WISCONSIN'S CHANGING CLIMATE

Impacts and solutions for a warmer climate

2021 Assessment Report

The second report of the Wisconsin Initiative on Climate Change Impacts

WICCI
WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

WISCONSIN'S CHANGING CLIMATE

Impacts and solutions for a warmer climate

Wisconsin's changing climate: Impacts and solutions for a warmer climate was produced by the Wisconsin Initiative on Climate Change Impacts (WICCI), a project of the Nelson Institute for Environmental Studies at the University of Wisconsin-Madison and the Wisconsin Department of Natural Resources (WDNR).

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This report is dedicated in memory of Sharon Dunwoody, Evjue-Bascom Professor Emerita of the School of Journalism and Mass Communication. Sharon was a kind leader and scholar who was a longtime faculty affiliate of the Nelson Institute for Environmental Studies, served as Academic Programs Chairperson, and served as co-chair of the WICCI Science Advisory Board for many years. As a leader in science communication research, she championed a new digital format for the WICCI report that would elevate the research with powerful storytelling through photography and interviews.

Our Team

The Wisconsin Initiative on Climate Change Impacts (WICCI) comprises a science council composed of a diverse group of scientists from a range of disciplines that oversees fourteen working groups, which are in turn made up of experts from a variety of fields. WICCI also includes a Working Group Council and Coordination Team. **Contact us**

Cover photo credit: Finn Ryan

WISCONSIN DEPT. OF NATURAL RESOURCES

Nelson Institute for Environmental Studies
UNIVERSITY OF WISCONSIN-MADISON

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ACKNOWLEDGEMENTS

We are grateful for the commitment, time, and collaboration of all the WICCI participants, including the fourteen working groups, Science Advisory Board, and Working Groups Council. Without their dedication this report could not have been written. Their work will help Wisconsin face climate challenges in the years to come. We are also grateful to everyone who participated in interviews for this report. By sharing their stories and expertise, we were better able to illustrate the impacts of climate change in Wisconsin.

We acknowledge the work of WICCI Science Writer Dea Larsen Converse and WICCI Coordinator Shruti Sarode, who coordinated and organized the publication of this report. We also acknowledge WICCI Climate Intern Alli Wenman for helping us begin to strategically address environmental and climate justice concerns.

We are indebted to the University of Wisconsin-Madison Nelson Institute for Environmental Studies communications team who provided expert strategic guidance and graphic design. We thank them for their patience as we navigated the contributions of the over 200 scientists and more than 50 organizations who contributed to this report.

EXECUTIVE SUMMARY

The catalyst for this report came from Governor Evers' Executive Order 52, which directed us to collect and update scientific data on the rate of climate change in Wisconsin and its impact on Wisconsin's natural environment. With this report, the Wisconsin Initiative on Climate Change Impacts (WICCI) is fulfilling this directive and carrying out WICCI's mission to generate and share information that can foster solutions to climate change in Wisconsin.

Wisconsin's climate continues to change. In the ten years since the 2011 WICCI Assessment Report, new data show continued warming, increases in rain and snow, and more frequent extreme rainfall events. Statewide temperatures have warmed by about three degrees Fahrenheit and precipitation has increased by nearly twenty percent since 1950. In the last decade, nearly every region of our state has experienced extreme rainfall events that led to flooding of roads, homes, businesses, and farm fields. New analyses reaffirm previous projections indicating that many of these trends will continue, with wide ranging consequences throughout Wisconsin's natural and built environments.

Communities in Wisconsin are feeling the widespread impacts of the changing climate and are starting to take action to protect themselves from future changes. In the Driftless Area, agricultural communities, who have suffered damage from years of flooding, have come together to find solutions. In Northern Wisconsin, the warmer and wetter climate is impacting roads, trails, wildlife, and plants. Coastal communities are banding together to address issues affecting the Great Lakes region, including rapidly fluctuating water levels and eroding bluffs. In Southern Wisconsin and along the Mississippi River, high flows from the wettest decade on record are impacting transportation and wildlife corridors, and sparking conversations about designing infrastructure to handle future climate conditions.

As climate change and the need for solutions are becoming more apparent, so too is the recognition that environmental and climate justice must be an integral aspect of our response. While not the focus of this report, WICCI scientists and practitioners underscore that historically disadvantaged communities bear a disproportionate burden and suffer the greatest harms and risks from climate impacts such as flooding, worsening air quality, heat waves, and drought. For example, changing conditions for plants and wildlife have uniquely affected Native Americans' important cultural, treaty, and subsistence resources. Decision-makers should acknowledge and understand these uneven impacts of climate change to ensure solutions are effective and equitable.

WICCI also stresses, as science has detailed, the need for large and rapid reductions in greenhouse gas emissions. Action at all levels of government is necessary. Without it, Wisconsin will see even greater impacts to roads, infrastructure, people, businesses, and natural resources. Wisconsin is uniquely positioned to lead in this transition. For example, our farms, forests, and natural lands can help solve climate challenges through practices that store carbon in soils and reduce emissions.

Lastly, this report was developed to be read digitally. It includes links to take the reader to WICCI Working Group web pages and the latest research, suggested strategies for adaptation and mitigation, and stories of climate impacts and action from individuals across the state. Working groups will update this web content as new resources and solutions emerge. Together, this report and the additional digital content provide the most comprehensive assessment to date of past and future climate change and its impacts in Wisconsin.

[in response to climate anxiety and hope]

"Some of us do have hope, others not so much. But that all depends on whether you want to take a more realistic perspective or a more hopeful perspective. People my age talk about whether we want to be parents and ask why would I bring a child into a world that is dying. There are big anxieties that we have to consider every day, knowing that water scarcity and air pollution could get worse…. Personally, the way I like to view climate change is, to be realistic. We will have to deal with climate change by 2050, one way or another."

–Stephanie Janeth Salgado Altamirano, Co-founder, Youth Climate Action, Madison, Wis.
Read the full interview

"There are so many innovative conservation approaches being developed and underway. Wisconsin has the urgent need and the potential to make this happen. It's going to take a monumental effort—with all of us working together to stop emitting greenhouse gases and start adapting to changes—and we're already taking the first steps. There are so many people thinking and acting on climate change from different angles. Stitch all of those together, and you have a vision for the future."

–Nick Miller, Director of Science and Strategy, The Nature Conservancy in Wisconsin
Read the full interview

Key findings & solutions

We are already feeling the impacts of climate change in Wisconsin, as detailed throughout this report, but we are also developing solutions and starting to come together to make communities more equitable and climate-resilient in the future.

Climate takeaways

- Wisconsin's average daily temperature has become three degrees Fahrenheit warmer since the 1950's.
- The last two decades have been the warmest on record, and the past decade has been the wettest.
- Wisconsin has become wetter – average precipitation has increased 17 percent (aboout 5 inches) since 1950.
- Warming is happening fastest in the winter and at night.
- Southern Wisconsin has experienced the highest increase in precipitation.
- Very extreme precipitation events will increase in the future.
- Extreme events are already causing immense impacts across the state, and the frequency of those events will generally increase.

Solutions

Decrease carbon emissions and promote environmental and climate justice by investing in solutions that reduce greenhouse gas emissions and associated climate impacts.

Land takeaways

- Warmer winters, wetter springs, and extreme weather events are impacting agricultural production in Wisconsin and overwhelming conservation practices to keep soil in place and protect water quality. A shift towards increasing living cover on farm fields and promoting rotational grazing can reduce greenhouse gas emissions, which have increased by 14.3 percent from 2005 to 2017. Well-managed pastures and farm fields build and retain soil carbon, help communities cope with the increase in extreme rainfall events, and reduce damage to roads, bridges, and other infrastructure.
- Warmer winters, increasing deer herds, extreme weather events, summer droughts, and longer growing seasons are stressing forest ecosystems and increasing the risk of outbreaks of new pests and diseases. Iconic species like paper birch are vanishing from northern forests as the climate warms. Forest management, logging, and the forest products supply chain are facing uncertainty, with implications for rural economies.
- Warmer and wetter conditions, extreme storms, summer droughts, milder winters, and longer growing seasons are amplifying non-climate stressors to the point where diverse native habitats are simplified, associated wildlife species are diminishing or disappearing, and species extinction rates are accelerating.
- Changing growing seasons, summer droughts, reduced snowpack, and increased flooding are reducing critical habitat and food sources for many wildlife species. Many species are shifting ranges and changing migration patterns to adjust to the changes. Climate-vulnerable species need help to adapt to rapidly changing conditions.

Kayaks on Lake Superior at Big Bay Town Park , La Pointe,Wis. Photo credit: Travel Wisconsin

Solutions

Promote effective conservation practices and adaptations to make agriculture more resilient to climate impacts

Improve resilience to increasing precipitation and flood events that cause nutrient and sediment runoff by avoiding grassland or natural vegetation conversion to row-crop production or urban development

Preserve and protect large tracts of land for wildlife, implement habitat management changes to provide food and cover for wildlife that align with expected future climate conditions and adjust harvest regulations for climate-vulnerable species

Maintain and expand forest cover and urban tree canopy, targeting lands that offer the greatest potential for continued carbon storage and sequestration

Water takeaways

- Warming temperatures and changing precipitation patterns are decreasing water quality and changing aquatic ecosystems.
- Warmer water temperatures and increasing variability in ice on and off dates, duration and thickness are changing the fish species that can live in Wisconsin's waters. Cool- and cold-water fish are particularly at risk. Loss of these resources will have spiritual, cultural, and health impacts to Wisconsin's eleven tribes and other subsistence fishers.
- Warming waters in the Great Lakes are impacting lake ecology, fisheries, and water-quality based recreation. Both increasing precipitation and drought are leading to extreme lake level fluctuations in Lake Superior and Lake Michigan that impact both habitats and structures built along the lakeshore.
- A wetter climate is increasing the volume of water flowing in the Mississippi River and impacting critical backwater habitat and recreational fishing opportunities

Solutions

Manage watersheds to reduce flood hazards and slow sediment and water movement in tributaries

Invest in flood risk reduction practices and pre-disaster mitigation programs that help communities address local flood risks and avoid catastrophic losses

Manage fisheries and make them more resilient to climate impacts by preventing overharvest, protecting productive populations, and preserving stronghold populations of brook trout and other important fisheries

Conserve water and encourage water infiltration to reduce the impact of both droughts and floods

Establish a long-term water monitoring network and a Wisconsin surface water applied research program to better track and manage surface waters as they respond to climate changes

Built Environment takeaways

- Our rural roads, highways, airports, ports, dams, stormwater and wastewater systems have been designed according to past climate conditions that do not account for changes in climate, including increasing precipitation, earlier spring thaws and more freeze/thaw cycles, higher water table elevations, and more humid heat waves. Lack of climate change projections available to local officials is leading to inefficient planning and expenditures.
- The production of material needed to build our infrastructure, like concrete and steel, represent a significant source of greenhouse gas emissions.
- Great Lakes coastal infrastructure, recreation, and homes are at risk from extreme and rapid fluctuations in lake levels and decreased stability of coastal bluffs. Warming temperatures are anticipated to decrease the ice cover extent and duration on the Great Lakes, exposing coastal areas to greater wave energy and increased erosion and flooding along the shoreline. Increasing total and frequency of extreme rain events will also reduce the stability of coastal bluffs.
- Increased frequency and severity of floods in the Mississippi River and smaller watersheds are impacting the region's economy, connectivity, ecology and built environment

Solutions

Support a State Climate Office to provide data and guidance for Wisconsin communities

Design and build infrastructure that accounts for future climate conditions

Provide state funding for climate resilient infrastructure repair and replacement

Conduct vulnerability assessments in coastal communities and explore options to adapt to a changing coastal climate

Develop tools for the Mississippi River to aid in flood forecasting and planning

People takeaways

- Extreme storms and flooding are the most prominent climate impacts being felt by communities across Wisconsin. These impacts extend to environmental resources and activities that are important to Native Americans and other subsistence fishers.
- Planning for these evolving climate challenges will be crucial for communities to maintain a vibrant economy in Wisconsin, reduce health risks, and promote public safety.
- Reducing greenhouse gas emissions and creating an equitable transition to renewable energy is the best way to minimize the impacts of future warming, protect our economy, and reduce risk to human health.
- Support for climate resiliency education, planning, and projects will help smaller communities protect their businesses, residents, economy, and infrastructure.

Solutions

Help communities become more resilient to climate change impacts by supporting comprehensive planning and community climate preparedness grants

Fully embrace clean energy, walkable communities, public transportation, and green building design

Protect the most vulnerable in response to extreme weather events and set up timely public communication on climate-health issues

Support efforts to develop diverse and sustainable tourism and outdoor recreation and preserve cultural resources

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INTRODUCTION

The Wisconsin Initiative on Climate Change Impacts (WICCI) is a statewide collaboration of scientists and stakeholders formed in 2007 as a partnership to evaluate climate change impacts on Wisconsin. This report is the product of over 200 scientists, practitioners, and Wisconsin residents representing more than 50 national, state, and local agencies, non-profit organizations, and universities. It was peer reviewed by a Science Advisory Board. With this report, we present information on impacts from climate change specific to Wisconsin and science-based solutions and strategies to address these impacts.

What's new since 2011

This report documents the issues and impacts of our warming climate on Wisconsin residents and describes the scientific progress made towards solutions since the 2011 Wisconsin Initiative on Climate Change Impacts Assessment Report. Although it is evident that climate impacts are being felt in Wisconsin, this report contains vivid stories that help illustrate those impacts at a human scale.

Another new feature of this report is a start toward identifying and integrating environmental and climate justice (ECJ) into our assessment and solutions. The issues identified by WICCI Working Groups are part of a greater effort by the WICCI network to include ECJ issues in our strategic vision for the future. For the purposes of this report:

Environmental and climate justice is ensuring all people have fair access to environmental benefits, equitable protection from environmental and health hazards (including climate change), fair access to decision-making processes, and a healthy environment in which to live, learn, work, and recreate.

Future research

Climate change affects nearly all aspects of our society, and as a result this report cannot and does not cover the full range of important issues that Wisconsin will face. Among these issues are the economic impacts of climate change, the migration of human communities seeking to escape the impacts of climate change, and technological advances that will reshape our response to a changing climate. WICCI is an open and evolving network, and we welcome new insights and research that will advance our ability to identify future climate solutions.

Opportunities to learn more

This report is directed to policymakers, engineers, planners, infrastructure managers, nonprofits, and others working to address climate impacts in Wisconsin. It summarizes the key findings of the WICCI working groups and offers insight into the impacts at a human scale. On each of the WICCI Working Group webpages you will find interviews and more detailed content. While not all inclusive, this content offers a glimpse of how the changing climate is impacting Wisconsin. Deeper content is also available through other resources linked to this report.

Riverside Obidient. Photo credit: Kevin Sink

Solutions

Each chapter of this report contains a list of solutions to create a more climate resilient landscape in Wisconsin. In general, the solutions call for a change in the way we design, plan, and manage our built environment and landscape. We note that challenges and barriers to change are significant, but the ongoing impacts of climate change call for swift action. The working groups also identified solutions to slow climate change by limiting the buildup of heat-trapping greenhouse gases through innovations and nature-based solutions. Future research is needed to quantify some of these mitigation solutions as part of a comprehensive approach to reducing greenhouse gas emissions in the state. You are invited to explore more about the listed solutions on the working group webpages.

AIR CHAPTER

Wisconsin's climate is warmer, wetter and we are experiencing more extreme events

Photo credit: Kevin Sink

"We have known that we are committed to climate change since the 1800s. The question is how far are we willing to go? And how fast are we willing to allow the climate to change? Our actions now will make a huge difference for avoiding the worst outcomes."

–Dan Vimont, Professor of Atmospheric and Oceanic Sciences and Director of the Nelson Institute Center for Climatic Research, UW-Madison
Read the full interview

Wisconsin's climate continues to change in ways that are consistent with the projections from the 2011 WICCI Assessment Report. Since the 2011 report was released, all regions of Wisconsin have reported their wettest decade in recorded history. Not only are we getting more precipitation, we are also experiencing more VERY extreme storm events. Wisconsin is also getting warmer, especially in the winter.

The impacts of extreme events – high heat days, flooding, reduced water quality – are disproportionately impacting vulnerable groups like communities of color, children and pregnant women, the elderly, immigrant groups, lower income households, and individuals with disabilities or chronic health conditions. As the climate continues to warm and impacts worsen, groups that cannot afford to move or adapt will be most at risk.

The past decade

Climate trends over the last decade continue to align with expected climatic changes. The decade from 2010-2019 was the wettest in Wisconsin since records began around 1900. Statewide annual average precipitation during this decade rose to 37.0 inches, a 17 percent increase over the previous long-term average. Warming trends in Wisconsin have also continued, with average temperatures in Wisconsin increasing by 3 degrees Fahrenheit since the 1950s (Figure 1).

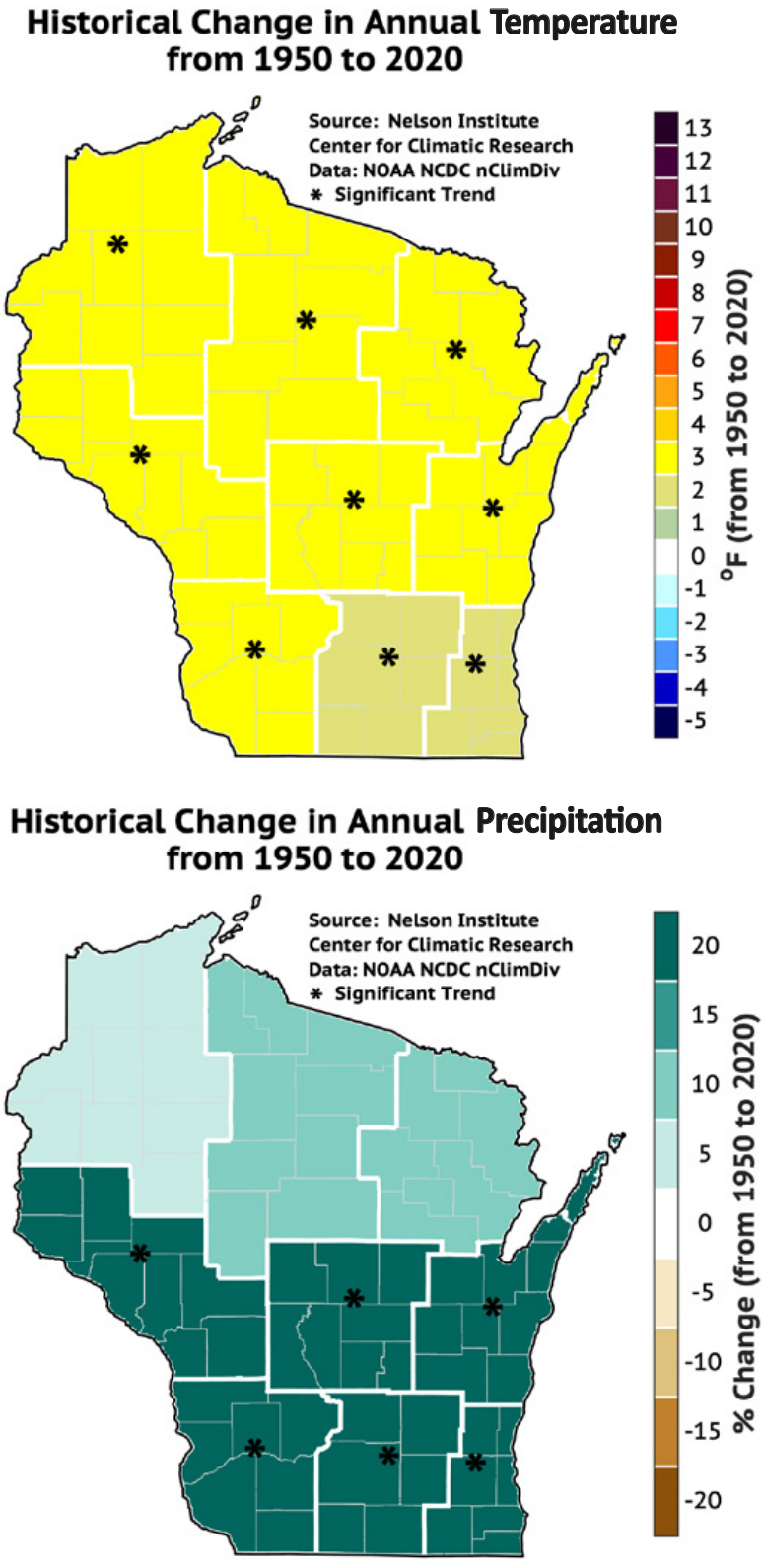


Figure 1: Wisconsin is getting warmer and wetter. The top panel shows that Wisconsin's annually averaged temperature has warmed by about 3 degrees F from 1950-2020. The botom panel shows that Wisconsin is getting wetter – especially southern Wisconsin. Asterisks indicate regions with statistically significant trends.

"I do have hope for the future, some days more than others. I liken our situation to a patient who is in the emergency room and needs to be treated immediately, but they are not in hospice. There are things we can do but we definitely need to take action quickly."

–Steve Vavrus, Senior Scientist of Atmospheric Sciences at the Nelson Institute Center for Climatic Research, UW-Madison
Read the full interview

"Climate change shouldn't be a political issue. It is an issue that we are all facing, even if it looks different according to where we live or the identities we carry. We should look at it through the lens of what we want for our future generation or what we want for our children. Especially people who are 18-20 years old will feel the effects of climate change by 2050."

–Stephanie Janeth Salgado Altamirano, Co-Founder, Youth Climate Action, Madison, Wis.
Read the full interview

Extreme weather has generally increased in frequency and magnitude (including high heat, extreme amounts of rain or snow, high winds, droughts, or extreme cold). For example, heavy daily precipitation events across Wisconsin show a rising trend in recent decades. Days with 1 to 2-inch rain events have increased the most, but 3-inch rainfalls are also increasing. While rare, these events are exceedingly damaging and are becoming more common as the climate warms. In the last decade we have experienced massive events, like the 15-inch rainfall event in Cross Plains in 2018 (Figures 2 and 3).

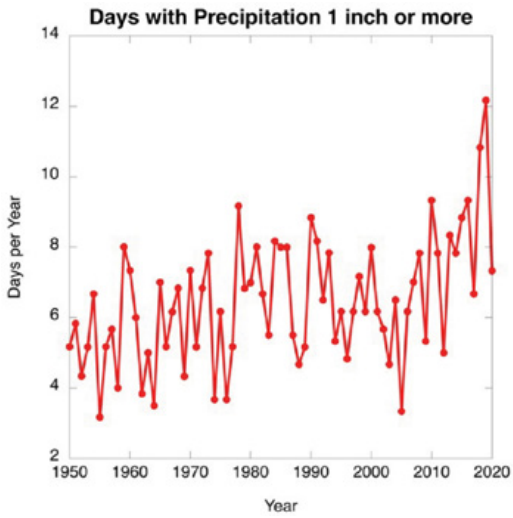


Figure 2: Heavy daily precipitation events across Wisconsin show a rising trend in recent decades. Source: Nelson Institute Center for Climatic Research, UW-Madison

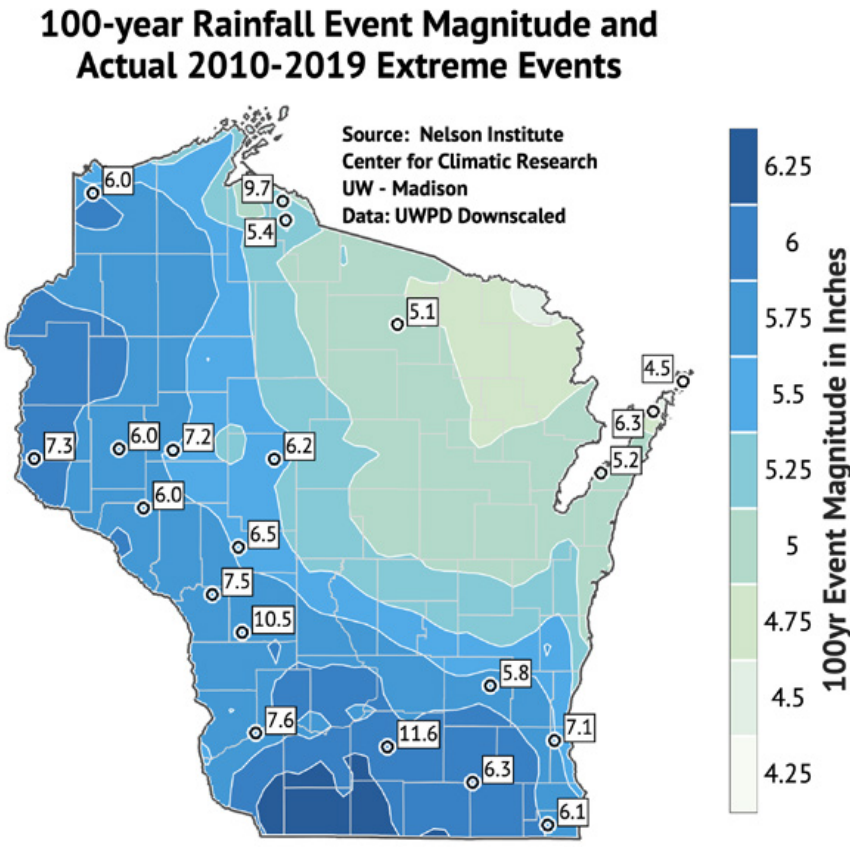


Figure 3: Wisconsin is experiencing more extreme rainfall events. The shading in this figure shows the magnitude of the "100 year" rain event in Wisconsin, ranging from about 6.25 inches in southwestern Wisconsin to about 4.5 inches in northeastern Wisconsin. In the decade from 2010-2019, Wisconsin experienced at least 21 rainfall events that exceeded the 100-year event in the locations indicated by the circles and labeled amounts.

