mean of models	23.1 in	24.5 in (6%)	24.5 in (6%)	24.6 in (7%)	25.2 in (9%)
Maximum model	23.4 in	26.6 in (14%)	26.1 in (11%)	25.8 in (10%)	28.3 in (21%)

Key Climate Change Stressors

Flooding and inundation and drought. Across the Northern Plains ecoregion, 30-year extreme wet incidence is projected to increase by approximately 69% compared to historical conditions by the end of the century, with 10 months of extreme wet expected within a 30-year period (Table 10). Thirty-year extreme drought incidence is also projected to increase by approximately 992%, with 39.7 months of extreme drought expected within a 30-year period (Table 11). These trends remain relatively consistent throughout the region (Figures 7; 8). The rise in extreme drought frequency, combined with increased spring precipitation, may drive substantial hydrological fluctuations, intensifying both inundation and drought stress and disrupting hydrological processes.

Table 10. Projected changes in 30-year extreme wet incidence in the Northern Plains. Projections use Standardized Precipitation-Evapotranspiration Index (SPEI) data obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme wet incidence is defined as the number of months within a 30-year period with an SPEI value of ≥ 2, corresponding to the wettest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000) and projected 30-year extreme wet incidence (months) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected 30-year extreme wet incidence under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	5.2	6.5 (27%)	6.6 (27%)	7.7 (50%)	3.8 (-26%)
Mean of models	5.9	9.2 (55%)	9.8 (65%)	10.6 (79%)	10.0 (69%)
Maximum model	6.3	8.9 (42%)	19.7 (214%)	12.7 (102%)	17.1 (172%)

Table 11. Projected changes in 30-year extreme drought incidence in the Northern Plains. Projections use Standardized Precipitation-Evapotranspiration Index (SPEI) data obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme drought incidence is defined as the number of months within a 30-year period with an SPEI value of ≤-2, corresponding to the driest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000) and projected 30-year extreme drought incidence (months) by mid- (2040–2069) and end of the century (2070–2099), as well as the percent change relative to the historical value (in parentheses), for each emissions scenario. To capture variation across climate models, models with the lowest (minimum model) and highest (maximum model) projected 30-year extreme drought incidence under RCP 8.5 are presented in addition to the mean of all models.

	1971–2000	2040–2069		2070–2099	
	Historical	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Minimum model	4.4	6.0 (38%)	12.6 (188%)	10.6 (143%)	11.4 (161%)
Mean of models	3.6	15.0 (313%)	21.7 (496%)	19.5 (435%)	39.7 (992%)
Maximum model	4.5	19.8 (338%)	21.7 (380%)	40.1 (789%)	69.5 (1441%)

