ENVIRONMENTAL LAW & POLICY CENTER

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



The Environmental Law & Policy Center, in concert with the Chicago Council on Global Affairs, commissioned the following scientists and experts to produce this report pro bono to educate policymakers and the public about the significant changes affecting the Great Lakes, and the vital importance of taking actions now to protect our natural resources.

Donald Wuebbles, *University of Illinois*
Andrew Ballinger, *North Carolina State University and NOAA CICS-NC*
Bradley Cardinale, *University of Michigan*
Keith Cherkauer, *Purdue University*
Robin Davidson-Arnott, *University of Guelph, Ontaria, Canada*
Rob de Loë, *University of Waterloo, Ontario, Canada*
Jessica Hellmann, *University of Minnesota*
Dana Infante, *Michigan State University*
Lucinda Johnson, *University of Minnesota, Duluth*
Kenneth Kunkel, *North Carolina State University and NOAA CICS-NC*
Brent Lofgren, *NOAA GLERL*
Aaron Packman, *Northwestern University*
Frank Seglenieks, *Environment and Climate Change Canada*
Ashish Sharma, *University of Notre Dame and University of Illinois at Urbana-Champaign*
Brent Sohngen, *The Ohio State University*
Michael Tiboris, *Chicago Council on Global Affairs*
Daniel Vimont, *University of Wisconsin, Madison*
Robyn Wilson, *The Ohio State University*

Contributor: Donald M. Waller, *University of Wisconsin, Madison*

Environmental Law & Policy Center

The Environmental Law & Policy Center is the Midwest's leading public interest environmental legal advocacy and eco-business innovation organization. We develop and lead successful strategic advocacy campaigns to improve environmental quality and protect our natural resources. We are public interest environmental entrepreneurs who engage in creative business dealmaking with diverse interests to put into practice our belief that environmental progress and economic development can be achieved together. ELPC's multidisciplinary staff of talented and experienced public interest attorneys, environmental business specialists, public policy advocates and communications specialists brings a strong and effective combination of skills to solve environmental problems.

HEADQUARTERS
35 East Wacker Drive, Suite 1600
Chicago, Illinois 60601
(312) 673-6500
www.ELPC.org
elpcinfo@elpc.org
/ELPCenter @ELPCenter



REGIONAL OFFICES
Columbus, OH
Des Moines, IA
Grand Rapids, MI
Indianapolis, IN
Madison, WI
Minneapolis/St. Paul, MN
Washington, D.C.

Executive Summary

Introduction

Climate change is causing significant and far-reaching impacts on the Great Lakes and the Great Lakes region. In recent years, our planet has experienced some of the warmest temperatures ever recorded, record-breaking weather extremes, powerful storms, increasing tragic flooding from rising sea levels and associated storm surge, huge wildfires, and continued melting of glaciers and polar sea ice. The accelerating pattern of changes in the Earth's climate is affecting the Great Lakes. Here, we draw on the array of existing research to assess how the shifting global climate impacts the unique Great Lakes region.

The Great Lakes have an enormous impact, seen and unseen, on the 34+ million people who live within its Basin. These millions of people rely on the freshwater lakes for drinking water, fisheries, recreation, and commerce and industry. The Great Lakes contain 5,500 cubic miles of freshwater, one of the very largest freshwater resources in the world. The Great Lakes support one of the world's largest regional economies similar to those of whole developed nations. Agriculture, industrial manufacturing, fishing, and recreation together form an economic engine. Regional fisheries alone represent a $7 billion per year industry. Tourism generates $16 billion more.

Heavy human use over the past two centuries has taken its toll in the forms of habitat loss and fragmentation, influxes of invasive species, and polluted air, water, and sediments. Soil and nutrient runoff from agricultural fields and concentrated animal feedlot operations (CAFOs) imperil water quality and wildlife populations in many parts of the basin, threatening public and wildlife health and the economic vitality of the region. Climatic changes now underway further stress these ecosystems, alternatively raising and lowering lake levels and threatening the region in new ways.

The Great Lakes sustain remarkable populations of fish and habitats for wildlife. More than 170 species of fish live in the lakes, streams, rivers, and connecting waterways. Trout, sturgeon, walleye, lake whitefish and other varieties of fish are once again becoming plentiful among the five Great Lakes. The basin's ecosystems support wolves and moose while providing resting and breeding grounds for large flocks of migratory birds and waterfowl. More than 3,500 species of plants and animals use its large network of streams, lakes, inland wetlands, coastal marshes and forests. Many of these species are rare or are found nowhere else.

