The Intersection of Socioeconomic Status & Climate Change Risks & Hazards in the United States Great Lakes Region: An Intern Report

American Meteorological Society
Policy Program Intern Report
September 2021

AMS

Policy Program Intern Report

The Intersection of Socioeconomic Status & Climate Change Risks & Hazards in the United States Great Lakes Region: An Intern Report

Kathryn Sullivan

American Meteorological Society

This report should be cited as:
Sullivan, K., 2021: The Intersection of Socioeconomic Status & Climate Change Risks & Hazards in the United States Great Lakes Region: An Intern Report. An AMS Policy Program Intern Report. The American Meteorological Society, Washington, D.C.

The American Meteorological Society's Policy Program is supported in part through a public—private partnership that brings together corporate patrons & underwriters, and Federal agencies. Supporting agencies include the National Aeronautics and Space Administration (NASA), the National Oceanic & Atmospheric Administration (NOAA), & the National Science Foundation (NSF). Corporate partners include Ball Corporation, Mazar, Baker Hughes, and Lockheed Martin.

The findings, opinions, conclusions, and recommendations expressed in this report do not necessarily reflect the views of AMS or its members and supporters.

The American Meteorological Society (AMS) is a scientific and professional society of roughly 13,000 members from the United States and over 100 foreign countries.

Additional copies of this report and other AMS Policy Program studies can be found online at: http://www.ametsoc.org/studies

Acknowledgements:

Many people were critical to the development of this study. Paul Higgins, Lauren White, Emma Tipton, Andy Miller, and Bill Hooke valuable comments and perspectives on numerous drafts and discussions. The AMS Policy Program is supported by a public-private partnership consisting of NASA, NOAA, NSF, Lockheed Martin, Ball Aerospace, Baker Hughes and L3 Harris Technologies.

Cover image photos:

“Chicago" by Danielle Williams

“Grand Mere at Sunset" by Danielle Williams

“Jollay Apple Orchards” by Danielle Williams

“Spring” by Danielle Williams

Table of Contents

Executive Summary ***i***
Introduction **1**
The Great Lakes Region **3**
Regional Socioeconomics **5**
- *Background*
- *Jobs & Industries*
- *Poverty*
- *Other Factors*

Climate Change in the Great Lakes Region **10**
- *Temperature*
- *Precipitation*
- *Ecological Impacts*
- *Human Health*

The Relationship Between Socioeconomic Status & Climate Change **21**
- *1) Increased Vulnerability*
- *2) Increased Exposure*
- *3) Increased Compounding Stresses*
- *4) Decreased Adaptive Capacity*
- *Reinforcing Disparities*
- *Reduction of Inequalities*
- *The Non-interactive Relationship*
- *Environmental Interactions Based on SES*

Integration of Socioeconomic Factors & Climate Change in the Great Lakes Region **31**
- *Temperature*
- *Precipitation*
- *Lake Levels*
- *Ecology*
- *Income, Jobs, & Industries*
- *Indigenous People*
- *Recent Policy Implications*
- *Interconnectedness of Inequalities*

Next Steps **44**
- *Proposed Solutions*
- *Predicting Future Vulnerabilities*

Limitations **50**
Discussion **52**
Conclusion **54**
References **56**

Executive Summary

The Great Lakes Region relies heavily on its natural resources, including 21 percent of the world's (liquid) freshwater, for the majority of its industries, jobs, and income. Various natural resources have been depleted and threatened by climate change. The fact that climate change presents a scarcity or change in resources, along with impacts to other natural processes, causes challenges for all residents throughout the region, especially for individuals subjected to socioeconomic inequalities.

If the region were a country, it would have the third largest GDP in the world (this study includes Canada). The region heavily relies on the manufacturing industry, making up 66 percent of the job force. Shipping, farming, tourism and recreation are other large industries in the region and each depend on natural resources.

As rapid climate change proceeds, the Great Lakes Region is projected to experience substantial impacts. A higher air temperature trend was observed in the region, when compared to the contiguous U.S., and is likely to continue. An increase in precipitation has already occurred within the region and is more than double the national average. These impacts strengthen concerns regarding water availability, warmer lake temperatures, and increased frequency of heat-related deaths. Impacts to land, water, food, plant, and animal species threaten cultural heritage sites and practices of indigenous people. All of these issues are coupled with their own subset of additional challenges, such as warmer lakes supporting an increase of harmful algal blooms (HABs).

The interactions between socioeconomics and climate change within the region reveal that alterations in temperature, precipitation, and lake levels all influence the region's health, jobs and industries. The biggest threats to public health in the region, as a result of climate change, include those associated with rising temperatures and precipitation extremes. For example, weather extremes such as flooding and droughts, cause issues with infrastructure, water contamination, and water availability for drinking and other uses.

Many of the region's main industries directly rely on natural resources and, as a result, are projected to be greatly affected as a result of climate change. The agriculture industry will face the economic consequences of rising temperatures, waste, ozone concentrations, and shifting of the traditional growing season. Conventional practices of tourism and recreation will alter as the intensity and duration of the seasons change, including beach closures due to bacterial contamination.

There are strong interactions between inequalities as a result of socioeconomic status (SES) and climate change impacts and vulnerabilities. Based on available research, climate change is widespread and typically interacts with socioeconomic status by exacerbating existing inequalities. This relationship is analyzed with a greater goal to more accurately understand how socioeconomic factors and climate change risks and hazards interact in the United States Great Lake Region.

Multiple factors, such as education, political power, and access to resources contribute to climate vulnerability. These factors determine how impacts from climate change affect socioeconomic inequality and to what degree of intensity. Residents of extremely susceptible populations experience challenges both as a result of their low SES and impacts from climate change. In this circumstance, climate change affects the

economy and limits financial capacity to adapt to climate change impacts. Meanwhile, individuals with a higher SES have the ability to live large carbon footprint lives and therefore make greater contributions to emissions. The same group of higher SES individuals have a higher capacity to be more politically active and garner influence to produce more effective change than those individuals with a lower SES. As a result, it is more likely that higher SES individuals are able to skew policies to their advantage.

This study can inform future action that considers environmental justice in efforts to mitigate climate change risks and hazards. This can be done by: 1) initially supporting disadvantaged populations so systems do not benefit from their disadvantage, 2) directly fighting climate change by addressing climate risks and hazards at the source, or 3) providing additional and effective resources to prevent and mitigate the effects of climate change.

Further research must be conducted to comprehensively understand the integration of socioeconomic status and climate change in the Great Lakes Region. This research may support existing action plans which address issues of socioeconomic inequalities and climate change risks and hazards. Solutions, such as increased education and awareness, may offer guidance to both problems of socioeconomic inequalities and climate change impacts. These solutions may encourage public support for environmental justice and informed decisions by policymakers. Solutions in which both issues are addressed, are the most effective and can be approached on, and benefitted by, various levels.

Significant obstacles, such as low socioeconomic factors and the impacts of climate change are difficult alone, however, many populations experience these challenges interacting to exacerbate each other. Financial resources, public awareness and concern, as well as collaboration between policymakers, scientists, and the general public must be strengthened to promote creative and urgent solutions. These solutions must consider vulnerable populations within the region which could potentially act as a model to other regions. If available research is utilized effectively, and the reduction of socioeconomic inequalities as well as climate change impacts are prioritized, the region will be better poised to experience success in economic, social, and environmental sectors. For example, the economy may be strengthened and biological systems and the natural resources they provide may be stabilized. Other regions of the country that struggle with similar issues of socioeconomic inequality and vulnerabilities to climate change risks and hazards, could potentially use the Great Lakes Region as a reference to combat these difficult problems.

Introduction

The effects of climate change are complicated and often amplifed when they intersect with socioeconomic inequalities (Islam & Winkel, 2017). Numerous complex factors of inequality, including education, political power, and access to resources interact to influence the intensity of impact. For example, individuals with strong political influence and power are likely to acquire effective assistance when faced with climate change risks and hazards, while individuals with minimal political influence are less likely to have equal access to the same assistance or resources (Islam & Winkel, 2017). However, political power and influence is only one among many factors that contributes to how climate change affects existing socioeconomic inequality. These factors mixed with impacts from climate change create a dynamic system that shapes the way inequalities are experienced by various populations.

Climate change has wide geographic effects and is already causing the Great Lakes Region to experience extensive impacts (Wuebbles et al., 2019). This is a significant concern as the region provides highly valuable and hard to replace resources regionally and nationally, including jobs, recreation, tourism, agriculture, and 21 percent of the world's freshwater (Wuebbles et al., 2019). It is important to note that the Great Lakes themselves are young, in geological terms, and therefore are vulnerable to threats (Folger, 2020).

This study examines the Great Lakes Region's regional socioeconomics and vulnerability to climate change. The impacts of climate change are so pervasive that they often trickle through our social systems. A better understanding of the relationship between socioeconomics and climate change in the Great Lakes Region can be accomplished through inferring how these elements are integrated, as pictured in **Figure 1**. Recognizing that many stressors overlap, this analysis is primarily concerned with drawing connections between various inequalities and how these may be exacerbated in the presence of climate disasters; additionally, there are less common instances in which SES and climate change are unrelated.

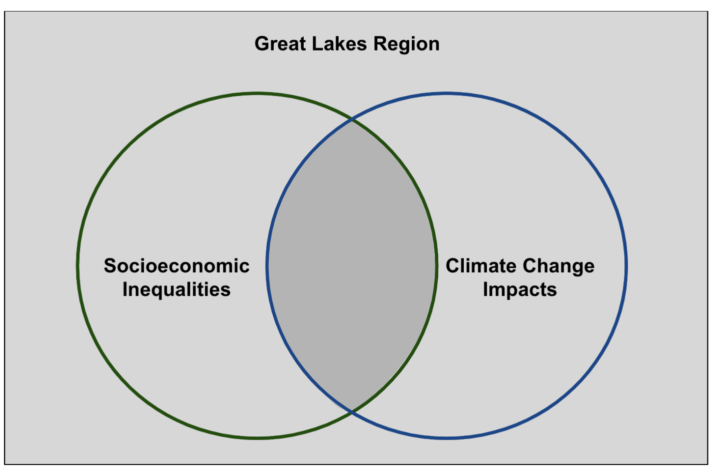


Figure 1: A visual representation of this report. The socioeconomics and effects of climate change will be analyzed separately within the Great Lakes Region. The stressors of these two components will then be integrated with a purpose to understand the relationship, and overlapping stressors, between the two components.

As the world enters a period of accelerating climate change, the Great Lakes Region must remain healthy and productive to continue providing resources for its residents and the United States as a whole (Kling et al., 2003).

This report is conducted with a greater goal to understand the interaction of socioeconomic factors and climate change in the Great Lakes Region, in order to inform decision-making related to climate change risks and hazards as well as social equity.

The Great Lakes Region

Carved out by glaciers, the Great Lakes Region encompasses broad wetlands, fertile soil, hilly northern terrain, sandy beaches, and of course, the lakes themselves (Kling et al., 2003). The region hosts the five major lakes which compose the Great Lakes: Lake Ontario, Lake Erie, Lake Huron, Lake Michigan, and Lake Superior. The lakes originated only about 3,000 years ago, making them significantly younger than the oldest of the Egyptian pyramids (Folger, 2020). The lakes' young geological age makes them less diverse than the oceans and therefore more vulnerable to threats (Folger, 2020).

The lakes are the largest body of freshwater lakes in the world and cover an area of over 94,000 square miles (U.S. Census Bureau, 2012). They contain over 5,500 cubic miles of water and extend for nearly 10,000 miles of coastline (Breffle et al., 2013). The region holds 95 percent of the United States' freshwater and 21 percent of the world's freshwater (Doss & Eder, 2017; The United Nations, 2016). Over 25 million people in the U.S. depend on the lakes' water for drinking (Breffle et al., 2013). The five lakes are arguably the continent's most precious resource, incalculably more valuable than oil, gas, or coal - as a result of the freshwater (Folger, 2020).

The region sits within the Midwest and Northeast regions of the United States (U.S. Climate Resilience Toolkit, 2019). Although definitions for the region vary, this report considers only the U.S. states that border the Great Lakes: Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York, as seen in **Figure 2** (U.S. Climate Resilience Toolkit, 2019). When incorporating studies with alternative definitions of the Great Lakes Region, it will be addressed.

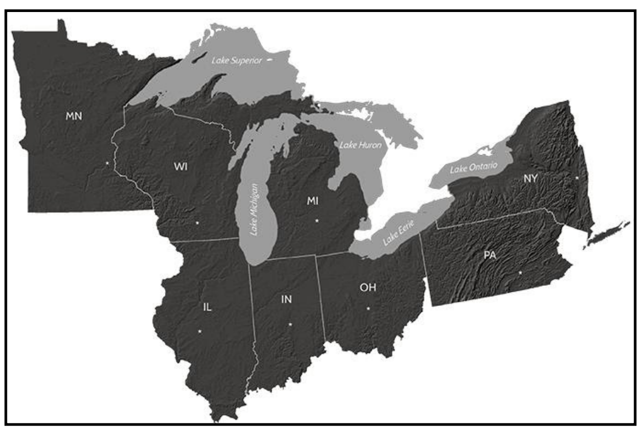


Figure 2: A map of the Great Lakes Region including all five of the Great Lakes (U.S. Climate Resilience Toolkit, 2019). Figure reproduced with permission

The lakes have influenced the region's culture, history, and economy. For centuries, the region's aesthetic value has been enjoyed by those who reside there, including many Indigenous people (Wuebbles et al., 2019). Historically, the lakes' navigable waterways have encouraged settlement, trade, resource mining, and manufacturing (Vaccaro & Read, 2011). This has shaped the economic landscape of the region by acting as a central trade location since the 17th century (Council of the Great Lakes Region, 2018). An economic study by the Council of the Great Lakes Region

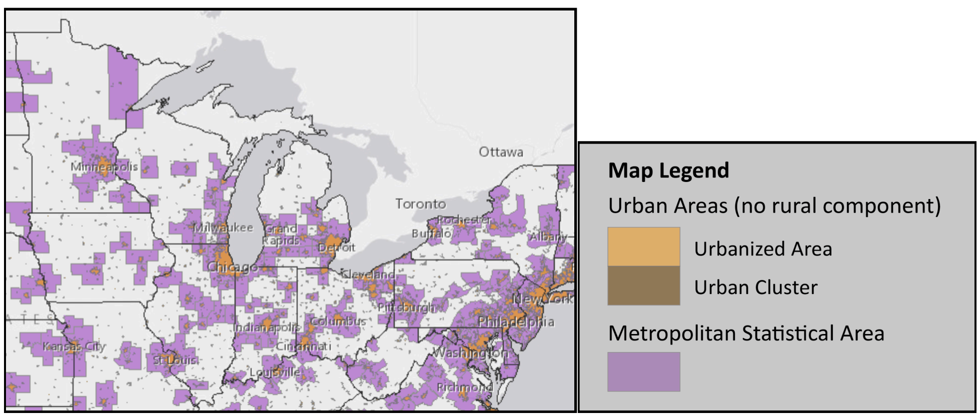
(CGLR) reports that if the region were a country, it would have the third largest GDP in the world (this study incorporates Quebec and Ontario) (Desjardin, 2017). The region is often associated with its manufacturing industry, although tourism, recreation, shipping and agriculture generate substantial business for the region as well (Desjardin, 2017). An analysis of economic data shows that more than 1.5 million jobs are directly connected to the Great Lakes, generating $62 billion in wages annually (Vaccaro & Read, 2011). The Great Lakes provide a large sum of resources to the approximately 60 million people in the region and the country as a whole (Kling et al., 2003). These resources, and the region's ecological systems, are influenced by the people that call this region home; conversely, these resources influence the people of the region.

Regional Socioeconomics

A complex combination of factors determines a person's socioeconomic status. An incomplete list of these factors include: 1) income, job, and industry, and 2) poverty. This study will analyze these factors of the region, highlighting its standards and particular challenges faced by the people of the Great Lakes Region.

Background

Over 60 million people reside in the Great Lakes Region (including Ontario) (Kling et al., 2003). The region is a mosaic of urban, metropolitan, and rural areas (**Figures 3 and 4**). Although much of the Great Lakes Region can be classified as rural, many major cities are found on the shores of the Great Lakes, such as Milwaukee, Detroit, Cleveland, Chicago, and Buffalo (Kling et al., 2003). These cities, and the other geographic areas that compose the region, are filled by people with diverse socioeconomic backgrounds.



Figures 3 and 4: Generated by the United States Census Bureau, this map is a visual representation of the region's urban and metropolitan areas (United States Census Bureau, 2015). Metropolitan Statistical Areas are defined at the county level (note that most counties have a mix of urban, rural, and metropolitan areas and are not completely one or the other). According to the newest American Community Survey, 54.5 percent of people living in rural areas are within a metro area (United States Census Bureau, 2015). Figures reproduced with permission

Income, Jobs, & Industries

Following the Great Recession, job security in the region has been negatively affected (this study excludes Pennsylvania and New York) (Pendall et al., 2017). The jobs in the Great Lakes Region have not been able to recover at the same rate as the rest of the country, according to the U.S. Department of Commerce Bureau of Economic Analysis Regional Economic Accounts (Pendall et al., 2017). New jobs in the Great Lakes Region experienced a less than 1 percent growth rate, from 2006 to 2010, while other states had grown by 7.8 percent (Pendall et al., 2017). Overall employment in the Great Lakes Region also declined by 4.4 percent, between 2006 and 2010, while other states only experienced a 1.2 percent decline (Pendall et al., 2017). In fact, the only job growth in the region during the past 15 years was in low-wage jobs (Pendall et al., 2017). This subsequently contributed to the drop of median household income which fell from 2000 to 2010 in all of the region's states, with the exception of Minnesota (Pendall et al., 2017).

Despite challenges faced by the region, it is still known as the "industrial heartland" of North America. This namesake largely stems from the low cost shipping, by water, of materials that are mined or harvested in the region. This practice has allowed for prosperous economic growth which has continued to the present day (Kling et al., 2003).

The region's largest industry is manufacturing, making up 66 percent of the job force (Vaccaro & Read, 2011). Although much higher than the national average of 7.9 percent, this statistic was found by analyzing the counties of every state bordering the Great Lakes as well as the entire state of Michigan (U.S. Bureau of Labor Statistics, 2020; Vaccaro & Read, 2011). This number is likely high for numerous reasons. One of them being that the lakes act as a natural highway and result in efficient transportation, which sustains manufacturing and steel production (Vaccaro & Read, 2011). However, following two decades of manufacturing stability in the region, there was a manufacturing employment collapse. Beginning in 1999, the collapse could largely be attributed to the Asian financial crisis of 1997. Between 2000 and 2010, the region lost over 1.6 million manufacturing jobs (Gold et al., 2018). After the recession, manufacturing jobs rebounded, although, 22 percent fewer manufacturing jobs remained in the region in 2014 than in 2000 (Gold et al., 2018). While the entire nation felt the difficulties associated with the Manufacturing Collapse, the Great Lakes Region was most affected. This can be explained by the higher proportion of workers in manufacturing in each state of the region, compared to the national average of 6.9 percent. Further, 18 percent of the gross regional product (GRP) for the Great Lakes Region could be attributed to manufacturing, while manufacturing is only responsible for 11 percent of the national GDP (Gold et al., 2018). This has contributed to a slower recovery for the Great Lakes Region following the recession, compared to the rest of the nation, as observed in **Figure 5** (Gold et al., 2018).

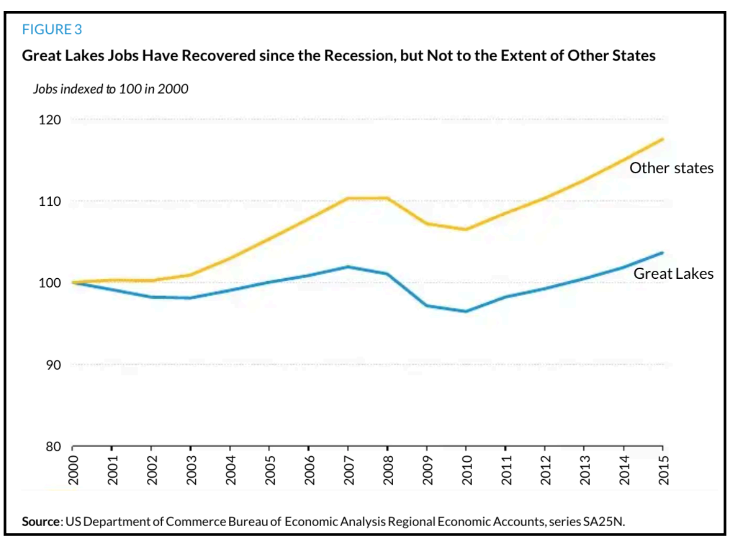


Figure 5: According to the U.S. Department of Commerce Bureau of Economic Analysis Regional Economic Accounts, the Great Lakes Region has had a more difficult

time recovering from the Recession, which can partly be attributed to the region's dependence on manufacturing (Gold et al., 2018). Figure reproduced with permission

Tourism and recreation jobs are also important to the region and compose 14 percent of the job force, making it the second largest industry (Vaccaro & Read, 2011). Small communities lining the Great Lakes especially rely on beaches and other natural areas the lakes provide to support exciting natural attractions. People spend around $19 billion every year on boating trips and equipment alone in the region, and boating sustains over 246,000 jobs (Breffle et al., 2013). Other natural resources that attract tourists to the Great Lakes Region include fishing, hunting, and bird watching activities which bring in an additional $18.5 billion in annual sales (Kling et al., 2003). Niche events, such as The Coast Guard Festival in Grand Haven, Michigan, attract crowds of 350,000 each summer to enjoy concerts, ship tours, and fireworks alongside Lake Michigan (Folger, 2020).

Shipping and Farming tie for the third largest industry in the region, each making up 8 percent of the region's jobs. Shipping is unique to the region because lake vessels can ship goods 10 times more efficiently than trucks and three times more efficiently than railway transportation (Kling et al., 2003). Great Lakes vessels transport 163 million tons of cargo annually (Kling et al., 2003). The region has established itself as a crucial shipping center because freighters are able to carry grain, soybeans, coal, iron ore, and other goods from the Midwest to the Atlantic and beyond. This traffic generates $3 billion annually and supports 60,000 jobs (Kling et al., 2003).