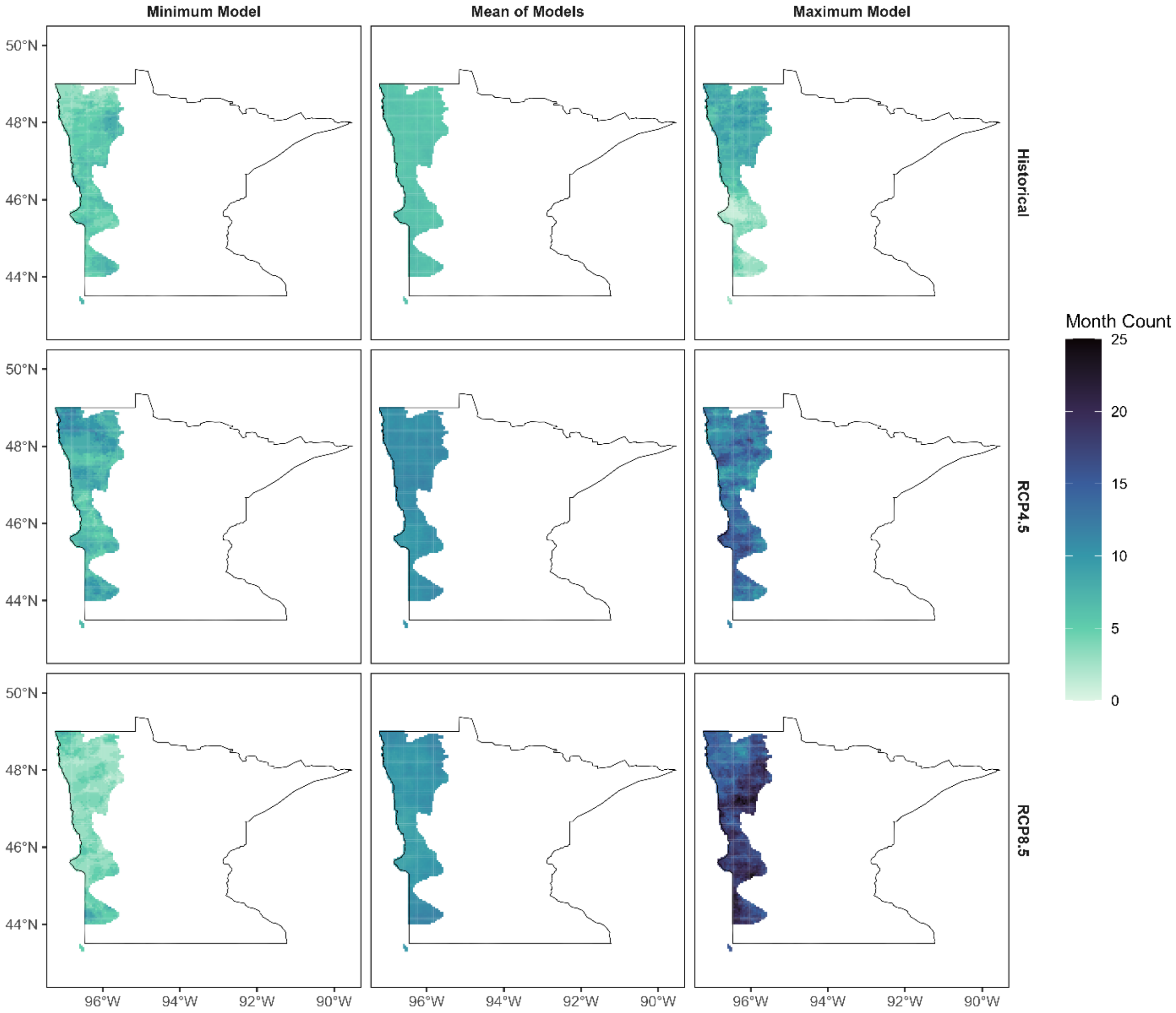

Figure 7. Projected changes in 30-year extreme wet month incidence in the Northern Plains. Projections use gridded Standardized Precipitation-Evapotranspiration Index (SPEI) values obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme wet incidence is defined as the number of months within a 30-year period with an SPEI value of ≥ 2, corresponding to the wettest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000, top row) and projected (2070–2099) 30-year extreme wet incidence (months) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected 30-year extreme wet incidence under RCP 8.5 are presented in addition to the mean of all models (middle column).