The Great Lakes are large enough to themselves influence weather in the region. The Lakes moderate temperatures throughout the year, helping to cool nearby lands in the summer and warm them in winter. Their humidity feeds cloud cover and precipitation both over the lakes and downwind. That causes both "lake effect" snowstorms, and summer rainfall that provides ideal growing conditions for orchards in Michigan's "fruit belt."

Climate change presents challenges to the Great Lakes, with complicated effects and inter-relationships.

Air Temperature Increases

The Great Lakes region has tracked global increases in temperature and outpaced trends in some parts of the contiguous United States. Between 1901-1960 and 1985-2016, the Great Lakes basin has warmed 1.6°F in annual mean temperature, exceeding average changes of 1.2°F for the rest of the contiguous United States. By the end of the 21st century, global average temperatures are expected to rise an additional 2.7°F to 7.2°F, depending on future greenhouse gas emissions, with corresponding changes in the Great Lakes region.

Heavy Precipitation and Flooding

A warmer atmosphere holds more moisture, increasing the frequency and intensity of heavy rain and snow events. Overall U.S. annual precipitation increased 4% between 1901 and 2015, but the Great Lakes region saw an almost 10% increase over this interval with more of this precipitation coming as unusually large events. In the future, precipitation will likely redistribute across the seasons. We expect wetter winters and springs, while summer precipitation should decrease by 5-15% for most of Great Lake states by 2100.

These increases in precipitation will likely increase flooding across the Great Lakes region. In cities with abundant roofs, concrete, and other impermeable surfaces, this will likely

damage homes, roadways, and other infrastructure. In rural areas, intense rains and melting snows will increase runoff and erode soils. In rural areas, increased flooding will also cause soil erosion. In combination with more unpredictable precipitation and warmer temperatures, these effects could seriously curtail Midwestern agricultural production.

Extreme Weather

Climate change is causing more extreme weather across the United States. Heat waves have become more common since the 1960s while extreme cold temperatures have generally decreased. Intense summer storms occur more often as temperatures rise.

Extreme weather events have already taken their toll on the Midwest. The 2012 Midwestern heat wave and drought caused more than $30 billion in economic damage, 123 deaths, and harmful long-term health impacts across most of the central and western United States.

Extremely warm days (above 90°F) will increase for states bordering the Great Lakes, especially in the southern parts of the region. By century's end, the region will experience 30 to 60 additional days each year of these extremely warm temperatures. Areas within the Great Lakes Basin will see an increase of 17 to 40 extremely warm days as annual average temperatures continue to rise.

Meanwhile, in states surrounding the Great Lakes, the number of extremely cold days (with temperature less than 32°F) will decrease significantly. Lake effect snowfalls could be even more dramatic, particularly across the Lake Ontario snowbelt in upper western areas of New York state where three- and four-feet snowstorms are already routine.

Agriculture, Irrigation, and Decreased Crop Yields

Changes in seasonal precipitation are already affecting farmers in Midwestern states, with planting delays caused by spring flooding and excessively wet soil conditions. Delayed planting puts crops at greater risk during hotter and drier conditions later in the growing season, and that increases the demand for irrigation to mitigate crop losses. Hot temperatures interfere with pollination in corn and other crops, thereby reducing yields.

Yet, even with increased water management in agricultural watersheds, climate change will likely reduce crop yields for both soybean and maize by 10% - 30% by mid-century in the southern parts of the Great Lakes watershed. Soybean and maize production will likely move northward.

Urban Issues

In the summer, high temperatures and heat waves cause poorer air quality, which harms public health, especially for the most vulnerable people – the elderly and children with asthma. For the many millions of people living in urban areas across the Great Lakes states, heat waves and summer air pollution events increase the risk for heat-related illness, respiratory diseases, and death.

Projected increases in extreme precipitation will likely exacerbate flooding, especially in winter, spring, and during summer thunderstorms. Extreme winter rain events in 2017 and 2018 led to serious flooding. Rain events exceeding 6 inches now occur regularly, exceeding the capacity of culverts and storm sewers to handle runoff. Under-resourced communities in low-lying, flood-prone areas have become vulnerable to infrastructure damage, transportation barriers, and displacement from homes due to these intensified floods.

Water Quality and Consumption

Climate change will likely threaten drinking water quality and place great stress on water infrastructure. For example, in southern Wisconsin, extreme precipitation could rise by 10% to 40%, overloading water treatment infrastructure, increasing sewer overflows, and increasing the quantity of water-born pathogens flowing into streams, rivers, and Lake Michigan.