Seasonal and regional changes

All seasons and regions of Wisconsin are getting warmer and wetter, but winters are warming more rapidly than summers and nighttime low temperatures are warming faster than daytime high temperatures. Winter warming has been most pronounced in Northwest Wisconsin (+4-6 degrees Fahrenheit). Winter warming is also reflected in fewer extreme cold periods (below 0 degrees Fahrenheit). Cold periods have been getting less common, and this trend is predicted to continue (Figure 4).

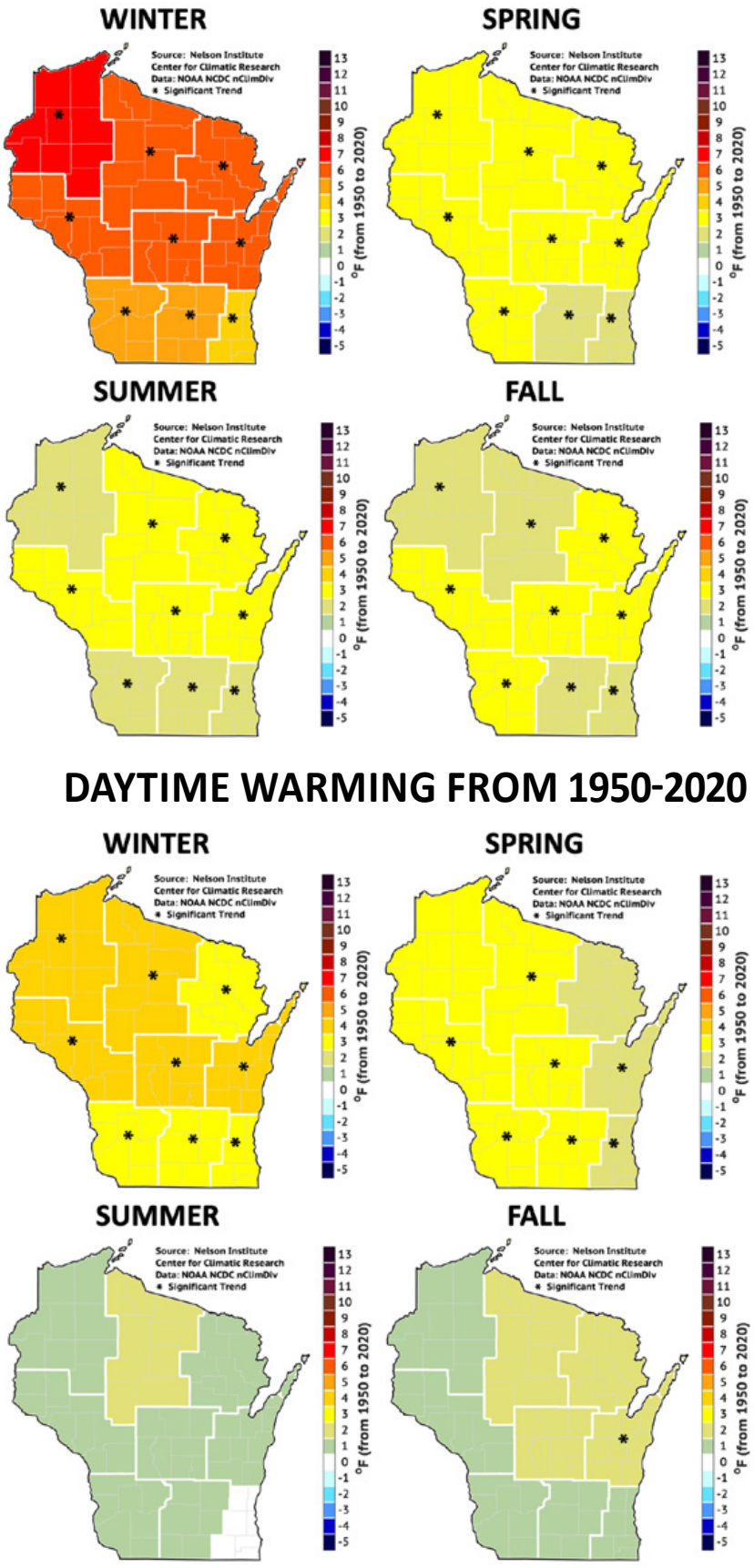


Figure 4: Wisconsin's warming trend is not evenly distributed between nighttime low temperatures (top panel) and daytime high temperatures (bottom panel), and from season to season. For example, Wisconsin's winter, nighttime temperatures (top row) have warmed by 4 degrees F – 7 degrees F since 1950. In contrast, summer, daytime high temperatures (bottom row) have only warmed by about 1 degree (not a significant trend) since 1950. Asterisks indicate regions with statistically significant trends.

Our winters are also getting wetter since 1950. Winter precipitation has increased by over 20 percent since 1950. Rain events during the winter are particularly concerning because water that falls on frozen, bare ground is more likely to carry runoff that worsens water quality. The southern two thirds of Wisconsin are experiencing the biggest increase in precipitation. Even so, Northern Wisconsin also experienced extreme rain events in 2012, 2016, and 2018 (Figure 5).

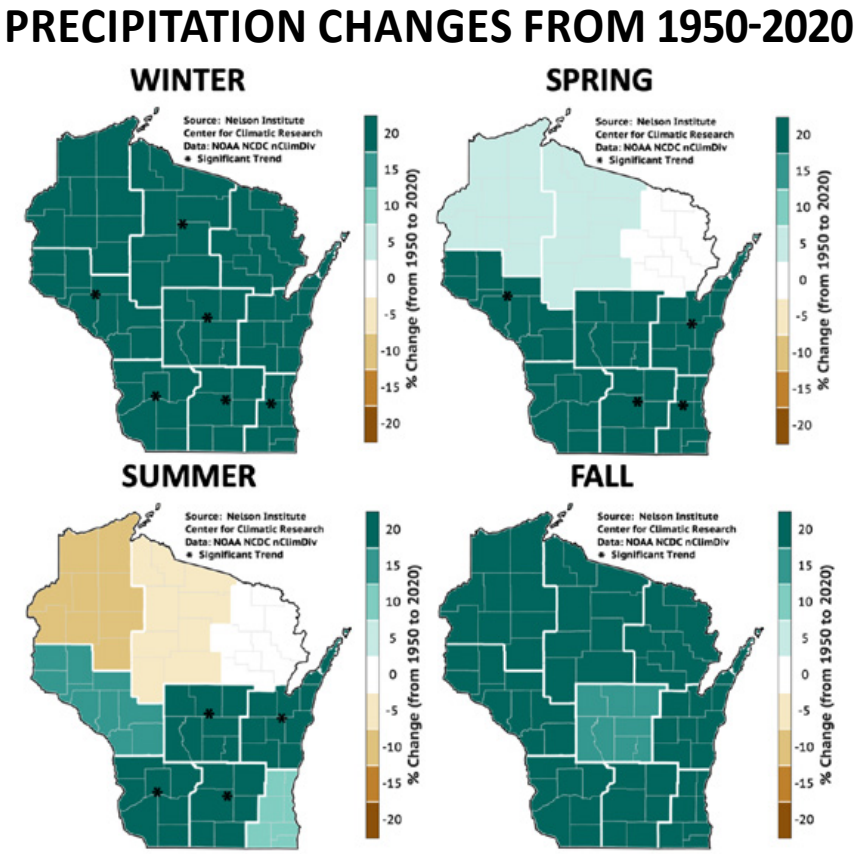


Figure 5: Wisconsin's changing rainfall is not evenly distributed from season to season. Wisconsin's winters (upper left map) have seen large, and significant increases in precipitation in the form of both snow and rain across most of the state. Rainfall trends during summer (bottom left map) are varied, with significantly wetter conditions only across the southern and central portions of the state. Asterisks indicate regions with statistically significant trends.

Future Scenarios

The Climate Working Group analyzed Wisconsin's projected climate under two different future climate scenarios, based on a mid-range and high-end estimate of future greenhouse gas emissions. By mid-century, both the high and middle range emissions scenarios suggest that average temperatures in Wisconsin will be about four to six degrees warmer compared to our baseline climate conditions at the end of the 20th century (our recent past). Further into the future, the emissions scenarios diverge dramatically and show a difference of six degrees between each other by the late 21st century. Each additional degree of warming will intensify the climate impacts described in this report. These scenarios illustrate the importance of reducing greenhouse gas emissions in order to avoid the worst consequences of climate change (Figure 6).

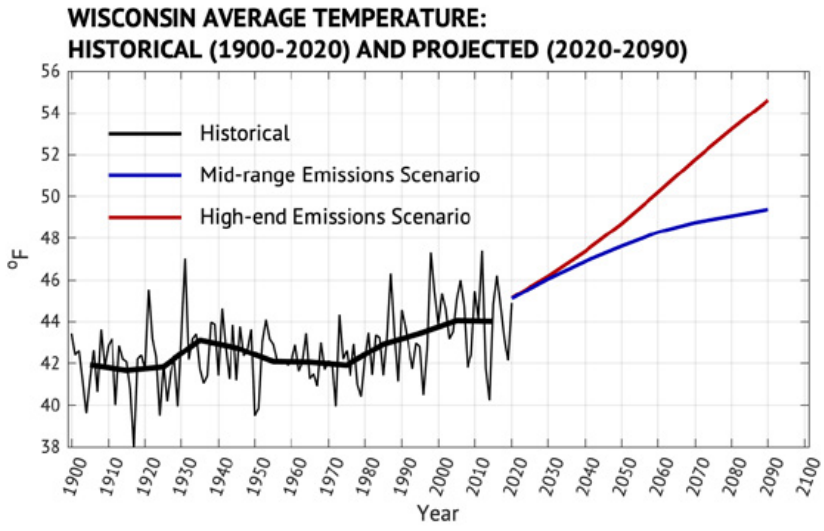


Figure 6: Wisconsin's historical warming (black line) is expected to continue into the coming century under both a high-end emissions (red curve) and mid-range emissions (blue curve) scenario.

By mid-century, under a mid-range scenario for greenhouse gas emissions, statewide average temperatures in Wisconsin are projected to warm by 2 – 8 degrees Fahrenheit above the late 20th century average. To put this in perspective, the warmest years in Wisconsin's history were 1998 and 2012.

By the middle of the 21st century, Wisconsin's *average* temperature should be similar to those years. Seasonally, by mid-century, our winters will probably continue to warm more than summers, and nighttime low temperatures will likely warm even more than daytime high temperatures (Figure 7).

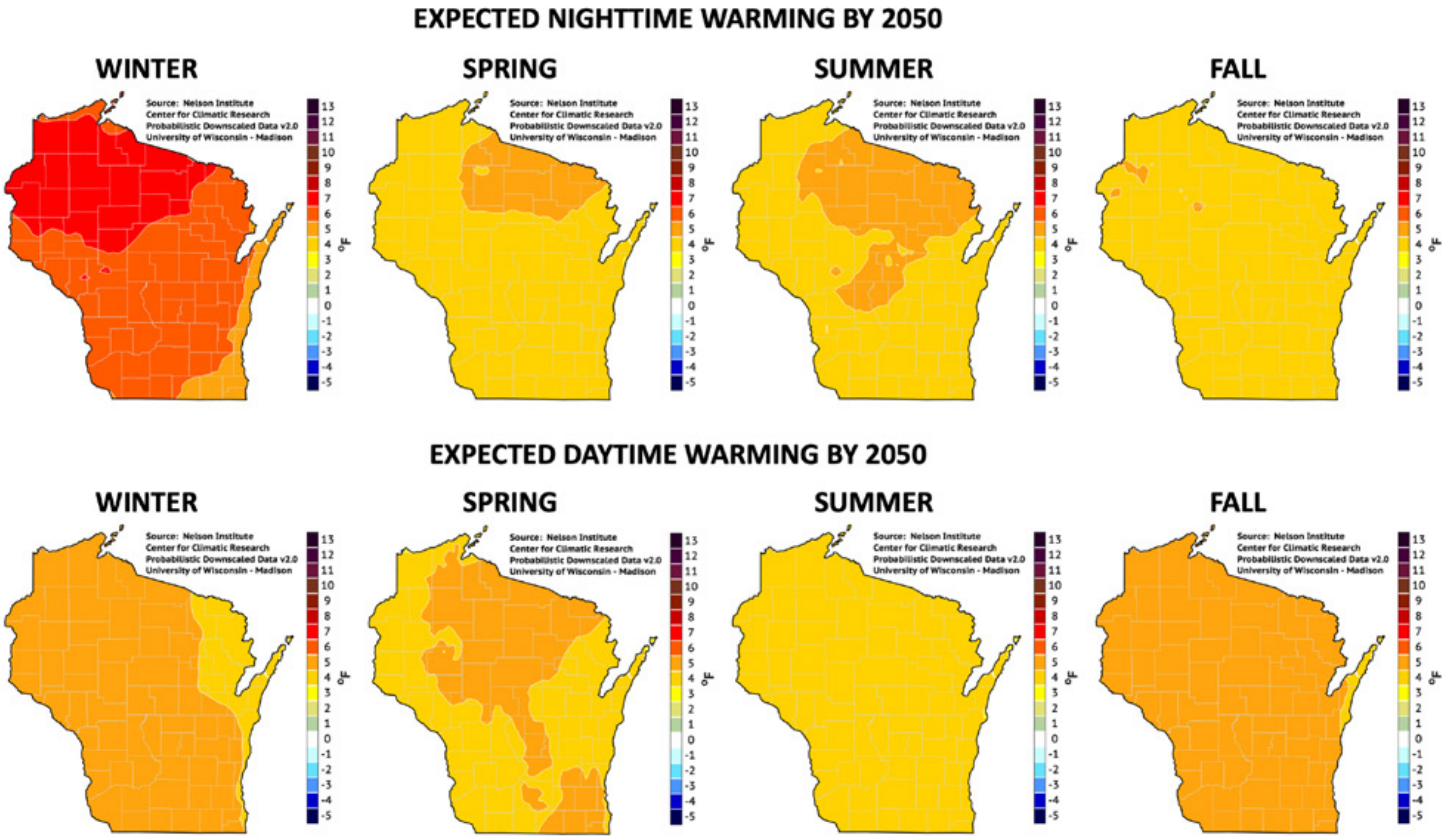


Figure 7: Wisconsin will continue to warm in all seasons through the coming century. Projections show that winter nights will warm the most, and summer days the least. These maps show the expected warming by mid-century, compared to conditions at the end of the 20th century.

These changes in average temperature will increase the frequency and magnitude of many extreme weather events. By mid-century extreme heat days over 90 degrees Fahrenheit in Wisconsin will likely triple. The number of hot nights when the temperature does not drop below 70 degrees Fahrenheit will likely quadruple (Figure 8).

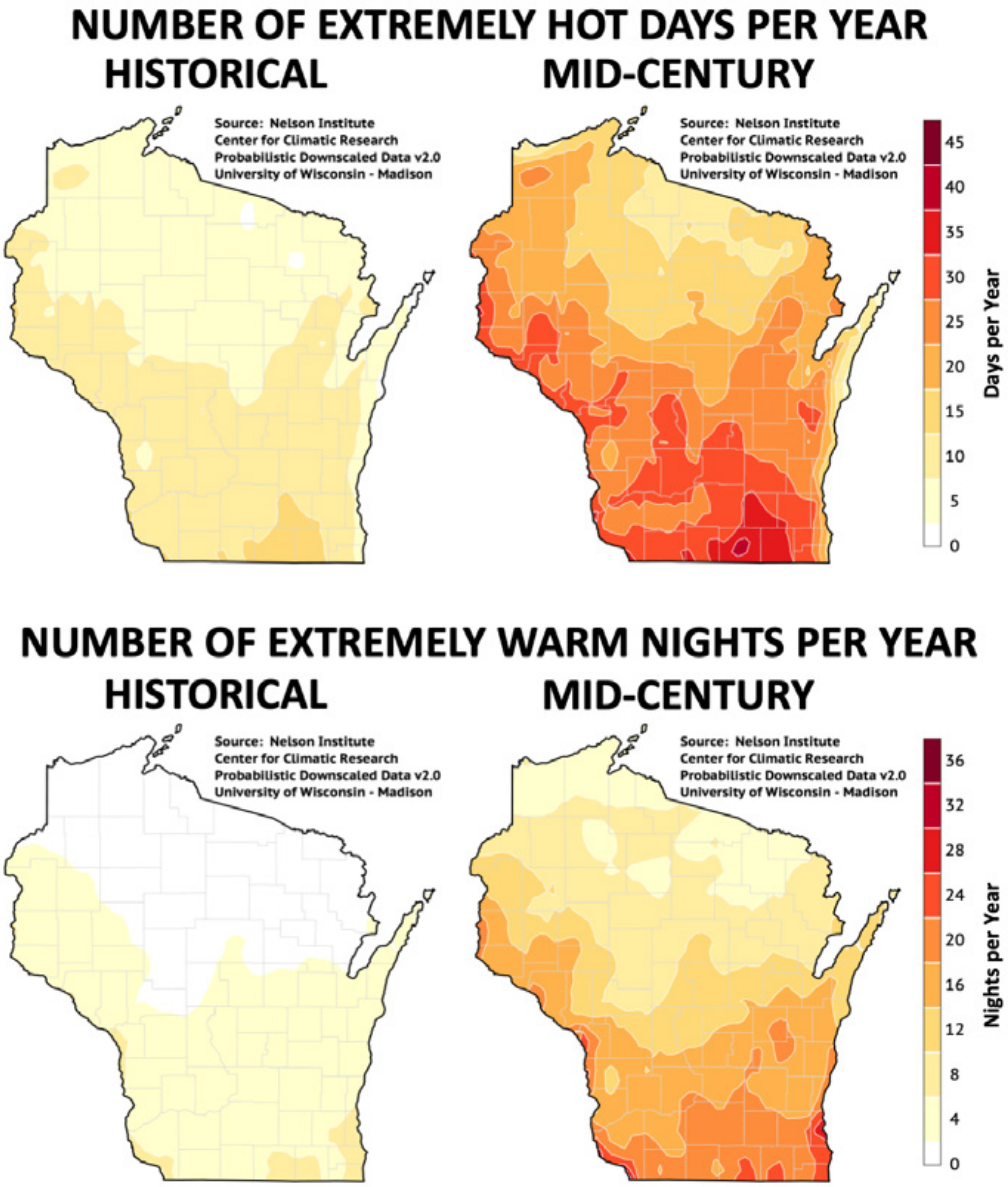


Figure 8: The frequency of extreme heat events will increase. These maps show the number of days when the temperature exceeds 90°F (top) and nights when the temperature does not dip below 70°F (bottom), for historical conditions (left) and mid-21st-century conditions (right). For example, the top map shows that Green Bay has historically experienced about 7 days per year when the daytime high temperature exceeds 90°F. By mid-century, Green Bay will likely experience 20 such days.

Wisconsin is likely to continue to trend toward wetter conditions, especially during winter, spring, and fall (Figure 9). Extreme rain events will also increase significantly. Extreme precipitation events are likely to remain most common in the southern and western parts of the state (Figure 10).

EXPECTED PRECIPITATION CHANGE BY 2050

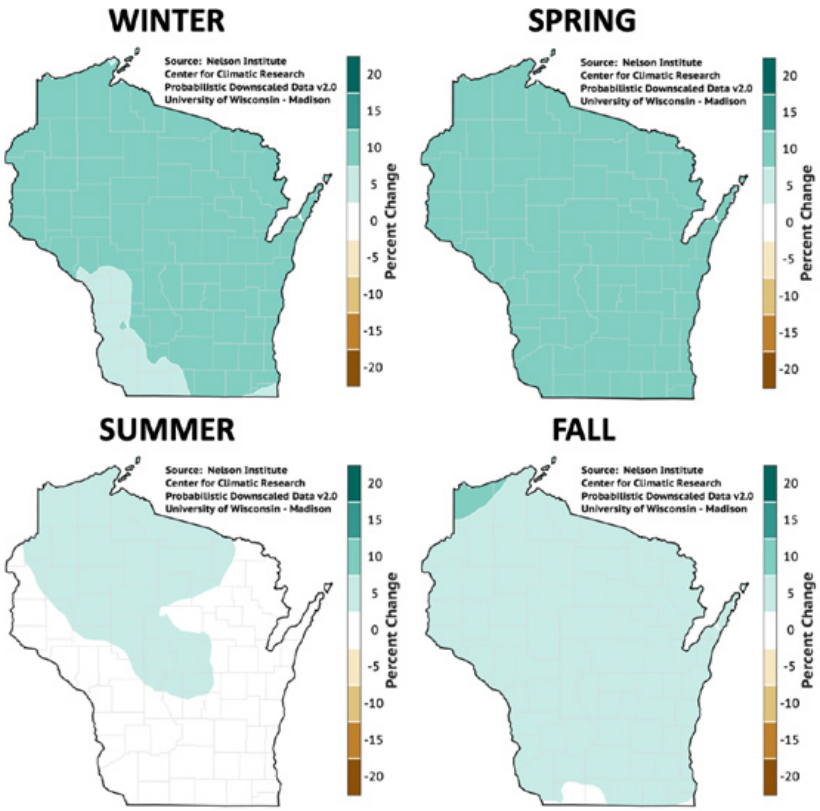


Figure 9: Wisconsin winter, spring, and fall will continue to get wetter through the coming century. These maps show the expected seasonal warming by 2050, compared to conditions at the end of the 20th century.

FREQUENCY OF EXTREME RAINFALL

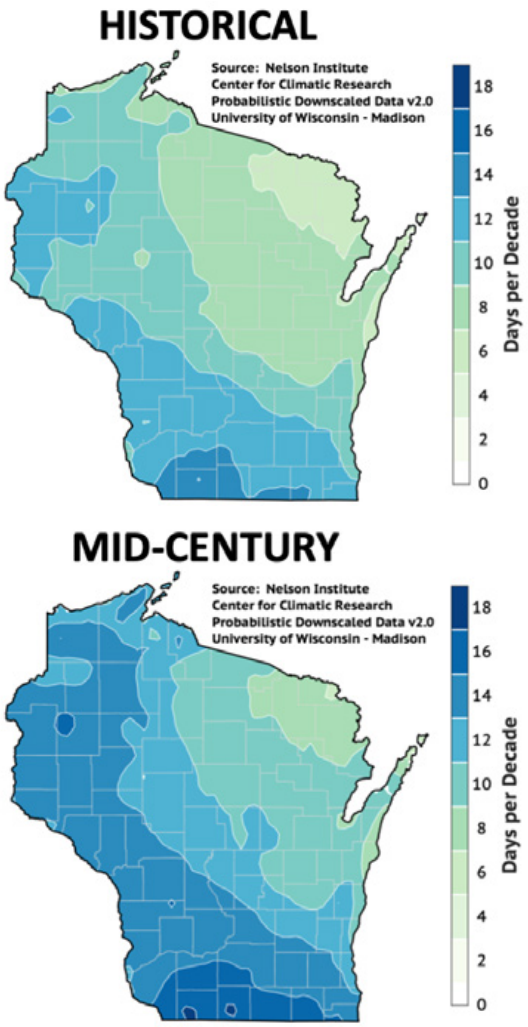


Figure 10: Extreme precipitation events will occur more frequently through the coming century. Shown here is the frequency of days with 2 or more inches of precipitation in a 24hr period.

The issues and impacts produced by this changing climate are already being felt and will become more drastic as the climate continues to warm.

Key Points

- Wisconsin's average daily temperature has become three degrees Fahrenheit warmer since the 1950.
- The last two decades have been the warmest on record, and the past decade has been the wettest.
- Wisconsin has become wetter – average precipitation has increased 17 percent (about five inches) since 1950.
- Warming is happening fastest in the winter and at night.
- Southern Wisconsin has experienced the highest increase in precipitation.
- Very extreme precipitation events will increase in the future.
- Extreme events are already causing immense impacts across the state, and the frequency of those events will generally increase.

Solutions

Decrease carbon emissions and promote environmental and climate justice by investing in solutions that reduce greenhouse gas emissions and associated climate impacts

Learn more

The **Climate Working Group** studied these and other issues and has produced downscaled climate model projections showing conditions under low-end and high-end greenhouse gas emission scenarios.

