2025 UPDATE

An Assessment of the Impacts of Climate Change on the Great Lakes

by Scientists and Experts from Universities and Institutions in the Great Lakes Region

ENVIRONMENTAL LAW & POLICY CENTER

In 2019, the Environmental Law & Policy Center published a special assessment by a team of 18 leading university and research scientists (Wuebbles et al. 2019) that examined the current and projected impacts of climate change on the Great Lakes and the region around the Great Lakes. The assessment encompassed the eight states in the United States and the province in Canada that surround the Great Lakes.

The 80-page assessment was coauthored by top research experts in the earth and natural sciences, engineering, the social sciences, and economics from the Great Lakes states, along with three experts from Canada. The scientists analyzed the peer-reviewed literature and assessed the state-of-the-knowledge regarding the effects of climate change on the Great Lakes region.

The 2019 scientific assessment continues to be a sound, valid examination of climate change impacts on the Great Lakes and region. This update includes new observations and lessons learned over the past six years. It is presented as more of a summary approach than a new comprehensive assessment.

More than 40 million people rely on Great Lakes for drinking water, fisheries, recreation, commerce, and industry, all of which are impacted by climate change. The lakes sustain more than 170 species of fish and habitats for over 3,500 species of plants and animals, many of which are rare or found nowhere else. People value this unique region for its ecological biodiversity, economic opportunity, and invaluable cultural importance.

The International Joint Commission's Water Quality Board binational poll in 2024 showed that more than 9 in 10 respondents (94%) believe it is important to protect the Great Lakes, increasing steadily over time since 2015 (85%). This same poll showed climate change is viewed as a source of increasing pressure on the Great Lakes, with respondents concerned about climate impacts on water quality and community well-being. Polling and focus group research conducted by public opinion expert researchers retained by the Environmental Law & Policy Center, Healing Our Waters, and others consistently show overwhelming support for protecting and restoring the Great Lakes. That strong support is from people from all walks of life in the Great Lakes region, is bipartisan, and is truly nonpartisan.

Continuing to update, assess, and understand climate change and its impacts is important to policymaking in order to better adapt and advance more resiliency. We should not and cannot take the Great Lakes for granted. Let's recognize the importance of this global gem, one of the world's most abundant freshwater resources, and work to effectively ensure its protection for generations to come.

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Climate Change in the Great Lakes Region

The ongoing changes occurring around the world are continuing to affect both the climate of the Great Lakes region and the physical behavior of the Great Lakes themselves. These changes include warmer air temperatures, fewer cold nights, increased precipitation, and more extreme weather events. Projections since the 2019 assessment remain unchanged: we anticipate more extremely warm days (>90°F), more erratic and extreme precipitation events, and reduced snowfall and lake ice cover.

Observed

THE GREAT LAKES STATES ARE CONTINUING TO WARM

The Great Lakes and their surrounding states, like the rest of the United States and almost all of the world, have extensively warmed over the last century. Mean annual temperature during 2017-2024 was 1.1°F warmer than during 1986-2016 and 2.5°F warmer than during the baseline period of 1901-1960 for the Great Lakes states of Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York. Since 1951, annual average air temperatures have increased by 2.9°F (1.6°C) in the U.S. Great Lakes region (GLISA 2025).

FEWER COLD NIGHTS

The number of cold nights continues to decline. The number of nights with minimum temperature below freezing during 2017-2024 was 0.7 days per year less than during 1986-2016 and 5.5 days per year less than during the baseline period of 1901-1960.