The Great Lakes have higher levels of E. coli bacteria than other U.S. coastal regions. This untreated effluent is a public health hazard and economically costly to mitigate. Cities like Chicago have spent enormous sums to protect against water pollution. Nutrients (primarily nitrogen and phosphorous) run off from farms into surface waters during intense rain events. These excess nutrients threaten human health both directly (e.g., "blue baby" syndrome)

and indirectly by contributing to toxic harmful algal blooms in shallow water bays of the Great Lakes and the "dead zone" in the Gulf of Mexico that has decimated shellfisheries.

In 2011, Lake Erie experienced the largest harmful algal bloom in its recorded history, with peak intensity more than three times greater than any previously observed blooms. In 2014, 500,000 people in the Toledo area were without safe local drinking water supplies for 72 hours because of toxic algae blooms in western Lake Erie. Algal blooms will likely become more frequent in the future as higher temperatures and heavy precipitation mix heavy nutrient loads with warmer waters. These pollutants have dramatically raised the cost of water treatment.

Lake Ecology

Climate change has already increased bacteria levels in the Great Lakes, as the water warms earlier in the spring and warming contributes to vertical mixing that changes lake ecosystems. Sewer overflows, the dumping of ship ballast water, and nutrient runoff from agriculture and industry all contribute to growth of bacteria and several invasive species in the lakes. Heavier rainstorms and warmer weather exacerbate these challenges.

Hundreds of new species of pathogenic bacteria, viruses, protozoa, and non-native species could be introduced and flourish in the warming conditions, displacing local native species. While climate change may not directly drive lake species extinct, the persistence of many native species will be threatened as they confront more invasive species, species replacements, and proliferating pest and disease organisms.

Fish

Fish respond sensitively to water temperature, assembling in distinct cold, cool, and warm water groupings. This means that warmer temperatures, seasonal weather shifts, and storms that bring a quick influx of water will all affect fish species. The geographic ranges of fish, demographics within species, system productivity, species-specific productivity, the spatial arrangement of species, and their physiological state and performance will all change in response.

For example, game fish like bluegill, smallmouth bass, largemouth bass, and brown bullhead have migrated poleward as water warms in those areas. This may increase diversity of species in some Ontario lakes by as much as 81% by the end of the century. Growth rates of yellow perch, lake whitefish, and many others, however, are likely to decrease.

Wildlife

The Great Lakes region supports many species of mammals, birds, amphibians, reptiles, and macroinvertebrates. As air temperatures increase and precipitation patterns shift, habitat conditions, soil moisture, and other conditions will shift, thereby driving some wildlife species northward and others westward. Individual species however, will respond in different ways to local conditions such as ice cover on lakes and specific patterns of regional precipitation.

Among mammals, moose may be especially vulnerable to climate change. In Minnesota, moose populations have already declined precipitously. Moose density is expected to also decline at southern parts of the Ontario region and increase at northern extents. Milder winters increase overwinter survival in white-tailed deer allowing them to expand northward into habitats historically dominated by moose.

With water levels falling and temperature rising, diseases like botulism will increase, spreading more disease and killing more birds that consume fish. Birds could also suffer from phenological mismatch, as the insect species they relied on for food hatch earlier with warmer springs or decline as vegetation shifts northward.

Shipping, Power Generation and Shorelines

Fluctuating lake levels resulting from climate change greatly affect the ability of ships to safely navigate shallow portions of the Great Lakes' channels and harbors. Both lower lake levels and higher water temperatures pose technical challenges for power generation. Changing lake levels affect marinas, docks, and shoreline homes and other buildings.

Recreation and Beach Closures

The Great Lakes Commission estimated that boating contributed approximately $9 billion to the Great Lakes economy in 2003. Boating activities such as skiing could be affected by warming temperatures, shifts in the length of seasons, and changes in lake levels.

It's become common in recent years for beaches in Chicago and Michigan to close or be under swim advisories because of bacterial contamination. Beach closures are expected to increase as heavy precipitation exacerbates issues associated with runoff and pushes up bacterial counts as well as algal blooms and E. coli alerts.

Conclusion

We should not and cannot take the vast natural resources of the Great Lakes for granted. Allowing the Great Lakes to be degraded through human activities, including climate change, is not an option. For economic, aesthetic, recreational, and ecological reasons, the Great Lakes should be restored to be healthy, unpolluted, and productive. We must reduce the effects of climate change on the Great Lakes.

Public support for protecting the Great Lakes is strong across the region. Scientific analyses clearly show that climate change has already greatly affected the region and that these impacts will continue and expand as the pace of climate change accelerates. It is critical that we recognize the importance of one of the world's most abundant freshwater resources and ensure its protection for generations to come.