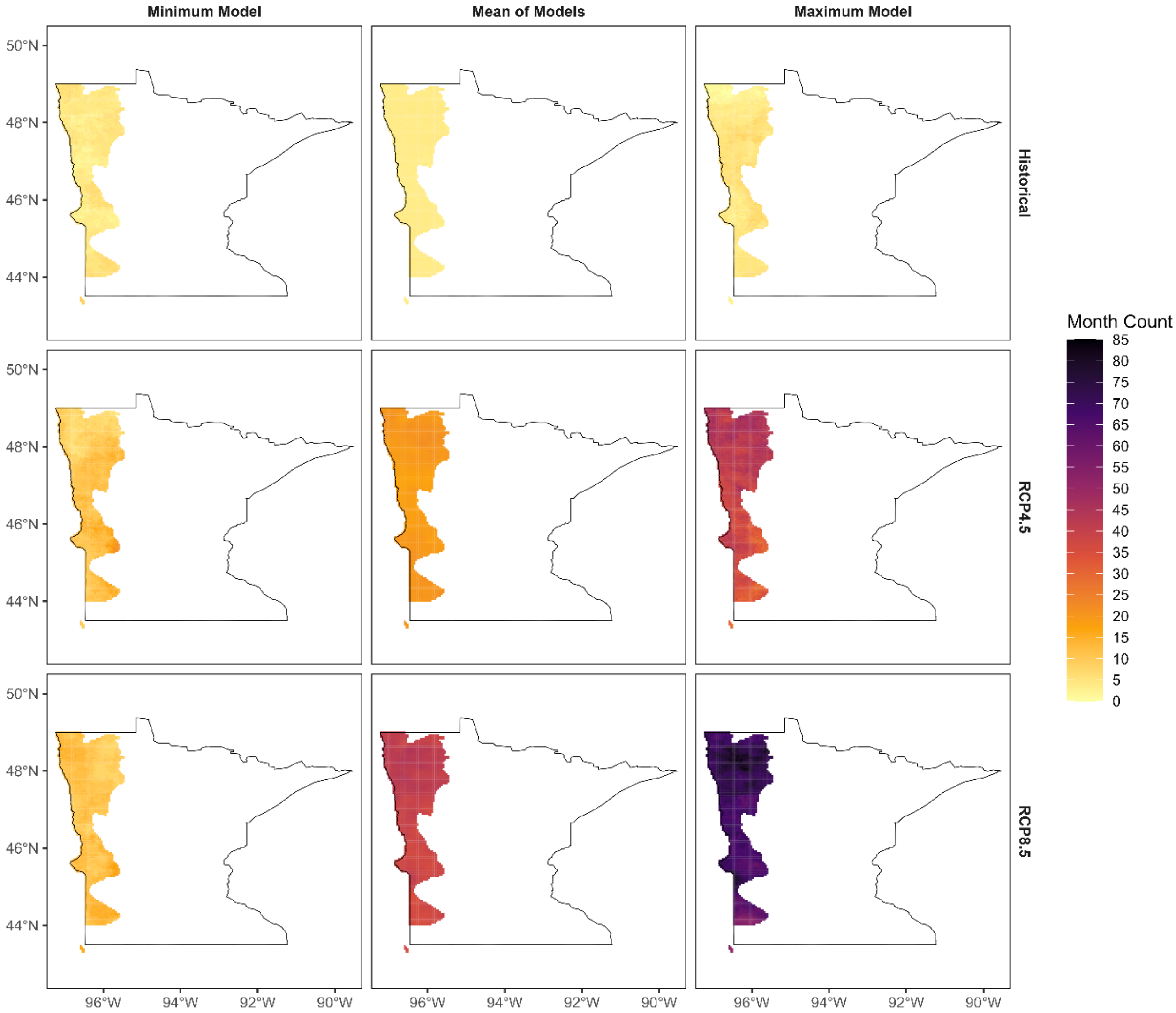

Figure 8. Projected changes in 30-year extreme drought incidence in the Northern Plains. Projections use gridded Standardized Precipitation-Evapotranspiration Index (SPEI) values obtained via Thota and others (2025) based on 20 CMIP5 climate models downscaled using MACAv2-METDATA for moderate- and high-emissions (RCP 4.5 and 8.5) scenarios (Abatzoglou, 2013; Abatzoglou and Brown, 2012). Thirty-year extreme drought incidence is defined as the number of months within a 30-year period with an SPEI value of ≤-2, corresponding to the driest 2.5% of months relative to a reference period (1981–2020) under RCP 4.5 (Li and others, 2015; McKee and others, 1993). Values show average historical (1971–2000, top row) and projected (2070–2099) 30-year extreme drought incidence (months) for each emissions scenario (RCP 4.5, middle row; RCP 8.5, bottom row). To capture variation across climate models, models with the lowest (minimum model, left column) and highest (maximum model, right column) projected 30-year extreme drought incidence under RCP 8.5 are presented in addition to the mean of all models (middle column).