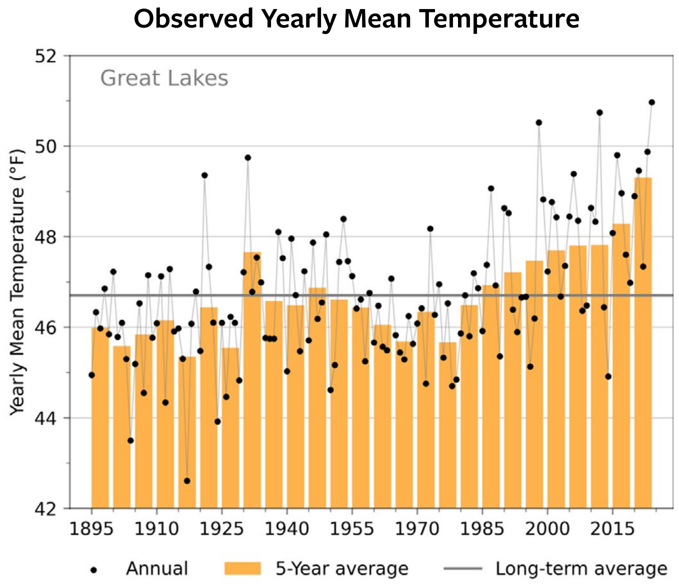

Figure 1. Time series of mean annual temperature for the Great Lakes states of MN, WI, IL, IN, MI, OH, PA, and NY.

MORE EXTREME PRECIPITATION

The frequency of extreme precipitation events continued to increase. The number of days with at least 2 inches of precipitation during 2017-2024 was 6% higher than during 1986-2016 and 37% higher than during the baseline period of 1901-1960. Since 1951, annual total precipitation has increased by 15% in the U.S. Great Lakes region.

SUMMER TEMPERATURE VARIATION

The absence of a long-term trend in extreme high summer temperatures continues in the Great Lakes region. For example, the number of nights during 2017-2024 with a minimum temperature of higher than 70°F was about equal to the long-term average of 4.9 days per year.

URBAN AREAS UP TO 10°F WARMER

The changing climate in the Great Lakes region, along with increasing urbanization, is resulting in temperature differences of up to 10°F in urban areas. When combined with population distribution and uneven tree canopy coverage, this contributes to higher heat stress levels in urban areas throughout the region. (https://databank.illinois.edu/datasets/IDB-0652675)

Projected

2019 ASSESSMENT PROJECTIONS UNCHANGED

The projections of climate change for the Great Lakes region are essentially unchanged since the 2019 assessment. Much more warming is projected over the rest of this century: as much as 10°F if we continue to follow the high pathway of heavily using fossil fuels, but more like 5.7°F if we follow a reasonably lower emissions pathway. The 2019 assessment indicated an increase of 3.3, 5.5, and 9.8°F (1.8, 3.1, and 5.4°C) for the 2030, 2050, and 2085 time periods for the higher scenario, and 3.0, 4.4, and 5.7°F (1.7, 2.4, and 3.2°C) for 2030, 2050, and 2085 time periods for lower scenario.

The more recent modeling study by Xue et al. (2022) with better representation of the Great Lakes gives somewhat different findings. For the high scenario, the Great Lakes basin is projected to warm by 2.3-3.8°F (1.3–2.1°C) by the mid-21st century and 7.4-9°F (4.1–5.0°C) by the end of the century relative to the early century (2000–2019). The lower emissions scenario reduces the mid-century warming to 1.4-3.2°F (0.8–1.8°C) and late-century warming to 3.2-4.9°F (1.8–2.7°C).

EXTREME HEAT AND COLD

Extremely warm days with maximum temperature >90°F are likely to increase significantly over this century, especially under the high scenario (60 more days in Great Lakes states for high scenario versus 30 more days for lower), while extremely cold days <32°F are likely to decrease significantly (45-55 fewer days by 2070-2100 under the high scenario, and 25-35 fewer days under the low scenario).

ERRATIC & EXTREME PRECIPITATION

Future projections suggest total precipitation changes ranging from -0.3 to +4.2 inches compared to the late 20th century. Seasonal variability will change, becoming more erratic during the summer, thereby increasing contrasts between wet and dry conditions.

REDUCED SNOWFALL & LAKE ICE COVER

Despite the increase in rain, total amount of snowfall in the Great Lakes states is likely to decrease overall, especially under the high emissions scenario (30-60% by 2070-2100). Reduced lake ice cover and enhanced evaporation may lead to increased lake-effect snowfall in the near-term, but rising temperatures will cause more winter precipitation to transition from snow to rain across the region by the late century.

DRIER LAND SURFACES

Despite increasing precipitation, land surfaces in the Great Lakes region may become drier due to increasing temperatures and evaporation rates.