The region also composes a large portion of the agricultural belt in North America. More than 25 percent of the total value of U.S. agricultural products are grown in the Great Lakes Region (Kling et al., 2003). This includes over 50 percent of the nation's corn (*Zea mays*) and over 40 percent of the nation's soybeans (*Glycine max*) (Kling et al., 2003). Within the region's farming industry, fishing acts as a large commercial sector (Wuebbles et al., 2019). Niche crops, such as wine grapes, cherries, and asparagus grow near coastal areas because of the lakes' moderation effects. These crops bring in revenue for the region and additionally contribute to other tourism and community events, including the National Cherry Festival in Traverse City, Michigan, which draws in over 500,000 tourists over the course of eight days (Vaccaro & Read, 2011; Traverse City Tourism, 2020).

Poverty

Poverty is defined as an individual's income being less than that individual's threshold of need (U.S. Census Bureau, 2019). Many Great Lakes communities have experienced increased rates of poverty (Vey et al., 2010). This can largely be attributed to inequalities due to racist policy, social, and/or economic factors (Vey et al., 2010). For example, one of these policies was the National Housing Act of 1934. This policy provided low-interest, government-backed mortgages to only White people (Gill, 2020). Contractors, subsidized by the government, built new subdivisions with the assurance that they would not sell to Black people and sometimes immigrants (Gill, 2020).

Some economic factors include previously discussed topics, such as the job or industry an individual belongs to. Social inequities are evident when observing national poverty rates across racial and ethic populations: 39 percent of the African-American population and 33 percent of the Latino population lives in poverty, which is over double the poverty rate for non-Latino, White, and Asian populations (American Psychological Association, 2017). These rates are also consistent with those within the region.

The decline of the manufacturing industry heavily influenced racial and income segregation for many areas of the region (Vey et al., 2010). This segregation is a driver of skyrocketing regional poverty rates. Between 2000 and 2008, the region's average poverty rate grew 2.0 percent, from 10.1 to 12.1 percent, while the nation only experienced a 0.8 percent difference (Vey et al., 2010). A majority of this poverty has occurred in urban areas of the regions, where economic instability strains already struggling neighborhoods. For example, in Grand Rapids, Michigan, the urban poverty rate climbed from 15.7 percent to 24.7 percent between 2000 and 2008 (Vey et al., 2010). These urban areas are often the same places in which residents have limited access to employment, education, and healthcare. However, rising poverty rates are not exclusive to urban centers: suburban communities of the region, which are typically more stable, also felt a great impact as a result of the Manufacturing Collapse. For example, the suburbs of Indianapolis experienced a beginning poverty rate of less than 5 percent raise to 7.3 percent (Vey et al., 2010).

The decline of available jobs in the manufacturing sector has destroyed many decent paying job opportunities for individuals without a college (or high school) education. Many of these workers are now experiencing difficulties finding employment in alternative industries because they lack necessary skills. Additionally, the pay levels in new industries are not comparable with past manufacturing jobs, leading to increased rates of poverty in urban areas of the region (Vey et al., 2010).

Other Factors

Additional factors including but not limited to age, race and ethnicity, do not determine a person's socioeconomic status but are deeply connected to socioeconomics (American Psychological Association, 2008; American Psychological Association 2010). Ageism and racism partly influence an individual's or population's capacity to contribute to societal change. Changes in the age distribution is expected to become older with time, with the majority of the population moving into the 65+ age bracket, which differs from the rest of the nation (Gold et al., 2018). According to The Urban Institute, the racial demographics of the people in the Great Lakes Region has diversified with time, although it continues to remain mostly white (Gold et al., 2018). As seen in **Figure 6**, the Great Lakes Region has not grown in diversity as much as the rest of the United States. The Great Lakes states are expected to racially and ethnically diversify by 2040, however, the white population is projected to remain proportionally higher in this region than those of other U.S. states (Gold et al., 2018). Additionally, the region has a small proportion of foreign-born, just 8.5 percent (Gold et al., 2018). It is important to recognize that the Great Lakes Region is also home to communities of Indigenous people and tribes, the original inhabitants of the region; this population is now a small minority (The United Nations, 2016).

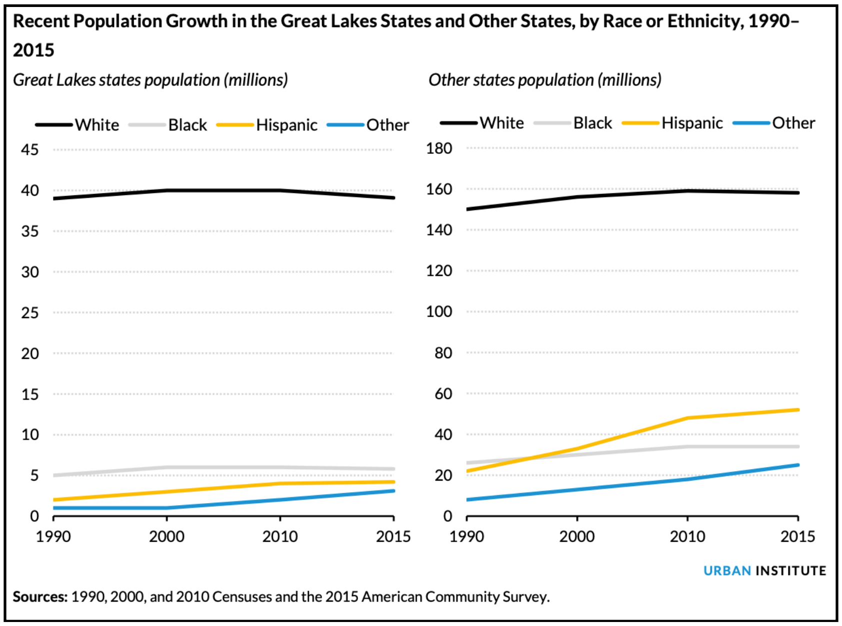


Figure 6: This graphic was generated by the American Community Survey of the 1990, 2000, and 2015 Censuses (population in millions). The Great Lakes Region has diversified with time, but not nearly as much as the rest of the nation. People of other races (including Asian, American Indian, unclassified, and multiple races) made up 2 percent of the Great Lakes States and 4 percent in other states (Gold et al., 2018). Figure reproduced with permission

Climate Change in the Great Lakes Region

Climate change is already occurring in the Great Lakes Region and causing disruptions in the natural systems and goods and services they provide (Wuebbles et al., 2019). Additional changes in 1) temperature, 2) precipitation, and 3) biological systems are expected throughout the next several decades due to past and projected emissions of greenhouse gases. These changes greatly impact 4) human health.

Below, higher and lower emission scenarios are referred to. Emission scenarios are future possible pathways society may take regarding the emission of greenhouse gases (Hanania & Donev, 2016). The determining factors for emission scenarios depend on driving forces such as: population growth, energy use changes, economic development, technological development, and land use change (Hanania & Donev, 2016). The IPCC has developed two emission scenarios (higher and lower) as a result of four different storylines titled: A1 (economic growth on a global scale), A2 (economic growth on a local scale), B1 (environmental protection on a global scale), and B2 (environmental protection on a local scale) (Hanania & Donev, 2016). These scenarios allow researchers to project future impacts based on how society might respond to climate change.

Temperature

In the Great Lakes Region, an annual average temperature increase of 1.4°F for the period between 1985 and 2016 was observed; this trend is higher than the overall change observed in the contiguous United States, 1.2°F (Angel et al., 2018). By the end of the 21st century, temperatures are expected to rise between 2.7°F and 7.2°F globally, which will greatly impact the region (Angel et al., 2018). The region is expected to experience challenges associated with 1) increased air temperatures and 2) warmer lake temperatures

Initially, temperatures are expected to increase more rapidly during the winter season, which could be attributed to the feedback loops related to melting snow (Hayhoe et al., 2009). Greater temperature changes are projected for summer months during the second half of the century, as observed in **Figure 7**, which heightens concerns regarding water availability (Hayhoe et al., 2009).

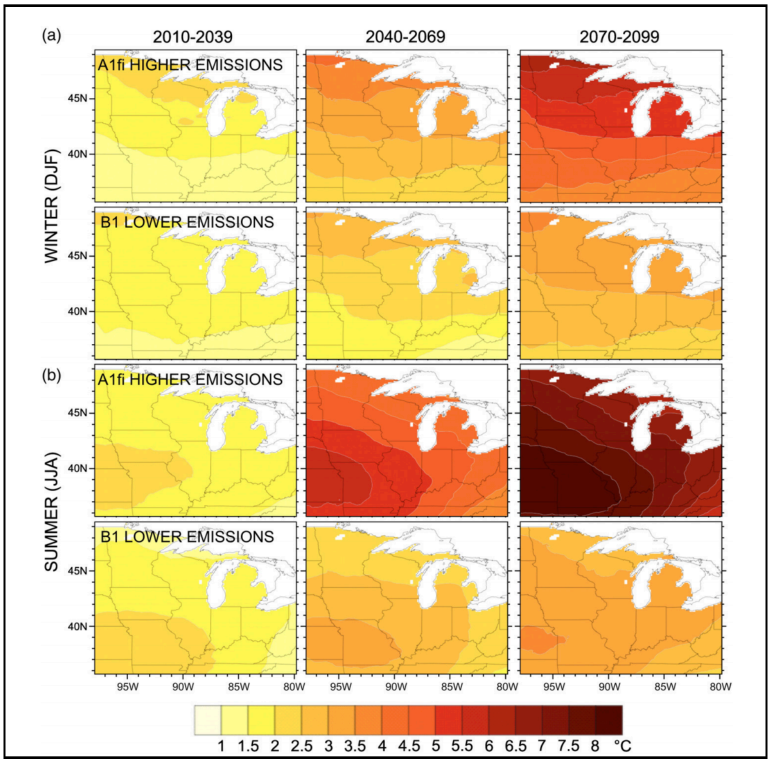


Figure 7: Predicted average temperature increase by Hayhoe et al. (2009) in (a) winter (December, January, and February) and (b) summer (June, July, and August). This graphic shows results for the Special Report on Emission Scenario (SRES) A1fi (higher) and B1 (lower) for near-term (2010–2039), midcentury (2040–2069), and end-of-century (2070–2099) (Hayhoe et al., 2009). Figure reproduced with permission

Larger temperature increases are projected for the more southerly Great Lake states, compared to the northern states of the region (Hayhoe et al., 2009). Warmer temperatures cause a variety of positive and negative effects for the region. In the winter season, there is an expected decreased use of energy as well as a risk of cold-related illnesses and death. However, summer months would require more energy use and extreme heat waves, which are associated with heat-related mortality (Hayhoe et al., 2009). Compared to other regions, the Midwest is expected to have the overall greatest increase in temperature-related premature deaths (Angel et al., 2018). By 2090, an additional 2,000 premature deaths due to heat are projected to occur each year in the region under the high emission scenario (Angel et al., 2018).

Additionally, extremely warm days (characterized by temperatures above 90°F) will become more frequent in the region, with a predicted 30 to 60 extremely warm additional days by the end of the century (Angel et al., 2018). The area is predicted to experience a decrease in extremely cold days (characterized by temperatures less than 32°F). Humidity in the region is also expected to increase (Angel et al., 2018).

Warming air temperatures lead to warmer lake temperatures. A study by Dr. Hayhoe showed that temperatures across the Great Lakes themselves could increase by as much as 3.5 to 11°F before the end of the century, depending on future emissions (Hayhoe et al., 2009). When air temperatures are higher, plants use more water and transpiration is increased, which leads to higher rates of evaporation from the ground and the lakes. Warmer lake temperatures change water circulation patterns, specifically altering the timing and duration of summer stratification. Warmer air temperatures also result in the reduction of the duration and extent of ice coverage on the lake (Hayhoe et al., 2009). Warm lakes are coupled with ecological difficulties for organisms who reside there (Folger, 2020).

Precipitation

The number of extreme rainstorms worldwide will double with each 1° Celsius increase: climate models project and consider that this trend may already be under way (Folger, 2020). When analyzing annual precipitation, the United States average has increased by approximately 4 percent, while the states in the Great Lake Region averaged a 9.6 percent increase: more than doubling the national average (Wuebbles et al., 2019). The timing and distribution of precipitation will likely be altered in the presence of intensifying climate change. Winter and spring precipitation is expected to rise by as much as between 20 and 30 percent by the end of the century. Although summer precipitation will not change by much, a small decrease may occur. This is a cause of concern because the lack of the summer precipitation will not be able to balance warmer temperatures projected during those summer months. This can be viewed in **Figure 8** (Hayhoe et al., 2009).

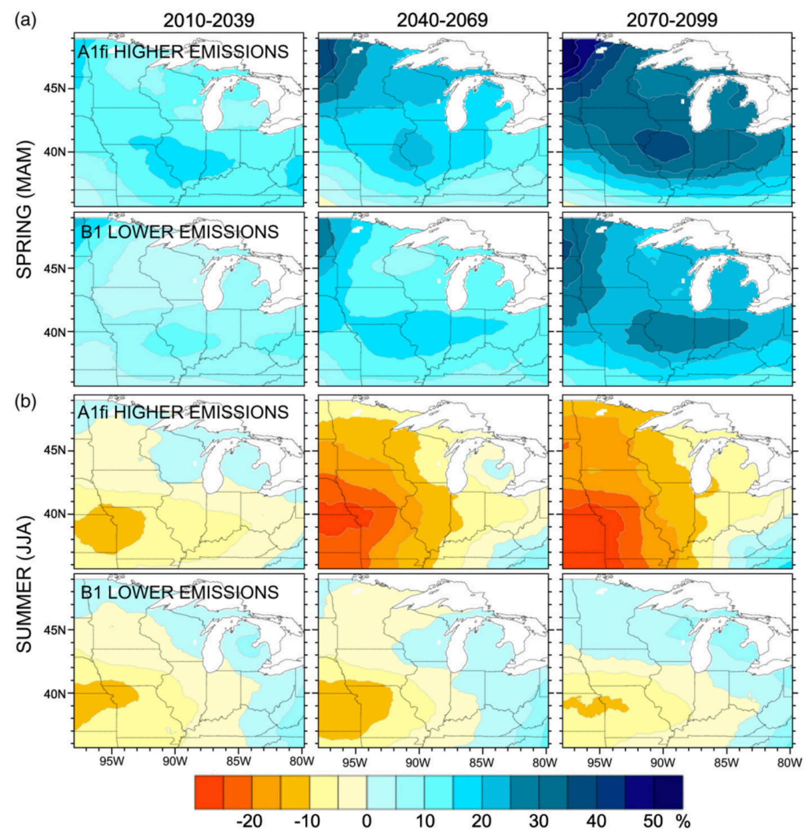


Fig. 7. Projected change in (a) spring (Mar–Apr–May) and (b) summer (Jun–Jul–Aug) average precipitation as simulated under the SRES A1fi (higher) and B1 (lower) emissions scenarios by the average of the subset of 3 AOGCMs used for the impact analyses presented in this volume. Precipitation projections are in units of percentage change relative to the 1961–1990 average and have been statistically downscaled to a spatial resolution of one-eighth degree.

Figure 8: According to Hayhoe et al., this graphic shows the predicted change in average precipitation as simulated under the Special Report on Emission Scenario (SRES) for (a) spring (March, April, and May) and (b) summer (June, July, and August) under A1fi (higher) and B1 (lower) emissions scenarios (Hayhoe et al., 2009). Figure reproduced with permission

An increase in precipitation is expected to increase flooding, making cities with impermeable surfaces susceptible to damage. In rural landscapes, increasing precipitation will also increase runoff and soil erosion. More precipitation in winter and spring could result in rivers that reach their peak levels in spring to overflow because of melting snow (Hayhoe et al., 2009). Already high river levels could increase flood risk for numerous areas within the region (Hayhoe et al., 2009).

Serious flood events have already occurred. In 2019, a flood event lasting over 100 days, stemming from the overflowing Mississippi River, affected many people in the southwest area of the region. The flooding was particularly extensive as it inundated streets, homes, businesses, agriculture fields, and sewage and water treatment plants (Cusick, 2019). In 2020, two dams collapsed due to extreme rainfall and poor infrastructure in Midland, Michigan (Blakely, 2020). This flood caused 11,000 people to be evacuated and experts have called it a 500-year flood event (Jordan & French, 2020). The dam's inadequate spillway capacity was failed to be addressed and inevitably overwhelmed infrastructure, causing trauma and damages for numerous people (Blakely, 2020). Specifically, in the Great Lakes Region, climate modeling projects a 50 percent to 120 percent increase in overflow events by 2100 (Patz, 2014).

Intensity of a precipitation event is primarily controlled by the amount of moisture in the atmosphere during a storm (Patz et al., 2008). Moisture-capacity of the atmosphere increases exponentially with temperature, therefore, it is expected that intense precipitation will accompany climate change (Patz et al., 2008). Extreme weather events (considered to be 1 in 50- and 1 in 100-year storms) are predicted to increase, subsequently increasing extreme precipitation levels. More common storms (considered to be 1 in 5 year return period) are also projected to increase by as much as 18.7 percent by 2085 (or 10.8 percent for the lower scenario) (Angel et al., 2018). Over the past five decades, there has already been an increase in observed precipitation from extreme weather events in the Great Lakes Region, and this pattern is expected to continue increasing over the coming decades (USGCRP, 2017; Wuebbles et al., 2019).

Contamination events occur when a discharge of stormwater contaminants enters water bodies if the volume exceeds the contaminant capacity (Patz et al., 2008). These events occur when rainfall exceeds 5-6 cm, or 2-2.5 inches (Patz et al., 2008). The frequency of contamination events are expected to increase by between 50 percent and 120 percent by the end of the century. In fact, rain events exceeding 6 inches now occur regularly (Wuebbles et al., 2019). Consequently, instead of continuing to experience one of these events 0.5 times per year, contamination events are projected to be experienced between 1 and 1.2 times a year (Patz et al., 2008). Additional precipitation will cause an increase in nutrient runoff from farms into surface waters during intense weather events, which is harmful to human health. As previously mentioned, HABs, a consequence of nutrient runoff, are expected to become more frequent and also present public health concerns (Angel et al., 2018). Numerous studies and events have shown a connection between rainfall and the amount of pollutants entering the Great Lakes. The lakes act as a water source for over 40 million people and extreme precipitation has the potential to overwhelm sewer systems which will threaten those who depend on clean and safe infrastructure (Patz et al., 2008).

Wetter periods are projected to delay harvest and planting for agriculture. Dry spells are also expected at times when crops are dependent on water. Both short-term wet and dry periods will cause crops to be especially vulnerable to extreme weather events, such as long-term floods and droughts (Kling et al., 2003).

The Great Lakes act as an influence on the region's climate. This includes moderating temperatures, increasing cloud cover and precipitation over and downwind of lakes during the winter, as well as decreasing clouds and rainfall during the summer (U.S. Climate Resilience Toolkit, 2019). Consistent with the region's climatic changes, the Great Lakes appear to be trending towards higher water temperatures and little ice coverage which will contribute to a disruption of the region's climate (U.S. Climate Resilience Toolkit, 2019). Between 1973 and 2010, ice coverage on the Great Lakes declined 71 percent (Wuebbles et al., 2019). A visual of the decline of maximum ice coverage over the entire Great Lakes over a 45 year period is shown in **Figure 9**. Less ice and an increase of frequency in intense storms, results in flooding and erosion which will continue to threaten the region with a changing climate (U.S. Climate Resilience Toolkit, 2019). Earlier ice break up will alter the timing of stream flows, which will also result in more frequent flooding (Kling et al., 2003). River flooding may also increase in frequency and intensity. This can largely be attributed to increased precipitation and collection as a result of impermeable infrastructure. This can also be coupled with erosion, additional water pollutants, pesticides, and delays in recovery from acid rain (Kling et al., 2003).

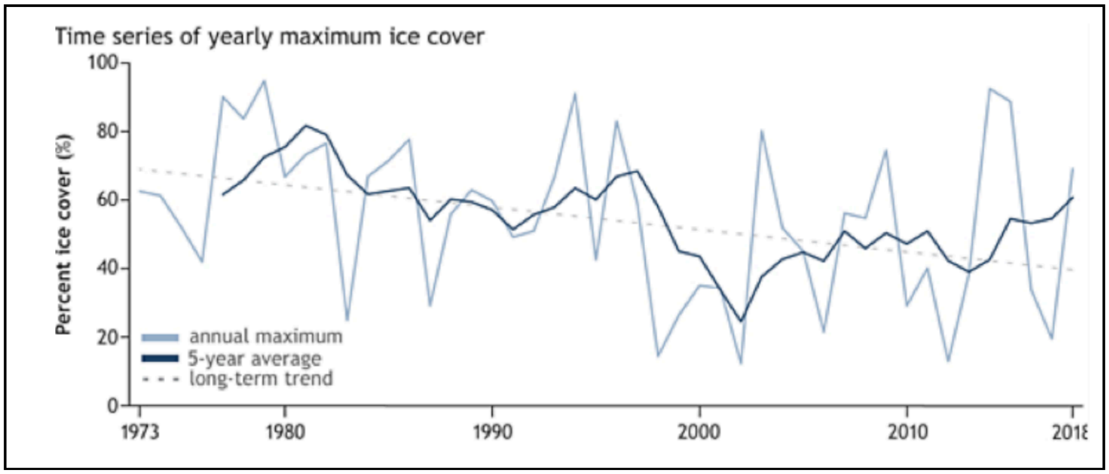


Figure 9: Time series of the maximum ice coverage over the entire Great Lakes from 1973 to 2018 produced by NOAA Great Lakes Environmental Research Laboratory (GLERL) (Wuebbles et al., 2019). The solid line denotes the 5-year running mean and the dashed line represents the long term linear trend (Wuebbles et al., 2019). Figure reproduced with permission

Lake effect snowfalls are also predicted to intensify (Wuebbles et al., 2019). However, lake effect snowfall may shift to lake effect rainfall as a result of warming lake temperatures and a reduction of lake ice (Angel et al., 2018).