Key Climate Change Impacts

This section summarizes how climate change is impacting the Midwest Wet Prairie, Wet Meadow and Shrub Swamp. It covers the specific effects of flooding and inundation and drought on key species (Table 12). The bullet points below provide a concise overview of these impacts on habitat structure, community composition, and invasive species.

Habitat structure:

- Flooding may increase nutrient and sediment inputs from adjacent agricultural and urban areas, promoting eutrophication, invasive species, and terrestrialization in shallow basins (Anteau and others, 2016; Helgen and Gernes, 2001; Jeppesen and others, 2009; Ma and others, 2025; Short and others, 2016; Staffen and others, 2019; Voldseth and others, 2007; Zedler and Kercher, 2004).
- Drought may cause seasonal or long-term habitat contraction by eliminating open water and drying soils (Hayashi and others, 2016; Liu and Schwartz, 2011; Vanderhoof and others, 2024; Zhang and others, 2021).
- Intensified cycling between inundation and drought may shift soils between aerobic and anaerobic states, slowing decomposition, denitrification, and plant nutrient uptake during saturation and accelerating decomposition, carbon dioxide release, and mineralization during dry periods (Batzer and Sharitz, 2014; Faber-Langendoen and Rocchio, 2005b; Galatowitsch, 2012; Ma and others, 2025; Pezeshki, 2001; Trettin and others, 2019).
- Alternating periods of flooding and drought may shorten hydroperiods in the eastern Prairie Pothole Region, initially accelerating vegetation turnover and eventually leading to a breakdown of typical successional patterns in all but the wettest, northern-most systems (Carter Johnson and others, 2016; Fay and others, 2016; Johnson and others, 2005; Vanderhoof and others, 2024; Werner and others, 2013; Xu and others, 2024).

Community composition:

- Climate change may increase the range of species like big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*) while decreasing populations of vulnerable or low-adaptive capacity species such as upright sedge (*Carex stricta*) and red-osier dogwood (*Cornus sericea*) (Inter-Tribal Council of Michigan, Inc, 2016; Mortsch and others, 2006; Rana et al. 2024; Smith et al. 2017).
- More frequent, prolonged, and severe flooding may destabilize plant communities by displacing dominant species, accelerating turnover, and compressing or eliminating vegetation zones, leading to more homogeneous assemblages as specialist species with narrow hydrological niches are lost (Table 12) (Batzer and Sharitz, 2014; Foti and others, 2012; Magee and Kentula, 2005; Markham, 2019; McLean and others, 2022; Ormshaw, 2014; Sun and others, 2022; Van Der Valk and Mushet, 2016; Werner and others, 2013; Wernerehl and Givnish, 2025; Zedler and Herrick, 2023).
- Flood-tolerant obligate species may expand or become more dominant under wetter conditions, while species less tolerant of inundation, including many forbs and sedges, decline (Table 12) (Brotherton and Joyce, 2015; Environment and Climate Change Canada and the U.S. Environmental Protection Agency, 2021; Faber-Langendoen and Rocchio, 2005b; Galatowitsch, 2012; Joyce and others, 2016; Magee and Kentula, 2005; Toogood and Joyce, 2009; van der Valk, 1981).
- Drought may facilitate rapid colonization and dominance by annuals and rhizomatous graminoids, potentially driving long-term shifts in community composition (Table 12) (Brotherton and Joyce, 2015; Didiano and others, 2018; Keddy and Reznicek, 1985; Mortsch and others, 2003; Poiani and others, 1995; Rose and others, 2023; Touchette and others, 2008; Touchette and Steudler, 2009; van der Valk, 1981).

- Lower water levels during drought may promote establishment and encroachment of shrubs and upland species, shifting composition toward drier-adapted communities (Hogenbirk and Wein, 1991; Keen and others, 2024; Rose and others, 2023).