SUMMER DROUGHT

More frequent summer droughts could affect soil moisture, surface waters, and groundwater supply, and the seasonal distribution of the water cycle will likely shift.

HOTTER URBAN AREAS

Over urban areas, like the Chicago metro region in the Great Lakes, cumulative hot hours (>95°F) during summertime are projected to increase from 30 hours as of 2018-2024 to more than 200 hours in the mid-2030s under a high emission scenario (RCP85). This increase in hot hours translates to ~420 additional annual cooling degree days (CDD) in the 2030s, 50% more than in the 2020s. This increase in hot hours will not only translate to higher loads on our energy systems and residents but also be dangerous to vulnerable populations and workers working outside. (https://databank.illinois.edu/datasets/IDB-0652675)

Changes in the Great Lakes

Human activities have significantly affected the Great Lakes over the past two centuries. Climate change is now adding more challenges and another layer of stress. Climate change is altering the exchange of heat between the atmosphere and the Great Lakes. Temperatures in the lakes continue to increase, especially in deeper waters. Ice cover continues to decrease. Great Lakes water levels will likely show greater variability and dispersion from the long-term average, with likely higher lake levels over time and related impacts on coastal communities and infrastructure.

Observed

HIGHER LAKE TEMPERATURES

Summer lake surface temperatures have increased in recent decades. Lake Superior summer temperatures increased by 4.8°F (2.7°C) from 1979 to 2023, the most of any of the Great Lakes. NOAA observations show that Lakes Michigan, Huron, Erie, and Ontario all experienced record-high average surface temperatures in 2024. This record warmth is partially due to the warm fall seasons the Great Lakes region has been experiencing, but also due to the notably warm 2023-2024 winter. It is important to keep in mind that water temperatures vary from day to day. Although four of the lakes have record-warm year-to-date average temperatures, more than half of the days this fall have not broken their records for daily lake temperatures. In other words, waters haven't been record-warm every single day.

WARMING DEEP LAKE WATER

The greatest rates of temperature increase continue to be in deeper waters, with smaller increases near shorelines. New analyses of the deep waters of Lake Michigan show not only that the deep waters are warming, but that the effects of winter in deep waters are vanishing, and that the timing and duration of fall overturn and winter cooling are changing with implications for the lake's ecosystem (Anderson et al., 2021).

INCREASING LAKE HEATWAVES

The mean spatial extent of heatwaves in the Great Lakes has increased since 1995 by up to two-fold in the most recent decade (Woolway et al., 2021). This increase is driven primarily by an increase in the duration of lake heatwaves, allowing them to grow to unprecedented levels. Lake heatwaves are generally expanding globally.

DECREASING LAKE ICE COVER

Since the 1990s, less annual average ice cover has been observed on the Great Lakes. However, with strong year-to-year variability, years with high ice coverage are still possible. 2024 had an annual maximum ice cover in the Great Lakes of ~16% and average winter ice cover of 4.3%. Within the 52-year period of ice observations from 1973-2024, 2024 ranks as the winter with the lowest average ice cover on record.

DECLINING MAXIMUM ICE COVER

Great Lakes' annual maximum ice cover (AMIC) has decreased, particularly after the winter of 1997/98, with increased interannual variability since 1993 (Lin et al. 2022). AMIC is influenced by changing teleconnections, being more influenced by the North Atlantic Oscillation, and the Pacific–North American pattern before the winter of 1997/98 El Niño-Southern Oscillation and then becoming more influenced by the Tropical-Northern Hemisphere pattern and Eastern Pacific Oscillation after that time.

INVASIVE MUSSELS CHANGING WATER QUALITY

Analyses of the drivers of water quality changes within the Laurentian Great Lakes region over the past 40 years show that the presence of invasive dreissenid mussels contributed to changes in water quality (Mahdiyan et al., 2021). The analysis shows that precipitation, air temperature, and morphology explained 73.1% of the variation in water quality trends for the Great Lakes, and explained 45.6% of the variation for smaller inland lakes.