Ecological Impacts

The Great Lakes Region experiences ecological disturbances as a result of climate change impacts. It is important to recognize that climate change is one stressor on biological systems and that many other stressors, such as habitat destruction and fragmentation, weaken the region's ecology and the goods and services they provide. The impacts of climate change are already present and are likely to intensify.

Destratification, or the turnover of water, is a crucial seasonal event for biological activity in the lakes. During destratification, cycling of the water mixes oxygen from the surface to the bottom and nutrients from the bottom to the surface. This typically occurs twice a year. The first, is in the spring when the temperature rises above 39°F, the point at which freshwater attains maximum density (U.S. Climate Resilience Toolkit, 2019). The next occurs in the fall when the water temperature drops below 39°F. Models suggest destratification in spring, which initiates aquatic "growing season," is projected to occur sooner and the fall overturn is expected to happen later in the year because of temperature changes (U.S. Climate Resilience Toolkit, 2019). As the duration of the destratification period lengthens, low oxygen levels at considerable depths as well as a lack of nutrients on the surface can result in declines in species populations for both zones (U.S. Climate Resilience Toolkit, 2019). This results in an increased risk of oxygen depletion which aids in the formation of "dead zones" and HABs (Kling et al., 2003).

The changing climate of the Great Lakes Region is likely to result in changing habitats for many native species and will be discussed in further detail directly below.

Forest distribution is likely to shift as a result of the warmer air temperatures. Boreal forests are expected to shrink and move north (Kling et al., 2003). Increased atmospheric carbon dioxide is likely to alter competitive interactions between plants and ecosystems. Plant tissues are expected to change with respect to the carbon to nitrogen ratio, which has implications in terms of the plant's nutritional content (Kling et al., 2003). Faster growing, typically weedy species, tend to be encouraged by the presence of carbon dioxide compared to slower growing species. Deposition of nitrogen in the atmosphere may also encourage forest growth in the short-term. Long-term effects include increased nitrate pollution in drinking water, groundwater, and waterways (Kling et al., 2003). Ground-level ozone concentrations will most likely damage forest trees, which may eliminate the potential positive effect of carbon dioxide on forest growth (Kling et al., 2003). Alterations in leaf chemistry due to carbon dioxide may diminish food quality and change terrestrial food webs.

Following mild and wet winters, populations of rodents carrying infectious diseases that can be transmitted to humans, rapidly increase (World Health Organization, 2020). This is a result of increased precipitation. Pest species, such as the gypsy moth (*Lymantria dispar dispar)*, are also likely to expand with changing temperatures (Kling et al., 2003).

Resident birds, such as northern cardinals *(Cardinalis cardinalis)*, titmice *(Paridae)*, and chickadees *(Poecile atricapillus)* may begin breeding sooner and raise more broods each season (Kling et al., 2003). This may cause problems of available resources and reduce the diversity of forest birds in the region. Canadian geese *(Branta canadensis)* may also winter further north. Long-distance migratory birds, like scarlet tanagers, warblers, thrushes, and flycatchers who time their migration by day length, instead of weather, may be in trouble because their food sources will likely be diminished when they arrive in the Great Lakes Region. Drought and lower water levels may increase ultraviolet radiation to frogs and other aquatic organisms (Kling et al., 2003). Flooding is likely to reduce breeding sites for migratory shorebirds, as well as amphibians and waterfowl. Birds in the region are already being affected, especially because of an increased spread of disease (Wuebbles et al., 2019). An increase in recent deaths of fish-eating birds within the region have been connected to birds ingesting fish that are infected with a type of avian botulism (*Clostridium botulinum)* (Culligan et al., 2002; Michigan SeaGrant, 2018). Outbreaks in botulism are becoming more frequent because they are related to higher summer water temperatures and lower water levels; the intensity of outbreaks are also projected to increase during the century (Wuebbles et al., 2019).

Mammals in the region are experiencing various direct and indirect effects of climate change. Many mammals are expanding north with increasing temperatures. In a recent study focused on distributions of nine common woodland rodent species in Michigan, several species revealed range declines in the state. The authors of this study assert that warming temperatures are likely the main driver, because the species shifted north (Wuebbles et al., 2019). Other mammals, such as moose *(Alces alces)*, have experienced serious declines. Some of their decline can be attributed to direct effects from climate change. For example, these effects include the change in moose's ability to thermo-regulate in both winter and summer because of changes in air temperature and precipitation. White-tailed deer *(Odocoileus virginianus)* are expected to expand north into habitats which have historically been dominated by moose. White-tailed deer commonly carry a parasite called brainworm (*Parelaphostrongylus tenuis)* which is fatal to moose. Parasites in general are surviving in greater numbers and have acted as serious stressors for moose. On Isle Royale National Park, located on an island in Lake Superior, moose have also decreased in size, a phenomenon scientists also attribute to warming winter temperatures. In accordance with these effects, climate changes will have indirect effects on moose. Habitats, and species that compose those habitats, will likely alter with changing forest cover. Finally, increased mortality from gray wolves *(Canis lupus)* may be an additional factor leading to declines in moose populations. Evidence for how a changing climate is altering behavior of wolves and increasing mortality of moose has been described in studies conducted on Isle Royale (Wuebbles et al., 2019).

Loss of ice in the winter will reduce winterkill in shallow lakes and harm the reproduction of whitefish in the Great Lakes, where ice cover protects eggs from storms (Kling et al., 2003). Cool and coldwater species, such as lake trout *(Salvelinus namaycush)*, brook trout *(Salvelinus fontinalis)*, whitefish *(Coregonus clupeaformis)*, northern pike *(Esox lucius)*, and walleye *(Sander vitreus)* are projected to decline in the southern parts of the region. Warm-water species, such as smallmouth bass (*Micropterus dolomieu*) and bluegill (*Lepomis macrochirus*) are likely to migrate and expand to the northern areas of the region. Warmer and more shallow lakes may encourage the accumulation of mercury and other contaminants in fish and the aquatic food chain (Kling et al., 2003). Warm waters will also accelerate the growth of fish which will subsequently increase their feeding rates. It is unknown if the region's resources will be capable of supporting this growth.

Invasive species will increase and place stress on native plant and animal populations in the region (Kling et al., 2003). Although this issue will continue to be a significant one for the region, it cannot be attributed to climate change. However, climate change and environmental degradation will most likely encourage the presence of invasive species. For example, native fish may experience enhanced growth because of warmer water temperatures. These same changes are not exclusive to native species and can also influence the growth and survival of invasive species. Nonnative species like the alewife (*Alosa pseudoharengus)*, zebra mussels *(Dreissena polymorpha)*, and quagga mussels *(Dreissena bugensis)*, have had great negative influences on the lakes and its natural processes. Therefore, warmer water temperatures may result in increased invasion success (Angel et al., 2018).

Lastly, the instability of diatoms have the potential to seriously disrupt the lakes and their ecosystems (Folger, 2020). Diatoms are single-celled algae that use light to convert water and carbon dioxide into simple carbohydrates; they supply the lakes with oxygen (Folger, 2020). Diatoms can be thought of as the lakes' primary food source and every organism and ecosystems depend on the health of the diatoms (Folger, 2020). Andrew Bramburger, a lake ecologist with Environment and Climate Change

Canada, the agency that administers and enforces much of the country's environmental policies explains that " ... diatoms in the oceans, rives, and lakes in the world make about half the oxygen in our atmosphere." (Folger, 2020). Researchers have found approximately 3,000 species of diatoms in the Great Lakes and there are likely more to be identified (Folger, 2020). Scientists have discovered that climate change seriously threatens diatoms and their role in the health of the ecosystem. Individual diatoms in the Great Lakes are shrinking and cannot harvest light as efficiently, an ongoing 115 year trend shows (Folger, 2020). This is resulting in low-quality or toxic food items to act as replacements, which subsequently harms the entire food web (Folger, 2020). A winter study on diatoms also showed that they were more efficient beneath snow-covered ice than ice alone (Folger, 2020). It is suspected that snow may protect them from excessive sunlight. If this continues, diatoms will likely be unable to provide the calories for larger components of the food web like bass (Folger, 2020). Invasive species also harm diatoms and have caused diatoms to drop by 90 percent in Lake Erie in 35 years (Folger, 2020). This keystone loss is equivalent to the African savanna losing 90 percent of its grasses (Folger, 2020).

Human Health

The Great Lakes Region faces many similar health difficulties as the rest of the United States. These ailments include diabetes, lung disease, and heart disease (Woolf & Aron, 2013). Generally, the Great Lakes Region aligns with the average of the country's rankings for these diseases and overall health. However, the region is faced with other unique and distinctive health obstacles.

Specific health concerns that are common in the region stem from: degraded air quality, changing habitats, increased temperature and precipitation. Degraded air quality has a substantial impact on people of the region (Angel et al., 2018). Increases in ground-level ozone and particulate matter are linked to multiple lung and cardiovascular diseases, such as chronic obstructive pulmonary disease (COPD) and asthma (American Lung Association, 2020). These diseases can lead to reproductive, nervous system, cardiovascular, and respiratory harm as well as result in premature death (American Lung Association, 2020). Dangerous ozone levels can also cause premature death, which will endanger the region, as seen in **Figure 10**. Pollen production has also recently risen which can aggravate those with pre-existing asthma and other respiratory diseases. The pollen seasons are starting earlier and lasting longer, which is a cause of considerable concern for individuals with respiratory illnesses (Angel et al., 2018). The elderly, children, poor, and chronically ill are particularly vulnerable (American College of Physicians, 2017).

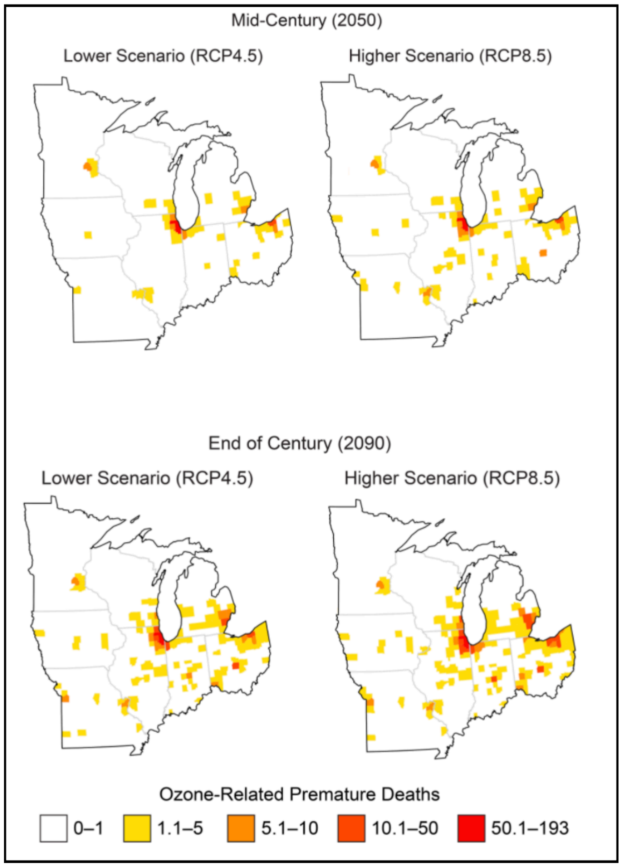


Figure 10: Maps of part of the region show estimates for the change in average annual ozone-related premature deaths (Angel et al., 2018; Environmental Protection Agency, 2017). These estimates are based on changes at the county level and are based on projections over the summer months in 2050 (2045-2055) and 2090 (2085-2095), with comparison to 2000 (1995-2005). These results show the average of five global climate models from EPA in 2017 (Angel et al., 2018). Figure reproduced with permission

Changing habitats for disease carrying-insects are associated with higher rates of infection and pose a great risk for the region (U.S. Climate Resilience Toolkit, 2019). These include mosquitoes (*Culex pipiens, Culex tarsalis,* and *Ixodes scapularis*) that transmit West Nile Virus and Lyme disease which will continue to become more common within the region (U.S. Climate Resilience Toolkit, 2019). Lyme disease has been a particular concern as the incidence of disease is spreading geographically and hyper-endemically (Johns Hopkins Lyme Disease Reach Center, 2020).

Cyanobacteria can be introduced into drinking and recreational water sources as a result of harmful algal blooms (HABs). The presence of nutrient-rich environments, higher water temperatures, and increased runoff are all conditions that promote the growth of cyanobacteria. These conditions are projected to increase within the region and will consequently increase HABs, which have the potential to obliterate surrounding ecology (U.S. Climate Resilience Toolkit, 2019). Contamination from cyanobacteria is associated with respiratory illness, gastrointestinal illness, liver damage, kidney damage, skin and eye irritation (U.S. Climate Resilience Toolkit, 2019).

Regional contamination events are becoming more frequent as a result of increasing extreme precipitation events (The United Nations, 2016).

Increasing temperatures, especially in urban centers, can cause dangerous working and living conditions. High rates of heat-related illness are present in rural populations where temperatures impact workers' health, safety, and productivity (U.S. Climate Resilience Toolkit, 2019). Many people of the region are expected to be significantly impacted, as the majority of the population lives in these areas (U.S. Climate Resilience Toolkit, 2019).

Increased flooding, caused by more frequent extreme precipitation and storm events, can result in water contamination, injury, and death (U.S. Climate Resilience Toolkit, 2019). Flooded buildings often host mold that may cause asthma attacks and allergies (U.S. Climate Resilience Toolkit, 2019). Flooding can also cause substantial mental stress, such as insomnia, anxiety, depression, and post-traumatic stress disorder (U.S. Climate Resilience Toolkit, 2019). Precipitation often acts as a vector for pathogens, like cyanobacteria, that cause gastrointestinal illnesses (U.S. Climate Resilience Toolkit, 2019). This specifically endangers populations who rely on untreated groundwater, such as wells, which is common for many rural communities in the Great Lakes Region (U.S. Climate Resilience Toolkit, 2019). These risks are projected to increase as a consequence of the increased incidence of flooding events (Hayhoe et al., 2009).

As described, these health issues are rooted in environmental issues such as air, temperature, precipitation, and ecological concerns. Climate change impacts human health, which can be a great burden for families with low socioeconomics to treat and acquire adequate medical access. Additionally, individuals with a low SES experience disparities in health behaviors (Pampel et al., 2011). For example, unhealthy behaviors such as tobacco use, physical inactivity, and poor nutrition have been empirically well demonstrated for individuals with a low SES (Pampel et al., 2011).

Good health status is largely dependent on adequate access to healthcare. Much of the Great Lakes Region is classified as rural, which is often considered a barrier to satisfactory healthcare. Rural residents may experience higher morbidity and mortality rates compared to their urban counterparts (Stanford Medicine, 2020). This, in part, can be attributed to the lack of physicians who practice in these communities. Nationally, 20 percent of the population lives in rural areas and only 10 percent of physicians practice in these same areas (Stanford Medicine, 2020). Additionally, fewer dentists and first responders are present in rural areas. Healthcare facilities that are located in rural areas are often small in capacity and service options. Residents have to travel farther distances to reach a healthcare provider, which is not only inconvenient but also contributes to a higher fatality rate. Emergency incidents, such as serious motor vehicle accidents and unintentional injuries, are more common in rural areas when compared to urban areas (Stanford Medicine, 2020). Additionally, timely access to emergency care remains limited in rural areas. Succeeding emergency care, follow-up care and proximate family support are both less common in rural areas (Stanford Medicine, 2020).

The Relationship Between Socioeconomic Status & Climate Change

Multiple independent lines of evidence demonstrate that people are rapidly causing the climate to change (IPCC, NASA, US National Climate Assessment). Approximately half of anthropogenic greenhouse gas emissions between 1750 and 2010 have been emitted since 1970 (Patz, 2014). Further, the increase in emissions has been the greatest in the last decade at 2.2 percent per year, compared with 1.3 percent per year (from 1970 to 2000) (Patz, 2014). Although the attribution of extreme weather events to climate change is complex, impacts of climate change are expected to include the increased frequency of events such as natural disasters, resource management issues, and extreme weather events (Stocker, 2013). These create injury, negative health effects, loss of life, and damage to infrastructure, livelihoods, and the environment. Between 1995 and 2015, there were 6,457 weather-related disasters which contributed to 600,000 deaths and affected an additional 4.2 billion in various aspects (Oxfam, 2015).

Numerous interacting complex factors may determine the intensity of impact under various circumstances. These factors include, but are not limited to: 1) type of impact, 2) magnitude of impact, 3) rate of change as a result of impact, and 4) existing institutionalized structures. These factors all influence the way a particular impact is distributed throughout society and who feels the impact most intensely. Existing institutions and societal structures can enable or interrupt inequalities in a way that determines who is impacted from climate change and how intensely.

Available evidence suggests that in some, but not all circumstances, climate change tends to exacerbate inequalities (Substance Abuse and Mental Health Administration, 2017; Stocker, 2013). In some cases, life skills may be more or less useful for dealing with the impacts of climate change; however, it seems virtually certain that power and influence are more influential factors to determining severity of climate change impacts. This existing relationship in which climate change risks and hazards exacerbate socioeconomic inequalities is reinforced in various scenarios, creating a cycle. **Figure 11** shows how a cycle of socioeconomic inequality is maintained when climate change impacts aggravate pre-existing inequalities. Additionally, socioeconomic inequality ensures that individuals with high SES can live large carbon footprint lives thus contributing to emissions, and CC results in many socioeconomic impacts.

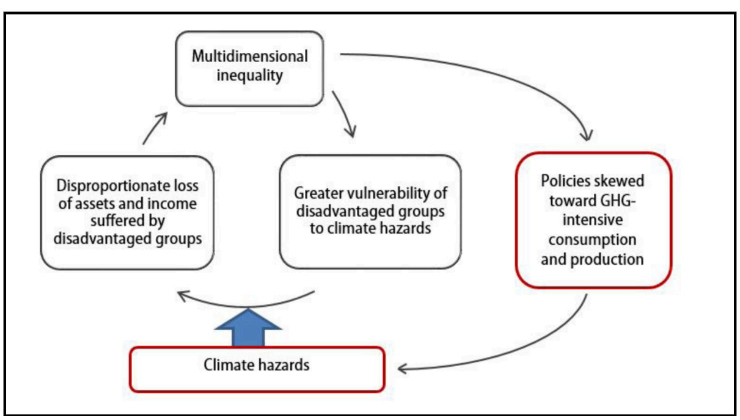


Figure 11: The reinforced cycle between inequality and climate change (Islam & Winkel, 2017). Note that greenhouse gases are referred to as GHG. Figure reproduced with permission

From this figure, the relationship can be observed as part of an amplifying cycle for four reasons in which pre-existing low socioeconomic status 1) increases vulnerability to risks and hazards, 2) increases exposure to risks and hazards, 3) increases likelihood of exposure affecting other compounding stressors (poor water or air quality, malnutrition, pre-existing health conditions, etc.) and 4) decreases adaptive capacity in the face of a given hazard. The limitations on adaptive capacity subsequently increase vulnerabilities and the cycle persists. J. Timmons Roberts, an environmental policy expert at Brown University, expresses worry over this exacerbating relationship and how to produce an adequate societal response. He states that this scenario is "… almost the worst possible setup for trying to solve the problem, to have some group that's already rich and powerful actually getting some boost from this effect, while the poor sufferers are suffering even more" (Borunda, 2019).

1) Increased Vulnerability

Those already burdened by marginalization and social exclusion experience the greatest losses in terms of lives and livelihoods due to climate change (Oxfam, 2015). If socioeconomically vulnerable populations were to experience equal levels of exposure to climate hazards as non-vulnerable populations, these groups would remain at a disadvantage due to existing social and economic stressors or factors because of socioeconomic factors, such as having adequate money and resources. For example, if a flood occured in a floodplain, those who lived in houses with inadequate materials are more susceptible to damage than those who reside in houses constructed with sturdy materials. Similarly, poor farmers have an increased vulnerability to changing rain patterns because they lack the financial resources to adapt (The United Nations, 2016). This is an example of how existing societal structures determine who is most vulnerable to climate risks and hazards. These structures go beyond economic struggles and present additional challenges to those with low socioeconomic status.

In a 1980 heat wave, free fans were distributed, but many of those who died were on fixed incomes and did not use the fans because of worries about high utility bills (U.S. House of Representatives, 1980, as cited in Fothergill & Peek, 2004; Substance Abuse and Mental Health Administration, 2017). A Chicago heat wave in 1995 claimed 739 lives and it was reported that most of those who died were low-income individuals (Klinenberg, 2002, as cited in Fothergill & Peek, 2004; Substance Abuse and Mental Health Administration, 2017).

Ethnicity and race are also connected to the degree of vulnerability that populations experience. Typically, more advantaged ethnic groups receive additional attention from leaders and social institutions which allow these groups to claim a disproportionate share of resources (Shrinath, Mack and Plyer, 2014). Low-income status is often unfairly and disproportionately related to race and ethnicity. Racially-motivated systems, structures, and policies such as redlining have placed certain racial minorities at a purposeful socioeconomic disadvantage. The repercussions of this were illustrated in New Orleans in 2005 when African-Americans and other disadvantaged groups living in poverty were the most susceptible to the damage inflicted by Hurricane Katrina. As a result of historic preservation-related laws, the housing industry in New Orleans at the time was relatively older than average, with 41 percent of houses in 2003 having been built before 1949 (Shrinath, Mack and Plyer, 2014). As the houses of African-Americans, and of other disadvantaged groups, living in poverty were not only old and fragile, they were also severely damaged from the hurricane's impact. Additionally, a large portion of the city's population were living in renter-occupied housing units. This rate was significantly higher among low-income and African-American households, which were more susceptible to damage (Logan, 2006; Masozera, Bailey and Kerchner, 2007).

