# Michigan Tribal Climate Change Vulnerability Assessment and Adaptation Planning: Project Report

**Inter-Tribal Council of Michigan, Inc.**

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# Executive Summary

Michigan Tribes are currently experiencing the impacts of climate change: warmer average annual air and surface water temperatures, more volatile weather characterized by extreme precipitation events, decreases in duration and extremity of winter temperatures, and increases in duration of summer temperatures. Changes in climate and weather patterns are accelerating, with an expected increase in mean annual temperature of 5.5 to 6 degrees Fahrenheit by mid century (2041 – 2070; GLISA 2016). These changes impact Michigan Tribes in numerous ways both directly and indirectly. Tribes are concerned with climate change and how to plan for potential and undefined impacts on natural features, traditional ways, public health, and infrastructure. Now is the time to evaluate and plan for climate change with adaptation strategies that mitigate degradation or losses in Tribal resources.

This planning document is the result of a cooperative effort among the Inter-Tribal Council of Michigan, Inc., and nine federally-recognized Tribes in Michigan (participating Tribes): Bay Mills Indian Community, Lac Vieux Desert Band of Lake Superior Chippewa, Grand Traverse Band of Ottawa and Chippewa Indians, Little River Band of Ottawa Indians, Little Traverse Bay Bands of Odawa Indians, Match-E-Be-Nash-She-Wish Band of Potawatomi (Gun Lake Tribe), Pokagon Band of Potawatomi, Saginaw Chippewa Indian Tribe, and Sault Ste. Marie Tribe of Chippewa Indians.

The Inter-Tribal Council of Michigan (ITCMI) is a consortium of federally recognized Tribes in Michigan and works across reservation boundaries and treaty ceded territories to provide technical assistance with human health and resource protection efforts to member Tribes. Through this project, the ITCMI facilitated a tribal-led process of analyzing climate projections at mid-century, assessing resource vulnerabilities, and identifying planning resources and adaptation strategies across jurisdictional boundaries to benefit Tribes in Michigan as they face a changing climate.

Participating Tribes identified important natural resources and infrastructure across the respective reservations and treaty ceded territories, which may be vulnerable to projected changes in climate. For the purposes of this project, the State of Michigan was subdivided into four climatic and ecologic regions: Western Upper Peninsula, Eastern Upper Peninsula, Northern Lower Peninsula, and Southern Lower Peninsula. Tribes located within each region are expected to experience similar climate changes and related challenges based on regional climates and geography. Participating Tribes worked together with ITCMI through the vulnerability assessment and adaptation planning processes in a true learning collaborative, contributing to and learning from each others' expertise and perspectives.

This project has served to connect tribally-driven climate change vulnerability assessments, identification of climate sensitive tribal assets, and finally, adaptation planning to support tribal decision making and prevent or minimize climate change impacts on important tribal resources. This work would not have been possible without the dedication of participating Tribe staff, who contributed their time and expertise in service of the Tribes.

# Introduction

Michigan Tribes maintain unique identities and priorities, yet adaptation to climate change is a priority ubiquitous amongst all Tribes participating in this Michigan Tribal Adaptation Planning Project. For this reason, the Inter-Tribal Council of Michigan, Inc. (ITCMI) led a cooperative tribal climate adaptation planning effort among nine of the federally-recognized Tribes in Michigan (participating Tribes): Bay Mills Indian Community, Lac Vieux Desert Band of Lake Superior Chippewa, Grand Traverse Band of Ottawa and Chippewa Indians, Little River Band of Ottawa Indians, Little Traverse Bay Bands of Odawa Indians, Match-E-Be-Nash-She-Wish Band of Potawatomi (Gun Lake Tribe), Pokagon Band of Potawatomi, Saginaw Chippewa Indian Tribe, and Sault Ste. Marie Tribe of Chippewa Indians. ITCMI is a consortium of federally recognized Tribes in Michigan and works across reservation boundaries and treaty ceded territories to provide technical assistance with human health and resource protection efforts to member Tribes. Through this project, the ITCMI facilitated a tribal-led process of analyzing climate projections at mid-century, assessing resource vulnerabilities, and identifying planning resources and adaptation strategies across jurisdictional boundaries to benefit Tribes in Michigan as they face a changing climate.