Projected

VARIABLE LAKE LEVELS GENERALLY INCREASING

Great Lakes water levels will likely exhibit greater variability and dispersion from the long-term average. This is a result of increased frequency of extreme water levels at both high and low ends and more tendency for higher lake levels. That potentially affects coastal communities and infrastructure (VanDeWeghe et al., 2022). One modeling study (Kayashi et al., 2022) projects that future Great Lakes water levels under climate change could generally increase by mid-century (2040-2049), with Lake Superior rising by 7.48 inches (0.19 meters), Lake Michigan-Huron by 17.32 (0.44 meters), and Lake Erie by 11.02 (0.28 meters), compared to 2010-2019 level.

MODELING IMPROVING

Major advancements in modeling the effects of climate change on the Great Lakes incorporate two-way lake atmosphere interactions and high-spatial resolution modeling (e.g., Briley et al 2021; Xue et al. 2022, 2025; Seglenieks and Temgoua, 2022). These new capabilities should provide important insights into future effects on the Great Lakes over the next few years.

Changes in Great Lakes Watershed Hydrology

Changes in climate and land use continue to affect watersheds in the Great Lakes region. Warmer and wetter conditions are generally expected, but increasing evaporative demand coupled with potential decreases in summer precipitation will likely lead to increased irrigation demand during the growing season. More precipitation, especially in winter and spring, will increase the need for urban stormwater management. Both agriculture and urban land use will continue to affect water quality in the future.

Observed

FLOW PATTERNS SHIFTING

U.S. Geological Survey analyses of stream gauge observations in the Great Lakes basin showed statistically significant trends between 1960 and 2015 (Norton et al., 2019). Downward trends in annual streamflow were concentrated in northern Wisconsin and the Upper Peninsula of Michigan, an area that has experienced a decrease in annual precipitation over the same period. Upward trends were found in almost all other locations, especially in areas east of Lake Michigan.

AGRICULTURAL PRODUCTION IS MIGRATING NORTH

Warmer conditions and increased precipitation have led to a migration of agricultural production, specifically corn and soybeans, further north into the Great Lake Basin (Hoffman et al., 2020).

WETTER SPRINGS DELAY PLANTING

Changes in seasonal precipitation are affecting farmers, resulting in planting delays caused by spring flooding and excessively wet soil conditions.

Projected

PRECIPITATION EXACERBATES FLOODING

Projected increases in extreme precipitation will likely exacerbate flooding most of the year.

MORE EVAPORATION

Higher summer and fall air temperatures will increase evaporation during the growing season.

INFRASTRUCTURE & FLOOD DAMAGE

Projected increases in droughts, severe storms, and flooding events can amplify the risk of erosion, sewage overflow, interference with transportation, and flood damage.

WATER MANAGEMENT NEEDED

Inter-seasonal water management will become increasingly important as winter and spring excess will be followed by summer and autumn deficits. Better short-term water management has the potential to mitigate spring flooding and wet conditions. Maximizing storage or groundwater recharge could also help to make some of that excess water available during the growing season (Cherkauer et al., 2021).

LOWER RIVER FLOWS

Coupled with summer precipitation that is increasingly variable and likely lower, summer river flows will likely be lower by the end of the century.

AQUATIC & WETLAND PLANT DIVERSITY

Changes in flow regimes, including the timing and duration of high and low flows, can potentially impact aquatic and wetland plant diversity in the basin. Culturally important species such as Manoomin (wild rice) may be damaged by increased frequency and magnitude of water fluctuations, as well as by changes to ice cover.

LAND USE CONCERNS

Future changes in land use can potentially impact water quality. Warming air temperatures and longer growing seasons are expected to lead to continued expansion of agriculture, specifically corn and soybean production, northwards (Hoffman et al., 2020), with the potential for more intensive practices, such as those contributing to hypoxia in western Lake Erie, to take up more land area within the Great Lakes basin.

HARMFUL ALGAL BLOOMS

The increasing seasonality of precipitation is likely to lead to higher spring discharge into the lakes. This is likely to lead to more fertilizer wash-off, as the potential for surface runoff increases during planting. Coupled with increased warming, this will increase the risk of harmful algal blooms within in-land waterbodies, affecting aquatic species and human health.