2) Increased Exposure

Those with a low socioeconomic status are more likely to be exposed to intense climate hazard exposure (Stocker, 2013). Fothergill and Peek report on heat waves in the Midwest in which the majority of the mortalities were of low socioeconomic status or low-income, as well as older adults (Substance Abuse and Mental Health Administration, 2017).

Economic and social factors may influence the place someone lives and how much exposure they receive because of it. For example, the impacts of climate change significantly affect geographically poor regions more than prosperous ones (Substance Abuse and Mental Health Administration, 2017). Further, low-income groups, and those subject to other forms of discrimination, are more likely to be forced to live in marginal areas because of restrictions on available land and housing. This may occur as a result of socially devised constructions, official or unofficial restrictions. An additional history of co-locating environmental hazards of low-income communities show that these hazards exacerbate risk between factors like air quality and temperature which compound and amplify each other. Vulnerability also increases for these populations when there is lack of income and asset diversification (Substance Abuse and Mental Health Administration, 2017). An international study reported by the Human Development Report Office on data from the Centre for Research on the Epidemiology of Disasters' Emergency Events Database exemplifies a trend in human development and deadliness of a disaster, as shown in **Figure 12** (United Nations Development Programme Human Development Report, 2019).

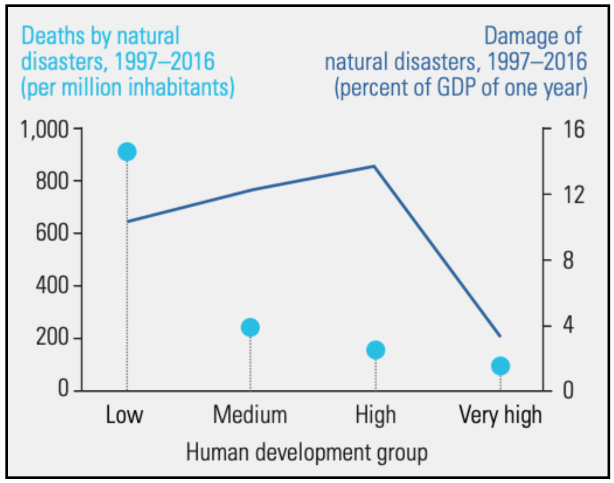


Figure 12: Data showing the correlation between deaths by natural disasters (per million inhabitants), damage of nature disasters (percent of GDP of one year) and human development group. The data is simple averages across human development groups. Country values are calculated from the sum of population or GDP over 20 years divided by the population or GDP in one representative year (United Nations Development Programme Human Development Report, 2019). Figure reproduced with permission

3) Increased Compounding Stressors

Compounding stressors, or multiple stressors in an individual's life, are also more likely to challenge those with low socioeconomic statuses. For example, low-income and minority populations were less able to relocate during storm warnings and therefore more likely to experience injuries and death during storms. The lack of ownership or access to a means of transportation was a significant factor affecting the probability of evacuation and relocation for these populations in Hurricane Katrina (Colton, 2006; Masozera, Bailey & Kerchner, 2006). Another challenge for these populations include the lack of financial and social resources needed to find a dwelling to relocate to. These factors exemplified why low-income, and in this case African-American inhabitants, suffer greater levels of loss and damage than the wealthier and white households as a result of their socioeconomic status. This concept of greater economic loss relative to other factors, such as income, can also be observed in the study of high-income, upper-middle-income, lower-middle-income, and low-income countries, as seen in **Figure 13.**

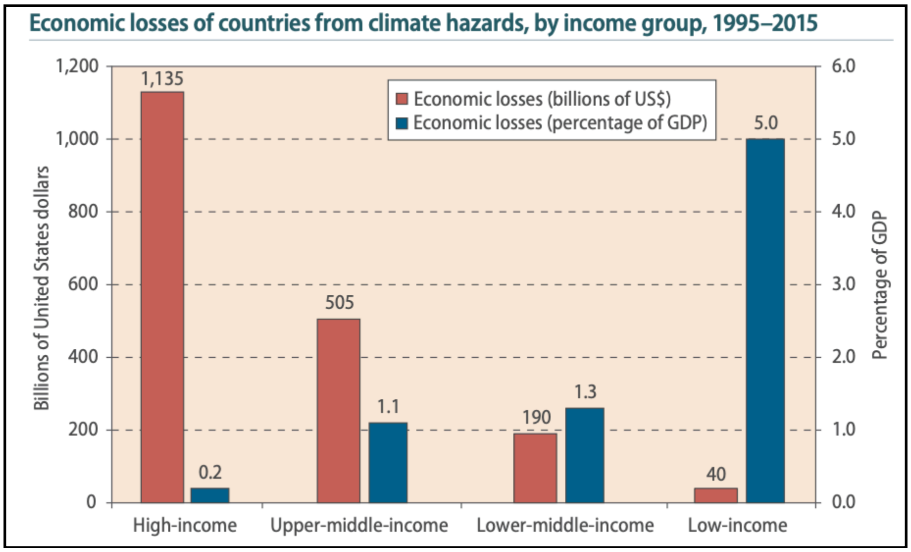


Figure 13: Total economic losses of climate hazards in terms of U.S. billions of dollars and percentage of gross domestic product (GDP) were gathered from high-income, upper-middle-income, lower-middle-income, and low-income countries. According to the Centre for Research on the Epidemiology of Disasters, total economic losses are categorized as the estimated damage to property (housing and infrastructure), crops, and livestock (The United Nations Development Program, 2019). The greater economic losses relative to national income are seen in countries with a lower average income. Low-income countries lost 5 percent of GDP, while high-income countries lost 0.2 percent (The United Nations Development Program, 2019). Figure reproduced with permission

Other stresses, such as a person's work and working conditions, have a large impact on social inequality and individual health. This makes those who already struggle with work or working conditions experience greater negative health outcomes (Burgard & Lin, 2014). Job insecurity is also connected to poor health and health risk behaviors (Khubchandani & Price, 2017). American adults who perceived their job as insecure had significantly higher odds of obesity, sleeping less than six hours a day, smoking every day, losing work in less than two weeks, and overall declining general health within the past year (Khubchandani & Price, 2017). These same job secure individuals (a total of 17,441 adults were included in the study) had an increase in the likelihood of serious mental illness within the past 30 days which was almost five times higher than those who were not job insecure. Other pain conditions, such as headaches and back pain, and lifetime histories of ulcers, diabetes, hypotension, and coronary diseases were more likely to be present in job insecure individuals (Khubchandani & Price, 2017).

The University of Wisconsin Institute of Research on Poverty indicates that social determinants of health, such as social and economic factors are arguably more important than health behaviors and care. It is explained that "...these [social and economic] factors appear to be very important in the degree to which some communities and even larger groups of people experience health inequities" (Swain, 2017).

Low socioeconomic factors amplify health effects of climate change in two primary ways, by: 1) reducing access to basic resources (water, food, air) and 2) increasing exposure to compounding stressors (health, environmental, sociological, financial, etc.). Basic resources are limited for those with low socioeconomic statuses; Hallegatte and others (2016) found that for various reasons, people living in poverty are more susceptible to diseases, such as water-borne, that climate hazards encourage the spread of. One explanation is that these populations often have limited access to piped water sources which forces them to drink water containing pathogens during floods (Hallegatte, 2016). These populations also encounter greater suffering during heat waves and high temperatures. They often do not have access to heat relieving amenities, such as air conditioning.

Additionally, impoverished people often experience greater exposure to pollution (Hallegatte, 2016). Exposure is thought to not only increase symptoms of present asthma, but also can initiate new-onset asthma because of long-term exposure (Guarnieri & Balmes, 2014). Further, a Harvard study exemplified the exacerbating effect pollution can have on health. It showed that Covid-19 death rates were higher in populations with additional exposure to pollutants (Koons & Ivry, 2020). Children with asthma in a family or neighborhood, with a low socioeconomic status, have an increased exposure to air pollution and greater susceptibility to the effects than children from families with high socioeconomic status (Guarnieri & Balmes, 2014). The impacts of increased exposure is exacerbated by climate change risks and hazards.

4) Decreased Adaptive Capacity

The disproportionate effects of climate risks and damages exacerbate existing socioeconomic inequalities and likely undermine the capacity of adaptation. Although individuals who have a familiarity of risk may have a more urgent and effective response to a threat, it seems existing inequalities often expose more weaknesses to a response (Oxfam, 2015). Research has found Americans of low socioeconomic status to be less prepared than other Americans for disasters (Substance Abuse and Mental Health Administration, 2017). A report on the impacts of natural disasters around the world, from the World Bank and the Global Facility for Disaster Reduction and Recovery, notes that “poor people, with fewer resources, tend to invest less in preventing and mitigating the adverse effects of natural hazards and environmental changes” (Hallegatte, VogtSchilb, Bangalore, & Rozenberg, 2017; Substance Abuse and Mental Health Administration, 2017). The consistency of numerous inequalities allude that disadvantaged groups will have access to fewer coping and recovery resources. These resources can be found in a households’ resources, community resources, resources provided by non-governmental organizations, and public resources provided by the government. Disadvantaged groups are likely to lack some, if not all, of these resources that are necessary for recovery. Consequently, their situation worsens after a climate hazard (The United Nations, 2016). As a result of the inability to cope and recover, vulnerable groups frequently experience a disproportionate loss of life, human capital, assets, and income. This creates a greater vulnerability for these populations when the next climate hazard strikes, noting that climate hazards will likely strike more frequently as the globe warms (Oxfam, 2015).

This cycle is likely to persist without any radical changes in society or an adequate response to climate change risks and hazards. For example, societal structures and existing institutions encourage this cycle to continue, and subsequently strengthen it. Impacts from climate change can be thought of as the results and consequences of these structures. An example of institutional structures which reinforce climate change is the difference of susceptibility to climate risks and hazards of marginalized individuals compared to those who have greater access to social, cultural, and financial capital (such as knowledge, income, and social networks which connect individuals to resources from outside of their immediate household) (Teller, 2017). Marginalized individuals are additionally less politically and administratively involved (Teller, 2017). This strengthens the gap between the groups because marginalized individuals are often unable to act as resiliently as those who have more accessibility to resources, therefore, resulting in a greater loss. By recognizing this gap, a need for equitable allocation of resources arises for individuals with decreased adaptive capacity and a low socioeconomic status.

Reinforcement of Disparities

Disparities due to climate change have a greater effect on those of lower socioeconomic status and are often reinforced. For example, rising temperatures more intensely affect individuals with fewer resources who cannot afford heating or cooling services and more frequently live in older buildings without proper insulation (Ruiz, 2019). This is most likely to occur in states where higher temperatures will be present and more intense cooling systems will be used (Hsiang et al., 2017). The same individuals who experience the greatest distress due to heat have the fewest resources available to cope with this distress. This results in the impacts from climate change encouraging socioeconomic inequality.

Research on the intersection of climate change and segregation reveal currently banned banking practices that continue to influence the way lower-income Americans are affected by climate change (Cusick, 2020). For example, researchers discovered that "redlining" of minority neighborhoods in over 100 American cities has resulted in residents experiencing a greater burden of heat than in other communities (Cusick, 2020). Redlining was a common bank and insurer practice in the mid-20th century in order to concentrate minority homeowners in certain neighborhoods which was eventually banned under the Fair Housing Act of 1968 (Cusick, 2020. Its legacy has persisted through segregation and often results in harmful environments for many minority populations. This is evident in various communities in the Great Lakes Region. For example, a two mile residential area of Southwest Detroit is surrounded by a mining company, a coal-fired power station, a water treatment facility, an oil refinery, a dry manufacturer, a salt pile, a lime quarry, a metal processor, a chemical plant, four concrete suppliers, an asphalt maker, an automobile production facility, and an interstate (Koons & Ivry, 2020). This neighborhood is 80 percent Black and is increasingly susceptible to health affects as a result of their environment. As Yaron Ogen, a postdoctoral researcher at Martin Luther University Halle-Wittenberg in Germany stated, "The healthier the environment, the healthier we are as people" (Koons & Ivry, 2020).

An additional example of this was discussed, in a 2015 paper by Islam and Winkel, focusing on environmental deterioration aggravated by inequality. This paper concluded that countries with higher inequality also had higher per capita levels of waste generation, consumption of water, meat, and fish. However, these positive correlations were not observed when considering the relationship between inequality and greenhouse gas emissions.

Analyzing inequalities between countries allows for a greater understanding of dynamics within them. A recent study showed that climate change is likely to result in a 75 percent average income decline in the poorest countries by 2100, compared to a world where climate change does not exist (Worland, 2019). In this same scenario, the richest countries are most likely to experience an average income gain (Worland, 2019). This study exemplifies the importance of addressing climate change on various scales.

Reduction of Inequalities

Inequalities could be reduced as a result of structural change in society. This could include an economy which favors the creation of new jobs for those with a low socioeconomic status. The World Bank estimates that a shift to clean energy would improve the country's economy. "U.S. wind and solar creates about 13.5 jobs per million dollars of spending, and that building retrofits — energy efficiency — creates 16.7 jobs per million dollars of spending. This is more than three times the 5.2 jobs per $1 million for oil and natural gas, and more than two times the 6.9 jobs per $1 million for coal." (Kats, 2016).

Reduction of inequalities could also be present with the implementation of policy. For example, the Energy Innovation and Carbon Dividend Act (H.R. 2307), introduced by members of the House of Representatives, places a steadily increasing fee on fossil fuels and gives 100 percent of the fees (minus administrative costs) back to all American households each month (Citizens' Climate Lobby, 2019). A study on financial impact on households for this bill concluded that those with the lowest income benefitted the most from the policy, while those with higher incomes did not receive an equivalent gain (Citizens' Climate Lobby, 2019). Dividends, like this one, flip the distributional consequences of carbon fees and favor those with low socioeconomic status, attempting to reduce economic inequalities.

This same idea is seen in applied research of health outcomes, when comparing individuals with low SES and individuals with high SES. A study on 121 children with asthma showed that children with low socioeconomic backgrounds who engaged in shift-and-persist strategies (defined as a combination of reframing stressors in a positive perspective while enduring adversity to find purpose in life), displayed less asthma impairment and inflammation (compared at baseline) after six months (Chen et al., 2011; Chen et al.., 2015). This same shift-and-persist strategy was not useful or advantageous for children with high socioeconomic backgrounds (Chen et al., 2011). This suggests that focusing on psychological qualities adapted by children with low socioeconomic statuses to manage stressors may help coping with stressors. Individuals with low socioeconomic factors may have a greater familiarity with multiple stressors and exhibit greater resilience over the same obstacles.

In order to reduce inequalities, societal responses are likely the most effective tool to address both socioeconomic factors and climate change impacts. Extreme weather events have potential to equalize inequalities if the end result is mass destruction, however, this possibility is beneficial to no one, regardless of socioeconomic status, and should not be idealized. Additionally, this possibility would only occur if societal responses to climate change are inadequate.

The Non-interactive Relationship

Although SES and climate change risks and hazards interact in complex ways, there are situations in which the components are independent of each other, as seen by the non overlapping portions of the Venn diagram in **Figure 1**. For example, it is clear that socioeconomic factors do not directly cause climate change impacts. Additionally, many factors unrelated to climate change can affect an individual's SES, such as race, gender, access to education, the SES of an individual's parents, and numerous others. Even though socioeconomic factors and climate change risks and hazards are interconnected, these elements don't directly affect each other perpetually and have instances in which they are non-interacting. Although much of this report focused on the ways that socioeconomic statuses and climate change interact, it is important to recognize that each element is separate.

It is also possible for socioeconomics and climate change to interact in a way in which there is no appreciable impact as a result of this interaction; inequalities could appear to remain unchanged, although this situation is less common.

Environmental Interactions Based on SES

The way an individual interacts with the environment may be partially determined by that individual's socioeconomic status. Those individuals with a higher socioeconomic status often practice more behaviors that harm the environment, when compared to individuals with a lower socioeconomic status. This represents the portion of the previously discussed cycle in which SES influences climate change.

This is observed on a global scale, as the poorest half of the world's population (3.5 billion people) are responsible for only 10 percent of carbon emissions, even though this same group is most threatened by climate change (Oxfam, 2015). Additionally, the average emissions of someone in the poorest 10 percent of the world population is 60 times less than that of someone in the richest 10 percent, as seen in **Figure 14** (United Nations Development Programme Human Development Report, 2019). An additional reflection in social organization can be observed in the correlation between the power or influence a person has and how that may be an indicator of how well that person's interests will be met.

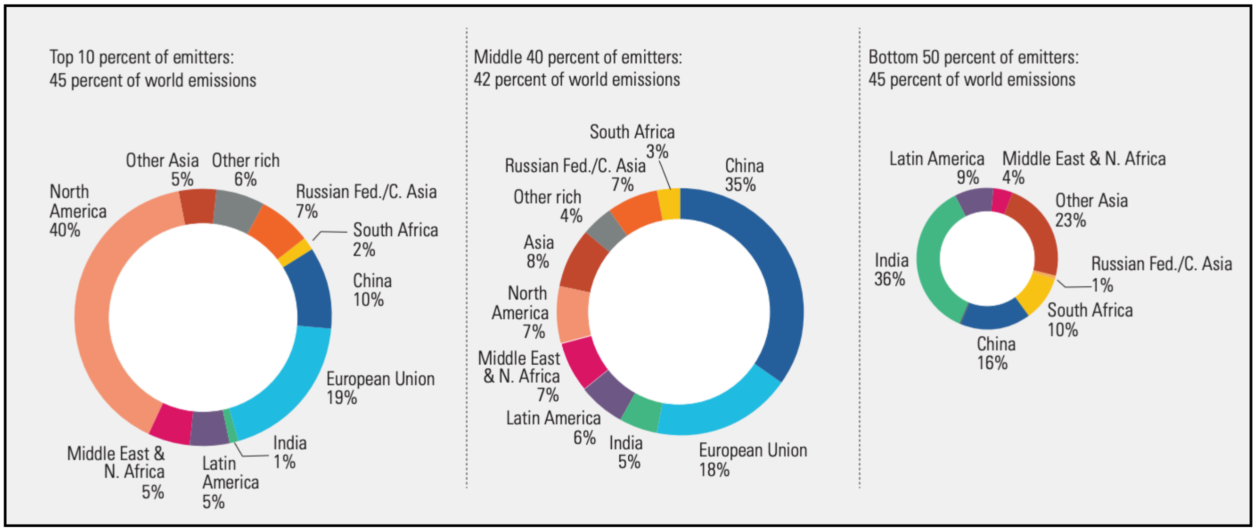


Figure 14: Top 10 percent of emitters, Middle 40 percent of emitters and Bottom 50 percent of emitters broken down by region of the world. 40 percent of the top 10 percent of global emitters of carbon dioxide emissions are in North America (Chancel and Piketty, 2015; United Nations Development Programme Human Development Report, 2019).

Integration of Socioeconomic Factors & Climate Change in the Great Lakes Region

With a foundational understanding of regional socioeconomics and how climate change impacts the Great Lakes Region, inferences can be made about how these elements interact and integrate. A changing climate will affect the region and its people, in various aspects, including social and economic. Changing 1) temperature, 2) precipitation, 3) lake levels, and general 4) ecological changes all contribute to a change in the region's 4) jobs and industries.

Temperature

As mentioned previously, temperatures are projected to increase. By 2050, many cities, such as Milwaukee, may have triple their current average of extremely warm days (exceeding 90°F) (Patz, 2014). The likelihood of record-breaking temperature extremes have increased and will continue to with the warming of the climate (Wuebbles et al., 2019). These rising temperatures come with a large economic cost to the region (U.S. Climate Resilience Toolkit, 2019). Some of these challenges include health and safety, economic costs for the region's workforce, and degraded air quality.

Increased temperatures in the region will be a large barrier for the region. Future projections indicate that the region will have the greatest increase in extreme temperature-related premature deaths, compared to other U.S. regions (U.S. Climate Resilience Toolkit, 2019). Human safety and economic concerns, such as decreased productivity among the workforce and industries, are especially evident in blue-collar workers.

High summertime temperatures cause degraded air quality which threatens public health, especially for vulnerable populations, such as the elderly and children with asthma. For large populations living in urban areas, heat waves and air pollution pose an increased risk for heat-related illness, diseases, and death (Wuebbles et al., 2019). Future risk of heat-related disease could increase because of these rising temperatures. Vulnerable populations and communities who have not experienced, and are not familiar with, high temperatures may be at an even larger risk for heat-related disease and death (U.S. Climate Resilience Toolkit, 2019). Additionally, it is noted that as health risks associated with extreme heat are likely to increase, cold-related illnesses are likely to decrease (Kling et al., 2003).

Warmer temperatures due to climate change may lower heating costs in winter, but this may be offset by higher costs for air conditioning in summer (Kling et al., 2003). Increased temperatures will lead to elevated utility bills felt throughout the region's workforce (U.S. Climate Resilience Toolkit, 2019). These increased utility bills are projected to cost the region approximately $10 billion by 2050 under the high emission scenario (U.S. Climate Resilience Toolkit, 2019). This estimate will increase with the frequency of extreme events. For example, the 2012 Midwestern heat wave and drought caused over $30 billion in economic damage and 123 direct deaths (Wuebbles et al., 2019). It also continued affecting the region with long-term health impacts. Other costs can be attributed to premature deaths, lost work hours, and increased demand for electricity alone is predicted to be around $1.2 billion by 2090 (U.S. Climate Resilience Toolkit, 2019). This increased cost of electricity may present financial and health burdens for those who are chronically ill or reliant on electronic medical devices (U.S. Climate Resilience Toolkit, 2019). These economic costs potentially worsen existing health disparities among those most at risk by placing additional financial burdens on already vulnerable populations (Rippey, 2015; The United Nations, 2016).

More days with high heat may worsen the formation of dangerous levels of ozone. Air pollutants, such as ozone, which are generated by coal-fired power plants in the region, are likely to encourage asthma and other respiratory diseases (Kling et al., 2003). Without mitigation, ground-level ozone concentrations are projected to increase across most of the Midwest, resulting in an additional 200 to 550 premature deaths in the region by 2050 (Angel et al., 2018). This accounts for about half of the total expected deaths due to increased ground-level ozone concentrations and may cost the region approximately $4.7 billion (Angel et al., 2018). Children, the elderly, and those with pre-existing lung issues are especially vulnerable. Urban areas are at the greatest risk (Angel et al., 2018).