Invasive species:

- Cycles between prolonged flooding and water deficits may weaken native competitors and favor invasive wetland species adapted to a broad range of hydrologic conditions, such as reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis* ssp. *australis*), and cattails (*Typha* spp.) (Table 12) (Bansal and others, 2019; Bunbury-Blanchette and others, 2015; Hall and Zedler, 2010; Lishawa and others, 2010; Magee and Kentula, 2005; Miller and Zedler, 2003; Mortsch and others, 2006; Zedler and Kercher, 2004).
- Elevated nutrient inputs from flooding and runoff may enhance the competitive advantage of nutrient-demanding species such as reed canarygrass (*Phalaris arundinacea*), European common reed (*Phragmites australis* ssp. *australis*), and cattails (*Typha* spp.), particularly in disturbed wet meadows (Bansal and others, 2019; Magee and Kentula, 2005; Zedler and Kercher, 2004).
- Warming trends may enable establishment of novel invasive taxa from southern or agricultural landscapes, potentially displacing some native species (Flanagan and others, 2015; Gillard and others, 2017; Tougas-Tellier and others, 2015; Wang and others, 2019).

Table 12. Summary of impacts from key climate stressors on Midwest Wet Prairie, Wet Meadow and Shrub Swamp species. Asterisks (*) denote species introduced to the region, while daggers (†) denote some species within the genus may be introduced to the region, though most are native. Some species appear in contradictory columns (e.g., showing both negative and positive drought impacts), reflecting conflicting findings in the literature.

Stressor	Impact	Affected species
Drought	When tolerance of water deficits is low, potential for reduced growth rates and abundance	*_Agrostis stolonifera_[1]
		Calamagrostis canadensis[1]
		Calamagrostis stricta[1]
		Carex aquatilis[1]
		Carex cristatella[1]
		Carex lacustris[1]
		Carex praegracilis[1]
		Carex rostrata[1]
		Carex scoparia[1]
		Carex stipata[1]
		Carex stricta[1,2,3]
		Carex tribuloides[1]
		Cephalanthus occidentalis[4]
		Cornus sericea[1]
		Lemna minor[1]
		Muhlenbergia richardsonis[1]
		*_Phalaris arundinacea_[1]

Stressor	Impact	Affected species
		**Phleum pratense*[1]
		*Phragmites australis ssp. *australis* [1]
		**Poa pratensis*[1]
		Salix bebbian[1]
		Salix discolor[1]
		Salix humilis[1]
		Spartina pectinata[1]
		Spiraea alba[1]
		Symphyotrichum lanceolatum[1]
		**Typha angustifolia*[1]
		Typha latifolia[1,5]
		†*Typha* spp.[1]
	When tolerance of water deficits is high, potential for competitive advantage and increased abundance	*Andropogon gerardii*[1,6,7]
		Calamagrostis canadensis[3,8]
		Carex lacustris[3]
		Carex pellita[5]
		Carex stricta[9]
		Cephalanthus occidentalis[1]
		**Cirsium arvense*[8]
		Cornus sericea[10]
		Gaylussacia baccata[1]
		Muhlenbergia richardsonis[11]
		Panicum virgatum[1]
		**Phalaris arundinacea*[3,9,12,13]
		**Phragmites australis* ssp. *australis* [14,15]
		**Poa compressa*[1]
		Rubus hispidus[1]
		†*Salix* spp.[2]
		Schizachyrium scoparium[1]
		Sorghastrum nutans[1]
		Spiraea tomentosa[1]
		**Typha angustifolia*[2,16]
		†*Typha* spp.[9,14,17]
Flooding/Inundation	When flooding/inundation tolerance is low, potential for reduced growth rates, mortality, or abundance	*Carex lacustris*[18–20]
		Carex stricta[18]
		**Phalaris arundinacea*[13,21,22]
		Salix discolor[23]