DATA CENTERS INCREASE WATER CONSUMPTION

As of May 2025, there are 855 data centers in operation in the states bordering the Great Lakes (https://www.datacentermap.com/usa/), out of a total of 3,725 in the United States. Illinois and Ohio are 4th and 5th on the list of states with the most data centers after Virginia, Texas, and California. Data centers consume up to 5 million gallons a day of water primarily for cooling (Olson et al., 2024). In many cases the data centers are sited along major rivers or large bodies of water, but there are also instances of centers drawing groundwater for cooling, which is then returned to local surface waters, substantially changing the local flow regimes. Given the general availability of water resources in the Great Lakes region, more data center developers are looking to site in this region.

Impacts on Ecology of the Great Lakes Region

The ecology of the Great Lakes region is affected by climate change. Species ranges are shifting northward, along with various other effects on ecosystems. Harmful algal blooms are occurring throughout the basin. Increases in storm frequency, intensity, and duration have demonstrated impacts on both terrestrial and aquatic habitats. A variety of tick species are undergoing range expansion and population increases throughout the Midwest. As the climate continues to change, the many impacts will likely increase. In addition, rising summer stream and river temperatures are likely to significantly affect fish populations. The distribution and composition of tree species will likely change and shift northward. Changes in seasonal precipitation are affecting farmers, resulting in planting delays caused by spring flooding and excessively wet soil conditions.

Fish and Other Aquatic Life

Many of the impacts observed on fish and wildlife are the result of multiple stressors, resulting from interactions of climate-driven processes (wind, temperature, precipitation, storms) and other direct and indirect drivers such as land use change, habitat loss and degradation, and influences of invasive species.

Observed

HABITAT SHIFTS

In response to climate change, many species are adjusting ranges northward or moving towards higher altitudes (Yu et al., in press). Based on a review of 400 species, ectotherms (cold-blooded species) appear to exhibit stronger range shift responses than endotherms (Ramalho et al., 2023).

INLAND LAKE FISH

A study by Renik et al. (2020) suggests that 29% and 33% of previously existing populations of Cisco (*Coregonus artedi Lesueur*) and Lake Whitefish (*Coregonus clupeaformis*), respectively, have been extirpated from Wisconsin inland lakes. Previous studies of these species have attributed the loss of suitable oxythermal habitat due to climate change as a major driver of extirpation (Lyons et al., 2017), and these changes in inland lakes are likely to negatively affect multiple coldwater fish species across the Great Lakes region (Jacobson et al., 2019).

GREAT LAKES WHITEFISH

Updated stock assessment models of lake whitefish in Lake Michigan are predicting that the species may disappear from some locations within the next five years, and that even if commercial fishing ceases entirely, the species may be headed towards extirpation (Katz, 2025). Warming winters have resulted in reduced ice cover, which is essential for protecting whitefish eggs (Lynch et al., 2015), and this is believed to be a contributing factor in their declines. However, a major driver of whitefish decline is also believed to result from the fact that larval whitefish are struggling to reach adulthood due to invasive quagga and zebra mussels, which reduce the number of available zooplankton, a major food source for the species (Cunningham et al., 2023; Katz, 2025).

Projected

TROUT AT RISK

Increasing summer stream and river temperatures in Wisconsin are predicted to reduce suitable habitat for brook trout (*Salvelinus fontinalis*) and brown trout (Salmo trutta) by 68% and 32%, respectively, by the mid-twenty-first century (Mitro et al., 2019). Declines in trout habitat across the Great Lakes basin are likely as air temperatures increase, although areas in the north with cooler air temperatures and streams with higher groundwater inputs are expected to be more resilient to increasing water temperatures (Stewart et al., 2015; Stewart et al., 2016).

INVASIVE LAMPREY MAY BENEFIT

Longer growing seasons, faster growth, and increased spawning habitat availability may benefit sea lamprey in changing climate, but there are uncertainties on the availability and suitability of larval habitat (Lennox et al., 2019). Future work to model what rivers may become hospitable to sea lamprey is needed, particularly if barriers within a river are removed.

PRECIPITATION, AIR, & HEAT IMPACTS

Aquatic secondary production (production of new heterotrophic biomass) was observed to decrease with increased precipitation in low-stream flow environments; modeling showed a relationship between increased secondary production and increasing air and water temperatures (Patrick, et al., 2019).