Precipitation

Anticipated increases in extreme precipitation will worsen flooding. Extreme precipitation in the spring of 2019 led to record-high lake levels and widespread flooding across the region (Folger, 2020). Rain events exceeding 6 inches now occur regularly, which exceeds the capacity of storm sewers and lead to contamination events, as previously discussed (Wuebbles et al., 2019). Water contamination will be exacerbated with heavy rainfall (World Health Organization, 2020). Communicable diseases are associated with heavy rainfall and flooding, such as *Vibrio* and *Leptospira* (Patz, 2014). Compared to other U.S. coastal regions, the Great Lakes has particularly high levels of E. coli (*Escherichia coli)* bacteria which contaminates their water (World Health Organization, 2020). Increased precipitation will encourage the spread of harmful bacterias like E. coli. This bacteria is a public health hazard and expensive to mitigate. Numerous cities, like Chicago, have spent large sums on preventative and reactive measures against water pollution like E. coli (Angel et al., 2018).

If the Great Lakes water levels decrease, water shortages and droughts would likely be prevalent for the entirety of the region. Droughts can also alter the frequency and patterns of certain diseases, such as Valley Fever and West Nile virus, two viruses that are expected to be specific challenges for the region, that are transmitted by mosquitoes. Worsened by a larger number of particulates in the air, droughts worsen wildfires and dust which ultimately intensify asthma, heart, and lung diseases. An increased risk of injury and death from heat exhaustion and heat stroke can be caused by droughts. They can also stress city or region-wide water systems that supply water to households, hospitals, and nursing homes (U.S. Climate Resilience Toolkit, 2019). According to the National Integrated Drought Information System, each drought cost an average of $9.6 billion (2020).

Precipitation changes such as increased rainfall also leads to the potential of flooding. Rural communities in low-lying, flood-prone areas experience a greater susceptibility to infrastructure damage, transportation barriers, and displacement from homes due to intense floods (Wuebbles et al., 2019). While rural areas will experience soil erosion and increased runoff, cities with impermeable surfaces will be especially vulnerable to damage (Wuebbles et al., 2019). All of these challenges come with emotional and economic price tags, such as anxiety, trauma, and infrastructure repair costs tied to extreme weather events.

An increase in lake-effect snowfalls have caused existing procedures for snow and ice removal to no longer be effective or reliable (U.S. Climate Resilience Toolkit, 2019). Changing conditions will require improvements in roadway monitoring and detection systems, which will be costly changes for many communities in the region (U.S. Climate Resilience Toolkit, 2019).

Ice coverage on the Great Lakes has slightly declined between 1973 and 2018, according to data from NOAA Great Lakes Environmental Research Laboratory (Wuebbles et al., 2019). Continued decrease in ice cover could increase damage to coastal infrastructure caused by winter storms (Angel et al., 2018). This may result in significant damage costs to small coastal communities that may not have the financial resources to recover.

Lake Levels

The Great Lakes are the largest freshwater system in the world and are composed of five major lakes: Lake Ontario, Lake Erie, Lake Huron, Lake Michigan, and Lake Superior (Nix, 2018). The lakes are all interconnected by a series of rivers, straits, and smaller lakes. They are connected to the Atlantic Ocean through the St. Lawrence Seaway (Michigan Technological University, 2020). The Great Lakes water levels are currently managed by multiple sources. These sources include the Soo Locks which regulate the outflow of water from Lake Superior, as well as numerous dams, locks and channel enlargements (Bush, 2009). These allow the lake levels to be controlled up and down to alleviate extremes. The current regulations do not have a significant effect on short term or long term lake level trends, according to Indiana's Department of Natural Resources (Bush, 2009). Additionally, in the northern Great Lakes, the effects of water level regulation can take over 15 years to be seen (Bush, 2009). Although it is possible to manage the amount of water moving through the Great Lakes from an engineering standpoint, the amount of rainfall and evaporation are not under human jurisdiction (Bush, 2009).

Regardless, water levels will continue to fluctuate with a changing climate and the way people interact with the shorelines will change. When lake levels are high, erosion and flooding harms properties and public safety. When water levels are low, development grows closer to the lake, navigational dredging is necessary, and emergent coastal wetlands are groomed, destroying ecosystems (U.S. Climate Resilience Toolkit, 2019).

The water levels in the Great Lakes have experienced significant fluctuations; throughout the Great Lakes, water levels have risen over the past several years (Wuebbles et al., 2019). However this rise is typically followed by a period of record low levels (Wuebbles et al., 2019). This pattern leads to some speculation that water levels could ultimately decline. Although the projection that water levels will decline appears to have widespread support, most supporting models incorporate the same underlying hydrologic model that does not provide an indication of baseline or historical water levels (Gronewold et al., 2013). In contrast, when baseline and historical water levels are utilized in models, it is evident that rapid transitions between extreme high and low water levels represent a "new normal" (Gronewold & Rood, 2019). Interactions between global climate variability, the regional hydrological cycle, increasing precipitation, high evaporation, and climate events create a complex and unfamiliar dynamic which ultimately leads to rapid shifts in lake levels (Gronewold & Rood, 2019). A study done by Gronewold et al., shows a "tug-of-war" between evaporation and precipitation within the region (2021). This is largely due to water availability and results in extreme oscillations between record high and record low levels (Gronewold et al., 2021).

Increases in lake levels are primarily driven by heavy precipitation. As mentioned previously, precipitation within the region is projected to increase. There are concerns of precipitation and extreme weather events causing lake levels to exceed the current infrastruce's ability to respond (Wuebbles et al., 2019). Inability to respond will result in flooding which has numerous consequences to human health and infrastructure, as previously mentioned. High lake levels have already caused significant damage for many members of the region's coastal communities.

However, previous evidence has shown that an alteration in any of the region's water balance components - atmospheric transfer of moisture of land, moisture storage in lakes and aquifers, and moisture loss through evapotranspiration - could result in extreme water level fluctuation (Gronewold et al., 2021). For example, decreased precipitation could lead to abrupt water level declines.

Lake levels influence the timing and magnitude of many steps of the water cycle in the Great Lakes Region and require decades, and in some cases centuries, to reach equilibrium during new climate conditions (Hayhoe et al., 2009). There is a growing consensus that water levels will ultimately increase in the Great Lakes Region, resulting in economic, aesthetic, and personal losses for residents. The variability in lake levels urges the necessity for greater understanding of lake levels, and improvement in water management and policy (Wuebbles et al., 2019).

Ecology

Vector-borne diseases are expected to increase as conditions become more favorable for insects who carry diseases, mostly because the range of mosquitoes and ticks will shift north (Wuebbles et al., 2019). The Midwest is currently observing the largest number of Lyme disease-carrying ticks (Meng, 2017). Lyme disease is a serious human health concern, and if left untreated can infect the heart, nervous system, and joints (Centers for Disease Control and Prevention, 2019).

Increased flooding and standing water can also increase the incidence of water-borne diseases. Microcystin, pathogens, and bacteria that increase in downstream water bodies during intense rain events are of particular concern (Wuebbles et al., 2019).

As discussed previously, algal blooms will most likely increase in frequency as higher air temperatures and heavy precipitation combine nutrient loads with warm waters. Almost each summer in the past two decades, Lake Erie has been plagued by algal blooms. Some of Lake Erie's blooms have been so large they are visible from space (Folger, 2020). Lake Erie experienced the largest HAB in its history in 2011, with a peak intensity of three times greater than any other previously observed bloom (Wuebbles et al., 2019). Just three years later, half a million people in the Toledo area were unable to access safe local drinking water supplies for 72 hours because of toxic algae blooms (Wuebbles et al., 2019). The city announced a "do not drink advisory" until the water was treated two days later (Folger, 2020). Toledo's current mayor states the HAB " ...

caused businesses to close. It caused hospitals to not be able to do surgeries—if there's no water, there's no surgery. It was a traumatic event for our region." (Folger, 2020). Since this incident, the city has put over a billion dollars towards upgrading its stormwater system and water-treatment plant (Folger, 2020). Although the city has devoted a large sum of monetary resources to this problem, it does not hold those accountable who encourage the blooms' growth through common agricultural practices (Folger, 2020). If these current trends continue, HABs are projected to double by 2040 (Folger, 2020).

Cyanobacteria, present in algal blooms, can produce toxins. These toxins can be exposed to humans in multiple ways, however, ingestion during recreation and consumption of contaminated drinking water are the most common exposure cases (Wuebbles et al., 2019). Interacting with soils that have been irrigated with contaminated waters can also lead to dermal exposure and rash development. Cyanotoxins also accumulate in fish tissue, thus frequent consumption of fish from waters with algal blooms may become dangerous. Those who regularly spend time or work near water may become exposed through inhalation and have an increased susceptibility (Wuebbles et al., 2019). This is a particular concern for many people of the region because tourism and recreation is one of the largest industries and much of this tourism is centered around water. Additionally, minority and low-income populations are more likely to live in rural areas with water contaminants (Patel & Schmidt, 2017). This increased exposure places a greater burden on individuals with a low socioeconomic status who have less resources to address health concerns.

Jobs & Industries

Effects of climate change will challenge and change the traditional way jobs and industries are conducted within the region. Manufacturing is expected to be impacted by a changing climate, mainly elevated temperatures. Decreased productivity due to high temperatures among the workforce and industries due to high temperatures is especially evident in blue-collar workers. Construction workers, cement masons, roofers, and brick masons are especially susceptible (Dong et al., 2019). Further, construction workers comprise 6 percent of the national workforce but accounted for 35 percent of heat-related deaths from 1992 to 2016. An elevated risk was present for Hispanic workers and those born in Mexico (Dong et al., 2019). These blue-collar workers typically earn less than other jobs in the region and therefore will most likely experience financial difficulties adapting to climate hazards and risks. Blue-collar workers, and others who generally earn less, are expected to be extremely susceptible to severe climate change effects within the region.

To better understand the effects of extreme temperature on manufacturing plants, half a million Chinese plants were analyzed between 1998 and 2007. Researchers found one day of extreme heat (temperatures above 90°F) resulted in a nearly $10,000 loss per plant or half a percentage drop in output (Zhang et al., 2017). This is applicable to the Great Lakes Region because increasing temperatures and frequency of extremely warm days will place significant stress on the manufacturing sector. A growing interest and investment in reducing environmental impacts and innovation could potentially cause the sector to grow while helping prevent and mitigate the effects of climate change.

Climate change's effect on agriculture has many serious economic implications. Not all of these are completely negative, although generally the consequences outweigh the benefits. For example, increased rainfall over the past 30 years has provided soil moisture and flexibility for planting. However, wet conditions at the end of the season can create increased levels of mold, fungus, and toxins (Angel et al., 2018). Heavy springtime precipitation in 2019 caused farmers to delay or cancel planting as a result of wet and muddy fields (Folger, 2020). Most farmers could not plant on a quarter of their land (Folger, 2020). The number of days with two inches of precipitation or more has more than doubled in the past two decades, which could continue to negatively impact the agricultural sector (Folger, 2020).

High temperatures impede on typical pollination in crops and reduce yields, even with growing emphasis on water management. The two main commodity crops grown in the Midwest are corn and soybeans, which take up 75 percent of the region's farmland (Wuebbles et al., 2019). Climate change is projected to reduce yields for both soybean and corn by between 10 and 30 percent by the middle of the century in the southern areas of the region. This will cause soybean and corn production to likely move north. It is unknown if the northern conditions that the plants will likely shift to, will sustain productivity (Wuebbles et al., 2019).

Daily minimum temperatures have already increased due to increasing humidity. An increase in humidity decreases the day-to-night temperature range and increases warm season precipitation. Rising humidity also results in longer dew periods and high moisture conditions that may favor agricultural pests and pathogens for growing plants and stored grain (Angel et al., 2018). The agriculture industry is projected to face various obstacles because of this. Some of these challenges may include crop loss and food or nutrition insecurity (Food and Agriculture Organization of the United Nations, 2020). Warming winters have also increased the survival and reproduction of insect pests and allowed a northern expansion of new pest and crop pathogens (Angel et al., 2018).

Additionally, compared to the length of the growing season between 1961 and 1990, the length of future seasons will continue to increase, becoming four to nine weeks longer (Kling et al., 2003). Although this may seem beneficial for the economics of the agriculture industry, unfortunately, this warmer and longer season will house new and larger pest populations that will contribute to an overall increase in crop losses. New diseases that benefit from the changing environment will also be a factor for crop loss. The range of the bean leaf beetle *(Cerotoma trifurcata)*, a soybean pest, is already shifting north. As soybeans are one of the region's biggest agricultural commodities, this is a serious concern. Warmer temperatures and an overall drier summer climate are also expected to maim livestock health and reduce the productivity of pasture grasses. Other costs, such as investments in irrigation may become necessary to maintain productivity. For example, a 1988 drought reduced US corn by 45 percent (Kling et al., 2003).

Runoff produced from agricultural waste and soil erosion will increase as a result of increased frequency of flooding, which is expected to continue to become more common (Kling et al., 2003). Planting delays caused by spring flooding and excessively wet soil conditions are already affecting farmers (Wuebbles et al., 2019). Delayed planting puts crops at an increased risk while conditions are hotter and drier in the late growing season. This leads to a greater reliance on irrigation to mitigate crop losses.

Ozone concentrations are currently at levels that damage soybeans and horticultural crops, common crops in the region. As ozone concentrations continue to increase, they have the potential to counterpoise the increased production expected from carbon dioxide fertilization (Kling et al., 2003).

The impact of climate change on agriculture, especially crop and livestock sectors, will largely be controlled by technology and market trends. Extreme weather events, such as storms, late spring or early fall frosts, and droughts all have potential to be huge productivity risks. Regardless, as the variability in the climate increases and weather extremes become more common, smaller farms are likely to experience the greatest economic risks (Kling et al., 2003). A changing climate provides opportunities for farmers to adjust. If environmental conditions can be accurately predicted, farmers can plant crop varieties better suited to new conditions (Kling et al., 2003). Unfortunately, the agricultural system is set up so certain groups may be able to capitalize on the expense of others. For example, if climate change causes an increase in production, price declines may hurt producers but help consumers (Kling et al., 2003).

Traditional practices of tourism and recreation in the Great Lakes Region will change as the intensity and duration of the seasons alter. Shorter, warm winters will come with losses to communities that depend on winter recreation, such as skiing, ice fishing, and snowmobiling. At the very least, these communities will have to spend more money for snowmaking (Kling et al., 2003). It is important to note that a loss, such as these, to an affluent area trickles through the system and consistently affects individuals and populations with a low socioeconomic status the hardest. For example, owners of tourism industries may have a higher socioeconomic status and be able to obtain outside social and financial support to cope with the loss. In contrast, workers of these industries experience decreased adaptive capacity and suffer greater losses. This is another example of how a cycle of inequality is perpetuated.

Tourism may increase in new areas, such as Duluth, Minnesota, which is thought of as a "climate migrant destination" (Malo, 2019). Duluth may act as a safeplace from heatwaves and extreme weather because of its northern location on Lake Superior. The Lake is not only a valuable source of freshwater but has a cooling breeze that offers respite to extreme heat. Scientists predict Duluth will become a top destination for Americans leaving areas of the country which will or have become uninhabitable or unbearable with climate change. Jesse Keenan, a professor at Harvard studying Climate Change Planning and Environmental Design, called Duluth "99% climate-proof." Of course, an extreme surge of residents moving to the area would present it with additional challenges such as housing shortages (Harvard University Center for the Environment, 2017; Malo, 2019).

Climate change may provide differences in the way fishing, hunting, and wildlife viewing are practiced in the region as the distribution of species shifts (Kling et al., 2003). This may hurt the economies of local regions. For example, the loss of goose hunting in southern Illinois, where over a million geese once resided, has significantly impacted the economy which was already one of the poorest in the state (Kling et al., 2003). Increased precipitation and higher temperatures of the lake will both contribute to beach contamination (Patz et al., 2008). To illustrate, Chicago beach closures depend on the extent of precipitation within the past 24 hours, lake temperature, and lake level. Expected increases in extreme rain, warmer lake waters, and lowered lake levels would all contribute to beach contamination (Patz et al., 2008). Beaches in Chicago and Michigan have already experienced closures or swim advisories due to bacterial contamination. These closures are expected to increase as heavy precipitation worsens issues associated with runoff, bacteria, HABs, and E. coli alerts. Popular boating activities could also be affected, which would cause significant impacts as it makes up a large portion of the region's tourism revenue (Wuebbles et al., 2019).

Recreational fishing currently provides the region with as much as $1 billion in annual revenue (Wuebbles et al., 2019). This industry is particularly threatened by climate change because many stressors, such as invasive species, HABs, and E. coli contamination are expected to deplete the quality, quantity, and biodiversity of fish in the lakes (Wuebbles et al., 2019). Additionally, the ranges of many fish species will likely shift. Currently, coldwater fishing provides more value than warm water fishing, and anadromous fishing is most valuable. If climate change shifts the composition of species from abundance in coldwater species to abundance in warm water species, the overall value of fishing may decrease over time (Wuebbles et al., 2019). Individuals with a lower socioeconomic status typically shoulder this loss. For example, fishers who do not have the financial resources to emerge into a new job sector.

Climate change will have a profound effect on shipping, one of the region's main industries. If lake levels drop, although seemingly less likely then levels rising, costs of shipping in the lakes will increase (Kling et al., 2003). Changes in lake levels will also influence the amount of cargo per ship. A 1,000 foot ship sinks approximately one inch lower in water for every 270 tons of cargo it transports (U.S. Climate Resilience Toolkit, 2019). If a ship is already limited by water depth, any lowering of lake levels will result in a reduction in the amount of cargo that it is able to carry to ports (U.S. Climate Resilience Toolkit, 2019). A study using the 1964–65 low water period as a model for future change showed more dredging than usual was required for both commercial and recreational use. Shipping loads were reduced by between 5 and 10 percent (Changnon, 1993). This resulted in more trips and increased costs. The total immediate cost was estimated at around $100 million, with economic impacts for a 1.5 meter drop ranging from $3.5 to $35 billion (Changnon, 1993). A more recent study by Schwartz et al. estimated that the cost for an individual lakeside town could be around $7 million to combat a 3 foot decline in lake levels, when considering marina and harbor dredging, and loss of freighter capacity (Schwartz et al., 2004; Hayhoe et al., 2009). Dropping lake levels could pose other economic costs, such as dredging channels and adjusting docks, water intake pipes, and other infrastructure, which all disturb ecosystems (Hayhoe et al., 2009). Comparatively, shorter and warmer winters will enable a longer shipping season (Kling et al., 2003). The navigation season increased by an average of eight days between 1994 and 2011 (U.S. Climate Resilience Toolkit, 2019). These extra days for shipping can mostly be attributed to ice-free waters and will benefit commerce. However, more time spent shipping will also result in shoreline damage and an increase of invasive species (U.S. Climate Resilience Toolkit, 2019). Fluctuating lake levels also affect the navigability of ships in shallow portions of the lakes' channels and harbors. These changing levels also affect marinas, docks, shoreline homes, and other infrastructure. It is crucial to recognize that the same could be true from the opposite angle; dropping lake levels could cause less shoreline damage and rising levels could sustain, and potentially strengthen, the shipping industry.

Economic losses may be experienced by individuals of many different SES backgrounds; however, when individuals with a low SES suffer economic losses a cycle of inequality is perpetuated. This is because this group is likely to experience economic losses more intensely and more frequently. For example, a significant hit to the shipping industry would affect all members of the workforce but cuts to lower-paid employees would seemingly be more prevalent. Although affluent industries and areas may take an economic hit as a result of climate change, these individuals and communities are unlikely to experience these impacts as frequently or intensely.

Indigenous People

The Great Lakes Region is home to many communities of Indigenous people and tribes (Wuebbles et al., 2019). Though these populations may experience similar climate change impacts to others in the region, they often face unique and disproportionate effects. For example, impacts to land, water, food, plant, and animal species threaten cultural heritage sites and practices. Some species important to tribes are declining and may shift out of the boundaries of reservations (U.S. Climate Resilience Toolkit, 2019).

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) represents 11 tribes in the Great Lakes states (GLIFWC, 2015). The organization provides natural resource management expertise, conservation enforcement, legal and policy analysis, and public information services in support of treaty rights. Their Climate Change Program incorporates Traditional Ecological Knowledge (TEK) and a vulnerability assessment in order to adequately address climate change risks and hazards (Panci et al., 2015). Tribal elders and harvesters have been noticing ecological changes within their tribe's area because they live and interact with a single ecosystem over a long period of time. These observations from tribe members may be acknowledged before scientists have the chance to document them. This provides a large opportunity for integrating community input from tribe members which can be used to create trusted adaptation strategies (U.S. Climate Resilience Toolkit, 2019).

Climate change harms Indigenous peoples' livelihoods and economies - including agriculture, hunting, gathering, fishing, forestry, energy, recreation, and tourism. Their economies not only depend on, but also face institutional obstacles to the management of resources. These include water, land, natural resources, and infrastructure that will be affected because of climate change (Wuebbles et al., 2019). Indigeous health specifically relies on interconnected social and biological systems that are likely to be disrupted as the climate continues to change (Wuebbles et al., 2019). Additionally, many reservations are located in isolated rural communities, which are vulnerable to extreme weather events for a variety of reasons such as insufficient emergency response procedures (U.S. Climate Resilience Toolkit, 2019). Climate adaptation efforts that prioritize certain species over others will likely be problematic because all species are deemed as equally important to these populations (U.S. Climate Resilience Toolkit, 2019).