LAND CHAPTER

Climate sensitive land management can help Wisconsin adjust to a rapidly changing climate

Contour farming in Wisconsin. Photo credit: WDNR

INTRODUCTION

Wisconsin residents and businesses are already feeling the impacts of climate change. Wisconsin is experiencing increases in annual average temperatures of 3 degrees Fahrenheit and is likely to increase an additional 2 - 8 degrees Fahrenheit by mid-century. This warming trend is bringing increases in the frequency of extreme storm events, leading to more flooding and disruptions to agriculture, forests, plants and natural communities, tourism and other industries. By the end of the century, these storms will probably be nearly twice as frequent throughout Wisconsin.

The topics covered in this chapter include issues, impacts and solutions in the areas of agriculture, forestry, plants and natural communities, and wildlife. These topic areas are covered in more depth on WICCI Working Group webpages with links

provided at the end of each topic section. Here is a brief highlight of the issues covered in this chapter.

Agriculture

Warmer winters and wetter springs, along with increased extreme rainfall events, have created economic and management hardships for Wisconsin farmers in recent years. Waterlogged soils have delayed planting in the spring and harvesting in the fall. These wet conditions have also harmed water quality due to more nutrient runoff and soil erosion from cropped fields. Extreme heat has decreased milk production from dairy cows and increased water usage. Changing agricultural practices can lessen impacts by reducing emissions and storing carbon.

Forestry

A warming winter climate is stressing Wisconsin's 17 million acres of forests. It is creating conditions favorable to new pests and diseases. Iconic species like paper birch are vanishing. Logging operations are struggling with storm damaged infrastructure and less frozen ground. Yet, there is hope. Forests are a valuable tool to reduce the impacts of climate change as they sequester carbon in active growth and store carbon in forest soils and living and dead wood. Efforts to monetize carbon and use forests as carbon sinks are forming.

Plants and natural communities

Even without a changing climate, Wisconsin's native habitats are stressed by habitat loss and fragmentation, invasive species, lack of natural or the appropriate conditions for prescribed fire, excessive deer browse, and nutrient runoff. Climate change amplifies these impacts to the point where once-diverse habitats are simplified, associated wildlife species diminish or disappear, and important ecosystem services, such as fewer wetlands to absorb floodwaters, are lessened. As a result, species extinction rates are accelerating and more species may be added to Wisconsin's list of threatened and endangered species. Connections between large tracts of land with native plant communities can help species adapt and move as the climate changes.

Wildlife

Warmer winters and less snow are stressing iconic Wisconsin species like ruffed grouse and snowshoe hares. New pests and warming waters are stressing common loons. White-tailed deer are benefiting from the changed conditions, but their increasing numbers are impacting forest regeneration and stressing native plant communities.

Deer browse damage on a young white pine. White pines are a preferred food source for deer, and repeated browse can stunt or kill young trees. Photo credit: Chequamegon-Nicolet National Forest

Key points

- Warmer winters, wetter springs, and extreme weather events are making agricultural production in Wisconsin less competitive and overwhelming conservation practices to keep soil in place and protect water quality. A shift towards increasing living cover on farm fields and promoting rotational grazing can reduce greenhouse gas emissions, which have increased by 14.3 percent from 2005 to 2017. Well-managed pastures and farm fields build and retain soil carbon, help communities cope with the increase in extreme rainfall events, and reduce damage to roads, bridges, and other infrastructure.
- Warmer winters, increasing deer herds, extreme weather events, summer droughts, and longer growing seasons are stressing forest ecosystems and increasing the risk of outbreaks of new pests and diseases. Iconic species like paper birch are vanishing from northern forests as the climate warms. Forest management, logging, and the forest products supply chain are facing uncertainty, with implications for rural economies.
- Warmer and wetter conditions, extreme storms, summer droughts, milder winters, and longer growing seasons are amplifying non-climate stressors to the point where diverse native habitats are simplified, associated wildlife species are diminishing or disappearing, and species extinction rates are accelerating.
- Changing growing seasons, summer droughts, reduced snowpack, and increased flooding are reducing critical habitat and food sources for many wildlife species. Many species are shifting ranges and changing migration patterns to adjust to the changes. Climate-vulnerable species need help to adapt to rapidly changing conditions.

Solutions

Climate sensitive land management can help Wisconsin adapt to a rapidly changing climate. Here is a summary of the solutions listed in this chapter. More information and background on these solutions and the climate issues and impacts covered in this chapter can be found on the WICCI Working Group web pages provided as links at the end of each section.

Promote effective conservation practices and adaptations to make agriculture more resilient to climate impacts

Improve resilience to increasing precipitation and flood events that cause nutrient and sediment runoff by avoiding grassland or natural vegetation conversion to row-crop production or urban development

Preserve and protect large tracts of land for wildlife, implement habitat management changes to provide food and cover for wildlife that align with expected future climate conditions and adjust harvest regulations for climate-vulnerable species

Maintain and expand forest cover and urban tree canopy, targeting lands that offer the greatest potential for continued carbon storage and sequestration

AGRICULTURE

Today there is a move in agriculture toward keeping fields green year-round. The change in land-use over the last 200 years across a large portion of Wisconsin from tallgrass prairie and oak savanna and grassland to row crop agriculture has led to high yields but also increased greenhouse gas emissions, decreased soil health, and increased agrochemicals in our surface and ground water. The trend toward larger animal confinement operations has amplified the reliance on grain over pasture to feed livestock. Tillage practices needed for row-crop farms have reduced soil health and the ability of agricultural soils to store carbon and hold water. This decline in soil health has led to higher rates of inorganic nutrient fertilizer and liquid manure applications to sustain production levels, one of the most pressing concerns for agriculture in Wisconsin today.

How agriculture can mitigate climate impacts

While Wisconsin greenhouse gas emissions declined by 9 percent overall from 2005 to 2017, the agriculture sector emissions have increased by 14.3 percent. As of 2017, greenhouse gas emissions from agricultural production were responsi-

ble for 15 percent of Wisconsin's overall total. The largest part of the emissions came from carbon dioxide released from soil management and plant residue burning (81.3%).

Strategies to reduce greenhouse gas emissions include a shift towards increasing living cover on farm fields and promoting rotational grazing. Practices to increase living cover on farm fields include improving the mixture of grasses, legumes, and other plants available for livestock grazing, using cover crops, and adding more perennials into the crop rotation. Well-managed pastures and farm fields build and retain soil carbon and so can help reduce atmospheric carbon dioxide concentrations. Grazing also helps communities cope with the increase in extreme rainfall events that climate change brings. Land in well-managed perennial pastures help slow, absorb and retain water. This can reduce the severity of flooding and damage to roads, bridges, and other infrastructure.

Managed grazing systems have also proven to be more resilient to climate change and the erratic and intense weather which is projected for Wisconsin. For example, in 2019 many farms that grow corn and soybeans were unable to plant their crops because of excessive rain, but perennial pastures grew well and could be harvested even when farm machinery was unable to get into fields. Grazed fields were also more resilient to severe wind storms in 2019, which damaged corn and other row crops.

Adding covering crops and perennials into the crop rotation can slow erosion, increase soil carbon, and reduce greenhouse gas emissions from farm fields. Photo credit: Wisconsin DATCP

"We no-till our crops and have for about thirty-five years. Over that time, we've increased our organic matter in the soil from about 2.5 percent to about 4 to 4.2 percent. That helped control flooding because for each percent of organic matter that your soil increases it has the capacity to hold about one inch more equivalent of rainfall. So, it's all the practices put together help support each other and help us weather that big event. While 2018 was a big event, there have been numerous other heavier and more frequent rains. It gives us a smaller window to plant, a smaller window to harvest, and forces us to invest in larger machinery so we can get more work done".

–Jack Herricks, Herricks Dairy, Cashton, Wis.
Read the full interview

"Different weather conditions and scenarios have been plaguing the progress of producers ever since people first started putting cultivated crops in the ground. The responsibilities of running a farming operation and dealing with the weather is nothing new… Improved technology and different growing methods will help play a pivotal role in the future of agriculture in response to our planet's changing climate."

–Kyle Hilger, Hilger Farm, Bloomer, Wis.
Read the full interview

Climate impacts on Wisconsin agriculture

The **Coon Creek story** helps illustrate how agricultural producers are being severely impacted by a combination of climate changes. Extreme rain events are washing away valuable topsoil, disrupting farm operations, and damaging infrastructure. Wetter springs and falls are reducing the ability to get into the fields for spring planting and fall harvesting. During sustained wet periods, groundwater flooding forms new lakes and flooded areas that cause farmland loss.

Wetter weather also increases the risk for plant disease on major crops in the state. For example, cool wet weather in the period from 2014 to 2019 created the conditions for white mold to thrive and damage soybean crops. These extreme heavy rainfall events are becoming more frequent as the climate warms.

The dramatic increase in heavy rainfall events is also challenging the conservation practices that have kept soil in place and helped protect water quality. These conservation practices are changing to adapt to the wetter climate. In the Coon Creek region, stream restoration designs and roads that cut across valley floors are changing. Dams are being revamped to consider the increasing risk that they may be overtopped during massive flood events.

Polar Vortex: As winter temperatures warm, snow cover is declining and winter "thaws" are increasing. Extreme but short-lived cold periods like the polar vortex during the winter of 2018-2019, which was also associated with less snow cover, can reduce the viability of crops like alfalfa, an important forage crop for the dairy industry. Individual farms are finding ways to deal with these challenges. Researchers and conservation professionals can help them find solutions to extreme events.

Changing seasons: While warming in the spring and fall can increase the growing season for some crops, warming during winter can also reduce the formation of ice and snow that cranberries and many other crops need to survive the winter. In addition, warmer winters may allow pests to overwinter more successfully or migrate to Wisconsin from southern states.

Summer heat: More summer heat can stress livestock, especially dairy cows, that thrive in cooler conditions and cool nights. With a warming climate, the frequency of extremely hot days above ninety degrees will continue to increase, with nights warming faster than daytime. Hotter summers also increase the need for irrigation, especially in the Central Sands region. Extreme weather could expand the magnitude and extent of droughts in some regions of Wisconsin.

Extreme Precipitation Levels: Both extremely high and low levels of precipitation tend to decrease crop yields overall. All these changes are causing uncertainty for Wisconsin's agricultural producers.

Food distribution system

Our food distribution system is highly energy-intensive and designed to move food across the continent. The system relies on a complex and interconnected network that is vulnerable to disruption from extreme events. Shifting our focus to supporting local food systems may increase energy efficiency and support local farmers. Researchers are looking at ways to improve the flow of food between where it is produced to where it is consumed. The upper Midwest region is one of the study focus areas.

Impacts on communities

The Agriculture Working Group explored the issue of climate impacts on farmers, farm workers, food safety, and other communities. Volatile weather patterns, extreme rain events, and disruption of farm operations all increase the health risk and anxiety associated with farming in Wisconsin. As the climate warms, heat and humidity will elevate the risk of heat stress, heat exhaustion, heat stroke and other impacts on farm workers, including

A shift toward rotational grazing lowers the carbon footprint of the system by reducing grain needed for livestock and increasing stored soil carbon. Photo credit: WDNR

migrants and immigrants, older workers, and children.

Climate change is also decreasing the safety of our food supply with the increasing exposure to new diseases, pests, and food pathogens due to standing water, flood conditions, and storing grains in humid conditions. With extreme weather becoming more common, the food production systems that support a thriving economy are increasingly at risk.

Solutions

Promote effective conservation practices and adaptations

Increase continuous living cover on agricultural lands to slow flood waters and prevent water pollution

Promote rotational grazing of livestock and cropping system management so that less grain is required for animal feed

Improve nutrient and manure management practices to reduce liquid manure storage and better align nutrient application rates with plant nutrient needs

Avoid grassland or natural vegetation conversion to row-crop production or urban development

Minimize water use and encourage water infiltration on agricultural lands

Accelerate efforts to reduce phosphorus and other nutrient runoff through total maximum daily load and programs and other watershed efforts

Learn more

The **Agricultural Working Group** considered these issues, impacts, and solutions. Their webpage contains more in-depth resources that discuss how agriculture can increase carbon storage and reduce its contribution of greenhouse gases. There is also information on the direct impacts to major agricultural sectors, including livestock, grain, specialty crops, orchards and vineyards, and pasture.

FORESTRY

Wisconsin's forests contribute to the state's well-being ecologically, socially, and economically. Wisconsin's Tribal Nations depend on healthy forests for cultural uses, forest products, and as a home for all related beings. Winter has warmed about twice as fast as other seasons in Wisconsin over the past few decades, leading to a variety of impacts on both rural and urban forests.

Warmer winters

In Northern Wisconsin, where most of Wisconsin's forests are located, warmer winters reduce snowpack that insulates trees and other organisms. Warmer winters also severely limit or disrupt forest operations such as harvesting and transportation that rely on frozen ground. The warming trend also creates less lethal conditions for pests and diseases, which can spawn more generations per year and spread further geographically to attack a larger area.

These impacts can help tip the competitive balance in forests from species like native boreal trees towards southern species that are better able to take advantage of the longer growing season. For example, red maple is projected to increase in Northern Wisconsin over the next century, while at the same time white spruce is projected to decline. The Wisconsin forestry community can use the **Climate Change Tree Atlas** to understand where species might find suitable habitat by the end of the century. The **Northern Institute of Applied Climate Science** used the atlas to create handouts for seven regions in northern Wisconsin and three in southern Wisconsin that provide information on species projections for those areas. Vulnerability assessments created by the Forestry Working Group bring together the best information on the major risks and vulnerabilities for forests in Wisconsin by the end of the century.

Increasing deer herds

One surprising but substantial impact of warmer winters is the increase in deer herds. Even though white-tailed deer are one of the most abundant large mammals in North America they are not as well adapted as other large mammals, like moose and caribou, to surviving severe winters. In order to survive winters in northern parts of their range, deer often migrate seasonally to dense conifer stands, termed 'deer yards,' that offer protection from winter elements. With less severe winters in Wisconsin, deer are migrating less and more are surviving the winter. Larger numbers of deer are browsing on understory plants, including sensitive species, and having a big impact on forest regeneration.

Extreme weather events

More of our rainfall is being delivered in large storms that cause a great deal of damage in forests through flooding, erosion, and deposition of nutrients and invasive species seeds. They also cause considerable damage to infrastructure on forest land, such as roads, trails, culverts, bridges, and campgrounds.

Derechos, or severe straight-line wind storms, are another type of extreme event that may become more frequent in the future. In 2019, a derecho hit northern and north-central Wisconsin, including the Chequamegon-Nicolet National Forest. It caused extensive damage to the area's forests and stranded campers. As the area rebuilds, there are opportunities to restore area streams and replant in a way that will make the forest more resilient to a warmer climate.

Summer droughts and longer growing seasons

Summer precipitation in northern Wisconsin has decreased in recent decades. This stresses forests and makes them more vulnerable to wildfire, pests, and disease. Longer growing seasons are also increas-

ing the risk for wildfires by allowing more plant growth. Vegetation also dries out at a faster rate in the spring and summer with reduced snowpack and earlier springs. These factors, combined with warmer air temperatures, are increasing our vulnerability to wildfires. While prescribed fires could help, it is becoming increasingly difficult to find a safe window to use them as the climate changes.

Forest management and the rural economy

Most of the forest management in Northern Wisconsin occurs during winter because loggers must operate heavy machinery on frozen ground or deep snow to avoid damaging wetlands and sensitive soils. Wisconsin's winters have been warming rapidly over the past several decades, meaning the reliable operating window has been shrinking steadily. Loggers are forced into narrower timeframes to complete their work and uphold their contracts, wood products mills are left with shortages during warm winters, and forests that used to be accessible for management are now open less reliably. This is a major issue for the forest products supply chain and the forest economy in our state.

The Forestry Working Group is developing education programs to help loggers and forest managers understand the changes that are occurring and to anticipate ways to adapt. Pilot research is underway to create a "frozen ground alert system" that might be equivalent to a wildfire risk system. Foresters and land management agencies are becoming more flexible and creative with logging contracts to ease the burden on loggers. More help is needed, such as innovations in harvesting practices, and more collaboration between mill owners, loggers, agencies, and townships that manage forest roads.

With most of Wisconsin's forests located in rural areas, climate-focused management will ensure rural lands' economic productivity and could have a ripple effect, benefiting long-term forest ownership as well as mills and secondary wood-using companies.

Impacts to culturally important species

Tribes are recognizing that extra attention may be necessary to help culturally significant species like paper birch adapt to changing conditions. Tribes are working with the US Forest Service and other partners to gather information about the current status of paper birch across the Ceded Territories and are experimenting with different management practices. With the guidance of tribal

White pine reserves in clearcut show composition and structure. American Legion State Forest, Oneida Co., Wis. Photo credit: Ron Eckstein

"The main thing we learned was that you need to have your emergency response plan ready and everyone needs to be prepared for major storms."

–John Lampereur, District Silviculturist, Chequamegon-Nicolet National Forest
Read the full interview

[on climate impacts in northern Wisconsin]

"Climate change is also affecting the logging industry. Warmer winters means fewer days when roads and swamps are frozen enough to support heavy equipment and trucks. Skidders get stuck and loggers are not able to access wooded areas to get their product out. Changing winter temperatures becomes a pocketbook issue."

–Cathy Techtman, Environmental Outreach Specialist, UW-Madison Division of Extension
Read the full interview

Diversity and reserve trees in jack pine plantation. Northern Highland-American Legion State Forest, Vilas Co., Wis. Photo credit: Ron Eckstein

"Warmer winters are the biggest impact we've seen. We are always struggling with having enough frozen days to log and winters have been starting late recently. In 2020, the first hard frost wasn't until the middle of February. And then, when it did get cold, it got really cold and it was too cold to work. Low, marshy areas where we need frost to work, never had frost. And that's been pretty common in the last couple of years. We might get a little cold weather in the beginning of the year but never quite enough cold weather, prior to snow, to get frost in the areas that we need frost."

–Scott Koerner, Koerner Forest Products, Oshkosh, Wis.
Read the full interview

leaders, elders, and harvesters, the Great Lakes Indian Fish and Wildlife Commission has developed **climate change vulnerability assessments**. They are designed as resources for tribes and their partners to respond to climate change in the Ceded Territories and help tribes maintain their treaty rights. Of the ten species rated as extremely vulnerable to climate change, three trees made the list – tamarack (*mashkiigwaatig*), northern white cedar (*giizhikaatig*), and balsam fir (*ininaandag*). All these trees are at the southern end of their range in the Ceded Territories. Two other trees listed as highly vulnerable are paper birch (*wiigwaasaatig*) and black ash (*baapaagimaak*). A non-climate stressor for paper birch is its popularity in home décor, which has led to harvest restrictions and has negatively impacted the ability of tribal members to use the tree for medicine, in traditional ceremonies, canoe building, and harvesting.

Urban forests

Large canopy trees can play a big role in helping urban areas become more resilient to climate change. A diverse tree canopy, both in terms of age and species type, can not only make cities more resilient as the climate changes, but can also cool urban landscapes and capture and slow runoff during extreme rain events. Parts of urban areas are difficult environments for tree growth due to the density of development and historic pollution. Most available soil is compacted, heavily disturbed, and may contain high amounts of salt or other contaminants. And the prevalence of impervious surfaces like streets, parking lots, and sidewalks prevent trees' access to water, nutrients, and structural support.

Despite these challenges, there is hope. There are species of trees that can thrive in a range of urban climates created by cityscapes, and cities have diverse landscapes. In addition, most urban trees grow in privately-owned residential areas (69 percent) and surveys have shown that people value tree canopy. An educated and proactive public could make a huge difference by planting trees on their property or supporting municipal funding for urban forestry.

Studies are also showing a disparity in the location of tree canopy in some cities. In Milwaukee, for example, higher income neighborhoods have more trees than areas with renters and minority homeownership. Tree-planting decisions by municipalities could make a difference in those areas.

Wisconsin forests can mitigate climate change

Forests cover nearly half of Wisconsin. They provide a unique op-

portunity to address climate change because they can both reduce concentrations of greenhouse gases while simultaneously providing essential social, environmental, and economic benefits. Forests are a natural carbon sink that absorb 10-15 percent of our nation's greenhouse gases. Forests in the upper Midwest, including Wisconsin, have been a steadily growing carbon sink for decades. But with changing conditions and additional stressors brought about by climate change, we must work to ensure that Wisconsin's forests continue to store carbon.

New markets are becoming available for forest landowners to earn credit for the carbon stored by their woods. The Governor's Task Force on Climate Change recommended making carbon a recognized forest product so that carbon can be a focal point for management, alongside wood products, clean water, and wildlife habitat. The Nature Conservancy and private companies are piloting some of these market mechanisms. Some forest carbon projects in Wisconsin are already certified for the California Air Resources Board Compliance Offset Program, for example.

Tribal Nations are also considering enrolling their land in forest carbon markets. Groups like the National Indian Carbon Coalition exist to help tribes enter these markets without the substantial upfront costs and technical barriers.

Taking a long view on private lands

Private landowners have an important role in keeping Wisconsin's woods healthy. More than half of the forests in the state are owned by private landowners. Just like forests grow and develop over decades, climate change will also play out over the rest of the 21st century. Forest landowners are already used to making decisions today that they might never directly benefit from by planting trees or working to restore an old woodlot. Climate adaptation will require that same mindset.

Solutions

Active management can help forests adapt to climate change, but the effectiveness and sustainability of many practices are still being studied. The Forestry Working Group webpage contains resources and adaptation tools that can help forest managers make decisions about adaptation. The link to the **Forest Service climate hub** has information on pilot projects and adaptation tools.

"We know that densely populated urban areas have this urban heat island effect, and trees in urban spaces contribute to lessening these effects. They create shaded environments on concrete surfaces to reduce the felt temperature. Trees can also create canopies that intercept rainfall, which reduces the effects of erosion and compaction from extreme rain events… Research has shown that trees can be linked to reduced crime rates and improved overall human health. The health improvements cover mental health, recovery from operations, and reduced reliance on medications. The medical field is more commonly recommending time in the outdoors and green spaces. Those are good reasons to justify increased forestry budgets and increased planting."

–Nathan Schuettpelz, Registered Consulting Arborist, Wachtel Tree Science
Read the full interview

Climate change is reducing the safe window to use prescribed fires. Photo credit: Matt Zine

Keep forests as forests

Support holistic deer management

Expand forest cover in both urban and rural areas

Support climate-focused planning and management

Support Wisconsin Wood Product Utilization

Learn more

The **Forestry Working Group** considered these issues, options to increase resiliency, and ways to mitigate climate change through forest regeneration. Their webpage contains links to the effects of deer browse on forests, documents and handouts for private landowners and forest managers, videos, and links to more resources.

PLANTS AND NATURAL COMMUNITIES

Wisconsin's native habitats are already under stress. Some habitats have been completely destroyed through development or cultivation and others are now competing with non-native invasive species. With less severe winters in Wisconsin, deer are migrating less and more are surviving the winter. As a result, larger numbers of deer are browsing on understory plants, including sensitive species. Fire suppression has degraded many of the ecosystems that depend on periodic fire to maintain their diverse plant species and unique habitats. Today, managers of natural areas use prescribed fire to restore ecosystems and manage invasive species, but impediments to this important practice persist. Stormwater runoff laden with nutrients (fertilizer, manure) and sediment also threatens aquatic and wetland communities by encouraging growth of invasive species and suppressing growth of desirable species. These non-climate stressors continue to increase across the state and are making plants and natural communities less resilient to climate change.

Climate change impacts are amplifying non-climate stressors. Increasingly frequent and intense storms are adding to the burden of nutrients and sediment on wetlands and water bodies. A change to a warmer and wetter overall climate is disrupting the window for prescribed fire in fire dependent ecosystems, thus diminishing habitats and the species that rely on them. At the other extreme, summer droughts and longer periods between rain events can dry soils and wetlands and lower groundwater. Milder winters, longer growing seasons, increased atmospheric carbon dioxide and longer drought periods favor germination and spread of both invasive and aggressive native species. Milder winters result in reduced snowpack, making trees more vulnerable to deer browse and from freeze-thaw damage to roots. Precipitation in the winter is falling more frequently as rain or freezing rain on frozen ground. This worsens water quality by allowing the transport of manure and road salt into nearby waterways and wetlands.

Climate change has amplified these non-climate stressors to the point where once-diverse habitats are simplified, associated wildlife species diminish or disappear, and important human benefits are lessened, such as fewer wetlands to absorb floodwaters. Species extinction rates are accelerating and more species may be added to Wisconsin's list of threatened and endangered species, potentially increasing regulatory burdens.