Aquatic Habitat

Observed

HARMFUL ALGAL BLOOMS

The formation, extent, and severity of harmful algal blooms (HABs) and hypoxic dead zones are enhanced by increases in precipitation, warmer lake temperatures, and earlier lake stagnation. Warmer surface water temperatures and earlier spring warm-up cause lake stratification to occur earlier and last longer which allow for HABs and hypoxic conditions to persist longer due to the lack of mixing. Increases in annual rainfall and extreme rain events generate more runoff from surrounding land and sewer overflow, increasing nutrient loading in the lakes.

AMPHIBIANS AFFECTED TOO

Harmful algal blooms (HABs) are occurring throughout the basin and have recently been observed in oligotrophic waters of Lake Superior (Bosse et al., 2024, Sterner et al., 2020). Carmichael and Boyer (2016) documented impacts on aquatic life (e.g. fish) as well as pets and livestock in the Great Lakes region. Impact to fish and birds have been widely reported and reviewed in the literature (Malbrouck & Kestemont, 2006; Rattner et al., 2022); however, fewer studies assessed impacts on amphibians, whose impacts may stem from a wide variety of drivers including direct toxicity (reviewed by Tornabene et al., 2024), habitat degradation (e.g., oxygen depletion), food source contamination or disruption, behavioral changes, and reproductive failures. The majority of these impacts are observed from toxicological studies because amphibian mortality is difficult to observe in the field as a result of rapid decomposition rates.

STORMS AFFECT AQUATIC HABITATS

Storm frequency, intensity, and duration have increased (see discussion above) and have demonstrated impacts on both terrestrial and aquatic habitats. Impacts on streamflow and watershed dynamics are discussed elsewhere in this report. Impacts of storms on lakes result in physical changes to the light, nutrient, and temperature conditions within lakes. Subsequent changes to the aquatic biota at all levels of the food chain persist for very short to very long time frames (Stockwell et al., 2020). Lake type and setting, as well as the dominant characteristics of the storm (e.g., wind direction and speed, amount of precipitation, antecedent conditions), are highly influential in determining these impacts. Phytoplankton biomass decreased consistently across all storm types; diversity consistently increased (Stockwell et al., 2020).

Wildlife

Observed

CHANGING HOW SPECIES LOOK & ACT

Both aquatic and terrestrial species are responding to climate change; direct physiological changes include changes in morphology and behavior, phenological changes, and range shifts (Weiskopf et al. 2020).

SNOWSHOE HARE

The southern range of snowshoe hare (*Lepus americanus*) is contracting northward as a result of land use and climate change (Wilson et al., 2020). Snowshoe hare, which commonly have a brown coat in summer and a white coat in winter, are experiencing increased predation due to camouflage mismatch caused by decreased snowpack in changing climate (Wilson et al., 2019; Zimova et al., 2016).

WHITE-TAILED DEER & MOOSE

A literature review by Weiskopf et al. (2019) on the effects of climate change on white-tailed deer (*Odocoileus virginianus*) and moose (*Alces alces*) in the Midwest reported that warmer air temperatures and reduced snowpack will favor white-tail deer survival, while warming may physiologically stress moose. Larger deer populations will also contribute to stress on moose populations due to increased transmission of diseases, such as meningeal worms, that are particularly harmful to moose (Lankester, 2010). Combined with parasites, winter ticks pose a significant risk factor for moose survival due to impacts on females and unborn calves (Debow et al., 2021). Overall, projections suggest that deer populations will increase in a changing climate, whereas moose populations will decrease (Weiskopf et al., 2019).

ARMADILLO IN ILLINOIS

In recent years, the estimated distribution of the nine-banded armadillo (*Dasypus novemcinctus*) has expanded into central Illinois (Haywood et al., 2021; Larreur et al., 2025). Their northern extent is perhaps limited by lack of precipitation and colder temperatures (Taulman and Robins, 2014; Feijó et al., 2020) but there is potential for expansion into the Great Lakes basin in the future (Feng and Papeş, 2015). Nine-banded armadillos may be vectors for diseases, such as *Trypanosoma cruzi* and *Mycobacterium leprae*. However, further research is needed to understand disease and transmission rates at their northern extent (Larreur et al. 2025).