Recent Policy Implications

In 2010, the Great Lakes Restoration Initiative (GLRI) was created by 16 federal agencies, including NOAA and Environmental Protection Agency (Great Lakes Restoration Initiative, 2020). GLRI strives to protect and restore the lakes and identify threats to the ecosystems. Through achieving this, the GLRI hopes to in turn achieve the eradication of algal blooms, a safe source of drinking and recreational water, and control of invasive species, among other goals (Great Lakes Restoration Initiative, 2020). The third GLRI Action Plan, published in 2019, incorporated state, tribal, governmental, university, and business perspectives to advance environmental progress in the region (Great Lakes Restoration Initiative, 2020). A study done in 2018 by the University of Michigan revealed that every dollar of federal spending on GLRI projects, between 2010 and 2016, was projected to profit the region $3.35 in economic activity through 2036 (Roth, 2020). Congress has spent $300 million on the GRLI since 2014 (Roth, 2020). Although the Trump administration attempted to cut the funding, by as much as 90 percent, an additional $20 million increase for the program was eventually sought with the pressure of regional representatives and an upcoming re-election (Roth, 2020; Grandoni, 2019).

The Great Lakes Region has experienced recent influence as a result of the Trump administration. The region was a large focus for 2016 and 2020 elections; swing states such as Michigan and Wisconsin were heavily targeted. In 2016, Donald Trump campaigned to working class voters by emphasizing the importance of manufacturing to the region and the positive implications that could come from keeping manufacturing here instead of overseas (Greenberg, 2020). Although Trump claimed to have "saved the auto industry," the industry experienced a decline in 2019, after steadily rising for a decade (Greenberg, 2020). Trump's hopes for new plants and foreign expansions in the region were also ill-fated.

By 2020 Trump rolled back, or was in the process of rolling back, 100 environmental rules, one of those being a regulation that required coal plants to treat wastewater in order to avoid contaminants infiltrating rivers and streams (Roth, 2020). Many coal plants in the region are located near water and the rolling back of this restriction allows contaminants to persist in the Great Lakes and their food webs for decades. Other instances of spills in the Great Lakes consistently have faced small, if any, reparations from Trump appointees at the Environmental Protection agency (EPA) (Hawthrone, 2020). One spill included a plume of cancer-causing metal 20 miles from a Chigao drinking water intake (Hawthrone, 2020). Climate change exacerbates water pollution and the frequency of contamination events, both are a growing concern for the region.

As EPA pull backs have increased, so has pollution. These pull backs contradict the EPA's data which show that since 2017, the Great Lakes Region is initiating fewer cases of confronting polluters while the number of facilities not complying with the federal Clean Water Act has risen, as seen in **Figure 15** (Matheny, 2020). The penalties for polluters and enforcement of regulations have also decreased significantly.

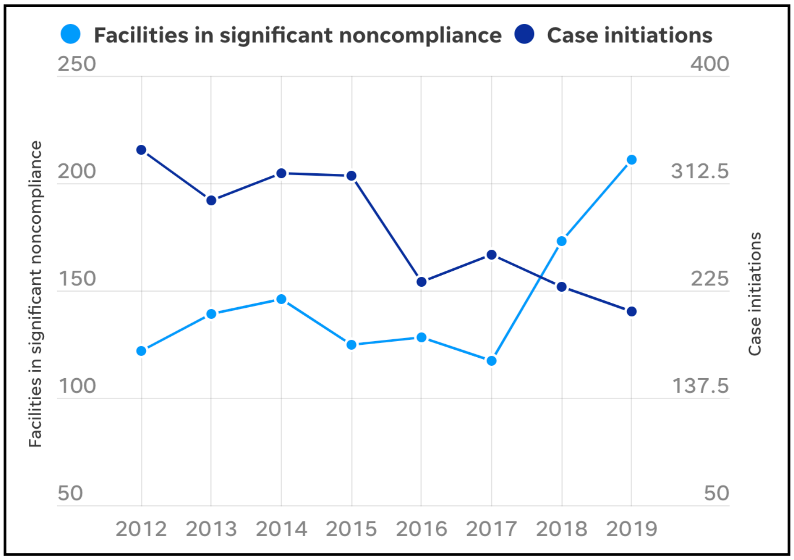


Figure 15: Created by Brain McNamara using the U.S. EPA data points on Region 5 (which includes the Great Lakes Region). This shows the significant noncompliance across the region with the federal Clean Water Act, essentially denoting that there is more water pollution and less looking for it (Matheny, 2020). Figure reproduced with permission

Recent developments in the Line 3 and Line 5 Enbridge pipelines have also caused significant concern for residents across the region. Line 3 is proposed to ship tar sands crude oil from Alberta, Canada, to Superior, Wisconsin, cutting across lakes, reservations, and three treaty areas along the way (Stop Line 3, 2020). The implementation of increasing Line 3's capacity has the potential to contribute to $287 billion in social cost of carbon and cause severe environmental harm (Stop Line 3, 2020). Building it would be equivalent to 50 new coal fired power plants (Stop Line 3, 2020). Additionally, Line 5 is 68 years old and ineffectively regulated, as exemplified by another Enbridge pipeline which contributed to the largest inland oil spill of 1.1 million gallons of tar sands bitumen into the Kalamazoo River in 2010 (Oil & Water Don't Mix, 2021). It crosses the Straits of Mackinac, which is an ecologically sensitive area (Oil & Water Don't Mix, 2021). University of Michigan scientists modeled the area's current and denoted that it is "the worst possible place for an oil spill in the Great Lakes." (Oil & Water Don't Mix, 2021).

Interconnectedness of Inequalities

Different areas of the Great Lakes Region face various types of vulnerabilities. Social or economic obstacles may be determined by a variety of factors. Racial and ethnic minorities, the elderly, impoverished people, rural communities, and people with existing health concerns already face unique challenges in the region. These populations will likely face more obstacles with the increased presence of severe climate change impacts. These impacts worsen inequalities experienced by these populations. Increasing temperatures will disrupt ecological processes and cause heat stress. Increasing precipitation and the frequency of extreme weather events will place harm on people and resources. The most susceptible populations are likely found where socioeconomic and climate change vulnerabilities overlap. Other possible challenges arising from the reduction or reinforcement of inequalities will be present. With climate change predicted to intensify, these areas will likely increase susceptibility and potentially generate special attention from policymakers.

There are deep-rooted interactions between socioeconomic factors and climate change impacts. Socioeconomic inequalities are most likely exacerbated in the presence of climate change, as previously discussed. This is a result of multiple factors which include, but are not limited to: differences in exposure to risk based on an individual's SES, differences in adaptive capacity based on an individual's SES, differences in capacity to recover based on an individual's SES, political power and influence based on an individual's SES, and countless others. These interactions imply that we cannot fully manage climate change risks and hazards without addressing underlying socioeconomic inequality; additionally that we cannot fully address SES inequality without mitigating climate change.

This is not suggesting that we cannot solve one problem independent of the other; instead, many successful societal responses towards socioeconomic inequalities will also benefit climate change, and vice versa. It is seemingly impossible to turn a knob on one issue and have no effect on the other. Although issues of socioeconomic inequalities and climate change are complex, there is great potential for opportunity to make progress in both areas, beginning with the simple recognition that they are inherently linked.

In order to reduce pre-existing socioeconomic inequalities aggravated by climate change, solutions to minimize the exacerbating interaction must be instituted. This may include implementing policies to increase awareness and reduce disparities, such as the potential solutions discussed in detail below.

As exemplified in this report, the intersection between SES and climate change is deep-rooted which further encourages serious consideration of environmental justice. True environmental justice is achieved by creating climate change policy that also addresses socioeconomic inequalities. Although there are inevitable tradeoffs, SES inequalities cannot be fully addressed without managing climate change risks and hazards; while climate change risks and hazards cannot be fully managed without addressing SES inequalities (discussed in further detail below). Additionally, unjust policies and institutional structures which strengthen socioeconomic inequalities are linked to climate change risks and hazards. For example, inequality of educational quality and access has been observed to reduce performance in education because of its segregating effects (Holmes. 2013). Low-performing students are more likely to have lower paying jobs, resulting in a low SES (Schleicher & Salinas, 2016). This disparity in the educational system results in individuals with a low SES who are more susceptible to climate risks and hazards. In theory, the two issues are inseparable, progress on each is progress for both. For example, policy to improve public education will increase resilience and decrease inequality of resources to better enable individuals to cope with climate change. This means that improvements in public education or public health is inherently climate change policy.

This idea is widely accepted and supported by numerous leaders with vastly different perspectives and backgrounds. Pope Francis, leader of the Catholic church, wrote about the intersection of science and the Christian faith. In his encyclical letter, *Laudato Si': On Care For Our Common Home*, he states "… we have to realize that a true ecological approach always becomes a social approach; it must integrate questions of justice in debates on the environment, so as to hear both the cry of the earth and the cry of the poor" (2015). Barack Obama described these interconnected problems as "the most compelling issue in the world today" and explained, "The reason I say those two things are connected is that it is hard to figure out how we solve sustainability issues and deal with climate change if you also have huge gaps in wealth and opportunity and education. Because what happens — and we're seeing this around the globe — is that as wealth gets more and more concentrated and more and more energy is used up by the few, the many become resentful and it undermines our sense of politics and a sense of community" (Nadler, 2019).

Both of these issues can be thought of as wicked problems - social or cultural problems that are extremely difficult to solve for reasons including but not limited to: numerous opinions, incomplete knowledge, economic burdens, and interconnectivity with other problems (Camillus, 2008; Kolko & Austin Center for Design, 2012). These wicked problems require mitigation techniques that will not act as immediate solutions, instead, will improve over time (Kolko & Austin Center for Design, 2012). Solutions to wicked problems involve a multidisciplinary approach and knowledge across science, economics, statistics, technology, medicine, politics, and other fields in order to collaborate towards effective change (Kolko & Austin Center for Design, 2012). Although their connectivity presents a great complexity, it also offers an opportunity for creative solutions that mitigate both issues, which will be discussed in further detail below.

Next Steps

Carefully constructed societal responses (e.g., policies) have great potential to simultaneously reduce vulnerability to climate change and promote greater SES equality. For example, a more educated public would increase socioeconomic status and create awareness towards climate risks and hazards for people of all socioeconomic statuses. Additionally, stronger climate hazard policy would refrain from contributing to the inequality cycle of socioeconomics and climate change impacts. Further, it could provide beneficial mitigation for climate change effects for the entirety of society. In many cases, effective climate and economic policy are not mutually exclusive, instead are favorable for society in both sectors. For example, policies that reduce greenhouse gas emissions may produce a net economic benefit and subsequent health benefits from air quality improvements to vulnerable populations (Patz, 2014). A key challenge to realizing this opportunity lies in the disproportionate political influence of those individuals with a high SES and individuals that oppose greater socioeconomic equality and/or efforts to mitigate climate change vulnerability.

The relationship between socioeconomics and climate change reveal that people experience disadvantages because of numerous factors and in order to reduce the intensity of climate change impacts, change must be put into action. This can be done at three different levels: 1) by initially supporting disadvantaged populations so systems do not benefit from their disadvantage, 2) by directly fighting climate change, or 3) by providing additional and effective resources to prevent and mitigate the effects of climate change. Of course, choosing to address any of these levels presents numerous challenges, especially when the problem cannot be solved regionally and must be fought in unison with other institutions. Regional solutions which have already been considered or implemented will be discussed below.

In order to separately combat socioeconomic inequality, so that disadvantaged populations are supported and systems do not benefit from their disadvantage, various solutions are possible. These include, but are not limited to: providing adequate healthcare access and minimizing healthcare disparities, providing equitable public education to ensure equal opportunity for all students, ensuring equal employment opportunities (such as pay equity and nondiscrimination in the workplace), providing resources for low income individuals (such as affordable housing and food assistance), and reforming the criminal justice system and re-entry into society. Another approach may be to directly address and mitigate climate change which could be accomplished through: policy, placing a price on carbon, transiting to clean energy (such as wind, hydropower, and/or solar), developing sustainable transportation (such as electric vehicles, biofuels, public transportation), supporting and restoring sustainable uses of lands and forests, and other innovative actions. Finally, in order to simultaneously address socioeconomic inequality and climate change risks and hazards, additional and effective resources to increase resiliency and adaptation to the effects of climate change must be instituted. This could be achieved by: providing effective disaster relief for infrastructure, health, and emotional damage due to climate change, strengthening emergency response, or conducting additional research to understand possible impacts and adaptation strategies which involve providing equal access to this information.

These solutions can be applied to the region in numerous ways, and some already have, as discussed below. Strengthening these solutions and continuing to recognize patterns of inequality will aid the Great Lakes Region in the reduction of inequalities. Doing so may allow for bountiful natural resources and a thriving economy. In this way, the region could act as a model for other areas of the country and the world. By utilizing available research and prioritizing the reduction of socioeconomic inequalities and vulnerabilities to climate change, the region will most likely find success. This positive impact may be seen in the region's people and their economy as well as the stability of biological systems and the goods and services they provide. Other areas of the country struggle with many of the same issues of socioeconomic inequality and vulnerabilities to climate change risks and hazards, and could potentially use the Great Lakes Region as a reference to tackle these same difficulties.

Proposed Solutions

To better understand how socioeconomic and climate change inequalities overlap, various studies have been conducted with an aim to strengthen the relationship between scientists and policymakers. An interactive map, titled Great Lakes Climate and Demographic Atlas, produced by Great Lakes Adaptation Assessment for Cities shows where these stressors intersect most intensely (Great Lakes Adaptation Assessment for Cities, 2020). The study was based on social, economic, and demographic statistics on 225 counties in the region. This tool is an example of one that may provide information for local and regional decision makers to address how climate change compounds stressors, in some cases. A picture of this map is shown below in **Figure 16 and 17**.

The United Nations also reports on reducing inequalities within countries in hopes of better understanding an approach to equitable solutions. (2019; 2020). A study conducted by The United Nations Development Programme Human Development Report looked at climate change impacts in 3,143 counties across the United States. This study found an uneven distribution in agricultural yields and mortality. Projected economic impacts varied across counties, with median losses exceeding 20 percent of gross county product to median gains exceeding 10 percent (2019). The study concluded that climate change will intensify existing inequality in the United States because the worst impacts are concentrated in already poor regions, on average. By the latter part of the 21st century, impacts on the richest third of counties are projected to be less severe (damages of between 1.2 and 6.7 percent of county income), while the poorest third of counties are projected to confront more extreme damages (between 2 and 20 percent of county income) (2019).

The United Nations Development Programme Human Development Report also proposed policy action from analyzing and identifying vulnerability hotspots, in terms of spatial and population. Granular analyses could also enable solutions in place-specific adaptation pathways, which may acknowledge values and tradeoffs as well as local and social issues (2019). To diminish inequalities experienced because of socioeconomic or climate change impacts, general inequality reduction studies, such as the United Nations' will be useful. The United Nations reports that equal access to opportunities, macroeconomic policy conducive to inequality reduction, and disadvantaged groups participation (largely promoted by tackling prejudice and discrimination) must be instituted (2020).

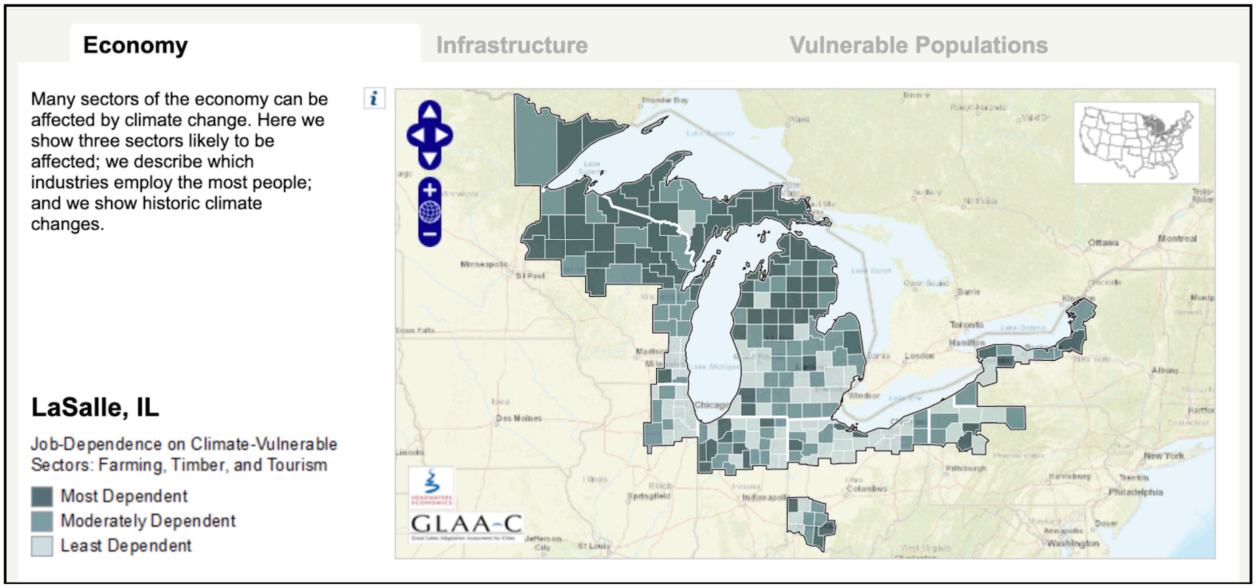


Figure 16 (above): Each county, for a large portion of the Great Lakes Region, was analyzed to determine economic, infrastructure, and population vulnerability (University of Michigan Graham Sustainability Institute, 2020). This picture shows the top three job-dependence on climate-vulnerable sectors for LaSalle, Illinois. More information can be gathered on all of these sectors produced by GLAAC (University of Michigan Graham Sustainability Institute, 2020). Figure reproduced with permission

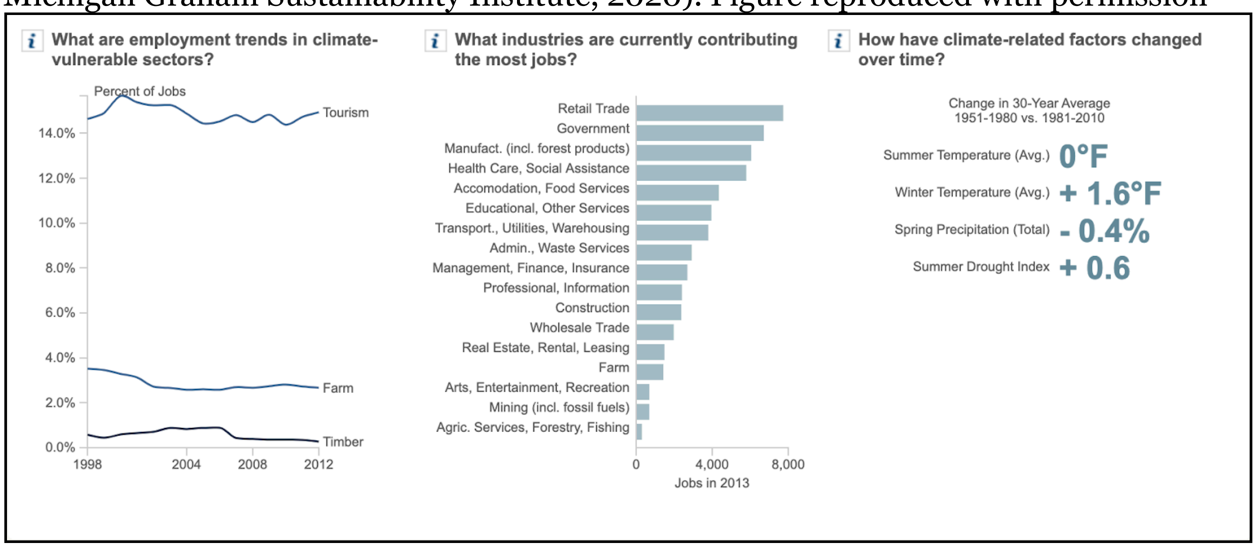


Figure 17 (above): Additional information on jobs in LaSalle, Illinois and how climate-related factors have changed in the region (University of Michigan Graham Sustainability Institute, 2020). All 225 of these counties have this information readily available for not only their economy, but also data concerned with infrastructure and population vulnerability produced by GLACC (University of Michigan Graham Sustainability Institute, 2020). This transparent information is a critical resource for decision makers and the general public. Figure reproduced with permission

The Great Lakes Climate Adaptation Network (GLCAN), is a project conducted by NOAA and the University of Michigan aimed at addressing climate action and planning while incorporating limited financial resources, as pictured in **Figure 18** (Angel et al., 2018). Climate information users and producers are collaborating to create customized climate information and resources. This has been especially successful because it increases trust in the community. Specific projects have been conducted with marinas and harbors in Michigan and Chicago through the Climate Action Plan in Illinois. These projects have exemplified the importance of using existing stakeholder networks to interact with producers of climate information (Angel et al., 2018).

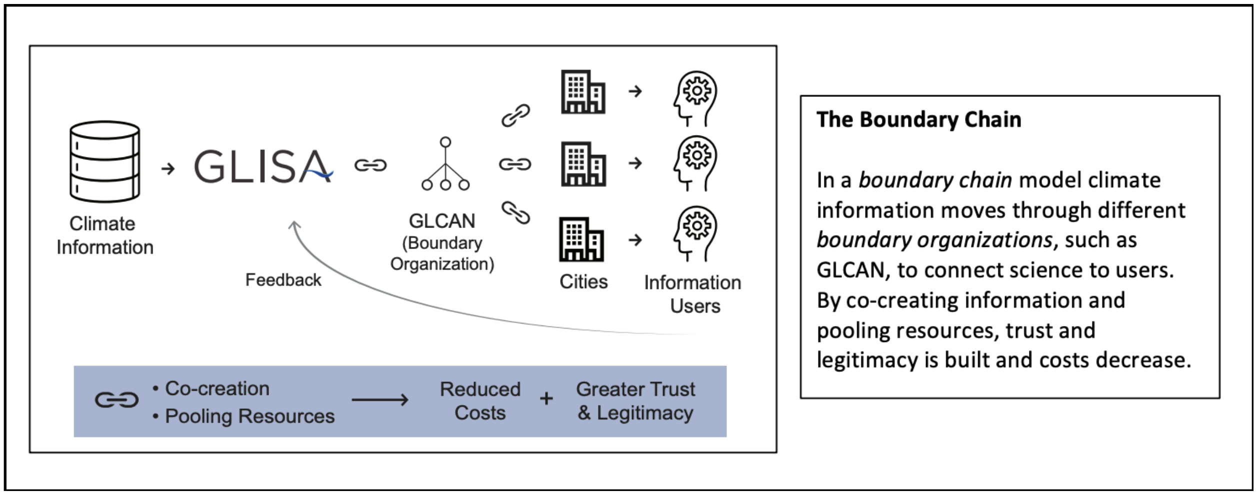


Figure 18: The Great Lakes Climate Adaptation Network (GLCAN) illustrates how they use a boundary chain model to collaborate on information and resources with users to create a trustworthy and low cost relationship to communicate climate information (University of Michigan School for Environment and Sustainability & National Oceanic and Atmospheric Administration's Great Lakes Integrated Sciences and Assessments, 2016). This figure was reproduced with permission

Other solutions are being experimented with by organizations for individual states, such as the Michigan Climate Action Network, which proposes moving to and fighting for clean energy, investing in electric transportation, and stopping oil pipelines. These solutions are helpful not just for the environment, but also the state's economy (2020). Collaboration between other states on solutions such as these could create a more widespread and powerful effect.