Stressor	Impact	Affected species
		Schizachyrium scoparium[24,25]
		Sorghastrum nutans[24]
		Spartina pectinata[19]
	When flooding/inundation tolerance is high, potential for competitive advantage and increased abundance	_Andropogon gerardii_[24,25]
		Calamagrostis canadensis[9,26]
		Carex pellita[5]
		Carex stipata[27]
		Carex stricta[3,9]
		Cephalanthus occidentalis[28]
		Cornus sericea[10,23]
		†_Cornus_ spp.[25]
		Lemna minor[26]
		*_Lythrum salicaria_[29]
		*_Phalaris arundinacea_[9,30,31]
		†_Salix_ spp.[25]
		Spartina pectinata[9,22,24,25,32]
		Typha latifolia[9]
		†_Typha_ spp.[33–35]

[1]USDA, NRCS (2025); [2]Lishawa and others (2010); [3]Wilcox and others (2022); [4]Connor (2004); [5]Sueltenfuss and others (2020); [6]Baty and others (2023); [7]Slette and others (2023); [8]Hogenbirk and Wein (1991); [9]Kercher and Zedler (2004); [10]Francis (2004); [11]Sedivec and Barker; [12]He and others (2011); [13]Rutherford and others (2022); [14]Anderson and others (2025); [15]Mortsch and others (2006); [16]Wilcox and Nichols (2008); [17]Tulbure and others (2007); [18]Budelsky and Galatowitsch (2004); [19]Chapman and others (2013); [20]Yetka and Galatowitsch (1999); [21]Charles and others (2023); [22]Miller and Zedler (2003); [23]Ormshaw and Duval (2020); [24]Wernerehl and Givnish (2025); [25]Zedler and Herrick (2023); [26]Reinartz and Kroeger (1982); [27]Hough-Snee and others (2015); [28]Donovan and others (1988); [29]Blossey and others (2001); [3023]Waggy (2010); [31]Zedler and Kercher (2010); [32]Bonilla-Warford and Zedler (2002); [33]Bunbury-Blanchette and others (2015); [34]Boers and Zedler; [35]Bansal and others (2019)

Focal Wildlife Species: Nelson's Sparrow

The Nelson's sparrow (*Ammospiza nelsoni*) breeds in wet meadows and marshes across northwestern Minnesota and into Canada (Shriver and others, 2020), where cordgrass (*Spartina* spp.), native reeds (*Phragmites* spp.), and sedges (*Carex* spp.) are common components of its breeding habitat (Shriver and others, 2020). In coastal breeding populations, tidal flooding is a major source of nest failure, with rates exceeding 30% (Shriver and others, 2007). Unlike the closely related saltmarsh sparrow (*Ammospiza caudacuta*), which has occupied and evolved in tidal systems over a longer period, Nelson's sparrow does not demonstrate nesting synchrony with lunar tides, potentially limiting its adaptive capacity to flooding events (Shriver and others, 2007). While hybridization with saltmarsh sparrows may increase fitness for some hybrids, it is unlikely to fully offset the impacts posed by flooding from climate change and sea-level rise (Maxwell and others, 2023). Notably, however, a subspecies (*Ammospiza nelson* ssp. *subvirgata*) shows behavioral plasticity in nest site selection, sometimes exhibiting higher nest success in human-created habitat (Owen and others, 2025).

For inland populations, climate-driven changes in the extent, hydrology, and phenology of wet meadows and marshes may significantly affect survival and reproduction (Anderson and others, 2023; Calero, Sara and others, 2015; Crawford, 1993; Johnson and others, 2010; Vanderhoof and others, 2024). Ongoing conversion of grassland to agriculture (Wright and Wimberly, 2013) further threatens both breeding and migratory stopover habitat in the Midwest. Conservation efforts focused on protecting and managing wetland-grassland complexes, such as those in the Prairie Pothole Region, are likely to be critical for supporting inland Nelson's sparrow populations under future climate scenarios (Shaffer and others, 2020).