Impacts to iconic and biologically important species

Certain iconic and biologically important tree

species, such as red pine and white pine, are threatened by climate change, impacting both the large number of wildlife species that use them and the timber industry. Sustainable harvests of culturally important species, such as wild rice, ginseng, and blueberries, are becoming limited. Pollinators, like bees, butterflies, and moths that play a key role in helping plants produce fruits and seeds are diminishing. As the climate continues to warm, the ongoing loss of pollinators can have untold impacts on our native habitats, agricultural production, forestry, and food systems.

Resisting, accommodating and mitigating climate change impacts on Wisconsin's native plants and natural communities can address social and environmental justice issues by ensuring harvests of culturally important species and continuing opportunities for subsistence hunting and fishing. Restoration of natural systems can also help minimize flooding of lower income populations living in floodplains and ensure sustainable livelihoods for smaller farmers.

Climate adaptation demonstration sites

The Plants and Natural Communities Working Group is working to evaluate local-scale climate change impacts and to assess the effectiveness of climate adaptation actions. For example, in 2020, the Wisconsin Department of Natural Resources, State Natural Areas Program worked with the Plants and Natural Communities Working Group and the Northern Institute of Applied Science to formally assess how the Rush Creek State Natural Area may be affected by climate change. The project included evaluating current management goals and identifying possible adaptation actions.

The Rush Creek State Natural Area comprises over 2,800 acres of exceptional quality dry prairie, upland oak forest/savanna, and floodplain forest along a two-mile stretch of the Mississippi River, and is owned and managed by the Wisconsin Department of Natural Resources. This site provides vital habitat for almost fifty rare and declining native species, including terrestrial and aquatic invertebrates, reptiles, birds, small mammals, fish, and plants.

Because intact, diverse ecosystems show the greatest resilience to climate change, site managers aim to restore and reconnect the two-mile stretch of remnant dry prairies that are overgrown with woody vegetation and invasive species, restore oak savanna and woodlands by thinning undesirable trees and applying prescribed fire, and convert cropland into native prairie and savanna using diverse 'climate

An organized statewide network of local partnerships can significantly help maintain and enhance Wisconsin's natural communities as the climate changes. Kevin Thusius, Director of Land Conservation for the Ice Age Trail Alliance, visits a site along the Ice Age Trail. Photo credit: Ice Age Trail Alliance

"Planting native plants is one of the most important things a landowner can do. Landowners will be amazed and delighted with the response from native bees, butterflies, and birds. Supporting state-level and international conservation efforts is also important."

–Craig Thompson, Chief of Program Integration, WDNR
Read the full interview

ready' seed mixes. The crew has adjusted their current approach to prescribed burning by having burn breaks, equipment, and gear prepared well in advance so that when suitable burn windows open, the burn crew can mobilize and execute burns immediately. Being flexible by burning in non-traditional seasons is another way the crew is adjusting. This important collaboration is helping advance adaptation science and management.

Restoring natural communities

Because healthy and diverse habitats can better absorb the stresses of a rapidly changing climate, there is an urgent need to increase "boots on the ground" to restore and protect vulnerable native habitats. Without this effort, hunting, fishing, hiking, bird watching, and other outdoor recreational opportunities will diminish as habitats degrade. Opportunities for subsistence hunting and fishing will also diminish. Restoration of native habitats will help protect native habitats, ensure opportunities for subsistence harvesting, increase access to public lands for all of Wisconsin's communities, and support a vibrant tourism economy.

The work to restore and monitor native habitats would be enhanced through a statewide network of local cooperative partnerships to leverage shared staff, expertise, equipment, outreach, and grant funding. For example, the Rush Creek State Natural Area restoration partnership is using decision-support tools like *The Nature Conservancy's Conserving Natures' Stage* to identify climate-change-informed priorities and adjust water management. The Nature Conservancy is also providing a new resilience mapping tool to help identify climate resilient landscapes for preservation. An organized statewide network of local partnerships can significantly help maintain and enhance Wisconsin's natural communities as the climate changes.

Solutions

Provide incentives to restore land and promote native plants and natural communities

Support prescribed fire efforts

Support holistic deer management

Detect and control new non-native invasive species

Learn more

The **Plants and Natural Communities Working Group** is promoting science-based, climate adaptation-focused management of plants and natural communities. Their webpage contains links to climate symposia and workshops, climate adaptation demonstration sites, and climate vulnerability assessments for Wisconsin's native plant communities.

WILDLIFE

Wisconsin is world-renowned for its diversity of wildlife. Our outdoor recreation and tourism economy, which is vital to rural communities, depends on access to this diversity of species. To Tribal Nations that live within our state boundaries, wildlife and subsistence hunting and gathering are essential to their spiritual, cultural, and physical well-being.

Climate impacts like more intense summer droughts and increased flooding reduce critical habitat and food sources for wildlife, especially wetland-dependent species like waterfowl. Warmer winters with reduced snow cover, new pests, and changing water levels are stressing wildlife.

Climate impacts are not the only threats to wildlife. It is increasing the risk and harm already happening through habitat loss and degradation,

pollution and disruptions from non-native species. Natural resource managers are concerned about these multiple threats and are working to change habitat management to provide food and cover for wildlife and align restoration efforts with expected future climate conditions.

Vulnerability assessments

Not all wildlife will "lose" in the face of these threats. Work on vulnerability assessments by natural resource managers and tribal governments are identifying different species and their vulnerability to climate change. Keystone species, rare species, and economically important species are being studied.

Protecting Wisconsin wildlife by identifying and supporting climate-vulnerable species and supporting habitat will help address some of the more harmful impacts of climate change in the state. Effective strategies to help wildlife adapt to rapidly changing conditions will not only benefit cherished activities in Wisconsin, including outdoor recreation, tourism and our hunting tradition. It is also an environmental justice issue by protecting the treaty rights of Tribal Nations to hunt, fish and gather in the upper third of Wisconsin.

Changing migration patterns

Climate change is leading to longer growing seasons due to earlier springs, milder winters, and delayed falls. In response, many species are attempting to shift their ranges and changing dates of migration to adjust to the changing climate. Reducing or limiting barriers to wildlife movement across private land and working with private landowners near public lands to provide buffer zones will be an important part of assisting that migration. Providing compatible wildlife use in cities through green infrastructure would also help.

Climate impacts on wildlife

This section presents a brief overview of impacts to a few keystone species to illustrate how a warming climate is stressing wildlife and their habitats in Wisconsin.

WILD RICE

Healthy stands of wild rice provide important benefits to many forms of wildlife, including migratory waterfowl, for food and habitat, and are important recreational areas. Wild rice is also critical to the Ojibwe Tribes' spiritual, cultural, and physical well-being. It

"Rush Creek State Natural Area is one of the "crown jewels" in the Driftless because it supports a large block of relatively unfragmented, high quality forest. Many area-sensitive, forest interior species, including Wood Thrush and Cerulean Warbler will breed in small, fragmented forests in southern Wisconsin, but they are subject to a host of problems including nest parasitism and predation. These birds have the greatest reproductive success in big blocks of forest like those found at Rush Creek.

–Craig Thompson, Chief of Program Integration, WDNR
Read the full interview

Supporting habitat will help address some of the more harmful impacts of climate change in the state. Rush Creek State Natural Area comprises over 2,800 acres of exceptional quality dry prairie, upland oak forest, savanna, and floodplain forest along a two-mile stretch of the Mississippi River. Photo credit: Eric Epstein

"All things are connected. It's a great ecological perspective but it's also an Ojibwe perspective. Wild rice provides food for other wildlife species… For the people I work for, the cultural use of this resource and the effects that climate change will have on their culture are critical and need to be understood… Tribes are seeing the climate impacts to wild rice now but it's not enough to prevent harvest. The impacts are having the immediate effect of reducing the rice harvest. The persistence of rice over the long term in these areas is unknown."

–Jonathan Gilbert, Biological Services Director, Great Lakes Indian Fish and Wildlife Commission
Read the full interview

"Wild rice is highly important to us. It is part of our migration journey and is what prompted us to live where we are… We would know if we were on the correct path when we would see an island in the beginning and end of our journey that looked like a turtle. At the end of our journey, at the final stopping place, that is where we would find the food that grows on top of the water. And that is wild rice."

–Edith Leoso, Tribal Historic Preservation Officer, Bad River Band of Lake Superior Tribe of Chippewa
Read the full interview

Wild rice is one of the species most vulnerable to climate change. Photo credit: WDNR

is being highlighted to include the perspective of Ojibwe tribes in Wisconsin.

Wild rice is in decline in Wisconsin and is one of the species most vulnerable to climate change according to the Great Lakes Indian Fish and Wildlife Commission's assessment of species that are important to their member tribes. Climate impacts to rice beds include fluctuation water levels, extreme rainstorms that uproot young rice plants, hot dry summers that reduce pollination, warming water temperatures and hot and moist conditions that are ideal for fungus and disease that kill the plants. The Ojibwe Tribes are still able to harvest the plants but the harvest has fluctuated in recent years.

The Department of Natural Resources has published a **Strategic Analysis of Wild Rice Management in Wisconsin** to help address its decline over the past century. Their work, in coordination with tribal governments, are of critical importance to the future of wild rice in Wisconsin.

COMMON LOONS

Warmer air and water temperatures, along with extreme fluctuations in lake levels have occurred in the past twenty years in northern Wisconsin. These weather changes have disrupted loon reproduction by changing the availability of nesting habitat and increasing the risk of intense black fly outbreaks during the breeding season. The black fly outbreaks can dramatically reduce reproduction in common loons by harassing the nesting adults and causing them to abandon their nests. There have also been mass die-offs of loons during the fall

migration on Lake Michigan due to Botulism E toxicity.

Wisconsin is at the southern extent of the breeding range of common loons in the Upper Midwest states and it is not known whether climate change will alter the favorability of Wisconsin to breeding loons into the future. Yet Mike Meyer, retired Wisconsin Department of Natural Resources wildlife toxicology research scientist who has spent twenty-five years studying loons, has hope for the future of loons in Wisconsin. Because they are so popular, there are multiple organizations dedicated to loon education, rehabilitation, protection, and habitat restoration.

Warmer weather has disrupted loon reproduction by changing the availability of nesting habitat and increasing the risk of black fly outbreaks during the breeding season. An adult loon (Gavia immer) with chick. Photo credit: Jeremy Cohen

SNOWSHOE HARES

Snowshoe hares are a critical species for forested ecosystems through Wisconsin. These hares go through a seasonal coat color change from brown in the summer to white in the winter to match a snow-covered landscape. This coat color change is driven primarily by day length. As the days become shorter, hares begin to turn white. The change in coat color is an adaptation that allows hares to better avoid predators in winter. As winters become warmer and the period of snow cover shortens, snowshoe hares are increasingly mismatched with Wisconsin winters that have less and less snow cover. Several studies have shown that hares that are more mismatched are less likely to survive. We are now beginning to see the shift of snowshoe hares out of the central forests of Wisconsin as their range begins to retract northward. Promoting the growth of aspen and alder trees and planting more dense cover can help

"To me, the most impactful ways to help loons in Wisconsin is to protect existing nesting habitat, increase nesting habitat through artificial nest platforms, getting lead fishing tackle out of fishermen's tackle boxes (there are alternatives!), and supporting wildlife rehabilitation efforts."

–Mike Meyer, Wildlife Toxicology Researcher (retired), WDNR
Read the full interview

"What we have seen over the past forty to fifty years clearly has been a pretty significant shift in the climate system. Species are responding to that in a number of different ways … Impacted species encompass not only what we consider the cold or winter adapted species that are moving northward, but also warmer adapted species moving northward and colonizing Wisconsin over the last forty years or so."

–Ben Zuckerberg, Associate Professor, Forest & Wildlife Ecology, UW-Madison
Read the full interview

"These are species that many of us who have grown up in this region are familiar with and expect to see when we go hunting or hiking or photographing. The idea that we are losing these native species is sad to us. For me, Northern Wisconsin without snowshoe hares will feel incomplete, and I think it would be the same to many others…. I have hope because there's an increasing groundswell of people realizing how important this is and because …people like Ben Zuckerberg and I are beginning to come up with creative solutions based on fundamental research and understanding how species respond to climate change."

–Jonathan Pauli, Associate Professor, Forest & Wildlife Ecology, UW-Madison
Read the full interview

"The projections show that ruffed grouse will largely retreat out of a lot of states that are in my region in the next forty years. A lot of that is solely due to climate change but there are a lot of other factors at play here. There's evidence in the scientific literature that we do not have very diverse forest when it comes to species composition and structure. We're not creating the types of habitat that our upland bird species need.… We as public lands managers and private forest landowners just have to be willing to overcome the hurdles presented to us to create good habitat."

–Jonathan Steigerwaldt, Forest Conservation Director, Ruffed Grouse Society and American Woodcock Society
Read the full interview

buffer snowshoe hares from coat color mismatch during winter. The Great Lakes Indian Fish and Wildlife Commission rates the snowshoe hare as highly vulnerable to climate change on their Climate Change Vulnerability Assessment.

WHITE-TAILED DEER

White-tailed deer are perhaps Wisconsin's most important game wildlife species generating billions in economic activity for the state. Fluctuating winter weather, associated with climate change, can have profound impacts on the deer population, and in-turn will require managers to adapt harvest strategies and regulations. For instance, in some recent years extended snow cover into spring has had considerable impact on herd productivity in the North. However, some recent winters have been incredibly mild allowing for herd growth, especially in Northern Wisconsin. Upward trending deer populations can have impacts on sensitive plant species through browsing impacts, adding yet another challenge to managing the deer population.

RUFFED GROUSE

Ruffed grouse are a native bird of Wisconsin that breeds in forests throughout the state. Their "drumming" can be heard during spring as they call out their territories. During the winter months, ruffed grouse bury themselves under the snow, a behavior called "snow roosting." Deep snow allows grouse to seek out this below-the-snow refuge and reduces their stress levels during periods of cold weather, increasing their chances of surviving the winter.

While ruffed grouse populations cycle about every ten years there were concerns in recent years when the population sharply decreased during what should have been the peak of their ten-year cycle. Several recent studies suggest that these declines could be due to changes in forest composition as forests age as well as the loss of snow cover and deep snow. Research is underway to test whether practices like promoting aspen and alder can help buffer ruffed grouse from the loss of snow cover.

KARNER BLUE BUTTERFLY

The Karner Blue Butterfly is an umbrella species for oak savanna, dry prairie, and pine barren habitat throughout much of the Upper Midwest Great Lakes area. Umbrella species are selected for making conservation-related decisions, typically because protecting these species indirectly protects the many other species that make up the ecological community of its habitat. Wisconsin has the best remaining oak barrens landscape in all of the Karner Blue Butterfly's range.

The Karner Blue Butterfly is highly vulnerable to climate change.

As winters become warmer, snowshoe hares are increasingly mismatched with Wisconsin winters. Snowshoe hare picture collected in the field via trail camera showing a white hare on a brown and white background in spring. Photo credit: Taylor Peltier

The loss of snow cover and deep snow due to climate change are stressing ruffed grouse populations in Wisconsin. Ruffed Grouse. Photo credit: Amy Shipley

It is already under stress from habitat degradation and lack of connectivity. The species is dependent on a single host plant as larvae, *Lupinus perennis*, wild lupine.

Creating additional quality habitat and increasing connectivity between protected areas are aiding the species. Private landowners can help by restoring habitat in and around viable populations that occur on protected lands. Since 1995, the Partners program has completed 267 Karner Blue Butterfly projects in Wisconsin. Private lands are a vital part of protecting the butterfly. For example, in 1999, an individual landowner had 24 Karner Blue Butterflies on a relic prairie site. After a decade of habitat work, an estimated 8,587 Karner Blue Butterflies were found in 2012, the largest single population in the state for the year.

Solutions

Adjust and reassess harvest regulations for climate-vulnerable species

Implement habitat management changes to provide food and cover and align with expected future conditions

Accommodate water control infrastructures to account for periods of high and low water availability

Promote wildlife habitat conservation on lands outside of protected areas with opportunities for private landowners to engage in wildlife conservation

Learn more

The **Wildlife Working Group** considered these issues, impacts, and solutions and provide more in-depth information on their webpage.

"For the communities that are living here there's a sense of holding your breath right now. The dams that were damaged in 2018 are still not repaired. You get a hard rain now and people get in their cars and drive to high ground."

–Tim Hundt, District Representative, Wisconsin's 3rd District, Congressman Ron Kind
Read the full interview

[From the Driftless Writing Center project]

*"**Stories from the Flood**, offers local residents a platform for working through their collective experiences, while providing an important foundation for regional planning about future flooding in the Kickapoo River and Coon Creek watersheds."*

–Caroline Gottschalk Druschke, Assistant Professor, English Department, UW-Madison, Tamara Dean, Board member, Driftless Writing Center, and Margot Higgins, Lecturer, UW-La Crosse
Read the full interview

Story Spotlight
Flooding in the Driftless Area

The Driftless Area in Wisconsin is a beautiful landscape characterized by rolling hills and deep valleys. When the land was settled and the prairies and forested areas were transformed into farmland, exposed soil in this hilly region washed off into the valleys during storms and filled streams with sediment. In 1933, Coon Valley became the first watershed study area in the United States designed to improve farm productivity, develop sustainable new farming methods, and improve conditions in local streams and rivers.

Lessons learned in the Coon Creek Watershed in the '30s led to the creation of the Soil Conservation Service and farming practices that helped turn around the ecological disaster of the Dust Bowl. Although many of those soil conservation practices are still in place in the area, land use is changing. Extreme storm events have become more frequent in the past decade, Wisconsin's wettest ever recorded. Communities in the region have come together to help each other, something they have done more and more as extreme storms have become more frequent.

Impacts on communities

One extreme storm event, on August 27-28, 2018, broke records. According to the National Weather Service, thunderstorms and high winds persisted from Monday afternoon into Tuesday morning. People had to be evacuated and rescued. Flash floods damaged highways and dams that were put in place to address persistent flooding in the area. The damage to infrastructure was severe enough to get the attention of federal agencies.

These are rural, isolated, under-resourced communities dealing with floods in many cases without federal, state, and local support. Communities have come together, informally, to aid each other through their recovery and are working on the difficult decisions about flood recovery two years on.

Impacts on agriculture

During the 2018 storm, agricultural producers in the region lost valuable topsoil and sustained damage to farm structures that slowed or halted production. Some producers credit the embrace of conservation practices with helping them withstand the storms,

practices including contour strips, grassed waterways, and pastured grazing. Other producers are still struggling with the loss of buildings and topsoil and frequently flooded fields.

Impacts on fisheries

While conservation practices are still being used in the region and are working to reduce the loss of soil from agricultural lands, more frequent extreme storms are causing concern that more may need to be done. Meanwhile, the legacy of sediment deposits from the early years of settlement is still impacting the streams. Trout Unlimited is one group that is working to restore and maintain the fish habitat. Their work benefits not only recreational fishing enthusiasts but also reduces flooding, improves conditions for agriculture, and brings $1.6 billion annually to the region.

Gilbert Creek in Dunn Co., Wis. Photo credit: Duke Welter

Impacts on plants and natural communities

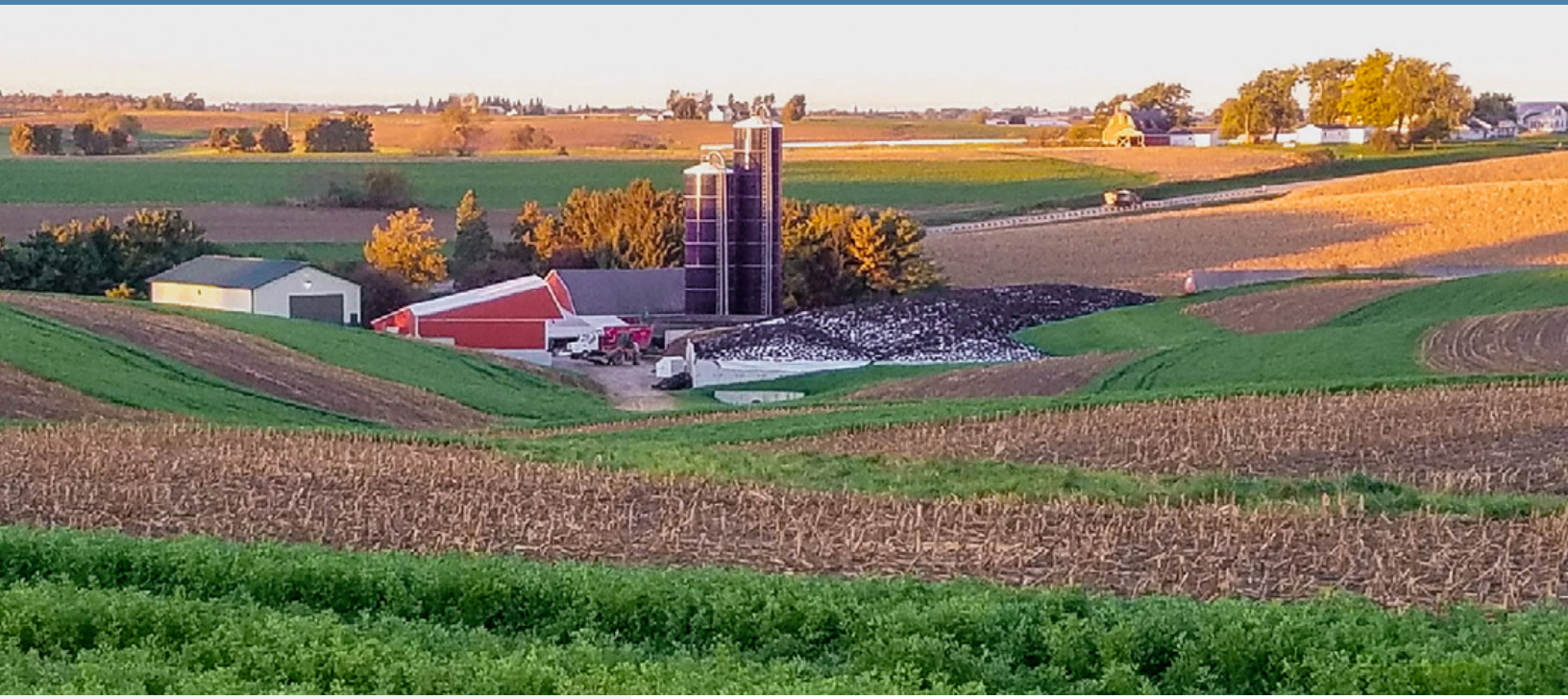
While the Driftless Area faces many climate challenges, it also provides vital habitat for almost fifty rare and declining native species, including terrestrial and aquatic invertebrates, reptiles, birds, small mammals, fish, and plants. It is home to Rush Creek State Natural Area that comprises over 2,800 acres of exceptional quality dry prairie, upland oak forest/savanna, and floodplain forest along a two-mile stretch of the Mississippi River. It lies within the

"We can quantify the losses from milk production and the cost to clean up but the real unknown and the largest expense was the amount of topsoil we lost in that kind of event..."

–Jack Herricks, Herricks Dairy, Cashton, Wis.
Read the full interview

"Since 2007, we have encountered a series of high intensity rain events that have damaged agricultural lands, overwhelmed conservation practices, and flooded communities. At the same time, dramatic increases in corn and soybean prices have led to the loss of conservation practices that farmers had been using. We have also encountered an increase in industrial farming…With habitat work and improved land use in the 21st century, classified trout water in the Driftless Area has risen from 4,000 to over 6,000 miles."

–Duke Welter, Driftless Area Restoration Outreach Coordinator, Trout Unlimited in Viroqua
Read the full interview



Herricks Dairy Farm in Cashton, Wis. Photo credti: Jack Herricks

"The real value of Rush Creek, from a bird standpoint, is its relatively remote location and its big blocks of canopy forest. This habitat is becoming more important with all the stressors birds are facing."

– Craig Thompson, Chief of Program Integration Bureau, WDNR
Read the full interview

Mississippi Flyway, providing important stopover habitat for this major migratory corridor.

The area illustrates one of the most important principles of natural area management in the age of climate change: large and connected landscapes with diverse microhabitats are more resilient to climate change.

Abundant plants and animals occupy the aquatic, wetland, upland, forest, savanna, and prairie habitats in the area. These species can shift through time and space in response to changing environmental conditions. Natural communities can recover from large disturbances as abundant plants and animals repopulate and rebound.

Natural area managers at Rush Creek are using prescribed fire to suppress brush invasion in prairies and activate drought- and frost-tolerance in native plants. Managers are also considering ways to enhance genetic diversity of the plant communities through introduction of seeds from proximal sites as a way to build climate resilience. Research is still needed to identify appropriate seed sourcing guidelines. In the meantime, Rush Creek managers will open up wooded corridors between prairie patches to promote local gene flow as well as create habitat corridors for prairie invertebrates.

Climate resiliency mapping tool

For those who protect and manage natural lands, it can be hard to find a place to start to address climate change. One approach

that can help comes from The Nature Conservancy, who created a new mapping tool to identify places that give plants, wildlife, and habitats the best chance of enduring as our climate changes. These areas are geodiverse and connected, helping to maintain healthy ecosystem processes and giving species many options to meet their life needs, such as finding food and locations for nesting.