Other organizations, such as Bluegreen Alliance, specifically focus on creating jobs in a clean environment and thriving economy. This organization unites America's largest labor unions and environmental organizations to collaborate on issues like climate change. They believe clean jobs can be created in a thriving economy by designing public policies, conducting research, enhancing public education for students and stakeholders, and advocating through campaigns for solutions. These solutions, proposed by Bluegreen Alliance, have been proposed as the result of dialogue between stakeholders such as environmentalists and union members who emphasize the job-creating opportunities of environmental protection (Bluegreen Alliance, 2016).

Bluegreen Alliance is not entirely focused on the Great Lakes Region, but has initiatives in many of the region's states.

On a larger scale, the Evergreen Action Plan aims to defeat the climate crisis and build a just and thriving clean energy economy. This can be found in their five key principles: powering the economy with 100 percent clean energy, investing in jobs, infrastructure, industries, and innovation; building a greater justice and economic inclusion, ending fossil fuel giveaways, and mobilizing global action (Evergreen Collaborative, 2018).

Initiatives, such as The Great Lakes Restoration Plan, offer an analysis and future actions to revive the health of the region and mitigate the effects of climate change (Dempsey et al., 2008). These actions include funding restoration for the lakes and the area's ecosystem, collaborating with Canada, reducing greenhouse gases, promoting green energy and green jobs, taking individual actions, conducting future research, and the passing of the Great Lakes Compact. The Great Lakes Compact bill addresses water management issues by banning diversion of water outside the Great Lakes Basin, and requiring water conservation to protect the resource (Dempsey et al., 2008).

Another analysis conducted by the University of Wisconsin revealed the state of Wisconsin's 2016 energy spending deficit (Abel & Spear, 2019). This analysis denoted that the state's heavy reliance on fossil fuels was extremely detrimental to their economy. This study also showed that transitioning to in-state energy resources would bring money and jobs back to the state, even with investing in a different energy source. The additionally in-state spending would directly increase the GDP by $13.9 billion or 5 percent (Abel & Spear, 2019).

Predicting Future Vulnerabilities

Using tools to understand possible future vulnerabilities allows for the inference of future risks and hazards. These risks and hazards will alter the way jobs and industries within the region, and outside the region, are conducted. The changes in the individual jobs and industries may provide an opportunity to better understand how climate change affects citizens in the region based on socioeconomics.

For example, if extreme flooding persists in the Great Lakes, erosion, shoreline damage, and beach loss would most likely harm all shoreline tourism industries. This would most likely cause a mix of impacts. The damages would not discriminate based on socioeconomic status, but would still harm different populations in various ways. The owners of tourism companies may experience loss in revenue and threaten them to lay off workers; the workers of these companies, most likely with a lower socioeconomic status, would also potentially experience job insecurity. Ultimately, distribution of resources, political will and influence, level of exposure, and other factors all favor individuals with a high socioeconomic status. Therefore, those with a low socioeconomic status are more likely to experience harmful impacts as a result of climate change impacts.

To accurately predict and understand future vulnerabilities specifically linked between socioeconomic and climate change inequalities, additional studies must be conducted. Generating inferences about the region is complicated because of compounding and complicated factors that change impacts based on individual situations.

Limitations

This paper attempted to comprehensively study the relationship between socioeconomics and climate change in the Great Lakes Region, but is limited for a variety of reasons. The region is defined by various criteria which presents difficulties to make complete distinctions at times.

The entire region could not be analyzed, because doing so would require information on areas of the region which are not readily available. Limitations were, to a degree, confined by studies which have been previously conducted and general data availability. These studies pose a possible inaccurate representation on the region as a whole because the information provided is an infinitely small amount that could be gathered, which at times led to generalizations. Throughout the study, generalizations may help the reader gather an improved overall understanding of the region, although these generalizations can also be vague or draw more attention than necessary to exceptions. Further, analyzing particular case studies within the region, such as Chicago, provided a beneficial example but should not be applied to all urban areas in the region, or the entirety of the region. More attention, resources, and research must be conducted on the link between socioeconomic factors and climate change within the region to truly understand its dynamics and lessen the limitations of this understanding.

Analysis of regional socioeconomics presented additional limitations. Although socioeconomics are often thought of in terms of "status," it was impossible to assign an accurate status to the entire region. The general socioeconomic factors of the region were evaluated to provide a general understanding of how the residents in the region live, however, there are numerous exceptions to these generalizations.

Economic analysis, in general, is limited in the wide use of the general equilibrium model. This model assumes climate change does not fundamentally change society, and can only make predictions based on what has already occurred. These models can not make predictions about the window of habitability, in which there is a non-zero chance that climate change could ultimately force society to address. This is a substantial limitation within the economic sector and does not allow the full potential of climate impacts to be analyzed in terms of economic consequences. Recently, research has attempted to account for the possibility of catastrophic climate events, which has strengthened the need for a more cautionary approach to the climate and the impacts humans have on it (United Nations Development Programm Human Development Reporte, 2019). This major economic limitation posed difficulties when analyzing the region's economy and the way it has and will potentially change as a result of climate change.

Examining climate change in the region, as a whole, posed multiple limitations. This, in part, can be attributed to the region's broad and diverse landscape. Discrepancies between scientists on future projections caused the greatest restrictions when reasoning possible implications of future effects. These projections were increasingly more difficult to predict when attempting to include large portions of the region. Effects that have already occured as a result of climate change, although unlikely consistent throughout the entire region, were easier to analyze.

The literature analyzed on the region's socioeconomic statuses and climate change impacts were stitched together in order to infer how these stressors are integrated. While writing this paper, there was an attempt to avoid establishing connections between the two topics where there was not one, however, limitations of data and knowledge availability constrained this goal. In general, many inferences were limited because of the numerous complex factors which were analyzed in conceptualization instead of in practice. A single comprehensive study conducted would potentially allow for more holistic conclusions to be drawn and potential solutions to be proposed based on evidence-based decision making. This would also require additional resources and may be difficult to conduct because of the broad and vast nature of the region.

This paper was researched and written between during the ongoing covid-19 pandemic. Although statistics were heavily used in this report, they were largely based on a world before the covid-19 outbreak. The pandemic undoubtedly caused various impacts on the region and the statistics reported about the region. The short-long and long-term effects of the covid-19 pandemic are currently unknown and playing out everyday. Regardless, the outbreak is sure to affect these numbers and must be remembered while interpreting this paper.

Although it is incredibly difficult to make complete conclusions regarding how socioeconomic and climate change related challenges interact within the region, the information analyzed within this report can still aid decision makers and the general public to make informed decisions about the intersection of SES and climate change.

Discussion

The accumulation of this information presents additional questions and potential for improvement in the region's ability to prevent and mitigate climate change impacts. As science progresses and studies continue, the use of information from this study, and similar ones, can greatly benefit the region. Policy and decision makers may utilize this report to understand the fragility of the region due to climate change, and how inequalities may persist for populations with low socioeconomic status. This report will be most effective if used alongside the engagement between scientists and policymakers, particularly on the local level. A need remains to determine how scientists can aid these decision makers to create change easily and effectively to address big issues like improving socioeconomics and tackling climate change; this report may help confront that need. Urgency towards addressing obstacles due to socioeconomic inequities and climate change risks and hazards is favorable as a result of the various challenges many populations in the region are facing daily. Additionally, because local government can be viewed as a laboratory for national policies, areas like the Great Lake Region are encouraged to experiment with forward-thinking policies and decisions. In this way, local governments in the region can potentially serve as models for the national level.

The region has proved susceptible to climate change impacts and adaptation in numerous aspects. The region is heavily reliant on natural resources, such as lakes for their freshwater and commodity crops, like corn and soybeans. There is also concern over the region's dependence on the manufacturing industry in particular, as it has the potential to experience severe difficulties as a result of its narrow focus. For example, much of the manufacturing industry in the region produces cars and may have difficulty adapting. If the shift to electric cars is made, although beneficial to the environment, this could potentially harm as much as 66 percent of the region's jobforce (assuming current and traditional car manufacturing plants are no longer needed). A significant change in one of the region's largest industries, such as manufacturing, could pose various challenges which require a substantial amount of adaptation efforts which may be hindered by budgetary limitations. Additionally, as previously discussed, the link between negative economic outcomes and negative health outcomes create supplemental pressure to keep the region's economy productive and subsequently keep people healthy.

Although climate change has, and will continue to affect the region significantly, uncertainty remains regarding specific ecological and economic changes. These changes will likely intensify in the future, but in the meantime, their uncertainties cause great potential for inaction. A question remains of how to emphasize the urgency of action before it is too late.

In a world where global change is often encouraged, climate change cannot be attributed to progressive global change. Science and technology are types of global change that have, and will continue to, accelerate the world towards effective and important change. This change will hopefully invert many of our social and economic norms to most successfully combat the effects of past and future destruction to our world. The earth and atmospheric systems will be inevitably impacted by our evolving world; however, these systems' and their impacts also have the potential to provide much needed positive change. This opportunity for change could address inequalities found in the intersection of socioeconomics and climate change.

Further, the positive effects of climate change policy cannot be necessarily attributed to climate change and should not be idealized. It is important to note that climate change is not needed in order to make society equitable. Theoretically, policymakers could reduce inequality without a serious threat such as climate change.

While extensive literature is available on the topics of climate change and socioeconomic inequality, a similar availability of solutions is lacking. Although the literature analyzed on the region's socioeconomics and climate change impacts provided great insight into how these stressors may interact, a single comprehensive study could provide better guidance for solutions based on evidence-based decision making. However, the region is so vast and diverse that this type of study may not be entirely feasible.

Effective evidence-based decision making includes: 1) evidence itself, 2) improved and widespread scientific and societal understanding of challenges, largely as a result of a proficient education system and 3) accurate communication from media informants which encourages 4) a policy process that serves societal interests and finally, the 5) humility and confidence needed to recognize limits within that process. Using evidence-based decision making serves public interest and increases the effectiveness of place-based initiatives.

Addressing these complex problems from an evidence-based approach, allows for decision makers to think about vulnerabilities; however, this is commonly and ineffectively approached from a single narrative and framework. Systems that combat these large issues will be most effective by incorporating and encouraging the engagement of diverse perspectives to successfully tackle these complicated problems. Broader collaboration from a wide range of individuals and industry sectors will create solutions that use various methods and tools to benefit a wide range of society. This will enable accessible and authentic solutions to problems experienced by numerous vulnerable groups and populations, instead of maintaining monolithic solutions as a result of monolithic approaches. Incorporating a more diverse set of perspectives may help disrupt cycles of inequality which are enabled and upheld when the majority of decision-makers encapsulate the same, high SES perspective and advocate for policy that exacerbates or maintains this inequality.

Patterns of inequality may be revealed on different scales determined by variables of social and structural vulnerability (United Nations Development Programme Human Development Report, 2019). These are shaped by individuals, households, towns, cities, districts, states, and regions. Impacts on these different levels largely depend on if and how the impacts affect the people or area in a negative and disproportionate way. Structural inequalities, specifically, are related to the communities' and counties' capacity to adapt to or be resilient to climate change (United Nations Development Programme, 2019). This urges action on a local level.

Conclusion

Research has found that in most circumstances, initial inequality causes disadvantaged populations, such as those with a low socioeconomic status, to experience disproportionate impacts from climate change, resulting in even greater inequality (Substance Abuse and Mental Health Administration, 2017; Stocker, 2013). Major difficulties, such as a low socioeconomic status and the impacts of climate change are exasperating in isolation, however, many populations experience these challenges as they interact and intensify each other. This relationship was analyzed within the Great Lakes Region. The region has and does depend on numerous valuable natural resources from the lakes, such as 21 percent of the world's freshwater that 40 million people in the U.S. use as a water source (The United Nations, 2016; Breffle et al., 2013). Manufacturing, tourism and recreation, shipping, and agriculture are the most successful industries and heavily depend on the region's resources (Vaccaro & Read, 2011; (Kling et al., 2003; Breffle et al., 2013). These resources are degraded by climate change and therefore lead to harmful impacts such as degraded air quality, changing habitats, increased temperature and precipitation, as well as difficulties stemming from rural living (Angel et al., 2018; U.S. Climate Resilience Toolkit, 2019; Hayhoe et al., 2009; Stanford Medicine, 2020). These impacts also influence health and will likely intensify in a time of accelerated climatic change. For example, increasing temperature will lead to more frequent and warmer days and lakes, which will cause heat stress and disrupt numerous biological processes (Angel et al., 2018). Further, precipitation increase and pattern change will harm regional resources and residents (USGCRP, 2017; The United Nations, 2016). Other ecological processes are expected to be disrupted, such as destratification, changing habitats, the spread of disease, and the presence of invasive species (U.S. Climate Resilience Toolkit, 2019; World Health Organization, 2020). The integration of socioeconomics and climate change within the region reveal challenges for industries and populations, such as difficulties due to the change in the traditional growing season in the agricultural sector and stressors experienced by indigenous people (Kling et al., 2003; Wuebbles et al., 2019). Especially vulnerable populations are commonly found at the intersection of low SES and climate change susceptibility. To more accurately understand the relationship of socioeconomic factors and climate change in the Great Lakes Region, it is proposed that further research is conducted to comprehensively understand the link between these issues and the populations who confront their unique and various challenges. This research would not only create public awareness, but can also inform and encourage decision- and policymakers to prioritize issues of environmental justice. Additionally, subsequent research on the intersection of these two components may help guide various action plans which have been proposed to address these issues with solutions such as restoring the region's ecosystems and creating clean energy jobs (Bluegreen Alliance, 2016; Angel et al., 2018; Dempsey et al., 2008). In the meantime, this report can be used to foster urgency in regional change due to the fragility it experiences as a result of climate change. Socioeconomic and other inequalities will persist as climate change intensifies. The consequences of climate change will continue to threaten the region and it is therefore critical to prepare and mitigate against future and unavoidable impacts. Communities must cultivate awareness to receive financial resources, public support and concern, as well as collaboration to ensure creative and urgent solutions that take into account the populations which are most vulnerable.

References

Abel, D. & Spear, K. (2019). Wisconsin opportunity in domestic energy production: the economic and health benefits of 100% in-state energy production. *Center on Wisconsin Strategy, University of Wisconsin - Madison*. Retrieved from https://states.ms2ch.org/media/uploads/Wisconsin_Opportunity_in_Domestic_Energy_Production_TgTAufZ.pdf

Adger, W.N.; S. Agrawala, Mirza, M.M.Q.; Conde, C, O'Brien, K.; Pulhin, J.; Pulwarty, R.; Smit, B.; & Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the *Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 717-743. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg2-chapter17-1.pdf

American College of Physicians. (2017). How will climate change affect health in the midwest region of the united states? Retrieved from https://www.acponline.org/system/files/documents/advocacy/advocacy_in_action/climate_change_toolkit/midwest_talking_points.pdf

American Lung Association. (2020). Ozone. Retrieved from https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/ozone

American Psychological Association. (2017). Ethic and racial minorities & socioeconomic status. Retrieved from https://www.apa.org/pi/ses/resources/publications/minorities

American Psychological Association. (2010). Aging & socioeconomic status. Retrieved from https://www.apa.org/pi/ses/resources/publications/age

American Psychological Association. (2008). Ethic and racial minorities & socioeconomic status. Retrieved from https://www.apa.org/pi/ses/resources/publications/factsheet-erm.pdf

Angel, J., Swanston, C., Boustead, B.M., Conlon, K.C., Hall, K.R., Jorns, J.L., Kunkel, K.E., Lemos, M.C., Lofgren, B., Ontl, T.A., Posey, J., Stone, K., Takle, G. & Todey, D. (2018). Midwest: in impacts, risks, and adaptation in the united states: fourth national climate assessment. *U.S. Global Change Research Program*. Washington, DC. Volume II. pp. 872–940. doi: 10.7930/NCA4.2018.CH21

Blakely, N. (2020). Midland flooding: climate change and rains exacerbate dam infrastructure issues. Great Lakes Now. Retrieved from https://www.greatlakesnow.org/2020/05/midland-flooding-climate-change-infrastructure/

Bluegreen Alliance. (2016). Creating good jobs, a clean environment, and a fair and thriving economy. Retrieved from https://www.bluegreenalliance.org/about/#

Borunda, A. (2019). Inequality is decreasing between countries - but climate change is slowing progress. National Geographic. Retrieved from https://www.nationalgeographic.com/environment/2019/04/climate-change-economic-inequality-growing/

Breffle, W.S., Muralidharan, D., Donovan, R.P., Liu, F., Mukherjee, A., & Jin, Y. (2013). Socioeconomic evaluation of the impact of natural resource stressors on human-use services in the great lakes environment: a lake michigan case study. *Resources Policy*. Volume 38, Issue 2. https://doi.org/10.1016/j.resourpol.2012.10.004

Brown-Iannuzzi, J., Lundberg, K.B., & McKee, S. (2017). The politics of socioeconomic status: how socioeconomic status may influence political attitudes and engagement. *Current Opinion in Psychology*. Volume 18, Issue 11-14. https://doi.org/10.1016/j.copsyc.2017.06.018

Burgard, S.A. & Lin, K.Y. (2014). Bad jobs, bad health? How work and working conditions contribute to health disparities. *American Behavioral Scientists*. doi: 10.1177/0002764213487347

Bush, A. (2009). Regulation of great lakes' water levels possible, experts debate effects. *Great Lakes Echo*. Retrieved from https://greatlakesecho.org/2009/06/01/regulation-of-great-lakes-levels-regulation-possible-experts-debate-effects #:~:text=The%20Great%20Lakes%20water%20levels,connects%20lakes%20Erie%20and%20Ontario.

Camillus, J.C. (2008). Strategy as a wicked problem. *Harvard Business Review*. Retrieved from https://hbr.org/2008/05/strategy-as-a-wicked-problem

Centers for Disease Control and Prevention. (2019). Lyme disease. Retrieved from https://www.cdc.gov/lyme/index.html

Changnon, S.A. (1993). Changes in climate and level of Lake Michigan: shoreline impacts at Chicago. *Climate Change*. 213–230. Retrieved fromhttps://link.springer.com/article/10.1007/BF01091616

Chen, E., Strunk, R.C., Tretheway, A., Schreier, H.M.C., Maharaj, N,. & Miller, G.E. (2011). Resilience in low socioeconomic status children with asthma: adaptations to stress. *The Journal of Allergy and Clinical Immunology*. DOI: 10.1016/j.jaci.2011.06.040

Chen, E., McLean, K., & Miller, G.E. (2015). Shift-and-persist strategies: associations with socioeconomic status and the regulation of inflammation among adolescents and their parents. Psychosomatic Medicine. Retrieved from https://www.ncbi.nlm.nih.gov/

pmc/articles/PMC5890430/
#:~:text=Objective,through%20finding%20purpose%20in%20life.

Citizens' Climate Lobby. (2019). The basics of carbon fee and dividend. Retrieved from https://citizensclimatelobby.org/basics-carbon-fee-dividend/

Citizens' Climate Lobby. (2019). Household impact study. Retrieved from https://citizensclimatelobby.org/household-impact-study/

Colton, C. (2006). Vulnerability and place: flat land and uneven risk in New Orleans. *American Anthropologist*, vol. 108, No. 4, pp. 731-734.

Council of the Great Lakes Region. (2018). The great lakes economy: the growth engine of north america. Retrieved from https://councilgreatlakesregion.org/the-great-lakes-economy-the-growth-engine-of-north-america/

Culligan, B. (2002). Botulism in Lake Erie: Workshop Proceedings. *National Oceanic* and Atmospheric Administration Sea Grant. Stony Brook, NY. Retrieved from http://www.seagrant.sunysb.edu/botulism/pdfs/Botulism-Proc02.pdf.