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Appendix 1

Table ii. Woody plant species common to the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland. Key species were identified using USNVC floristic descriptions (USNVC, 2020), filtered by associations occurring within the Midwest that collectively comprise the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland ecosystem. Asterisks (*) denote species introduced to the region, while daggers (†) denote some species within the genus may be introduced to the region, though most are native. Taxonomic authority, common name, growth habit, and native status are determined according to the PLANTS Database (USDA, NRCS, 2025).

Species	Common name	Growth habit	Eastern North American Freshwater Marsh	Midwest Wet Prairie, Wet Meadow and Shrub Swamp
Aronia × prunifolia (Marshall) Rehder, (pro sp.) [*arbutifolia × melanocarpa*]	Purple chokeberry	Shrub		×
Cephalanthus occidentalis L.	Common buttonbush	Shrub, tree		×
Cornus sericea L.	Redosier dogwood	Shrub, tree		×
Gaylussacia baccata (Wangenh.) K. Koch	Black huckleberry	Shrub		×
Rubus hispidus L.	Bristly dewberry	Shrub		×
Salix bebbiana Sarg.	Bebb willow	Shrub, tree		×
Salix discolor Muhl.	Pussy willow	Shrub, tree		×
**Salix fragilis* L.	Crack willow	Tree		×
Salix humilis Marshall	Prairie willow	Shrub		×
Salix petiolaris Sm.	Meadow willow	Shrub, tree		×
†*Salix* L.	Willow	Shrub, tree		×
Spiraea alba Du Roi	White meadowsweet	Shrub		×
Spiraea tomentosa L.	Steeplebush	Shrub		×
Vaccinium angustifolium Aiton	Lowbush blueberry	Shrub		×

Table iii. Non-woody plant species common to the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland. Key species were identified using USNVC floristic descriptions (USNVC, 2020), filtered by associations occurring within the Midwest that collectively comprise the Eastern North American Temperate Freshwater Marsh, Wet Meadow and Shrubland ecosystem. Asterisks (*) denote species introduced to the region, while daggers (†) denote some species within the genus may be introduced to the region, though most are native. Taxonomic authority, common name, growth habit, and native status are determined according to the PLANTS Database (USDA, NRCS, 2025).

Species	Common name	Growth habit	Eastern North American Freshwater Marsh	Midwest Wet Prairie, Wet Meadow and Shrub Swamp
**Agrostis stolonifera*	Creeping bentgrass	Graminoid		×
Alisma subcordatum Raf.	American water plantain	Forb/herb	×	
Alisma triviale Pursh	Northern water plantain	Forb/herb	×	
Andropogon gerardii Vitman	Big bluestem	Graminoid		×
Arnoglossum plantagineum Raf.	Groovestem Indian plantain	Forb/herb		×
Bacopa rotundifolia (Michx.) Wettst.	Disk waterhyssop	Forb/herb	×	
Bartonia virginica (L.) Britton, Sterns & Poggenb.	Yellow screwstem	Forb/herb		×
Bolboschoenus fluviatilis (Torr.) Soják	River bulrush	Graminoid	×	
Boltonia asteroids (L.) L'Hér.	White doll's daisy	Forb/herb		×
Calamagrostis canadensis (Michx.) P. Beauv.	Bluejoint	Graminoid		×
Calamagrostis stricta (Timm) Koeler	Slimstem reedgrass	Graminoid		×
†*Carex* L.	Sedge	Graminoid		×
Carex aquatilis Wahlenb.	Water sedge	Graminoid		×
Carex bicknellii Britton	Bicknell's sedge	Graminoid		×
Carex buxbaumii Wahlenb.	Buxbaum's sedge	Graminoid		×
Carex cristatella Britton	Crested sedge	Graminoid		×
Carex lacustris Willd.	Hairy sedge	Graminoid		×
Carex molesta Mack. ex Bright	Troublesome sedge	Graminoid		×
Carex pellita Muhl. ex Willd.	Woolly sedge	Graminoid		×