What is being done to help communities

Advocates from the area are working together with county, state, and federal agencies to find solutions and funding to make them more resilient to future storms. They hope the work they are doing today can benefit not only their communities, but also other communities facing repeat flooding due to climate change. For example:

- Federal agencies like the Natural Resources Conservation Service and Environmental Protection Agency are studying the situation and will be developing recommendations for infrastructure improvements and strategies to improve water quality.
- Vernon and Monroe Counties have put together advisory groups to find solutions.
- Vernon County has developed flood warning and emergency action plans.
- Monroe County, Wisconsin's Green Fire, and many other partners are collaborating to create a "climate readiness" plan to help county residents adapt to flooding and other challenges from climate change through climate-adaptive forestry, agricultural practices, and natural infrastructure. Many WICCI Science Advisory Board members are part of this project.
- UW-Madison professors from various departments are working with local partners to develop workshops to help with flood planning and ways to create more opportunities for perennial grassland farming, a practice that helps increase infiltration and decrease runoff during storm events.
- Advocates from the area are working together with county, state, and federal agencies to find solutions and funding to make them more resilient to future storms.

Learn more

Community Sustainability Working Group

Agriculture Working Group

Forestry Working Group

Plants and Natural Communities Working Group

Wildlife Working Group

Fisheries Working Group

[regarding The Nature Conservancy Climate Resiliency Mapping tool]

"Who benefits? First and foremost, wildlife and habitats will benefit. As the climate changes, species will be able to move across the landscape and find suitable places to thrive. People will also benefit. Nature has always been our life support system, and this becomes ever more important as our climate changes and people and communities are stressed."

–Nick Miller, Science & Strategy Director, The Nature Conservancy in Wisconsin
Read the full interview

"I changed my view from looking at the past and managing for pre-settlement conditions to looking at the future and adapting to conditions we anticipate with climate change. We are seeing the most need for change in the central and northern parts of the state… We are planning for a warmer and drier future in that region… [that] will hopefully make the forest more resilient."

–Kevin Thusius, Director of Land Conservation, Ice Age Trail Alliance
Read the full interview

WATER CHAPTER

Big cultural shifts are needed to protect Wisconsin's water resources

Windy Lake Michigan, 2015 Great Lakes Photo Contest. Photo credit: Eve Schrank

INTRODUCTION

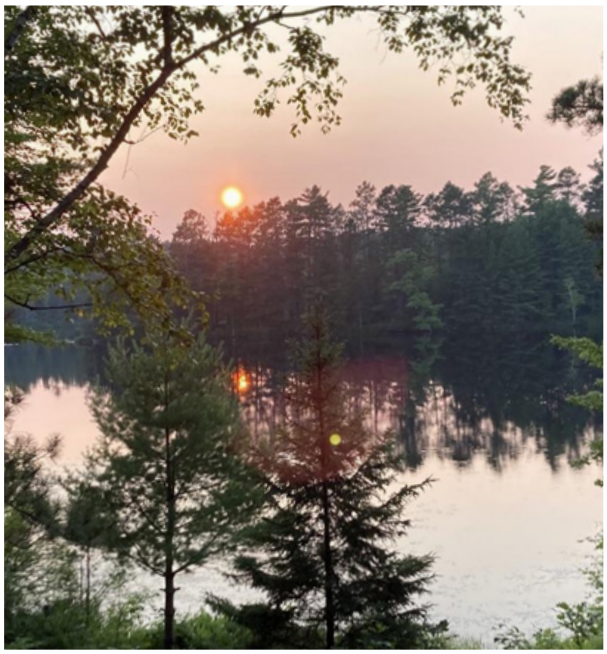
Wisconsin industry, communities, plants, wildlife, and fisheries depend on the quality of our 84,000 miles of rivers and streams, 15,000 lakes, 5.3 million acres of wetlands, and groundwater resources. The Mississippi River and two Great Lakes, Lake Superior and Lake Michigan, border Wisconsin, providing 1,000 miles of Great Lakes coastline. These water resources add to our economy and provide unique natural resources. We are already seeing major impacts to these water resources because of climate change.

The topics covered in this chapter include issues, impacts, and solutions in the areas of water resources, fisheries, Great Lakes, and the Mississippi River. These topic areas are covered in more depth

on WICCI Working Group webpages with links provided at the end of each topic section. Here is a brief highlight of the issues covered in this chapter.

Water resources

Warming temperatures and changing precipitation patterns are leading to more harmful algal blooms, reduced water quality, changing aquatic ecosystems, loss of ice cover, alternating periods of flooding and drought. Despite these challenges, steps can and are being taken to make Wisconsin's water resources more resistant and resilient. Our expectations and regulations for managing the areas around our lakes, rivers, and wetlands need to shift to accommodate this rapidly changing climate.



Warming temperatures and changing precipitation patterns are impacting water resources in Wisconsin. Ross Allen Lake, Vilas Co. Photo credit: Dea Larsen Converse

Fisheries

Fishing is an important part of the culture and economy in Wisconsin. Lakes, streams, and rivers provide vital tribal subsistence, commercial, and recreational fisheries worth nearly $2 billion annually to the state. As water temperatures warm, the fish species that can live in our waters will change. More frequent extreme storms and heat events are already damaging fish habitat and stressing fisheries. These impacts will intensify as the climate continues to warm.

Great Lakes

Wisconsin is bordered by two Great Lakes, Lake Superior to the north and Lake Michigan to the east. It is hard to overstate how influential the Great Lakes are to the region. They not only support the local economy; they also greatly influence the weather. The area along the Great Lakes is warming faster than the general pattern of warming across the state, leading to physical changes to the Great Lakes that are already being felt. Water level fluctuations, changes to water temperature and lake mixing, and ice cover changes are impacting coastal land, habitats, water quality, and iconic species like walleye and wild rice.

Mississippi River

Climate change is increasing variability in river flows in the Mississippi River. In high water years, the excessive volume of water damages infrastructure and significantly reduces the reliability of river transportation. Natural resources like aquatic plant populations, a critical food source for hundreds of thousands of migrating waterfowl, and floodplain forests have suffered. High water years also increase the delivery of sediment and nutrients to the river and backwater areas, which increases the prevalence of harmful algal blooms and contributes to the expansion of the Gulf of Mexico hypoxic zone.

Key points

- Warming temperatures and changing precipitation patterns are decreasing water quality and changing aquatic ecosystems.
- Warmer water temperatures and increasing variability in ice on and off dates, duration and thickness are changing the fish species that can live in Wisconsin's waters. Cool- and cold-water fish are particularly at risk. Loss of these resources will have spiritual, cultural, and health impacts to Wisconsin's eleven tribes and other subsistence fishers.

- Warming waters in the Great Lakes are impacting lake ecology, fisheries, and water-quality based recreation. Both increasing precipitation and drought are leading to extreme lake level fluctuations in Lake Superior and Lake Michigan that impact both habitats and structures built along the lakeshore.
- A wetter climate is increasing the volume of water flowing in the Mississippi River and impacting critical backwater habitat and recreational fishing opportunities.

Solutions

Water resources support all aspects of Wisconsin life, but are threatened by climate change. To help solve these water challenges, the following is a summary of the solutions that have been proposed by the working groups featured in this chapter. More information on these solutions and the issues and impacts covered in the individual sections can be found on the working group web pages available through links at the end of each section.

Manage watersheds to reduce flood hazards and slow sediment and water movement in tributaries

Invest in flood risk reduction practices and pre-disaster mitigation programs that help communities address local flood risks and avoid catastrophic losses

Manage fisheries and make them more resilient to climate impacts by preventing overharvest, protecting productive populations, and preserving stronghold populations of brook trout and other important fisheries

Conserve water and encourage water infiltration to reduce the impact of both droughts and floods

WATER RESOURCES

Warming temperatures and changing precipitation patterns affect Wisconsin's wealth of water resources, including lakes, streams, wetlands, and groundwater. The changes are leading to more harmful algal blooms, degraded water quality, changing aquatic ecosystems, loss of ice cover, flooding, and drought. Despite these challenges, strategies can and are being taken to make Wisconsin's water resources more resistant and resilient.

Water levels

Long term records suggest that in general, groundwater and lake levels in many areas of Wisconsin fluctuate on a near-decadal cycle with lows occurring after multiple years with little rainfall and highs after many years of above-average rainfall. These long-term fluctuations are natural and important for aquatic ecosystems, but they may change if there is a shift in the balance between evaporation and precipitation with a changing climate.

Average precipitation and storms delivering large amounts of water in short periods of time are increasing in Wisconsin, and both can result in flooding problems. June 2020 photo showing flooded homes along Fish Lake's former western shoreline. Photo credit: Ted Bier

Average precipitation and storms delivering large amounts of water in short periods of time are increasing in Wisconsin, and both can result in flooding problems. Areas with permeable soils are especially vulnerable to groundwater flooding,

which occurs when the water table comes above the land surface after periods of higher-than-average precipitation. This type of flooding occurs around lake shorelines, in wetlands, and in other areas where the water table is near the surface.

Stream flooding associated with large storms is also a concern, causing damage to infrastructure, habitat loss, and risks to human health. The fast-flowing water during floods increases erosion and can also cause deep channels to form that intensify the flow of stormwater. These channels further reduce flood storage, degrade water quality, and increase downstream flooding.

Increasing water storage across the landscape, installing green infrastructure, protecting wetlands, building outside of flood zones, and installing flood warning systems are just some of the many strategies available to prepare for and minimize damage done by floods.

Though high water and flooding have posed major problems in recent years, low water levels and drought were the concern around 2010. Longer periods between rainfall events and increases in evapotranspiration are both expected in the future so drought conditions certainly may occur again in some parts of the state or over extended periods of time. During multi-year periods of drought, water levels and stream flows drop. Wetlands can become disconnected from other surface waters, and decreased groundwater inputs to surface waters can result in warmer temperatures and altered chemistry. Lower lake levels reduce water volumes, concentrating nutrients and algae. Drinking water wells may dry up or suffer from water quality problems due to increases in dissolved solids, concentrated contaminants, and increases in water-borne pathogens. As the climate continues to warm, water withdrawals for human use need to account for variability in climatic conditions and available water resources. Water conservation practices are key to minimizing drought impacts.

Water quality

Warmer water temperatures combined with more runoff from extreme precipitation events threaten water quality. In built areas with large amounts of impervious surface, runoff receives little natural filtration and surface waters can be contaminated by sewage overflows and a wide variety of pollutants. Nutrient runoff from agricultural lands is a major water quality issue that fuels algal blooms statewide. Erosion and sedimentation are a concern in many areas, including forested lands. The large inputs of contam-

[on flood impacts in Northern Wisconsin]

"... We are experiencing more flooding due to more large-scale rain events, like what is happening across Wisconsin. We've had several successive floods since the early 2000's. The latest major flood in 2016 destroyed Saxon Harbor in Iron County with the loss of a life. This event also significantly impacted the Bad River Tribe, our neighboring Ojibwe community. Regionally, it washed out highways and transportation systems, some of which may never be rebuilt including rail lines. It caused a lot of economic and personal hardship and destroyed infrastructure that will be expensive, and perhaps impossible for our communities to replace."

–Cathy Techtmann, Environmental Outreach Specialist, UW-Madison Division of Extension
Read the full interview

"All people have a right to clean drinking water and Milwaukee Water Commons engages all sectors of our community on these issues, not only marginalized communities. We all face important decisions regarding our waters. We all rely on them for fishing recreation, transportation, commerce, and to have world class drinking water... At Milwaukee Water Commons, we believe that by inviting leadership, and the innovation that comes from throughout the community, only then can we truly get a good grasp on climate resilience."

–Brenda Coley, Co-Executive Director, Milwaukee Water Commons, Milwaukee, Wis.
Read the full interview

Harmful algal blooms are more likely to occur with warmer water temperatures and more nutrient runoff from extreme precipitation. Photo credit: Gina LaLiberte

inants during extreme precipitation events make ongoing efforts in Wisconsin to improve water quality even more essential.

Precipitation and flooding in portions of the state with Karst geology and fractured bedrock are a special concern. Karst geology contains soluble rocks like dolomite and limestone and create conduits that act as underground streams. In Wisconsin, Karst geology forms a "V" shape that extends southeast from St. Croix County, along the Mississippi River, across the bottom of the state, and northeast along Lake Michigan up to Marinette County. In those areas, water has less chance to be filtered through the soil, delivering more pollutants to surface and ground waters.

In areas where septic drainfields treat wastewater, elevated groundwater can create substandard treatment of the wastewater. High water levels may also decrease the quality of water in private drinking wells by overtopping the well casing and introducing microbes and other contaminants into the well. Proper above ground well casing heights and properly sealed well caps can reduce well contamination risk.

Water temperatures

Lake water temperatures have warmed overall, with different warming rates between lakes depending on their size, depth, and water clarity. For example, in the summer in deeper lakes, water stratifies into a cooler bottom layer and a warmer upper layer. As waters warm, this process, known as stratification, becomes more pronounced and increases the risk of fish kills due to low oxygen levels and nutrient release from lake sediment in the bottom layer. Warmer surface water temperatures combined with more stable stratification also increases the risk for toxin-producing algal blooms.

As the air temperature continues to warm, lake surface water temperatures in all lakes will also warm, changing lake ecology. For example, cool-water fish like walleye will be found in fewer lakes, and warm-water fish like largemouth bass will be much more common as waters warm by mid-century. Land conservation and nutrient reduction can help sustain lakes and the animals that live in them despite warmer water.

Ice cover

Ice cover duration has decreased in Wisconsin over the last century, and ice thickness has also decreased. Warmer air temperature is the main driver for this loss of ice. By the end of the century, ice cover is projected to decrease in duration and thickness. In southern Wisconsin, larger lakes, like Lake Mendota in Dane County, may see some years without ice cover by the middle of the cen-

tury. River ice in much of Wisconsin will also decrease in duration. However, smaller lakes respond quickly to cold air during the winter and will likely continue to see ice cover for short periods. In the northern part of the state, lakes will likely continue to remain ice covered.

Changing timing and extent of ice cover may have a wide range of impacts on aquatic life and the water cycle. For example, lakes that have less ice cover lose more water through evaporation. In addition, as the climate continues to warm, the resulting weaker, thinner ice on lakes and rivers increases the risk of drowning, necessitating more ice safety education. The overall loss of ice-cover also impacts Wisconsin's winter cultural traditions and economy.

Climate resilience

Efforts to protect and restore land adjacent to lakes, rivers, and wetlands can enhance the quality of our water resources in this rapidly changing climate. Wetlands and natural depressions are important land features that can slow flood waters and reduce damage to bridges, structures, and poorly vegetated lands. Updated zoning regulations that protect the near-shore environment from development could prevent damage to infrastructure along lake shorelines and rivers. Protecting and restoring wetlands in upper watersheds will help store and infiltrate floodwater and prevent nutrients and contaminants from entering lakes and rivers. Strategic changes to the way that land is managed can help to increase resilience in lakes, streams, wetlands, and groundwater.

Solving water challenges

Water resources support all aspects of Wisconsin life, but are threatened by climate change. To help solve these water challenges, Wisconsin should strengthen existing networks of university, federal, state, and local researchers who, with funding, could tackle environmental, social, and economic questions related to surface water quality and quan-

Top: Ice cover duration is shorter due to warmer air temperatures. Photo credit: Katie Hein Middle: Less stable ice conditions increase the risk of winter drownings and hamper recreational activities. Photo credit: Tyler Logan

Wetland protection and restoration make Wisconsin more resilient to extreme precipitation. Photo credit: Katie Hein

A long-term monitoring network of water resources in Wisconsin can help managers respond to climate changes. Deer Lake Morning. Photo credit: Kevin Sink

"Unless all of human kind begins to change their way of thinking and their way of using the things in the environment, including the fossil fuels and corn and things like that, we will continue to move in this direction of changing climate until we can't breathe anymore. We have degraded our breath of life so much. But we know that if we start thinking ahead of everybody else and if we start implementing things, then perhaps we can have something in place for the generation down the road. And their seventh generation to be able to pick it up."

–Edith Leoso, Tribal Historic Preservation Officer, Bad River Band of Lake Superior Tribe of Chippewa
Read the full interview

tity. The recent UW System Freshwater Collaborative of Wisconsin in an example of an emerging network.

A long-term monitoring network of stream, inland lake, shoreland, Great Lake, and wetland monitoring sites would help track and manage surface waters as they respond to climate changes. Educational materials and management plans for Wisconsin's water resource leaders can be developed from the knowledge gained from this network.

Finally, finding and implementing water solutions will require a collective approach. The UW-Extension's existing network of educators are positioned to facilitate these complex community conversations. Tribal governments and their perspectives will also be important to develop holistic ways to approach the changing climate.

Solutions

Support community resilience planning for water resources

Protect and restore water resources, including lake and river shoreland areas, floodplains, wetlands, and groundwater recharge areas

Enhance water storage and employ practices to minimize stormflow, including restoring upper watershed wetlands and reconnecting floodplains

Alter land management practices to reduce runoff of nutrients and contaminants into water bodies and groundwater

Conserve water to reduce the impact of droughts

Prevent the spread of aquatic invasive species

Establish a long-term water monitoring network and a Wisconsin surface water applied research program to better track and manage surface waters as they respond to climate changes

Learn more

The **Water Resources Working Group** explored these issues, impacts, and solutions and provide more information on their webpage, including resources for educators and factsheets on water issues.

Wisconsin Groundwater Coordinating Council Report priority recommendations

Wisconsin Wetlands Association | Exploring the Relationship between Wetlands and Flood Hazards in the Lake Superior Basin

FISHERIES

Fishing is an important part of the culture and economy in Wisconsin. Wisconsin has 15,000 lakes and 84,000 miles of rivers and streams that provide vital tribal subsistence, commercial, and recreational fisheries worth nearly $2 billion annually to the state. As water temperatures warm, the fish species that can live in our waters will change. More frequent extreme storms and heat events are already damaging fish habitat and stressing fisheries. These impacts will intensify as the climate continues to warm. Wisconsin's cool- and cold-water fish assemblages are particularly at risk, including some of the most popular and sought-after fish, like brook trout, lake trout, cisco, lake whitefish, walleye, yellow perch, and muskellunge. Without action, habitat loss, combined with overfishing and expansion of invasive species and warm-water competitors may cause local cold- and cool-water fish populations to decline.

Shifting seasons

The increasing variability in ice-on and ice-off dates and warmer waters in Wisconsin's lakes could have a significant impact on recreational and subsistence fishing in the state. From the duration of ice thick enough to be safe for ice fishing to the increasingly unpredictable timing in annual freezing and thawing dates that set up lake and tributary environments for fish spawning, climate change could hurt recreational and subsistence fishing opportunities while simultaneously reducing the survival of iconic fish like walleye and perch.

Warmer lakes and streams

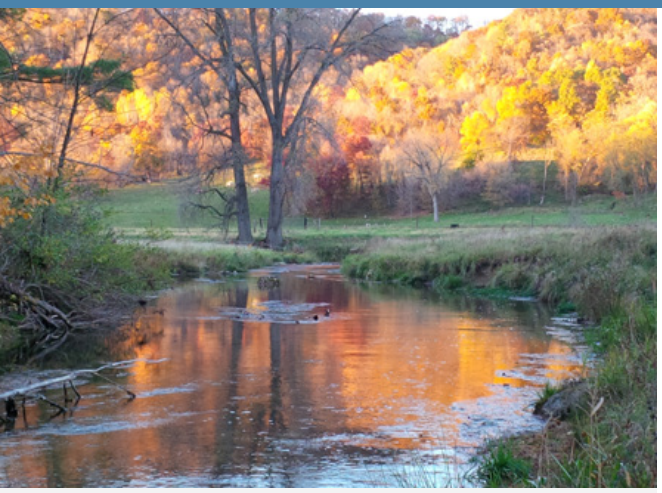
Fish communities are changing as a result of climate change and warming lake waters. Current models show 21,300 miles of streams in Wisconsin are suitable for brook trout and 12,400 miles for brown trout. By mid-century, models project a decline of sixty-eight percent in stream habitat for brook trout and thirty-two percent for brown trout. Some areas of Wisconsin will be more resilient to habitat loss, including the Driftless Area and the Lake Superior basin. These areas have an abundance of cold groundwater feeding streams. Northern forested areas of Wisconsin with less groundwater-fed streams are more vulnerable to the warming trends.

Wisconsin's inland lakes face similar shifts due to climate change. A recent survey of inland lakes with coldwater fisheries in Wisconsin

As water temperatures warm, the fish that can live in our waters will change. Sean Sass holds a walleye he caught while ice fishing, January 2021. Photo credit: Greg Sass

"Probably the biggest change in the walleye fishing is that the first five years I was here, '93 to '97, the DNR would come to our annual meetings and they would not stock this lake with walleyes, not any kind of walleyes. They said it was the best naturally reproducing lake in Northwest Wisconsin. They said there wasn't any reason to do anything about it. By 2006 they [the walleye] had all disappeared ..."

–Jerome McAllister, Board Member, Big Sissabagama Lake Association, Sawyer, Co., Wis.
Read the full interview



Habitat restoration and improved land use can make fisheries in Wisconsin more resilient to climate change impacts. A Driftless Area trout stream in Vernon Co., Wis. Photo credit: Matthew Mitro

When I first started coming here in 1985 for fishing on the lake, we had an overabundance of walleye in the lake. There was a time where we had forty walleyes per acre…. the walleye population decreased significantly to the point where ten years ago we were down to four walleyes per acre."

–Rick Lindner, President, Nelson Lake Association, Sawyer Co., Wis.
Read the full interview

"Just a few degrees of warming in our lakes can put walleye outside of the optimal range for successful reproduction… By mid-century, we're going to have maybe half of the naturally reproducing walleye populations that we have today…There are still going to be cool places in Wisconsin to fish for walleye.…. Our lakes will never be empty, but we are seeing changes to what's out there."

–Max Wolter, Senior Fisheries Biologist, WDNR
Read the full interview

found that cisco have already disappeared from twenty-nine percent of their lakes, and lake whitefish have disappeared from thirty-three percent. Overall, Wisconsin is expected to lose 160 lakes currently classified as "cool" by 2049, and all but four of those lakes by 2089. This means, within a century, Wisconsin's inland lakes will be dominated by warm lakes that are largely unsuitable for major cool-water game fish like walleye, perch, and muskellunge. Instead, many fish communities are expected to become dominated by warm-water species like bass and bluegill.

A combination of invasive species expansions, excess nutrients, and less well-oxygenated habitat can exacerbate these losses. As the climate warms and the summer season gets longer and warmer, the likelihood of fish kills increases as oxygen is depleted from the warming lake waters. While smaller, shallower and more productive lakes will be the most vulnerable, deep lakes that stratify in summer may also experience an increased risk of oxygen depletion in the deeper waters during longer summers, imperiling coldwater fish that rely on those habitats. If lake temperatures increase as expected, the number of fish kills may double by mid-century and increase more than four-fold by the end of the century.

Climate models project a decline of sixty-eight percent in stream habitat for brook trout. A brook trout *(Salvelinus fontinalis)* captured from a Driftless Area stream. Photo credit Matthew Mitro

Great Lake fisheries

In the deep and open waters of Lakes Michigan and Superior, fish communities include cold-water fish species like introduced salmon and native lake trout, lake whitefish, cisco, and deepwater chubs. The shallower bays, such as Green Bay, mainly support cool-water species like walleye and yellow perch. As the temperature warms and precipitation patterns change over the next century, warmer-water species, such as smallmouth bass, would be able to compete in the more southern and shallower habitat currently occupied by cool-water fish. As fish populations shift due to a warmer climate, fish managers will be faced with contentious policy issues, such as harvest allocations and quotas for walleye and yellow perch. These changes to critical fisheries will impact commercial and recreational fishers, as well as traditional tribal fishers.

Solutions

Identify and preserve stronghold populations of brook trout

Manage fisheries to prevent overharvest and protect productive populations

Identify and protect sentinel lakes with resilient cool and coldwater fish, riparian buffers, and land management to reduce runoff

Prevent expansion of native warmwater fishes and invasive species

Protect commercially and recreationally important Great Lakes fisheries

Learn more

The **Fisheries Working Group** explored these issues, impacts, and solutions and provide more detailed information on impacts to trout distribution in Wisconsin streams and other impacts on Wisconsin fisheries.

GREAT LAKES

Wisconsin is bordered by two Great Lakes, Lake Superior to the north and Lake Michigan to the east. It is hard to overstate how influential the Great Lakes are to the region. They not only support the local economy; they also greatly influence the weather. With the area along the Great Lakes warming faster than the general pattern of warming across the state, physical changes to the Great Lakes are already being felt. Water level fluctuations, changes to water temperature and lake mixing, and ice cover changes are impacting water quality, and lake habitats,

Extreme precipitation

As air temperatures rise in the Great Lakes region, precipitation in the form of both snow and rain will also increase. Very extreme precipitation events in Northern Wisconsin along Lake Superior in 2012, 2016, and 2018, have already impacted communities and are likely to continue to be frequent events as the climate warms.