Cusick, D. (2019). No end in sight for record midwest flood crisis. *Scientific American*. Retrieved from https://www.scientificamerican.com/article/no-end-in-sight-for-record-midwest-flood-crisis/

Cusick, D. (2020). Past racistin "redlining" practices increased climate burden on minority neighborhoods. *Scientific American*. Retrieved from https://www.scientificamerican.com/article/past-racist-redlining-practices-increased-climate-burden-on-minority-neighborhoods/

Dempsey, D., Elder, J., & Scavia, D. (2008) Great lakes restoration & the threat of global warming. Healing Our waters - Great Lakes Coalition. Retrieved from https://www.nwf.org/-/media/PDFs/Water/
200711_ClimateChangeandGreatLakes_Report.ashx?
la=en&hash=647676E6830B8FD6807802503ACE13096B383841

Desjardin, J. (2017). The great lakes economy: the growth engine of north america. *Visual Capitalist*. Retrieved from https://www.visualcapitalist.com/great-lakes-economy

Dong, X.S., West, G.H., Holloway-Beth, A., Wang, X., & Sokas, R.K. (2019) Heat-related deaths among construction workers in the united states. *American Journal of Industrial Medicine*. Volume 62, Issue 12. https://doi.org/10.1002/ajim.23024

Doss, M. & Eder, T. (2017). An agenda for great lakes restoration and economic revitalization. Great Lakes Commission Federal Priorities for 2017. Retrieved from https://www.glc.org/wp-content/uploads/2017/03/GLC-LegPri-2017-FINAL-web.pdf

Environmental Protection Agency. (2017). Multi-model framework for quantitative sectoral impacts analysis: A technical report for the Fourth National Climate Assessment. U.S. Environmental Protection Agency, EPA 430-R-17-001Evergreen Collaborative. (2018). The evergreen action plan. Retrieved from https://collaborative.evergreenaction.com/plan

Francis, P. (2015). Laudato Si': On Care For Our Common Home. *Perspectives on Science and Christian Faith*, *68*(4), 266+. Retrieved from http://w2.vatican.va/content/dam/francesco/pdf/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si_en.pdf

Folger, T. (2020). North America's most valuable resource is at risk. *National Geographic*. https://www.nationalgeographic.com/magazine/2020/12/north-americas-most-valuable-resource-is-at-risk-feature/

Food and Agriculture Organization of the United Nations. (2020). Plant pests and diseases. Retrieved from http://www.fao.org/emergencies/emergency-types/plant-pests-and-diseases/en/

Fothergill, A. (2004). Poverty and Disasters in the United States: A Review of Recent Sociological Findings. *Natural Hazards*. 32. 89-110. 10.1023/B:NHAZ.0000026792.76181.d9.

Gardner, P., & Morse, C. (2020). Numbers show impact of Michigan coastline flooding and erosion from high water. *MLive*. Retrieved from https://www.mlive.com/news/2020/03/numbers-show-impact-of-michigan-coastline-flooding-and-erosion-from-high-water.html

Gill, K. (2020). Housing discrimination in Detroit: an example of systemic racism. *Click On Detroit*. Retrieved from https://www.clickondetroit.com/news/local/2020/06/24/housing-discrimination-in-detroit-an-example-of-systemic-racism/

Global Environmental Facility. (2020). Climate change mitigation. Retrieved from https://www.thegef.org/topics/climate-change-mitigation#:~:text=Mitigation%20strategies%20include%20retrofitting%20buildings,sustainable%20uses%20of%20land%20and

Gold, A., Pendall, R., & Treskon, M. (2018). Demographic change in the great lakes region. *The Urban Institute*. Retrieved from https://www.urban.org/sites/default/files/publication/98572/demographic_change_in_the_great_lakes_region_1.pdf

Grandoni, D. (2019). The energy 202: Trump administration was against funding Great Lakes program before it was for it. *The Washington Post*. Retrieved from https://www.washingtonpost.com/news/powerpost/paloma/the-energy-202/2019/10/23/the-energy-202-trump-administration-was-against-funding-great-lakes-program-before-it-was-for-it/5daf314d602ff10cf14f96a7/

Great Lakes Indian Fish and Wildlife Commission. (2015). Focus areas. Retrieved from: http://www.glifwc.org/index.html

Great Lakes Restoration Initiative. (2020). Accelerating efforts to protect and restore the largest system of fresh surface water in the world. Retrieved from: https://www.glri.us/about

Greenberg, J. (202). Fact-checking Trump on auto-industry, new Michigan companies. *Austin American-Statesman*. Retrieved from https://amp.statesman.com/amp/114015426

Gronewold, A.D., Do. H.X., Mei, Y., & Stow, C.A. (2021). A tug-of-war within the hydrological cycle of a continental freshwater basin. *Geophysical Research Letters*. 48. Retrieved from https://doi.org/10.1029/2020GL090374

Gronewold, A.D., Fortin, V., Lofgren, B.M., Clites, A., Stow, C.A., Quinn, F. (2013). Coasts, water levels, and climate change: a Great Lakes perspective. *Climate Change*. 120. 10.1007/s10584-013-0840-2. Retrieved from https://www.researchgate.net/publication/257548180_Coasts_water_levels_and_climate_change_A_Great_Lakes_perspective

Gronewold, A.D. & Rood, R.B. (2019). Climate change is driving rapid shifts between high and low water levels on the Great Lakes. *The Conversation: Academic rigor, journalistic flair*. Retrieved from https://theconversation.com/climate-change-is-driving-rapid-shifts-between-high-and-low-water-levels-on-the-great-lakes-118095

Guarnieri, M., & Balmes, J. R. (2014). Outdoor air pollution and asthma. *Lancet (London, England)*, *383*(9928), 1581–1592. https://doi.org/10.1016/S0140-6736(14)60617-6

Gude, P.H. (2017). Great lakes cities vulnerability assessment tool. *Headwaters Economics*. Retrieved fromhttps://headwaterseconomics.org/economic-development/great-lakes-vulnerability-assessment-tool/

Hallegatte, S., Vogt-Schilb, A., Bangalore, M., Rozenberg, J. (2017). Unbreakable: building the resilience of the poor in the face of natural disasters. *World Bank*. Washington, DC. Retrieved from https://openknowledge.worldbank.org/handle/10986/25335

Hanania, J. & Donev, J. (2016). Emission scenario. *University of Calgary*. Retrieved from https://energyeducation.ca/encyclopedia/Emission_scenario

Harvard University Center for the Environment. (2017). Faculty associates: Jesse M Keenan. *Harvard University*. Retrieved from https://environment.harvard.edu/about/faculty/jesse-m-keenan

Hawthrone, M. (2020). Under Trump, the EPA has cut back on enforcement of clean water laws in the Great Lakes Region. *Chicago Tribune*. Retrieved from https://www.chicagotribune.com/news/environment/ct-trump-epa-great-lakes-enforcement-decline-20200421-ddrijfviyrchpa2khe6za5d5m4-story.html

Hayhoe, K., VanDorn, J., Croley II, T., Schlegel, N., & Wuebbles, D. (2009). Regional climate change projections for chicago and the US great lakes. *Journal of Great Lakes Research*. Retrieved from http://climate-action.engin.umich.edu/figures/Rood_Climate_Change_AOSS480_Documents/Hayhoe_Projections_Chicago_Great_Lakes_JGreatLakesRes_2010.pdf

Holmes, A. (2013). Some economic effects of inequality. *Parliament of Australia*. Retrieved from https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/EconEffects

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Ramussen, D.J., Muir-Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., & Houser, T. (2017). Estimating economic damage from climate change in the United States. *Science*. Retrieved from https://science.sciencemag.org/content/356/6345/1362

Ingram, H. (2019). Hydro is largest source of renewable energy in 19 U.S. states. *Hydro Review*. Retrieved from https://www.hydroreview.com/2018/09/11/hydro-is-largest-source-of-renewable-energy-in-19-u-s-states/#gref

Islam, S. N., & Winkel, J. (2017). Climate change and social inequality. *Department of Economic & Social Affairs*. Retrieved from https://www.un.org/esa/desa/papers/2017/wp152_2017.pdf

Johns Hopkins Lyme Disease Reach Center. (2020). Lyme Disease. *Johns Hopkins Medicine*. Retrieved from https://www.hopkinslyme.org/lyme-disease/

Jordan, H. & French, C. (2020). Flood damage extends beyond midland county, causing millions in damage in northern michigan. *Michigan Live*. Retrieved from https://www.mlive.com/weather/2020/05/flood-damage-extends-beyond-midland-county-causing-millions-in-damage-in-northern-michigan.html

Kats, G. (2016). How many jobs does clean energy create? *GreenBiz*. Retrieved from https://www.greenbiz.com/article/how-many-jobs-does-clean-energy-create

Kennedy, C. (2014). Great lakes ice cover most extensive since mid-90s. *National Oceanic and* Atmospheric Administration Climate.gov: science & information for a climate-smart *nation*. Retrieved from https://www.climate.gov/news-features/event-tracker/great-lakes-ice-cover-most-extensive-mid-90s

Khubchandani, J., & Price, J.H. (2017). Association of job insecurity with health risk factors and poorer health in american workers. *Journal of Community Health*. DOI: 10.1007/s10900-016-0249-8

Klinenberg, E. (2002). *Heat Wave: A Social Autopsy of Disaster in Chicago, Chicago, University of Chicago Press.*

Kling, G. W., Hayhoe, K., Johnson, L. B., Magnuson, J.J., Polasky, S., Robinsom, S.K., Shuter, B.J., Wander, M.M., Wuebbles, D.J., & Zak, D.R. (2003). Confronting climate change in the great lakes region. *The Union of Concerned Scientists and The Ecological Society of America*. Retrieved from https://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/greatlakes_final.pdf

Kolko, J. & Austin Center for Design. (2020). Wicked Problems. *Wicked Problems: Problems Worth Solving*. Retrieved from https://www.wickedproblems.com/1_wicked_problems.php

Koons, C., & Ivry, B. (2020). Covid plus decades of pollution are a nasty combo for detroit. Bloomberg Businessweek. Retrieved from https://www.bloomberg.com/news/features/2020-10-21/covid-pandemic-southwest-detroit-faces-pollution-covid-19-outbreaks?sref=VGqaY5U2&fbclid=IwAR3W7DwZLNyA5V9zSdG7Ml_ht4E-RJx k5hL-bMXRj_Y7Jnb3NTWRwsIG8

Logan, John R. (2006). The impact of Katrina: race and class in storm-damaged neighborhoods. *Spatial Structures in the Social Sciences*, Brown University. Providence, RI. Retrieved from https://www.worldcat.org/title/impact-of-katrina-race-and-class-in-storm-damaged-neighborhoods/oclc/63663325

Malo, S. (2019). Future cool: Minnesota city ponders new boom as a climate migrant destination. Thomson Reuters Foundation News. Retrieved from https://news.trust.org/item/20191016103325-fija0/

Masozera, M., Bailey, M., & Kerchner, C. (2007). Distribution of impacts of natural disasters across income groups: A case study of New Orleans. Ecological Economics, 63(2–3), 299–306. doi: 10.1016/j.ecolecon.2006.06.013

Matheny, K. (2020). Climate change transforming where fish in the great lakes region live. Detroit Free Press. Retrieved fromhttps://www.freep.com/in-depth/news/local/michigan/2019/09/16/climate-change-transforming-great-lakes-fish-habitats/2223549001/

Matheny, K. (2020). Report: As EPA pulls back under Trump, serious pollution rises on Great Lakes. Detroit Free Press. Retrieved from https://www.freep.com/story/news/

local/michigan/2020/04/20/epa-back-under-trump-causes-spike-great-lakes-pollution/5155411002/

Meng, A. (2017). Midwest faces increase in ticks carrying lyme disease. *The Nation's Health: A Publication of the American Public Health Association*. Retrieved from http:/thenationshealth.aphapublications.org/content/47/7/E33

Michigan Climate Action Network. (2020). Solutions. Retrieved from https://www.miclimateaction.org/solutions

Michigan Sea Grant. (2018). Botulism in the Great Lakes. Retrieved from http://www.miseagrant.umich.edu/explore/coastal-communities/avian-botulism/faqs-botulism-in-the-greatlakes/#whatis, accessed May 2020.

Michigan Technological University. (2020). How do ships travel on the great lakes? *The Great* Lakes Maritime Research Institute. Retrieved from http://techalive.mtu.edu/glmri/ShipsTravel.htm#:~:text=The%20Great%20Lakes%20are%20connected,water%20system%20on%20the%20planet.

Nadler, B. (2019). Obama talks climate change, inequality at green conference. *Associated Press News*. Retrieved from https://apnews.com/f7229999763b44bfa9c3694a519b5326

National Aeronautics and Space Administration. (2021). The causes of climate change. *Global Climate Change: Vital Signs of the Planet*. Retrieved from https://climate.nasa.gov/causes/

National Center for Environmental Health. (2016). Drought and public health in the U.S. Centers for Disease Control and Prevention. Retrieved fromhttps://stacks.cdc.gov/view/cdc/40526

National Integrated Drought Information System and National Oceanic and Atmospheric Administration's. (2020). The high cost of drought. *National Integrated Drought Information System*. Retrieved from https://www.drought.gov/drought/news/high-cost-drought

Nix, E. (2018). Are the great lakes connected? *History*. Retrieved from https://www.history.com/news/are-the-great-lakes-connected

O'Connell, P.M. & Briscoe, T. (2020). In 2019- the 2nd wettest year ever in the U.S. - flooding cost Illinois and the midwest $6.2 billion. Scientists predict more waterlogged days ahead. Chicago Tribune. Retrieved fromhttps://www.chicagotribune.com/news/environment/ct-climate-disasters-cost-midwest-20200115-jubchhqe7bfdnolpw3z7cwjwvm-story.html

Oil & Water Don't Mix. (2021). The Problem: Line 5. Retrieved from https://www.oilandwaterdontmix.org/problem

Oxfam. (2015). Extreme carbon inequality. Retrieved fromhttps://oi-files-d8-prod.s3.eu-west-2.amazonaws.com/s3fs-public/file_attachments/mb-extreme-carbon-inequality-021215-en.pdf

Pampel, F.C., Krueger, P.M., & Denney, J.T. (2011). Socioeconomic disparities in health behaviors. *Annual Review of Sociology*. doi: 10.1146/annurev.soc.012809.102529 Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3169799/

Panci, H., Bartnick, T., Montano, M., Shultz, A., Stone, K. (2015). A climate change vulnerability assessment in the upper Great Lakes integrating Traditional Ecological Knowledge. *Great Lakes Indian Fish and Wildlife Commission*.

Patel, A.I. & Schmidt, L.A. (2017). Water access in the United States: health disparities abound and solutions are urgently needed. American Public Health Association. DOI: 10.2105/AJPH.2017.303972 Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5551618/#

Patz, J., Frumkin, H., Holloway, T., Vimont, D.J., Haines, A. (2014). Climate change: challenges and opportunities for global health. Department of Health and Human Services. DOI: 10.1001/jama.2014.13186

Patz, J., Vavrus, S., Uejio, C. K., & McLellan, S.L. (2008). Climate change and waterborne disease risk in the great lakes region of the U.S. *American Journal of Preventive Medicine*. DOI: https://doi.org/10.1016/j.amepre.2008.08.026

Pendall, R., Poethig, E., Trekson, M., & Blumenthal, E. (2017). The future of the great lakes region. *The Urban Institute*. Retrieved from https://www.urban.org/sites/default/files/publication/89087/great_lakes_0.pdf

Rippey, B.R. (2015). The U.S. drought of 2012. Weather and Climate Extremes, 10, 57-64. Retrieved from https://www.researchgate.net/publication/283966904_The_US_drought_of_2012

Roth. (2020). Trump casts self as Great Lakes champion, but his policies may do lasting damage. *Michigan Live*. Retrieved from: https://www.mlive.com/public-interest/2020/09/trump-casts-self-as-great-lakes-champion-but-his-policies-may-do-lasting-damage.html

Ruiz, I.B. (2019). Climate change reinforces inequalities - even in developed countries. *Deutsche Welle*. Retrieved from https://www.dw.com/en/climate-change-reinforces-inequalities-even-in-developed-countries/a-50596957#:~:text=Environment-,Climate%20change%20reinforces%20inequalities%

20%2D%20even%20in%20developed%20countries,also%20in%20industrialized%2C%20wealthy%20ones.&text=It%20reveals%20that%20the%20economic,smaller%20without%20the%20climate%20crisis.

Schleicher, A., Salinas, D. (2016). Low performing students: why they fall behind and how to help them succeed. *United States Organisation for Economic Co-operation and Development (OECD)*. Retrieved from: https://www.oecd.org/unitedstates/PISA-2012-low-performers-United-States-ENG.pdf

Schwartz, R., Deadman, P., Scott, D., & Mortsch, L. (2004). Modeling the impacts of water level changes on a Great Lakes community. *Journal of the American Water Resources Association* 40, 647–662. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.2004.tb04450.x

Shrinath, N., Mack, V., & Plyer, A. (2014). Who lives in New Orleans and metro parishes now? *The Data Center*. Retrieved from https://www.datacenterresearch.org/data-resources/who-lives-in-new-orleans-now/

Stanford Medicine. (2020). Healthcare disparities & barriers to healthcare. Retrieved fromhttp://med.stanford.edu/ruralhealth/health-pros/factsheets/disparities-barriers.html

Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M.M.B., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P.M. (2013). Climate change 2013: The Physical Science Basis. *Intergovernmental Panel on Climate Change*. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf

Stop Line 3. (2020). Issues. Retrieved from https://www.stopline3.org/issues

Substance Abuse and Mental Health Administration. (2017). Greater Impact: How Disasters Affect People of Low Socioeconomic Status. *Department of Health and Human Services*. Retrieved from https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf

Swain, G.R. (2017). Focus: How does economic and social disadvantage affect health? *University of Wisconsin-Madison Institute for Research on Poverty*. Volume 33, Number 1. ISSN:0195-5705. Retrieved from: https://www.irp.wisc.edu/publications/focus/pdfs/foc331a.pdf

Teller, A.S. (2017). Moving the conversation on climate change and inequality to the local. *Sociology of Development*. Retrieved from https://doi.org/10.1525/sod.2016.2.1.25

The United Nations Development Programme (UNDP). (2019). Human development report 2019. Retrieved from https://doi.org/10.18356/838f78fd-en

The United Nations. (2020). World social report 2020 inequality in a rapidly changing world. *Department of Economic and Social Affairs.* Retrieved from https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/02/World-Social-Report2020-ExecutiveSummary.pdf

The United Nations. (2016). World economic and social survey 2016: climate change resilience—an opportunity for reducing inequalities. Retrieved from https://wess.un.org/wp-content/uploads/2016/06/WESS_2016_Report.pdf

Traverse City Tourism. (2020). National cherry festival. Retrieved from https://www.traversecity.com/events/summer-events/national-cherry-festival/

United Nations Development Programme Human Development Report. (2019). Climate change and inequalities in the anthropocene. Retrieved from https://doi.org/10.18356/838f78fd-en.

United States Census Bureau. (2015). Rural america. Retrieved fromhttps://gis-portal.data.census.gov/arcgis/apps/MapSeries/index.html?appid=7a41374f6b03456e9d138cb014711e01

University of Michigan Graham Sustainability Institute. (2013). Great Lakes Adaptation Assessment for Cities. Retrieved fromhttp://www.graham.umich.edu/media/files/GLAA-C/(Web)%20Final%20Draft%20GLAA-C%20Public%20Survey%20FactSheetFinalDraft_3_13.pdf

University of Michigan Graham Sustainability Institute. (2015). Great Lakes Adaptation Assessment for Cities. Retrieved fromhttp://www.graham.umich.edu/media/pubs/LocalLeaders-ClimateAdaptation-2015.pdf

University of Michigan Graham Sustainability Institute. (2020). Great Lakes Adaptation Assessment for Cities. Headwaters Economics & University of Michigan Graham Sustainability Institute. Retrieved from http://www.graham.umich.edu/glaac/great-lakes-atlas

University of Michigan School for Environment and Sustainability & National Oceanic and Atmospheric Administration. (2016). Great lakes climate adaptation network (GLCAN). Retrieved from http://glisa.umich.edu/media/files/5_%20Case%203.pdf

U.S. Census Bureau. (2012). Great lakes length of shoreline in separate basin. *Statistical Abstract of the United States: 2012*. Retrieved from https://www2.census.gov/library/publications/2011/compendia/statab/131ed/tables/12s0360.pdf

U.S. Census Bureau. (2019). How the Census Bureau measures poverty. Retrieved from https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html

U.S. Climate Resilience Toolkit. (2019). Great lakes. Retrieved from https://toolkit.climate.gov/regions/great-lakes

U.S. Climate Resilience Toolkit. (2019). Human health. Retrieved fromhttps://toolkit.climate.gov/regions/midwest/human-health

U.S. Climate Resilience Toolkit. (2019). People and communities.Retrieved from https://toolkit.climate.gov/regions/great-lakes/people-and-communities

U.S. Global Change Research Program (USGCRP). (2017). Climate Science Special Report: Fourth National Climate Assessment, Volume I. Washington, DC. doi: 10.7930/J0J964J6.

U.S. Bureau of Labor Statistics. (2020). Employment by major industry sector. Retrieved from https://www.bls.gov/emp/tables/employment-by-major-industry-sector.htm

Vaccaro, L., & Read, J. (2011). Vital to our nation's economy: great lakes jobs. *National* Oceanic and Atmospheric Administration Michigan SeaGrant. Retrieved from https://www.michiganseagrant.org/wp-content/uploads/2018/10/11-203-Great-Lakes-Jobs-report.pdf

Vey, J.S., Austin, J.C., & Bradley, J. (2010). The next economy: economic recovery and transformation in the great lakes region. *Metropolitan Policy Program at Brookings*. Retrieved from https://www.brookings.edu/wp-content/uploads/2016/06/0927_great_lakes.pdf

Woolf, S.H., & Aron, L. (2013). U.S. health in international perspective: shorter lives, poorer health. *National Research Council and Institute of Medicine*. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK154469/

Worland, J. (2019). Climate change has already increased global inequality. It will only get worse. *Time*. Retrieved from https://time.com/5575523/climate-change-inequality/

World Health Organization. (2020). Climate change and human health. Retrieved fromhttps://www.who.int/globalchange/summary/en/index4.html

Wuebbles, D., Cardinale, B., Cherkauer, K., Davidson-Arnott, R., Hellmann, J., Infante, D., Johnson, L., de Loë, R., Lofgren, B., Packman, A., Seglenieks, F., Sharma, A., Sohngen, B., Riboris, M., Vimont, D., Wilson, R., Kunkel, K., & Ballinger, A. (2019). An assessment of the impacts of climate change on the great lakes. Environmental Law & Policy Center. Retrieved from http://elpc.org/wp-content/uploads/2019/03/Great-Lakes-Climate-Change-Report.pdf

Zhang, P., Deschenes, O., Meng, K.C., & Zhang, J. (2017). Temperature effects on productivity and factor reallocation: evidence from a half million chinese manufacturing plants. *National Bureau of Economic Research*. Retrieved from https://www.nber.org/papers/w23991.pdf