Species	Common name	Growth habit	Eastern North American Freshwater Marsh	Midwest Wet Prairie, Wet Meadow and Shrub Swamp
Carex praegracilis W. Boott	Clustered field sedge	Graminoid		×
Carex rostrata Stokes	Beaked sedge	Graminoid		×
Carex sartwellii Dewey	Sartwell's sedge	Graminoid		×
Carex scoparia Schkuhr ex Willd.	Broom sedge	Graminoid		×
Carex sterilis Willd.	Dioecious sedge	Graminoid		×
Carex stipata Muhl. ex Willd.	Awlfruit sedge	Graminoid		×
Carex stricta Lam.	Upright sedge	Graminoid		×
Carex tribuloides Wahlenb.	Blunt broom sedge	Graminoid		×
Clinopodium arkansanum (Nutt.) House	Limestone calamint	Forb/herb		×
Deschampsia cespitosa (L.) P. Beauv.	Tufted hairgrass	Graminoid		×
Heteranthera limosa (Sw.) Willd.	Blue mudplantain	Forb/herb	×	
Juncus arcticus Willd. ssp. *Littoralis* (Engelm.) Hultén	Mountain rush	Graminoid		×
Leersia oryzoides (L.) Sw.	Rice cutgrass	Graminoid	×	
Lemna minor L.	Common duckweed	Forb/herb		×
**Lythrum salicaria* L.	Purple loosestrife	Forb/herb		×
Muhlenbergia richardsonis (Trin.) Rydb.	Mat muhly	Graminoid		×
Nuphar advena (L.) Sm.	Yellow pond-lily	Forb/herb		×
Oligoneuron ohioense (Frank ex Riddell) G.N. Jones	Ohio goldenrod	Forb/herb		×
Osmunda regalis L.	Royal fern	Forb/herb		×
Panicum virgatum L.	Switchgrass	Graminoid		×
Parthenium integrifolium Britton	Wild quinine	Forb/herb		×
Pedicularis canadensis L.	Canadian lousewort	Forb/herb		×
Plantago eriopoda Torr.	Redwool plantain	Forb/herb		×

Species	Common name	Growth habit	Eastern North American Freshwater Marsh	Midwest Wet Prairie, Wet Meadow and Shrub Swamp
**Poa compressa* L.	Canada bluegrass	Graminoid		×
Poa palustris L.	Fowl bluegrass	Graminoid		×
**Poa pratensis* L.	Kentucky bluegrass	Graminoid		×
Pontederia cordata L.	Pickerelweed	Forb/herb	×	
†*Sagittaria* L.	Arrowhead	Forb/herb		×
Sagittaria latifolia Willd.	Broadleaf arrowhead	Forb/herb	×	
Schizachyrium scoparium (Michx.) Nash	Little bluestem	Graminoid		×
Schoenoplectus acutus (Muhl. ex Bigelow) Á. Löve & D. Löve	Hardstem bulrush	Graminoid	×	
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	Softstem bulrush	Graminoid	×	
Sorghastrum nutans (L.) Nash	Indiangrass	Graminoid		×
Sparganium eurycarpum Engelm.	Broadfruit bur-reed	Forb/herb	×	
Spartina pectinata Bosc ex Link	Prairie cordgrass	Graminoid		×
Symphyotrichum lanceolatum (Willd.) G.L. Nesom	White panicle aster	Forb/herb		×
**Typha angustifolia* L.	Narrowleaf cattail	Forb/herb	×	×
Typha latifolia L.	Broadleaf cattail	Forb/herb	×	×
Typha × glauca (pro sp.) [*angustifolia or domingensis × latifolia*]	Hybrid cattail	Forb/herb	×	
Viola lanceolata L.	Bog white violet	Forb/herb		×
Zizania aquatica L.	Annual wildrice	Graminoid	×	
Zizania palustris L.	Northern wildrice	Graminoid	×	