High water levels combined with intense storm events are leading to losses in dune and swale systems and coastal wetlands that are unique to Great Lakes shorelines. Great Lakes beaches that provide access to the public for recreation are often closed due to human health concerns from high *E. coli* levels after these extreme events.

Variable water levels

While the 2011 WICCI report focused on extremely low lake levels, Great Lakes are now seeing record high levels. All of Wisconsin's Lake Michigan and Lake Superior coasts have been impacted by extreme lake level fluctuations in the past decade. The lakes are expected to continue to experience these variations, with extreme highs and extreme

low-level conditions, with less time between the extreme conditions. Local communities will need support to plan for these variabilities to protect both built infrastructure and natural communities.

Warming waters

Lake Superior is one of the most rapidly warming lakes in the world and is projected to change more than any other Great Lake by the end of the century. The impact of this warming may cause ecological cascades that could affect economically and culturally significant fisheries and water-quality based recreation like swimming and kayaking.

Ice cover

Ice cover on the Great Lakes is sensitive to even small variations in air temperatures. In the last four decades, the Great Lakes experienced a decrease in the extent and duration of ice cover. Nine of the top ten lowest ice cover years have occurred since 2002. This trend is expected to continue. On Lake Superior, ice cover is expected to decrease by one to two months by the end of the century. Loss of ice cover can increase erosion because ice helps prevent damage to shorelines during the winter and can lead to warmer spring water temperatures, creating a feedback loop of ever-increasing water temperatures.

The Great Lakes are experiencing a decrease in the extent and duration of ice cover. Danger Thin Ice, 2015 Great Lakes Photo Contest. Photo credit: Edward Deiro

Water quality

Extreme precipitation events and warming waters impact the amount and cycling of nutrients and contaminants in the nearshore lake environment. Beaches are predicted to have more microbial contamination, leading to beach closures.

While Green Bay has been experiencing algal blooms for decades, it is a new phenomenon in Lake Superior. In 2018, extreme storm events elevated nutrient levels along the South Shore of Lake Superior for months and fueled major algal blooms along the shoreline. Warmer waters also create conditions that can lead to potentially toxic cyanobacteria blooms. All of these changes are overwhelming the progress currently being made in reducing nutrient runoff into the lakes.

Coastal ecology

Wisconsin's Great Lakes region is home to over 3,500 species of fish and wildlife, including very rare and endangered species. Coastal habitats include nearshore waters, coastal wetlands, sandy beaches, and vegetated dunes. Coastal wetlands provide habitat for fish, wildlife, and wild rice that support Great Lakes communities, including Tribal Nations, economically. They also improve water quality and provide protection from storms and floods. Protecting these important habitats will have ecosystem-wide impacts across the Great Lakes.

As the lake levels rise and fall, these habitats expand and shrink naturally. However, rapid changes in Great Lakes water levels, extreme storms, and longer wet periods are increasing flooding along coastal shorelines. These changes are impacting both habitats and structures built along the lakeshore. Coastal beaches are eroding away. Native plant communities in coastal wetlands are being displaced by invasive plants.

Many of the species found in the lakes are culturally important to coastal communities. For example,

Efforts to reduce stormwater runoff and find nature-based solutions can improve water quality and improve recreation. Summer Fun, 2016 Great Lakes Photo Contest. Photo credit: Carol Toepke

wild rice, called manoomin by the Ojibwe Tribal Nations, is culturally significant to the Ojibwe and is a vital part of the Great Lakes ecosystem. Wild rice is an annual plant that grows in shallow waters of lakes, streams, and rivers and is found primarily in Northern Wisconsin. The harvest rate from this important plant has gone down over time and is considered by the Great Lakes Indian Fish and Wildlife Commission to be highly vulnerable to climate change. While the tribes in Wisconsin have reserved rights to fish, hunt, and gather in off-reservation areas, these rights may become mis-matched with where the fish, wild rice, and other beings they depend upon are able to survive.

Great Lakes ecology

Changes in air temperature influence the amount of ice cover, water levels, clarity, and chemistry associated with fish habitat. Warm- and cool-water fish habitat is expected to increase as the water temperatures rise and cold-water fish habitat decreases. Cold-water fish will likely move into northern and deeper parts of the lakes. The impact of climate change on fish born in the Great Lakes is still unknown. Because they currently contain expansive coldwater habitats, increasing temperatures in northern Lake Michigan and Lake Superior will open up more thermal habitat for coolwater fish like walleye. However, changing precipitation patterns could potentially lower their growth rates and damage spawning habitat. Lake sturgeon, already at risk compared to their historical presence, live for a long time and grow slowly, which makes them highly sensitive to climate change. Brook trout depend on cold, fast-flowing tributary streams and are also highly vulnerable to climate change.

The Great Lakes ecology has already been damaged and changed through the introduction of dams and hardened shorelines, and the introduction of new and invasive species. These factors make lakes less resilient as the climate warms. Runoff into the Great Lakes during storm events brings contaminants into the lakes, which can further stress the ecosystem. These contaminants have the potential to be transported through the food web into fish that are an important part of the diet for subsistence fishers from tribal nations, Hmong populations living in Sheboygan, Green Bay and Milwaukee, and other subsistence fishers. The impact of climate change on fish populations and contaminant transport through the food web is not well understood.

Efforts to address these issues are underway. The Great Lakes Working Group technical report includes case studies and other resources that outline these efforts. For example, Sam Myers Park in Racine, Wisconsin, has recently undergone extensive restoration to turn a beach with poor water quality and invasive species issues into a vibrant wetland dune ecosystem which has a swimming area of high-water quality. Restoration of the park has created an additional high quality public access point to Wisconsin's Great Lakes coasts for residents without the financial means to own coastal property.

Solutions

Identify, purchase, and protect coastal wetlands and ridge and swale dune systems

Implement practices on the landscape to increase storage capacity of Great Lakes watersheds

Encourage agricultural conservation practices to reduce nutrient and sediment runoff and improve water quality

Regulate and control high-risk invasive species in the Great Lakes basin

Coastal wetlands provide important habitat for fish, wildlife, and wild rice. Great Blue Heron, 2016 Great Lakes Photo Contest. Photo credit: Janna Soerens

Learn more

The **Great Lakes Working Group** has analyzed these issues and impacts and are recommending strategies and solutions to build resilience in the region. In case studies included in their technical report, they examine recommendations for "Slow the Flow" practices and nature-based solutions, dune restoration to improve water quality and improve recreation, and efforts to address stormwater runoff that bring nutrients and contaminants into the lakes.

MISSISSIPPI RIVER

The Mississippi River provides Wisconsin with a diverse array of services and natural capital. The Wisconsin Great River Road, 250 miles along the Mississippi River that is designated as Wisconsin's National Scenic Byway and All-American Road, includes thirty-three historic river towns and villages and is a major tourism attraction. Hundreds of thousands of migrating waterfowl rely on the aquatic plant populations in the river as a critical food source. The agriculture sector relies on the river for deliveries of agricultural chemicals and shipments of commodities.

But the Mississippi River and communities in Wisconsin are at risk due to the increasing variability in river flows caused by changes in precipitation, snow melt, storm intensity, and land use. The amount of water that flowed in the Mississippi River in 2019 was about double the historical average. Extended high water and fall flooding have occurred in seven of the last ten years.

Restoring and maintaining large blocks of natural cover along the Mississippi River corridor will reduce downstream issues such as flooding that

affect many people living in the watershed, particularly lower income individuals who can't afford to relocate as the river's floodplain expands into new areas.

Impacts to the ecosystem

High and variable flow conditions are causing significant damage to the Mississippi River ecosystem. Island habitat, levee breaches, loss of floodplain forests, changes in water exchange rates between the main channel and backwater lakes, are all examples of the impact on Mississippi River ecosystems. Backwater lakes (waters in the river floodplain away from the main channel) are central to the biological productivity and diversity in the system. They provide refuge from the high flows in the Mississippi, habitat for fish to spawn and overwinter, and essential habitat for waterfowl and other wildlife.

Impacts to tourism and transportation

Due in large part to flooding, growth in tourism along the Great River Road was down by seventy-seven percent in 2019. The excessive volume of water also caused damage to transportation infrastructure and deliveries of agricultural chemicals and shipments of commodities were delayed. This was particularly hard on the agricultural sector, which represents a $25 billion annual economic return to the Upper Mississippi River states, including Wisconsin. High water years also deliver sediment and nutrients that lead to harmful algal blooms and contribute to the expansion of the Gulf of Mexico hypoxic zone.

What is being done?

Community groups in partnership with state and federal agencies are undertaking climate change adaptation projects in the backwater areas of the Mississippi. These projects are vital to maintaining productive local fisheries and access to subsistence fishing for communities. One project on the Blackdeer Channel of the Mississippi River took place after the community alerted the Department of Natural Resources to damage to the fishery.

The project involved an innovative solution and the work of local volunteers. Invasive buckthorn was cut and bundled to limit flow into the Blackdeer Channel in Lake Onalaska, a benefit for the fishery and a creative use of invasive buckthorn. The Mississippi River has a rich history of this type of community engagement and stewardship.

"The level of degradation was shocking. This is just one example of how the river is bleeding. We are dealing with double the discharge in many of our backwaters and functionality is being lost as a result."

–Shawn Giblin, Water Quality Specialist, WDNR
Read the full interview

We're fortunate that there's a lot of interest in conservation in the outdoors here. The Brice Prairie Conservation Association dates back to the 1950s…. The group we have to reach to continue our work is young people. …When I was a kid growing up here, there were hundreds of places I could just ride my bike down to the shore and fish or do whatever. Now it's all private and the places where young people can get access are very few and far between. We need to address the barriers to kids getting out, on their own, to discover and explore."

–Fritz Funk, Brice Prairie Conservation Association, Black River Watershed, La Crosse Co., Wis.
Read the full interview

High and variable flow conditions are causing significant damage to the Mississippi River ecosystem. Floodplain trees as the water levels decline after the 2019 flood. La Crosse, Wis. Photo credit: Kathi Jo Jankowski

"Results from the latest Intergovernmental Panel on Climate Change (IPCC) report showed us that we are locked into at least three decades of intensifying climate change. Given that reality, what gives me hope is that the Mississippi River is not new to major challenges. We have had to deal with nutrient pollution, invasive species, and all kinds of other pressures on the ecosystem. Because of the partnerships that resulted to address those threats, we are well set up to work together to address the big one - climate change. That gives me hope."

–Kathi Jo Jankowski, Research Ecologist, United States Geological Survey
Read the full interview

Solutions

Manage adjacent watersheds to reduce flood hazards and slow sediment and water movement in tributaries

Invest in flood risk reduction practices and pre-disaster mitigation programs that help communities address local flood risks and avoid catastrophic losses

Invest in solutions to increase transportation reliability within the Mississippi River region

Develop a two-dimensional hydraulic model to help with Mississippi River habitat projects, community flood risk evaluation, and management

Learn more

The Mississippi River sub-group explored these issues and impacts and you can learn more on the **Water Resources Working Group** webpage.

Flooding has caused damage to transportation infrastructure on the Mississippi River. Mississippi River lock and dam under water during 2019 flood in the Rock Island District, Iowa. Photo Credit: United States Army Corps of Engineers

Story Spotlight
Northern Wisconsin communities at a turning point

The extreme storm events in the past decade in Northern Wisconsin could prove to be a turning point for communities, plants, and wildlife in the region. Communities that thought they might be immune from the changing climate are concerned.

Impacts on communities

All seasons and regions of Wisconsin are getting warmer and wetter, but winters are warming more rapidly than summers and the area along the Great Lakes is warming faster than the general pattern of warming across the state. Physical changes to the Great Lakes are already being felt by communities. Water level fluctuations and changes in water temperature, along with changes to ice cover, are impacting water quality and lake habitats. Increased shoreline erosion is also a concern in some areas.

Extreme weather and water quality

Increasing extreme storms are bringing more nutrients and contamination into Lake Superior. There have been record rainfall events from two 500-year events and one 1,000-year event since 2012. These events combined with high water levels in Lake Superior erode bluffs and bring more sediment and nutrients into the lake.

The nutrients and higher water temperatures create the right conditions for algal blooms, a relatively new phenomenon for Lake Superior. The first bloom was reported in 2012. In 2018, runoff from an extreme storm fueled a fifty-mile-long algal bloom from the city of Superior to the Apostle Islands.

Cyanobacteria, also known as blue green algae, can produce toxins that are a risk to human health. They can also impact tourism, beaches and fishing. Today people's perceptions of Lake Superior's waters as being pristine and clear are being challenged.

Impacts to the built environment

More and more of the rainfall in Northern Wisconsin is being delivered in heavy events. On July 11, 2016, a severe storm brought rainfall from four to ten inches in a 24-hour period throughout

"People are tremendously concerned - locals in Northern Wisconsin thought they might be immune to climate change but things are changing so fast. Temperatures in Lake Superior are rising dramatically. We are going to have different kinds of fish, or no fish. There is less ice, which increases the potential for year-round water transport. People didn't expect to see any changes and now things are changing so fast."

–Larry MacDonald, Former Mayor, Bayfield, Wis.
Read the full interview

"It's a new thing to have algal blooms on Lake Superior. Blooms never happened before the warming of the water. I'm concerned about how the blooms will affect the beaches."

–David Eades, Executive Director (past affiliation), Bayfield Chamber of Commerce & Visitor Bureau, Bayfield, Wis.
Read the full interview

"During the 2016 EPA ***Cooperative Science and Monitoring Initiative (CSMI)*** *on Lake Superior, educators joined researchers through a joint professional development opportunity coordinated by Sea Grant. Underway from Houghton, Michigan, lightning struck the radar system on this large Great Lakes research vessel, an early warning of the night to come. By nightfall, waves were cresting over the deck of the ship and lightning struck at a strobe light pace. Watching the weather radar, the crew watched the storm spin over the region, in a manner similar to a hurricane. The vessel rocked wildly through the night. Meanwhile very nearby on shore, the marina at Saxon Harbor was blowing apart under the force of floodwaters. In the morning, everyone onboard woke to dark chocolate milk-colored waters and post storm still winds. Pulling in to the Washburn marina, guest speakers arrived late and pale, shaken by the extreme damage to roads and infrastructure in their communities."*

–Deanna Erickson, Director, Lake Superior National Estuarine Research Reserve
Read the full interview

"The torrential rain had been falling for at least two hours at this point, so even in that relatively sandy area, the water had begun to rise, and road visibility was diminished. Every few seconds I heard the whooshing of the tires ever-so-briefly hydroplaning on that leg of the drive… The next day, news stories, town road maintenance personnel reports, and social media posts poured in. That's when I saw photos of the exposed concrete box culvert and fifty-foot vertical drop between it and the surface of U.S. Highway 63."

–Andrew Teal, Town of Barnes, Bayfield Co., Wis.
Read the full interview

More and more rainfall in Northern Wisconsin is being delivered in heavy events as the climate changes. U.S. Highway 63 northbound, east of Grand View at the Twentymile Creek stream crossing on July 11, 2016. Photo credit: Andrew Teal

Northwest Wisconsin that killed three people and caused a number of road closures and washouts including U.S. Highways 53, 63 and 2. A travel advisory for much of the area closed roads due to washouts and standing water and cut off the city of Ashland. Saxon Harbor in Iron County was destroyed and vessels were beached and set adrift.

The Bad River Band of Lake Superior Chippewa was hit hard by the flooding and suffered damage to roads, homes, and other infrastructure. Flooding damaged roads and separated the tribal community from medical services and businesses in Ashland. The storm caused about $26 million in damage to public infrastructure and the area was declared a federal disaster area.

Other extreme storms have hit the region in the past decade and caused a great deal of damage. In some cases, repeat floods have damaged the same stretch of roads because the repaired infrastructure could not stand up to the extreme events. They also create public safety hazards.

Impacts of ice cover

As winters warm, ice fishing on Lake Superior is also changing. Cold-weather sports and tourism, another large portion of the economy for Lake Superior's coastal towns, are also at risk. Ice coverage on the Great Lakes, especially Lake Superior, is declining.

This phenomenon is part of a trend in the region. Winter temperatures are heating up faster than summer temperatures. Some research suggests that ice-covered lakes are warming twice as fast as others. The Madeline Island Ferry that covers the channel between the island and the mainland is able to run longer during the year with the shrinking ice duration. Local agencies will need to adapt quickly to changing conditions and are looking at innovative solutions to encourage tourists to keep coming back.

Impacts on tribal nations

The risk to natural communities is particularly acute for tribes in the region. The wild rice beds, fish, and wildlife that are an important part of their culture and provide them with food security are stressed by the change in climate.

On the Bad River Reservation on the south shore of Lake Superior, unprecedented flooding events and water level fluctuations in the past decade have affected tribal wild rice harvests and wild rice beds on the Kakagon and Bad River Sloughs, large healthy freshwater estuaries that are significant for the tribe and on the National Natural Landmark registry as the largest naturally grown wild rice bed on the Great Lakes.

The Natural Resources Department of the Bad River Band of Lake Superior Chippewa is developing a number of innovative climate resiliency strategies to adapt. The Bad River Band partnered with the Northern Institute of Applied Climate Science on an adaptation site on two stands of aspen forest near the Kakagon and Bad River Sloughs. This **case study** illustrates how climate change is adversely affecting the environment, safety, and economies of Native communities, but also demonstrates their resilience.

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC), in consultation with the tribes, has developed an **adaptation menu** to guide resource agencies that are working with tribes to protect natural resources. GLIFWC has also worked with the tribes on vulnerability assessments for species, or "beings," that are culturally important.

"Tribes have been looking at climate impacts for a long time. How do you take thousands of years of cultural knowledge and systems and conform to what is happening with the current environment? They are trying to figure out which species are thriving and doing well in the current conditions and what we can do with them… Subsistence is a large part of the economy of tribal communities. It is at the pinnacle of what tribes are concerned about and how they have survived."

–Dylan Jennings, Director of Public Information, Great Lakes Indian Fish and Wildlife Commission (past affiliation), Heal Earth Partnership Doctoral Fellow, UW-Madison Earth Partnership, Bad River Tribal member
Read the full interview

"I think that people need to be reminded of that seventh generation down the road. We shouldn't be doing anything that will negatively impact them. We should look down the road and think, is this going to be good for them, how is it going to be good, what is it going to do. There should be no harm to humanity. We should be looking at humanity as sacred and take care of the breath of life that we have."

–Edith Leoso, Tribal Preservation Officer, Bad River Band of Lake Superior Tribe of Chippewa
Read the full interview

"We are starting to get a lot of these big storm events, which is a huge change from the '80s and '90s. The water levels rise to eight or nine feet during a number of these storm events…I have concerns, but there is still a viable fishery in both Bayfield and Ashland Counties… organizations like Trout Unlimited and Wisconsin Wetlands Association are working to 'slow the flow' in the headwaters of many of the other trout streams in the area, with a lot of success."

–Bill Heart, President, Wild Rivers Chapter of Trout Unlimited
Read the full interview

Impacts on wildlife

Iconic Northern Wisconsin wildlife like the common loon can benefit from the tribal efforts to protect the beings that are at the center of their life and culture. These efforts are also benefiting all Wisconsin communities that rely on these species for tourism and outdoor recreation.

A cooperative approach that protects large tracts of land benefits wildlife by providing them with refuge and assisting their migration to more hospitable areas as the climate changes. Saving what we can of the remaining large tracts of public land and providing corridors between them across private lands will benefit wildlife in Wisconsin. This approach will not only preserve the richness of wildlife that tourism and recreation depend upon, it has the added benefit of reducing the stress on human populations by lessening the risk of floods and minimizing harm from excessive heat and algal blooms.

Impacts on fisheries

The opportunities to fish and hunt in the region are still abundant, but are at risk from the warmer climate.

Life along the Great Lakes has always meant living with dynamic water conditions but climate change threatens more extremes in water level conditions in the future. Breaking Blue, 2016 Great Lakes Photo Contest, Cave Point County Park, Door Co., Wis. Photo credit: Michael Braaten

Although recreational and commercial fishing are important to the local economy, some groups depend on them for food. Climate change could further exacerbate fish contamination concerns. Increases in precipitation and large storm events could alter flow and resuspend contaminated sediments from higher in the watershed into river mouths. This could be especially concerning in areas such as Sheboygan, Green Bay, and Milwaukee where contamination burdens are already a public health concern and Hmong subsistence fishers rely on Great Lakes fish.

What is being done?

Life along the Great Lakes has always meant living with dynamic water conditions, with lake levels that rise and fall daily, with the seasons, and over the course of decades. But climate change threatens more extremes in water level conditions in the future.

Communities are working on ways to become more resilient. The **Lake Superior Collaborative** network is composed of local, state, Tribal, and federal government agencies and academic institutions and non-profits working on climate resilience in the Wisconsin portion of the Lake Superior watershed. Also, in 2020, a new community of practice known as **Coastal Hazards of Superior (CHAOS)** was formed to promote regional connection and knowledge sharing around Lake Superior coastal hazards challenges. Supported by a steering committee of coastal outreach organizations, CHAOS is a voluntary gathering of western Lake Superior community leaders, local and tribal government staff, natural resource managers, coastal outreach liaisons, coastal engineers and designers, and land and property owners who have a stake in coastal resilience.

Timely and wide-reaching communities of practice such as CHAOS are a forum for building trust and can support regional solutions and coordination in response to climate challenges that are shared across jurisdictions. Non-profits like the **Wisconsin Wetlands Association** are also working in the region to restore the natural ability of wetlands in the area to store floodwaters.

Learn More

Water Resources Working Group

Fisheries Working Group

Great Lakes Working Group

Community Sustainability Working Group

Infrastructure Working Group

Wildlife Working Group

"Tribes are and will continue to be disproportionately affected by climate change. In the past the Ojibwe tribes in the Great Lakes region were able to successfully respond to changes in their environment because they were able to move within a large land base. Now tribes are constrained by fixed reservation and ceded territory boundaries and may someday lose their ability to maintain relationships with beings that have sustained them for millennia."

–Aaron Shultz, Rob Croll, Hannah Panci, and Melonee Montano, Great Lakes Indian Fish and Wildlife Commission
Read the full interview

BUILT ENVIRONMENT CHAPTER

Climate resiliency means changing our approach to building infrastructure

Flooding is putting infrastructure investments at risk. Drain tile exposed by flood waters. Photo credit: City of Madison Engineering

INTRODUCTION

Investments in infrastructure have long-lasting impacts. Flooding, high water levels, changing freeze/thaw patterns and other climate impacts are putting those infrastructure investments at risk. As communities build back from disasters and plan for the future, they need better access to data, modeling, and designs to protect their economies and residents. Re-examining how we fund and construct our infrastructure are important to our overall efforts to reduce greenhouse gas emissions.

The topics covered in this chapter include issues, impacts and solutions in the areas of infrastructure and coastal resilience. These topic areas are covered in more depth on WICCI Working Group webpages with links provided at the end of each topic section. Here is a brief highlight of the issues covered in this chapter.

Infrastructure

Greenhouse gases released during the production of our most common construction materials, concrete and steel, represent about 20 percent of greenhouse gas emissions globally. Updated climate projections need to drive design decisions

and how and where to build. This is something that is often beyond the limited resources of infrastructure managers or other decision makers, especially in smaller communities.

Coastal resilience

Both high and low water level extremes are anticipated under a changing climate along the Great Lakes coastline. The variable water levels will have more rapid fluctuations between the highs and lows than seen in the historical record. Increased waves and storm surge are decreasing the stability of coastal bluffs. These climate change impacts are putting coastal-dependent industries and millions of people who live in the coastal area at risk.

Key points

- Our rural roads, highways, airports, ports, dams, stormwater and wastewater systems have been designed according to past climate conditions that do not account for changes in climate, including increasing precipitation, earlier spring thaws and more freeze/thaw cycles, higher water table elevations, and more humid heat waves. Lack of climate change projections available to local officials is leading to inefficient planning and expenditures.
- The production of material needed to build our infrastructure, like concrete and steel, represent a significant source of greenhouse gas emissions.
- Great Lakes coastal infrastructure, recreation, and homes are at risk from extreme and rapid fluctuations in lake levels and decreased stability of coastal bluffs. Warming temperatures are anticipated to decrease the ice cover extent and duration on the Great Lakes, exposing coastal areas to greater wave energy and increased erosion and flooding along the shoreline. Increasing intensity and frequency of extreme rain events will also reduce the stability of coastal bluffs.
- Increased frequency and severity of floods in the Mississippi River and smaller watersheds are impacting the region's economy, connectivity, ecology, and built environment.