WHITE PELICAN IN OHIO

For the first time, white pelican (*Pelecanus erythrorhynchos*) nesting sites were documented in Ohio in 2023 (Buckingham et al., 2024). This observation follows documented nesting sites in the Canadian waters of western Lake Erie and in Michigan (Weseloh et al., 2019), which suggest an expansion of their breeding range to the lower Great Lakes.

TICK TERRITORIES EXPAND

A variety of tick species are undergoing range expansion and population increases in the Midwest. This presents an increased risk of disease transmission for humans and wildlife (Alkishe et al., 2021; Madison-Antenucci et al., 2020). In 2025, Michigan officials discovered Asian longhorned tick (*Haemaphysalis longicornis*), which can spread disease among wildlife, domestic cattle, and pets. This invasive species reached the United States in 2017 and has since spread to 21 states, including Indiana and Ohio.

The northward expansion of black legged ticks (*Ixodes scapularis*), a primary vector of Lyme disease, has been associated with warming temperatures (Clow et al., 2017). Similarly, the range of the lone star tick (*Amblyomma americanum*) has expanded further into the Midwest, although it is debated whether this is a result of climate change or if it is a recolonization of the species' historic range (Lado et al., 2020; Raghaven et al., 2019; Rochlin et al., 2022). The lone star tick range expansion presents increased risks of several diseases, such as the Bourbon and Heartland viruses, as well as alpha-gal syndrome, a potentially life-threatening allergy to a carbohydrate found in red meat (Higuita et al., 2021).

Projected

AMPHIBIANS & REPTILES

For amphibians and reptiles, changes in temperatures, snowpack, and precipitation have complex implications for species distributions, growth rates, fecundity, and survivability (King and Niiro, 2013; Li et al., 2013). For instance, eastern massasauga rattlesnakes are expected to have faster growth, smaller sizes, and reduced lifetime reproductive success of females (Helferich et al., 2025). Amphibians and reptiles function as major predators and link aquatic and terrestrial systems. Therefore, impacts to their communities in changing climate will impact other species at all trophic levels (Brown and Ribic, 2022). Combined effects of climate and land use change result in reduced suitable habitat for many amphibian species (Struecker and Milanovich, 2017). (See also discussion above about the impacts of harmful algal blooms on amphibians).

INVASIVE SPECIES

Rising temperatures provide more favorable conditions for new and invasive species to proliferate in the region, which increases resource competition with native species.

COLD-WATER FISH

Rising lake temperatures diminish certain cold-water fish species, causing their habitat ranges to shift northward.

EROSION

Declining ice coverage leaves shorelines, ecosystems, and spawning areas increasingly exposed to erosion.

Forests

Observed

OLDER TREE GROWTH VARIATION

A new study of tree ring data from over 9,000 trees in Northern Wisconsin found 16 of the 20 studied species' growth rates (basal area increments) continue to increase, challenging the longtime assumption that tree growth slows down as trees grow older. Increases in biomass and carbon are far more dramatic in bigger trees, reflecting the allometry of tree growth. The mix of tree species that continue to grow in the Great Lakes region may change in the future as climate change impacts accelerate, but many temperate tree species across northeastern North America have shown marked increases in growth over the past 50 years. This perhaps is a result of increases in atmospheric carbon dioxide, nitrogen deposition, and longer growing seasons. These results could have important implications for managing forests. Delaying harvests to allow vigorous growth sequesters higher levels of carbon. Uncut forests act as carbon sinks for atmospheric carbon dioxide and thus play a key role in modulating greenhouse warming and climate change. Logged forests, in contrast, release large quantities of greenhouse gases which take decades to recoup.

Projected

TREE SPECIES SHIFT

As temperatures rise, the distribution and composition of tree species will change and shift northward.

URBAN TREES

Urban forest stressors, such as exposure to pests and diseases, more frequent heatwaves and drought, increased atmospheric pollution, urban heat island effects, salt damage, and variable water supplies, will be amplified by shifting trends.