Solutions

Support a State Climate Office to provide data and guidance for Wisconsin communities

Design and build infrastructure that accounts for future climate conditions

Provide state funding for climate resilient infrastructure repair and replacement

Conduct vulnerability assessments in coastal communities and explore options to adapt to a changing coastal climate

Develop tools for the Mississippi River to aid in flood forecasting and planning

Alternative uses for dredged material could provide significant cost savings as well as sustainable environmental benefits. Clean, coarse-grained sediment dredged from the Two Rivers Harbor, Two Rivers, Wis. is pumped to the placement site and spread across the beach with heavy machinery. Photo credit: Jim Killian

"We also need to be aware of who will produce and manufacture these new technologies and where these will investments go. Smaller states and smaller contractors are not ready and may be pushed out of this market. These are likely the same people that will suffer more in terms of climate change impact but will not enjoy the benefit of innovation or new technology in the market."

–Bu Wang, Assistant Professor of Civil and Environmental Engineering, UW-Madison
Read the full interview

"In my work I have seen severe damage to stormwater infrastructure and other roadway and public works infrastructure, primarily caused by the severe intensity of rainfall events that appears to be more commonplace each year."

–Rick Eilertson, Project Manager/Engineer, former Public Works Director, AECOM
Read the full interview

"The big need in terms of research priorities was for developing rainfall data. We also saw a need for finding new design approaches. The people we surveyed felt this is what's holding them back in the engineering world. They wondered how they could move forward if their data is outdated and they did not know how to design for the new data?"

–Maria Viteri Hart, Principal, Nomad Planners, LLC
Read the full interview

INFRASTRUCTURE

Investments in infrastructure are long term. Our rural roads, highways, airports, ports, dams, stormwater and wastewater systems – everything that supports our lives and livelihoods – have been and are currently being designed according to past climate conditions, not the present or the future. Our infrastructure will be subject to conditions, such as floods, that they are not designed for. The materials needed to build that infrastructure, steel and concrete, are also contributing to greenhouse gas emissions. New approaches to building, designing, and funding our infrastructure can help mitigate climate change and make communities more resilient to climate change impacts.

Providing communities with the best available climate information can help them prepare for a wetter climate. Flooding in Lamplighter Park after the June 2008 storm. Photo credit: Tom Grisa

Floods and uncertainty

Climate conditions already being experienced in Wisconsin are responsible for infrastructure wear and tear. Some of these conditions include more frequent and intense precipitation, higher annual precipitation amounts, earlier thawing in the spring and more freeze/thaw cycles, higher water table elevations, extreme variation in

lake levels, and more humid heat waves. These changing conditions and uncertainty in the climate change projections available to local officials is leading to inefficient planning and expenditures. This situation makes urban flooding worse and puts investment at risk. It also highlights the need for providing communities with the best available weather and climate information.

Municipal barriers

Overall Wisconsin's infrastructure community is starting to consider the impacts of climate change; however, they face barriers to moving forward due in part to a lack of funding and a lack of direction, but also due to current regulations that mandate use of climate data that is already out of date. As Wisconsin becomes hotter and wetter in the coming century and extreme events increase in frequency and magnitude, municipalities need support to make infrastructure more resilient to extreme weather events.

The Infrastructure Working Group conducted a survey to better understand the state of practice and how municipalities are thinking about climate change in the planning, design, and management of infrastructure.

Political climate was found to be a barrier. "Climate change" as a term is not widely used. More commonly used terms are "sustainability" and "flood mitigation." This is especially true at the township level. According to the survey, managers at the state and tribal levels are the most engaged in climate change work, while township officials are the least engaged.

Aging infrastructure was another top concern, yet, while forty-three percent of respondents have identified critical infrastructure, only twelve percent of the respondents have conducted climate change vulnerability assessments. The survey clearly shows that engineers want a better understanding of future rainfall statistics and new approaches for designing infrastructure to address them.

Wisconsin rainfall project

The Wisconsin Rainfall Project, a research project led by the UW Department of Civil Engineering, is working to update rainfall statistics and modeling and make it available for design engineers. More accurate rainfall data will help define flood risks for communities in flood-prone areas, which often are in areas where

"Unless you can name something, you can't address it. For many people, there is hesitancy to even talk about climate change so it remains out of sight and out of mind. By helping people find ways to respectfully discuss climate change, we can find common ground to take action together to respond to it."

–Cathy Techtman, Environmental Outreach Specialist, UW-Madison Division of Extension
Read the full interview

"Manufacturing concrete and steel alone account for about a quarter of our global carbon emissions. In order to get down to carbon neutral, we have to deal with the emissions generated in the production of these materials."

–Bu Wang, Assistant Professor of Civil and Environmental Engineering, UW-Madison
Read the full interview

historically disadvantaged communities live. The data will be geographically specific to areas across the state and will help guide investment in Wisconsin's infrastructure. This work will help stormwater engineers and planners better evaluate risks and reduce damage to roadways and other infrastructure.

Embedded carbon

Carbon dioxide, a greenhouse gas, is released during the process of creating the most common construction materials like concrete and steel. The emissions from the production of these materials represents a significant source of greenhouse gases. While agencies and the construction industry are aware of the issue and starting to address it, they would benefit from consistent standards to be able to compare construction bids as part of reducing greenhouse gas emissions.

Infrastructure sustainability programs that encourage the use of sustainable materials, recycling, better planning, and more efficient construction practices can reduce carbon emissions from construction materials. These programs can also benefit the regional economy by encouraging locally sourced materials and spur technical and business innovations.

Solutions

Support efforts to plan and design infrastructure projects that specifically consider vulnerability and risk associated with future climate conditions

Provide additional funding for infrastructure replacement or repair to proactively make infrastructure more resilient to future changes.

Provide a standardized method to evaluate and report embodied carbon emissions from the most commonly used construction materials in Wisconsin

Learn more

The **Infrastructure Working Group** considered these issues, impacts, and solutions and are working closely with infrastructure engineers and scientists to find practical solutions that will work for the transportation industry.

COASTAL RESILIENCE

Wisconsin's Lake Michigan and Lake Superior coasts have been impacted by extreme and rapid fluctuations in lake levels in the past decade. Along Lake Michigan, near record high water levels in 2020 followed record low water levels in 2013. In the past decade, fluctuations in Great Lakes water levels have been rapid. For example, the monthly average water levels on Lake Michigan rose 1.7 feet in six months from the record low level in January 2013 to July 2013; 1.7 feet in four months from March to July 2014; 1.7 feet in five months from February to July 2017; and 1.8 feet in five months from February to July 2019.

Both high and low water level extremes are anticipated under a changing climate along the Great Lakes coastline. This could include potentially higher highs, lower lows, and more rapid fluctuations than seen in the historical record. High variability in water levels combined with bigger waves and storm surge could increase erosion and decrease the stability of coastal bluffs.

These climate changes will impact coastal-dependent industries and people who live in the coastal area. At low water levels, concerns include insufficient water depths for navigation in ports, harbors, and marinas and increased scour around coastal

structures. At high water levels, concerns include increased erosion, flooding, bluff failure, and infrastructure damage from high water levels combined with storm surges. Also, as water temperatures increase, coastal beaches and drinking water intakes are more likely to be impacted by potentially toxic blue-green algal blooms.

Increasing wave energy

Wave energy reaching Great Lakes coasts is expected to increase in the future, in part due to anticipated decreases in ice cover extent and duration. A reduction of ice cover will expose the coast to waves for a greater portion of the winter, the season when coastal storm intensity is greatest and large wave events are most frequent. Great Lakes wave energy has also been observed to increase during the summer months, associated with an increased frequency of extreme wind speed events.

Greater wave energy reaching the coast will lead to increased erosion and flooding of the shoreline. During times of higher water levels, these large waves will be able to reach further inland and cause greater coastline erosion and flooding.

During times of lower water levels, greater wave energy will increase erosion of the lakebed, a process known as downcutting. With the lakebed steepened by erosion, waves travel towards the coast in deeper water and are able to reach the coast at a greater height.

Nature-based solutions like this constructed wetland with native plantings can make coastal areas more resilient. Sam Myers Park, Racine, Wis. Photo credit: Adam Bechle

"We have two sections of Beach Drive within 20-30 feet of the shoreline and a sanitary sewer main that is literally in the lake… In October and November of 2019 and January of 2020, storms threw debris, driftwood, and concrete rubble, up and onto the road a distance of fifty or sixty feet. It was really something else. We documented, in the six weeks between mid-October and early December of 2019, that we lost upwards of seven feet of shoreline just in that six-week period."

–Scott Brandmeier, Director, Public Works Department, Fox Point, Wis.
Read the full interview

"Bluff erosion is an issue we've been seeing both on our coastal park properties and private land and residences. I've been with the county a little over twenty years now and I can say that these last few years we've seen the most change in our coastal park properties because of erosion. We've also seen pretty severe erosion at some private properties we deal with on a planning level. Some of those houses have had to be evacuated because of the rapid loss of the bluff."

–Andrew Struck, Director, Parks and Planning Department, Ozaukee Co., Wis.
Read the full interview

Increasing precipitation

Trends of increasing precipitation totals and heavy rainfall event frequency are expected to continue under a changing climate. Increased heavy rainfall will lead to more frequent flooding in rivers and stormwater infrastructure that drain to the Great Lakes, especially during periods of higher water levels, which can limit the ability for outlets to drain into the lake.

An increase in rainfall total and frequency of extreme events will likely reduce the stability of coastal bluffs and cause more bluff slumping. Surface water runoff down the bluff face erodes surface soils and can carve gullies into the bluff face where flow concentrates. Water that infiltrates into the bluff's groundwater table lubricates soil particles and reduces the stability of the bluff slope, increasing the likelihood of collapse. In times of drought, the dryness can create deep fissures in shoreline bluffs. These fissures allow surface water access to deeper parts of the bluff. Thus, heavy rainfall amidst drought conditions can lead to major slope failure.

In the long term, to stabilize Great Lakes coastal bluffs, improved coastal-specific stormwater and groundwater management practices are needed for near coastal bluff areas.

Vulnerability assessments

Vulnerability assessments identify critical infrastructure and help to protect homes, ports, harbors, and marinas. Since periods of high and low water levels typically fluctuate on the scale of decades, it can be easy to forget the threat of either extreme. Documenting vulnerabilities to both high and low water levels and incorporating hazard mitigation strategies into long-term plans can help communities keep building resilience to these impacts.

A recent project to address coastal resilience, the **Southeastern Wisconsin Coastal Resilience** project, made communities more aware of their vulnerabilities and sparked specific projects to strengthen their resilience to coastal hazards during both low- and high-water periods.

Vulnerability assessments to identify critical infrastructure can help communities adapt to periods of high and low water levels along the Great Lakes. High water levels overtop a seawall and inundate a sidewalk in Manitowoc, Wis.
Photo credit: Adam Bechle, Wisconsin Sea Grant

Managed retreat

Relocation of homes and communities in response to erosion and flooding is becoming increasingly common in coastal areas around the United States. Relocation of buildings away from high-risk coastal areas is often considered part of a larger planning strategy referred to as a "managed retreat." This strategy focuses on purchasing, relocating or demolishing homes that are in imminent danger from coastal erosion processes rather than constructing control structures.

Outreach and education are often needed to help make the case for managed retreat programs. While the cost of relocation can be a significant portion of the value of a home, relocation can oftentimes be the cheapest and most effective strategy to deal with coastal erosion compared to attempts to halt erosion.

The voluntary acquisition and conversion to open space of at-risk coastal property may improve public access to Wisconsin's Great Lakes coasts for residents without the financial means to own coastal property.

Dredging

The need to dredge to maintain critical channel depths in Wisconsin's Great Lakes harbors may increase under a changing climate, as periods of low Great Lakes water levels are likely in the future, potentially reaching lower lows due to increased periods of drought and/or increased evaporation from warmer temperatures and reduced ice cover. Much of the material dredged to maintain channels may be relatively uncontaminated. Instead of putting the dredge material into rapidly filling and costly confined disposal facilities, alternative uses for dredged material could provide significant cost savings as well as sustainable environmental benefits. The material could be used in civil engineering projects.

Nature-based shorelines

Wisconsin's **Coastal Management** and **Sea Grant** Programs have resources that can help communities manage beaches given the extremes in Great Lakes water levels. Sam Meyers Park on the City of Racine's waterfront was restored and is an example of nature-based shoreline restoration work. The extensive restoration turned a beach with poor water quality and invasive species into a vibrant wetland dune ecosystem with a swimming area that has good water quality. Restoration of the park has created an additional high quality public access point to Wisconsin's Great Lakes coasts for residents without the financial means to own coastal property.

Nature-based solutions can protect shorelines and, once established, be more appealing and beneficial for wildlife. Rock sill and marsh vegetation plugs installed to protect the Wisconsin Point shoreline in Allouez Bay, Superior, Wis.
Photo credit: Adam Bechle

Wisconsin Point is a large freshwater sandbar on the eastern boundary of the City of Superior in Douglas County, Wisconsin. Changing water levels and uncommon wind directions in Lake Superior led to erosion along the one road going down the center of the peninsula, cutting up close to and compromising the road. The City of Superior parks director pushed for a non-traditional approach to address the erosion and rebuild the road. The

"In my mind, government often doesn't even have the resources to do things in the first place. We certainly don't have the time to keep redoing them. If we can take a little bit of time, effort and money in the front end, and something's going last longer and it's going be more resilient, visually appealing and beneficial for the wildlife, than it simply makes sense. It's a more upfront cost to have long term benefits."

–Linda Cadotte, Director, Parks and Recreation, Superior, Wis.
Read the full interview

approach will not only protect the road, but also filter runoff and provide visual appeal and wildlife benefits.

Other examples of nature-based shorelines can be found in Wisconsin Sea Grant's publication "**Nature-Based Shoreline Options for the Great Lakes Coasts**."

Solutions

Conduct vulnerability assessments in coastal communities to identify buildings and critical infrastructure that are highly vulnerable

Consider relocation, elevation, or acquisition/demolition of infrastructure and homes to increase resilience to natural hazards

Evaluate the potential for the beneficial use of material dredged from Great Lakes harbors

Explore the benefits and drawbacks of a wide range of options to adapt to a changing coast and seek to incorporate nature-based solutions in appropriate settings

Learn more

The **Coastal Resilience Working Group** has resources to help coastal city planners and coastal resource managers adapt to the consequences of climate change. Adaptation fact sheets and guides are available to help property owners, marinas, and local officials.

Story Spotlight
Southern Wisconsin is feeling the impacts of more frequent and intense storms

Since 2011, Wisconsin has experienced the wettest decade in recorded history. Not only are we getting more precipitation, we are getting more extreme storms. Since 1950, the southern two thirds of Wisconsin has experienced the biggest increase in precipitation and that trend is expected to intensify as the climate continues to warm.

Increases to the number of extreme rainstorms in Wisconsin are impacting a wide range of critical infrastructure used to handle stormwater. Examples include culverts, bridges, detention ponds, roadways, railways, and stormwater pipes. Our infrastructure is not built for the type of extreme rainfall events that are increasingly common due to climate change. In addition, our planning tools, such as floodplain maps, are outdated. Since extreme storms are predicted to become significantly more frequent by the end of the century, we can expect more damage and disruptions from floods without upgraded infrastructure.

Impacts to communities

Closed lake systems with no natural surface water outlets face rising lake levels that may become the new normal if adaptations are not found. Lakes with natural outlets, like the Madison lakes, may be able to adapt to the greater amount of water entering the system by increasing the flow from the river outlet.

Extreme flooding in Madison

According to the National Weather Service, in August 2018, 11.63 inches of rain fell over 24 hours in Middleton, an area west of the City of Madison.

Closed lake systems with no natural surface water outlets may face rising lake levels in a wetter climate. June 2020 photo showing flooded homes along Fish Lake's former western shoreline. Photo credit: Ted Bier

"Communities located around water bodies need to be able to maintain their lakes at a normal water level range so they can handle extreme rain events. In drainage lakes, the chronic problem has solutions by getting water away faster through the lake outlets. In closed basin lakes, installed outlet pipes discharging water passively via siphon systems or expensive pumps may be needed. If such systems can't be used, people will have to adapt to the new normal higher water levels. At Crystal Lake, they have relocated their homes to higher ground; in Fish Lake the destroyed shoreline homes were purchased by Dane County and will soon be removed.

Communities will also have to deal with extreme rainfall events to protect their infrastructure. They need to hold the water back on the land, infiltrate it, retain the water, and reduce the peak flows with detention basins to help lessen the erosive power of peak flows during the extreme event."

–Richard Lathrop, Research Limnologist (retired), WDNR, Honorary Fellow, Center for Limnology, UW-Madison
Read the full interview

"In the Madison area two things are happening. We are getting more rain in terms of pure volume. Average rainfall in Madison has gone from thirty-two to close to forty inches per year…. The second problem is extreme events which exceed the capacity of modern systems, including culverts under roads, pipes, and pond systems."

–Greg Fries, Deputy City Engineer, Engineering Division, Madison, Wis.
Read the full interview

"The families shared how their apartment buildings had not recovered from the flooding in 2008, and by 2012 their basements were boarded up due to the mold that had also seeped into the vents. Every time it rained even a few inches, their basements and yards flooded because their apartment buildings are literally sinking into the ground."

–Jessica LeClair, Public Health Nurse and Clinical Instructor, UW-Madison.
Read the full interview

The series of storm systems led to widespread flooding and severe weather across southern Wisconsin. Flash flooding throughout the city made major intersections impassible, flooded homes and businesses, and caused millions of dollars in damage. The huge storm surged through the Pheasant Branch Conservancy in Middleton, Wisconsin and caused massive damage to the banks, walkways, and bridges throughout the stream corridor. The runoff from this record-setting rain event led to the third time in twenty years that Lake Monona hit 100-year flood levels.

The extent of the event was a wake-up call for the region. County and city staff began work to increase the flow through the Yahara chain of lakes. City of Madison engineering staff have undertaken a series of public meetings to identify areas most impacted by the flooding and come up with localized solutions.

With extreme rainfalls expected to be more frequent as the climate warms, the city of Madison, located between two lakes in the Yahara chain of lakes system, is continuing to focus on solutions for a wetter future.

Lakes with natural outlets, like the Madison lakes, may be able to adapt to a wetter climate by increasing the flow out of the system. Madison isthmus flooding in August, 2018. Photo credit: City of Madison Engineering

This chronic flooding is impacting everyone in the region but some residents are less able to adapt. With the lack of affordable housing in the city of Madison, low-income families living in areas where there have been repeat flooding events have nowhere to go to escape the health impacts of wet, moldy basements.

Flooding in Brookfield

In the past decade, the City of Brookfield in southeastern Wisconsin has been hit with a series of extreme storms that have led to millions of dollars of property and infrastructure damage. The back-to-back nature of the events led to the political will to make major improvements throughout the city. Still, there is worry that the data used for the projects is outdated.

Flood impacts on at-risk groups

A lack of infrastructure resilience in a changing climate threatens the safety and economic security of all Wisconsin residents and will be felt hardest by poorer residents and minority groups. In rural areas, water supplies, including drinking water, are impacted by overflows or failures of infrastructure associated with concentrated animal feeding operations (CAFOs). In Vernon and Monroe Counties in the Driftless Area, rural communities are having to build back after repeat storms, a strain on their budgets, and are still looking for solutions to the repeat flooding.

What is being done?

The Infrastructure Working Group is working on solutions to help communities plan for increasing precipitation in the region. They are developing strategies and tools for infrastructure managers to use in determining climate risks and designing, operating, and maintaining climate-resilient infrastructure.

Learn more

Infrastructure Working Group

Community Sustainability Working Group

"But those improvements were based on the old rainfall data. When the new data are published, we as a professional group of stormwater engineers will need to make a determination on using the new number or retaining the old number. If you retain the old number, you might build too small. If you design to the new number, which is based on less data, those designs cost the community more. Ideally, you would design for the rainfall predicted for your area and that will be different in Southeast Wisconsin and Northwest Wisconsin."

–Tom Grisa, Director, Public Works Department, Brookfield, Wis.
Read the full interview

"Between 2007-2018, about every two years there was a flood of various degrees. In 2018 the flood was a record breaker. That was the point when people looked back over the past decade and said, 'What's going on?' They are telling us we are having 500 and 100 year floods every few years…When you have communities along a river that get wiped out every two years, people think it's a tragedy but it doesn't get the attention because it's happening over this long period of time."

–Tim Hundt, District Representative, Wisconsin's 3rd District, Congressman Ron Kind
Read the full interview

PEOPLE CHAPTER

Communities are feeling the impacts and planning for a changing climate

Backpacker on Ice Age Trail in Cross Plains, Wis. Photo credit: Travel Wisconsin

INTRODUCTION

Communities across Wisconsin are feeling the impacts of climate change. Hot and muggy weather, more intense and frequent heavy rainfalls, freezing winter rain instead of snow, polar vortexes, derechos and other extreme events are challenging communities across Wisconsin. Human health and safety in all Wisconsin communities are increasingly at risk from climate impacts like flooding, the spread of disease, extreme heat, and exposure to pollution. These impacts extend to environmental resources and activities that are important to Tribal Nations, Hmong communities, and other communities of color. Support and funding for planning efforts are needed to position communities for future climate impacts. Ultimately, efforts to reduce greenhouse gases emissions and create an equitable transition to renewable energy will be the most important way to protect human health and mitigate the impacts of a warming climate on future generations.

The topics covered in this chapter include issues, impacts and solutions in the areas of community sustainability, human health, and tourism and out-

door recreation. These topic areas are covered in more depth on WICCI Working Group webpages with links provided at the end of each topic section. Here is a brief highlight of the issues covered in this chapter.

Community sustainability

Adapting to climate change means reducing risks and a long-term perspective that considers potential impacts on current and future generations. Yet, the capacity to comprehensively plan and adapt to evolving climate challenges varies across the state. Local governments and Tribal Nations lack easy access to accurate information on at-risk populations, properties, and infrastructure. Climate education and funding can help communities develop the approaches they need to promote resilience to evolving climate conditions.

Human health

Climate impacts pose regional and local health risks in Wisconsin. These risks are not felt equally by all. When considering climate policy to protect the health of Wisconsin communities, it is imperative that policies address historical injustices. In the long run, reducing activities that release greenhouse gases in our daily lives is the primary way to protect human health from the impacts of climate change.

Tourism and outdoor recreation

Tourism is one of the largest economic drivers in Wisconsin. Outdoor recreation across all four seasons contribute to our sense of place and are the basis for many tourist activities in Wisconsin. These activities are being impacted by warmer winters and precipitation fluctuations, severe storms, and extreme heat events. Assisting communities with sustainable design ideas for their tourism and outdoor recreation assets will help ensure continued access to the outdoors, both for local residents and visitors, and help maintain an important part of Wisconsin's economy.

Key points

- Extreme storms and flooding are the most prominent climate impacts being felt by communities across Wisconsin. These impacts extend to environmental resources and activities that are important to Native Americans and other subsistence fishers.
- Planning for these evolving climate challenges will be crucial for communities to maintain a vibrant economy in Wisconsin, reduce health risks, and promote public safety.
- Reducing greenhouse gas emissions and creating an equitable transition to renewable energy is the best way to minimize the impacts of future warming, protect our economy, and reduce risk to human health.
- Support for climate resiliency education, planning, and projects will help local governments protect their businesses, residents, economy, and infrastructure.

Solutions

Help communities become more resilient to climate change impacts by supporting comprehensive planning and community climate preparedness grants

Fully embrace clean energy, walkable communities, public transportation, and green building design

Protect the most vulnerable in response to extreme weather events and set up timely public communication on climate-health issues

Support efforts to develop diverse and sustainable tourism and outdoor recreation and preserve cultural resources

"Overarchingly though, a community must commit to policies and practices which consider long-term perspectives, holistic thinking, a focus on place, all while supporting active involvement in problem solving. Ultimately, the will of the community will shape approaches that define the breadth and depth of a community's sustainability agenda."

–**Community Sustainability Working Group Report**

[on sustainability and efforts to reduce greenhouse gas emissions in the city]

"We tend to think of ourselves as realists here in Eau Claire - we want to push the envelope but we also have to be practical about how to move things forward logically, financially, and sensibly. Rather than create a pledge with some arbitrary vision, we focus on how to get there. This practical-based focus creates buy in for the community."

–Ned Noel, Senior Planner, Eau Claire, Wis.
Read the full interview

SUSTAINABLE COMMUNITIES

Wisconsin's climate is changing. Climate challenges include more hot and muggy weather, more intense and frequent heavy rainfalls, freezing winter rain instead of snow, and deep winter freezes, known as polar vortexes. These changes affect the stability of Wisconsin's communities and economies as well as human health and safety. The impacts extend to environmental resources and activities that are important to Tribal Nations, such as wild rice and subsistence fishing.

Adapting to climate change means reducing risks and a long perspective that considers potential impacts on current and future generations. The capacity to adapt to evolving climate challenges varies across the state. To enhance community resilience to climate extremes, local governments and Tribal Nations need accurate information on at-risk populations, properties, and infrastructure and place-based responses that limit negative climate impacts and promote resilience to evolving climate conditions.

More intense and frequent heavy rainfalls affect the stability of Wisconsin's communities and economies. Flooding in downtown Wisconsin Rapids, Wis. Photo credit: Anna Haines

Planning for climate change

Comprehensive plans are an important tool that can guide communities towards climate resiliency and sustainability. The plans are broad, visionary, guiding documents created for a twenty-year timeline to address issues such as land use, transit, green energy, and economic development. Creating the plan provides an opportunity to identify populations vulnerable to climate change impacts

and set the stage for more sustainable development. Emergency management plans required by the Federal Emergency Management Agency are also important tools to guide communities and identify at-risk populations, mainly to address flood issues but also to plan for extreme weather events, like extreme heat or cold. As our climate is changing, more communities are using these planning processes to sustainably guide their growth. For example, in the **Bayfield County Comprehensive Plan**, sustainability practices are the cornerstone of the document and are part of the discussion throughout.

Sustainability policies

State and local government policies shape the built environment and impact the natural environment in profound ways. Policies can be catalysts for community sustainability, prosperity, and enhanced quality of life. Or policies can increase community vulnerability and exacerbate potential climate risks. At the local level, planning varies widely and zoning codes are the day-to-day standards that guide development. Stretch, or reach, codes are locally mandated building codes that can be used to make buildings more energy efficient and go beyond the state uniform dwelling code. They allow local governments to keep up with advances in technology and design practices and could be an important tool for local governments to reduce greenhouse gas emissions if they are authorized in Wisconsin by the state legislature.

Recent extreme weather events throughout Wisconsin have shown the shortcomings of existing infrastructure and disaster relief systems. They highlight the need to provide access to relevant scientific information to promote resiliency to climate change impacts in our communities. Providing accurate climate data to Wisconsin communities will relieve the burden of data assembly that is disproportionately heavy for small, rural, or at-risk communities. Climate data can also help identify, engage, and address risks in historically disadvantaged communities. State-funded adaptation grants could help local governments and Tribal Nations take action to update comprehensive plans, revise codes and land use policies, and develop plans to implement resilient infrastructure.

Tribal Nation adaptations and plans

Tribal Nations have already begun planning for climate change and are sharing their work on the **Northeast Indigenous Climate Resilience Network** webpage. State and regional institutions working closely with local governments and Tribal Nations can help assess community risks, develop effective risk mitigation plans, and

Oneida Pow Wow. Photo credit: Travel Wisconsin

"…tribes are now demonstrating their adaptability in new ways, including by assessing the vulnerability of culturally important beings, planning for an uncertain future, and leading the fight against climate change."

–Aaron Shultz, Rob Croll, Hannah Panci, and Melonee Montano, Great Lakes Indian Fish and Wildlife Commission
Read the full interview

implement risk-reduction solutions that also create social, economic, and environmental co-benefits.

Solutions

Provide funding for community comprehensive planning and develop guidelines to help communities address climate risks

Deliver research-based climate change adaptation education statewide for local governments and Tribal Nations

Fund community climate preparedness grants to help local governments and Tribal Nations implement climate adaptation plans and policies

Fund research to assess the costs and benefits of climate adaptation policies and practices

Learn more

The **Community Sustainability Working Group** has considered these issues, impacts, and solutions and provides more background and tools for creating more sustainable communities on their webpage.

Governor's Task Force on Climate Change

UW-Madison Division of Extension

Green Tier Legacy Communities

Wisconsin's Office of Energy Independence – Energy Independent Communities

Natural Step Framework – Guide to Eco-Communities that want to develop an ecologically, economically, and socially healthy community for the long term. In 2005, Ashland, Washburn, and Madison became the first eco-municipalities in the United States.

Resources - Community Planning - Center for Land Use Education | University of Wisconsin-Stevens Point

Publications - Eco Municipalities, Sustainability - Center for Land Use Education | University of Wisconsin-Stevens Point

HUMAN HEALTH

In communities across the Midwest, climate change is harming our health now. These harms include heat-related illness, worsening chronic illnesses, injuries and deaths from dangerous weather events, infectious diseases spread by mosquitoes and ticks, illnesses from contaminated food and water, and mental health problems. As flooding is becoming more common in our state, our communities are at risk from contaminated drinking water that can trigger outbreaks of water-borne illnesses. When houses flood, there are also serious concerns of respiratory health risks, including asthma, which can be irritated by mold growth. Wisconsinites who rely on well water are some of the most likely to be harmed by water contamination due to flooding. Unless we take concerted action, these harms to our health are going to get much worse. The most important actions we can take to protect our health is to strengthen communities' resilience, while also reducing heat-trapping pollution from burning fossil fuels. Accelerating the transition to clean renewable energy in Wisconsin also offers immediate health benefits.

Direct health harms

Extreme heat events will become more common as the climate warms. By mid-century, Milwaukee will likely experience triple the number of days with a heat index above 105 degrees (a combination of air temperature and humidity). The health of anyone can be harmed by extreme heat events but some of us face greater risk than others. Older adults and people with chronic conditions are at risk for heat stroke and dehydration at those temperatures.

Low-income residents that live in areas with an increased amount of cement and asphalt are also at risk. Asphalt and concrete surfaces absorb the sun's energy instead of reflecting it, a process known as an urban heat island effect. Low-income families may not have access to cool places or

air conditioning to protect them from the heat. Integrating green spaces and green infrastructure into cities can help combat these heat island impacts. Outdoor workers, athletes, military personnel, pregnant women and others who lack air conditioning also face greater risks.

As Wisconsin is warming, it is also becoming wetter. We are already seeing an increase in flooding events and that trend is expected to continue into the future. In addition to the physical damage of flooding, flood waters can contribute to contaminated drinking water. About two thirds of Wisconsin residents get their drinking water from groundwater that may be susceptible to water contamination from extreme rain events. Heavy rains can overwhelm sewage systems leading to water-borne infections that cause diarrhea.

In addition to the physical damage of flooding, flood waters can contribute to contaminated drinking water. Photo credit: Peyton Hellenbrand

Flooded basements, which promote the growth of mold, often trigger asthma attacks or other respiratory risks. During flooding events, more nutrients are washed into lakes and streams and fuel potentially toxic algal blooms.

With longer growing seasons and warmer average temperatures in Wisconsin, disease-carrying ticks and mosquitoes are becoming more widely distributed. These insects carry Lyme disease, West Nile virus and other diseases. As the climate continues to warm, the active transmission season for these diseases is lengthening and some of these types of infections will likely increase.

Clean energy

In addition to limiting climate change, accelerating a transition to

"Oftentimes, teachers are forced to separate students that are at higher risk of health effects from extreme heat due to medical conditions. After being placed in the library, the only air-conditioned room in the building to protect their health on hot days, these students often express feeling excluded from their peers and friends."

–Angela Hall, elementary school teacher, Madison Metropolitan School District, Madison, Wis.
Read the full interview

"As storms and flooding increase, not only will more people be sent to the emergency room, but hospitals may begin flooding as well. My colleagues and I have cared for critically ill patients on ventilators who have had to be evacuated from other hospitals due to severe flooding. We also get concerned about blocked transportation for employees, ambulances, and helicopters during storms. Any delay in critical care, even a short one, can impact the outcome and recovery of a patient."

–Caitlin Rublee, Emergency Physician and Assistant Professor, Division of Global and Population Health, Medical College of Wisconsin
Read the full interview

"Flood waters in this area contain sewage, bacteria, mold, and agricultural chemicals from a nearby creek. These exposures cause emergency outbreaks. Promoting health and racial equity should be a central component of strategies designed to combat the health effects of climate change."

–Jessica LeClair, Public Health Nurse and Clinical Instructor, UW-Madison
Read the full interview

"As the Health Director in our area, I see the risk of mosquitoes increasing as their active season creeps into October and early November. In these colder months, visitors, outdoor workers, and other community members are typically not thinking of mosquito protection. However, the climate is changing. As our county grows warmer and wetter, so, too, grows the risk of these diseases… the risk is very real, and it is at our doorstep."

–Angela Weideman, Health Director, Department of Public Health, Chippewa Co., Wis.
Read the full interview

clean energy has the added benefit of cleaning up our air and water so that we can all immediately enjoy better health. Exposure to air pollution is associated with an increased risk of severe outcomes with respiratory disease. In the current COVID-19 pandemic, researchers are finding that counties in the United States with increased exposure to air pollution have higher death rates from COVID-19.

A **report** prepared by David Abel and Katya Spear of the Center on Wisconsin Strategy looked at an energy scenario of 100 percent in-state electric power, mostly from renewables. Wisconsin health benefits from improved air quality include an annually avoided 1,910 premature deaths, 650 respiratory emergency room visits, 1,580 cases of acute bronchitis, 49,400 respiratory symptom cases, 873,000 minor restricted activity days, 148,000 work loss days, 34,400 cases of asthma exacerbation, 670 hospital admissions, and 650 heart attacks. Switching to 100% clean energy in Wisconsin alone translates into an economic value of $21 billion dollars annually.

The health benefits of acting now to promote cleaner energy are numerous. Shorter car trips and more biking have added benefits in terms of increased physical activity, improved health, and quality of life. Shifting food systems to more sustainable methods can reduce greenhouse gas emissions from that sector, and supporting sustainable local agriculture and more plant-based diets can improve health.

Climate-specific public alert systems

Climate impacts are already being felt in Wisconsin and the likelihood is high that these trends will continue into the future. As our climate continues to warm, therefore, support for steps to build resilience in our communities can help prevent some of the worst health impacts. Early warning systems to monitor, prepare for, and provide timely public communication on weather-related health risks is a needed first step. This would include early warning systems for heatwaves and other extreme weather events, advising hospitals and health systems on preparedness, and enhancing community infrastructure to be resilient in the face of climate-related disasters. Fostering public discussions on climate-related issues and effective collaborations among professionals in local and state government in the areas of transportation, agriculture, natural resources, and zoning can help in finding solutions. People need to know the risks they face and if they are vulnerable to health harms.

Winterfest Curling. Photo credit: Travel Wisconsin

Solutions

Fully embrace clean energy, walkable communities, public transportation, and green building design

Protect the most vulnerable in response to extreme weather events

Set up timely public communication on climate-health issues

Learn more

The **Human Health Working Group** explored these and other issues, impacts, and solutions. They have created user-friendly toolkits and other materials to promote a shift towards cleaner energy and better public health.

Wisconsin Department of Health – Climate and Health website

Provides access to the latest research on health impacts

Wisconsin Health Professionals for Climate Action

Provides a communication toolkit for ways for health professionals to engage on this topic

TOURISM AND OUTDOOR RECREATION

Tourism is one of the largest economic drivers in Wisconsin. Tourism-related business sales in the state totaled over $22 billion in 2019 before the pandemic. Outdoor recreation across all four seasons contribute to our sense of place and are the basis for many tourist activities in Wisconsin. Wisconsin also has eleven federally recognized Tribal Nations that promote unique tourism opportunities. As the climate continues to warm, rising temperatures are changing and shifting the seasons for outdoor pursuits. The summer recreational season is lengthening and the winter recreation season is shortening. Freeze-thaw cycles from changing temperature patterns are impacting outdoor resources like natural trails. Communities need help in developing best practices to diversify their tourism offerings and to prepare and respond to extreme weather.

"Some of our early winter events, like Hurley's Red Light Snowmobile Rally, once allowed the area to 'capture' the market because of its reliable early snowfalls. This event has not happened for many years due to lack of consistent snow. We have also seen more winter precipitation come as rain rather than snow. Thanks to being in the Lake Superior 'snowbelt,' we are still getting enough snow to support winter recreation and tourism when other areas of the state lack snow, but the winter is changing."

–Cathy Techtman, Environmental Outreach Specialist, UW-Madison Division of Extension
Read the full interview

"One of the resources we mentioned in our working group report is the Northern Institute of Applied Climate Science (NIACS). On their website, they have climate change adaptation menus. Those are meant to be applied on a project scale. If there's a project that a community wants to work on, they can use the strategies to incorporate climate resiliency instead of trying to deal with how to do that on their own."

–Natalie Chin, Climate and Tourism Outreach Specialist, Wisconsin Sea Grant
Read the full interview

Warming temperatures are lengthening the seasons for warm weather activities when tourism is at its highest in Wisconsin. Boy jumping in lake at Lake Winnebago in Oshkosh, Wis. Photo credit: Travel Wisconsin

Summer seasonal changes

Warm weather activities in Wisconsin are too vast to list but include swimming, birding, hiking, and biking. Warming temperatures are lengthening the seasons for warm weather activities when tourism is at its highest in Wisconsin. This gives the state a competitive advantage compared to other places that can become uncomfortably hot during the warm seasons. Tourism during the warm months is increasing and will likely continue to increase as the climate continues to warm. Extreme heat, however, could make events held in the middle of the summer, when temperatures peak, risky for older adults, young children, and other vulnerable populations. Urban areas are particularly vulnerable to extreme heat events.

With 15,000 inland lakes, two Great Lakes, and over 84,000 miles of rivers and streams, there is a high demand for beaches and water-based activities in Wisconsin. Severe storms and rainfall are becoming more frequent as the climate warms and could endan-

ger public safety and make recreational areas inaccessible. Severe storms are also contributing to more water quality issues, including frequent and severe harmful algal blooms in our lakes, beaches, and other nearshore areas. Lake levels are becoming more volatile and swing more rapidly between high and low extremes. This puts lake shore amenities like beaches, trails, roads and marinas at risk and makes boating more challenging. We are also seeing an uptick in pests and infectious diseases.

Fall seasonal changes

Wisconsin's fall color season could lengthen in the future as the climate warms. However, natural events like fall colors are affected by extreme heat events and unpredictable precipitation levels. These natural events impact both the length and intensity of the state's fall color touring opportunities and activities. Wildlife, plants and natural communities are responding to these changes as well. As species migrate and/or decline in response to climate impacts, visitors will be seeing a changed landscape for birding, fishing, and other outdoor activities.

Winter seasonal changes

Wisconsin is known for winter activities like snowmobiling, cross-country and downhill skiing, sledding, winter fat tire biking, ice-skating, and ice fishing. These activities are very vulnerable to warmer winters and the effect on the snowfall, snowpack, and ice conditions that Wisconsin's winter recreation is built upon. By the end of the century, average snowfall is predicted to be reduced significantly, with Northern Wisconsin seeing the greatest decrease in the depth of snowfall and Southern Wisconsin seeing the greatest percentage reduction. Many winter activities, like cross-country skiing, will be pushed to Northern Wisconsin.

Spring seasonal changes

Fish season opener events and bird-watching are major spring-time activities. Wildlife watchers looking for migrating species are a major driver of Wisconsin's tourism economy. As seasons shift, migration patterns and habitat availability are changing for many species. This could lead to differences in the species available on the landscape for hunting and observing. Heavier rain events in the spring are also leading to flooding, trail closures, and higher maintenance costs. With the increase in risk to public safety, costs for holding events may increase.

"We will continue looking twenty to fifty years into the future and partnering with others to co-manage properties to ensure our management approaches work together. We will continue ... using tools to promote resilience, including trail related tools developed by The Nature Conservancy, and pull them together using GIS to guide our work."

–Kevin Thusius, Director of Land Conservation, Ice Age Trail Alliance
Read the full interview

Adapting to a changing environment

The shifts in seasons in Wisconsin will present both benefits and challenges to the tourism industry. Planning ahead for future climate impacts will be an important part of ensuring that Wisconsin's tourism industry remains strong. Communities can start to position themselves for the future by learning about heat and extreme weather safety and preparedness, beach and ice safety, and emergency response options. They can also diversify their offerings. To do that, Wisconsin's local communities need help with sustainable design of tourism and outdoor recreation assets. Help includes funding for trail maintenance, training for resilient management plans, and resources that help local decision makers incorporate data and climate change projections into project development. State tourism and outdoor recreation businesses also need help to diversify their offerings.

Comprehensive planning

Comprehensive planning at the local level can include ways to sustain tourism by addressing emergency response, resource needs, extreme storm events, heat safety, beach safety, protection for at-risk populations in the case of an emergency, and best practices in the field of outdoor recreation. Funding may be needed by smaller communities to put the plans into action.

Solutions

Help communities sustainably diversify outdoor recreational opportunities

Support comprehensive contingency planning and emergency preparedness

Enhance beach safety with better safety information and support research into innovative solutions to reduce harmful algal blooms

Protect vulnerable species by supporting habitat restoration and planning

Adjust trails and access points to accommodate our changing climate and protect access for all populations

Work with tribal historic preservation officers to develop solutions to protect and preserve cultural resources, including wild rice

Learn more

The **Tourism and Outdoor Recreation Working Group** explored these and other issues, impacts, and solutions. They welcome input from the broader public to help ensure the long-term viability of Wisconsin's tourism and outdoor recreation businesses.

Story Spotlight
Creating climate resilient and equitable communities

Wisconsin has over 1,923 units of government, including counties, cities, villages and towns. More frequent and intense storms and warmer winters are exacerbating existing inequities in Wisconsin communities and making it clear that more sustainable approaches are needed to build and maintain our infrastructure.

Creating sustainable communities involves long-term thinking that considers both current and future risks. Across Wisconsin many communities have adopted or are working towards sustainable approaches that work for them. The driving forces behind these efforts include efficiency, cost savings, and analyzing the entire community to identify challenges and opportunities for becoming

Backpacking in Chequamegon National Forest. Photo credit: Shruti Sarode

"How do you leave these communities better, with more resources or other things that they need?... We know there are disproportionate impacts in our more vulnerable communities, so community decision making is extremely critical."

–Nadia Vogt, Senior Project Manager, Milwaukee Metropolitan Sewerage District, Milwaukee, Wis.
Read the full interview

"One of the things we feel mediates flooding is green infrastructure, but, when you talk about bringing green infrastructure to a community, we talk about why green infrastructure is important. We also, and this is where the intersectionality comes in, we also try and communicate in transparent and authentic ways, alert folks, tell them our work is not being done to gentrify the neighborhood... We are really working with the community to bring about changes the neighborhood feels are necessary."

–Brenda Coley, Co-Executive Director, Milwaukee Water Commons, Milwaukee, Wis.
Read the full interview

"The first steps are intentionally reaching out to individuals and groups and saying 'we'd like to have this conversation.' Not just reaching out to the person you know, but reaching out to the person you know and saying 'who would be an important person to have at this table.' Get the conversation out of the safe and comfortable zone, to where work can be done. It can't be a matter of convenience. After engaging them effectively, then ask, "how does our changing climate affect you?"

–Christopher Kilgour, Founder, Color in the Outdoors, Madison, Wis.
Read the full interview

"...the best way to involve youth is to actively get to know what they're doing. You could go to our protests and just listen in. Another one is to listen to First Nations and understand that Black and indigenous people are the first ones who created this movement and now they're being left out of the conversation. It is really sad. I also think it's important to let these people have agency to choose, not just ask for their input, but ask them to take a role in making this idea that we have move forward."

–Stephanie Janeth Salgado Altamirano, Co-Founder, Youth Climate Action, Madison, Wis.
Read the full interview

sustainable. A 2020 survey by UW-Madison Division of Extension with funding by the Office of Energy Independence found that sixty percent of Wisconsin communities that responded are engaged in efforts to generate a portion of their power and transportation fuels from renewable resources. Many sustainability planning efforts are now reaching beyond environmental concerns to include social, economic, and climate justice components. Actively engaging residents in the design of sustainability projects empowers them and creates a sense of ownership.

Gaining trust for infrastructure projects

The Milwaukee Metropolitan Sewerage District (MMSD) is leading the way towards climate resiliency by integrating equity into infrastructure projects and ensuring the full participation and inclusion of at-risk communities in project planning. They started by developing a resilience plan using a holistic management approach that includes identifying risks and opportunities to reduce those risks. They begin working with neighborhood groups up to two years in advance to gain trust and allow space for locals to be a part of the project design. In some cases, project leaders have facilitated field trips from under-resourced neighborhoods to other, more well-off neighborhoods to show the possibilities. These and other approaches are helping build more resilient and long-lasting impacts for many areas that have been marginalized in the city.

Another organization, **Milwaukee Water Commons**, a cross neighborhood, multi-cultural organization, is engaging and empowering Milwaukee communities in solution making and water stewardship. They have created a water city agenda that covers arts and culture, education and recreation, green jobs, green infrastructure, clean drinking water, and water quality.

Setting the table for more diverse viewpoints

In outdoor recreation planning forums, communities of color are not always represented. Yet, the demographics show that these communities will be an important part of the future in tourism and outdoor recreation. Tourism and recreation planners need to ensure communities of color feel welcome in these spaces. Groups like **Color in the Outdoors** and Youth Climate Action Team Madison provide valuable expertise and ideas on how to include diverse viewpoints.

Impacts on Tribal Nations

Wisconsin has eleven federally recognized Tribal Nations. For Tribal Nations, current and future climate impacts are threatening their way of life. In many ways, Tribal Nations are leading the way in identifying climate risks and exploring the connections needed to sustain their culture. Their work in developing **adaptation menus** and thinking about future generations is a holistic approach to sustainability.

Impacts to cultural resources

An emerging climate change impact is the risk to cultural resources. At Whitefish Dunes State Park recently, a knowledgeable visitor noticed cultural artifacts coming out of a highly eroded dune face along the water. This type of event is happening across the state. In the Driftless Area, mounds are at risk from toppled trees during periods of extreme storms and flooding. Petroglyphs are being lost. This is an emerging issue for local communities trying to protect their cultural resources.

Impacts on tourism

Tourism is one of the largest economic drivers in Wisconsin. Outdoor recreation across all four seasons contribute to our sense of place and are the basis for many tourist activities. A shift in the seasons, extreme storms, warming winters, and impacts on lakes are changing the opportunities for the tourism and outdoor recreation industry. At the local level, communities are paying attention and shifting their focus to accommodate the changing climate.

Key ingredients for sustainability

Having the political will in your community and creating community buy-in are important components of successful sustainability efforts. The city of Bayfield has the right ingredients for success with informed staff, an engaged community, and supportive elected officials. The city of Eau Claire is looking at the big picture when it comes to climate resiliency. Their approach includes a focus on fuel efficiency and shifting the community away from fossil fuels. Residents are on board with their approach, which emphasizes practical solutions and building community with ways residents can take action in their own lives.

As the climate changes, communities are having to plan for extreme events and back-to-back flooding that has washed out roads

"The first step is to generate awareness of the issue and these archeological sites. Broadly, the general public doesn't have a good understanding of the cultural heritage of our state. If we can generate some cultural awareness, that's really worthwhile."

–Jennifer Haas, Director of the Archaeological Research Laboratory Center, UW-Milwaukee
Read the full interview

"There's a lot of flooding, and that has seriously affected archeological sites. Climatologists are saying this is the new normal, so we may need to completely revamp how we deal with archeological sites and burial sites in the state."

–Janet Speth, Archeologist (retired), Wisconsin Historical Society and Honorary Fellow, UW-Madison Zoological Museum
Read the full interview

"Businesses are shifting and accommodating. For example, fifteen years ago there were three different companies that did dog sled rides. Now there's one. There were no companies that did winter biking, now there's two… We are kind of shifting our economic and tourism activity like we have always done."

–David Eades, Executive Director (past affiliation), Bayfield Chamber of Commerce & Visitor Bureau, Bayfield, Wis.
Read the full interview

"We provide a 'low carbon diet' workbook for the teams to work through. The program is incentivized with prizes for the greatest decarbonization. We adapted this campaign from a program in Urbana, Illinois. We are trying to provide a fun way for people to get involved and build community."

–Ned Noel, Senior Planner, Eau Claire, Wis.
Read the full interview

"We can't plan anymore for what has happened historically. If you continue to plan for the event that's already happened, then you are behind… I hope to see more innovative projects… that meet multiple resiliency goals and make Wisconsin a better place to live."

–Robyn Fennig, Hazard Mitigation Section Supervisor, Wisconsin Emergency Management
Read the full interview

and bridges. Yet they often lack the climate-ready engineering designs and are stretching limited funds to keep their residents safe. Emergency management personnel can help create resilient infrastructure and communities by accessing grants available from the Federal Emergency Management Agency. A new grant program for community-level mitigation projects, **Building Resilient Infrastructure**, gives extra consideration to smaller communities that are applying for the funds. The program is helping communities move from just responding to disasters to more long-term recovery strategies that reduce risk.

Learn more

Community Sustainability Working Group

Tourism and Outdoor Recreation Working Group

Infrastructure Working Group

Father hikes with his young son on an autumn day. Photo credit: Travel Wisconsin

APPENDIX

The Wisconsin Initiative on Climate Change Impacts is a statewide collaboration of scientists and stakeholders formed as a partnership between UW-Madison's Nelson Institute for Environmental Studies and the Wisconsin Department of Natural Resources. Below is a list of those who helped us successfully compile this assessment report.

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Melting ice on Mississippi River (Location/ La Crosse, WI,) Photo credit: Kathi Jo Jankowski

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