WILDFIRES

Smoke from continental and regional wildfires can lead to poor air quality. Local wildfire risk during flash droughts is likely to increase, especially in grasslands.

Public and Economic Impacts of Changes to the Great Lakes

The well-being of the 40 million people living in the bi-national Great Lakes watershed is being affected by the changing climate, including the effects on the Great Lakes. Economic impacts in the region cross all societal sectors.

From 2017 to 2024, the United States had a 4.65% population increase (U.S. Census, https://www.census.gov/topics/population.html) and 4.31% urban land sprawl (through 2023, NLCD, https://www.mrlc.gov/data/type/urban-imperviousness). Among the Great Lakes region, Illinois was the only state with a population decline (-0.54%), while Minnesota (4.08%) and Indiana (4.00%) had the highest growth. Urban sprawl varied, with New York expanding the least (1.34%) and Indiana (3.56%) and Wisconsin (3.45%) seeing significant increases. Overall, most Great Lakes states experienced moderate population growth and urban expansion.

Public & Economic Impacts

Observed

INDIGENOUS PEOPLE AFFECTED BY CLIMATE CHANGE

The Anishinaabeg (Ojibwe, Ottawa, and Potawatomi) and the Indigenous peoples reside in the Great Lakes basin. Though they may be affected by climate change in ways that are similar to others in the United States, Indigenous peoples are affected uniquely and disproportionately as they express their ancestral relationship to the land through subsistence practices (GLIFWIC Climate Change Team, 2023; USGCRP, 2023).

These practices today are upheld by federally guaranteed treaty rights and Tribal sovereignty (GLIFWIC Climate Change Team, 2023). Climate impacts to lands, waters, foods, and other plant and animal species threaten cultural heritage sites and practices that sustain intra- and intergenerational relationships built on sharing knowledge systems, food, and ceremonial or cultural objects. Despite these impacts, Anishinaabeg and Indigenous peoples more broadly are working to respond to climate issues with solutions that involve traditional knowledge systems (Status of Tribes and Climate Change Working Group, 2025).

LAKE ICE REDUCTIONS AFFECT LOCAL BUSINESSES

Great Lakes communities have strong economic ties to ice cover on the lakes, and changes can have big impacts. Many fishing and outdoor sports businesses in the Great Lakes region rely on thick and solid ice.. Some fish species also use the ice for protection from predators during spawning season, and there is increasing evidence that the ice plays a role in regulating many biological processes in the water throughout the winter. Commercial shipping schedules are heavily impacted by ice formation as well.

PUBLIC HEALTH CONCERNS

Heat waves and increased humidity amplify the risks of heat-related deaths and illnesses, and respiratory diseases. More storm activity and flooding increase the risk of water-source contamination and waterborne illnesses. Vector-borne diseases are also expected to increase due to more favorable conditions for insects that carry disease (e.g., shifts in the range of mosquitos and ticks, etc.; Susong et al. 2022).

Projected

INDUSTRIAL WATER NEEDS

Reduced summer water availability due to drought and drier conditions may interfere with some industrial operations (e.g., hydropower, fossil fuel energy generating, and nuclear power plant cooling).

TRANSPORTATION IMPACTS

More extreme heat events may increase the risk of damage to roadways, airports, and railroads. More extreme precipitation may compromise transportation routes and damage infrastructure. On the other hand, reduced ice cover and shorter ice seasons may allow some shipping lanes to open earlier and longer. Low lake levels can affect navigation channels and reduce the maximum loads carried by vessels, which amounts to substantial monetary losses.

HIGHER ELECTRICITY BILLS

Warmer temperatures and more frequent heat waves will likely increase electricity use demand, particularly in urban areas during summer months.

TOURISM INDUSTRY

Reduced ice and snow cover and shorter winters will impact seasonal tourism and recreational activity. Increased lake contamination from algal blooms may degrade shoreline water quality and coastal ecosystem health. A longer summer season may increase demand for beaches. Summer tourism may grow in the near term, before the temperature and humidity increases become unfavorable for many recreational activities.

FISHING

Many cold- and cool-water species of fish important to recreation (e.g., whitefish, trout, walleye) may decline, while populations of warm-water species are likely to grow (Feiner, 2021).

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