Michigan Tribes have longstanding relationships to the lands and waters, seasons and cycles, and non-human beings of the Great Lakes region. Cultural traditions have been maintained over millennia through the ongoing relationships among Anishinaabek and the natural resources of the Great Lakes region. These traditions continue today in the form of subsistence hunting and fishing, gathering, commercial fishing, and other Anishinaabek ways of life. Native plants and animals support traditional and modern ways of life by offering important medicine, food, craft, and continual reminders of Anishinaabek creation stories. Tourism has become an economic mainstay for the participating Tribes, typified by the climate, natural features, and infrastructure of each Tribe's reservation, service area, and ceded territory. Climate change imposes risks on the continuity of each of these ways of life and necessitates adaptation planning.

Tribal climate change adaptation planning project involves an iterative process of analyzing tribal resources, assessing resource vulnerability or response to changes in climate, and identification, prioritization, implementation, and revision of strategies to support resource health or sustainability. This project involved collaborative analysis of tribal resources valued across the State of Michigan, consensus-based vulnerability assessment by tribal natural resource professionals, and adaptation strategy identification for tribal planning. This work was undertaken on behalf of current and future generations of Anishinaabek and the plants, animals, other beings, and natural features of the Great Lakes Region.

Participating Tribes each identified important natural resources and infrastructure across the respective reservations and treaty ceded territories, which may be vulnerable to projected changes in climate. The identified resources include: plant, fish, and wildlife species, natural features, public health, and infrastructure. The connection between natural resources and tribal public health, cultural well-being, and economic success cannot be overstated. Great Lakes natural resources are essential to tribal ways of life; degradation of these resources has the potential to cause significant impacts on tribal ways of life. Climate change is one of many stressors impacting Great Lakes natural resources, including land use change and invasive species. These stressors are often linked; however, climate change may exacerbate existing stressors and lead to cascading effects across tribal lands and waters, with significant changes in tribal resources.

For the purposes of this project, the State of Michigan was subdivided into four geographic areas based on climate and ecology: Western Upper Peninsula (WUP), Eastern Upper Peninsula (EUP), Northern Lower Peninsula (NLP), and Southern Lower Peninsula (SLP) (**Figure 1**). Tribes located within each geographic area may experience similar climate changes and related challenges based on the area's geography, climate, and ecosystems.

Participating Tribes worked together with ITCMI to conduct collaborative vulnerability assessments for each tribal resource identified, within each of the four geographic areas. The vulnerability assessment process was similar to the process of risk assessment, in risk management. Through assessing the vulnerabilities of resources, Tribes may work to manage the risks posed by potential changes in climate. Once we know how climate threatens a resource, then we can determine what can be done to manage those risks and reduce vulnerability. If feasible actions exist, they can then be prioritized, included in planning efforts, and implemented.

Climate-sensitive tribal resources were identified through the vulnerability assessment process, along with the ways in which each resource may be sensitive to projected changes in climate. Adaptation strategies were then developed and collated for the climate sensitive resources.

It is important to note that Tribal natural and infrastructure resources are exposed to a vast array of stressors, such as land use change, pollution, and invasive species. Climate change may amplify the impacts of existing stressors; this highlights the importance of identifying and detailing specific strategies that Tribes can use to manage the vulnerability of valued resources. The complexity and uncertainty associated with climate change vulnerability also serve to increase the importance of ongoing monitoring, vulnerability assessment, and strategic adaptation planning.

This project has served to connect tribally-driven climate change vulnerability assessments, identification of climate sensitive tribal assets, and finally, adaptation planning to support tribal decision-making to prevent or minimize negative climate change impacts on important tribal resources for current and future generations.

## Tribes and Tribal Resources

The nine participating Tribes in this project include: Bay Mills Indian Community (BMIC), Lac Vieux Desert Band of Lake Superior Chippewa (LVD), Grand Traverse Band of Ottawa and Chippewa Indians (GTB), Little River Band of Ottawa Indians (LRB), Little Traverse Bay Bands of Odawa Indians (LTBB), Match-E-Be-Nash-She-Wish Band of Potawatomi (GLT), Pokagon Band of Potawatomi (PBP), Saginaw Chippewa Indian Tribe (SCIT), and Sault Ste. Marie Tribe of Chippewa Indians (SSMT) (**Figure 1**). Three other Tribes in Michigan include Hannahville Indian Community (HIC), Keweenaw Bay Indian Community (KBIC), and Notawaseppi Huron Band of the Potawatomi (NHBP). The participating Tribes represent the Three Fires of Anishinaabek: the Ojibwe or Chippewa, Odawa or Ottawa, and Bodewadomi or Potawatomi. While each Tribe maintains distinct histories, governments, cultures, and landscapes, they are connected as Anishinaabek.

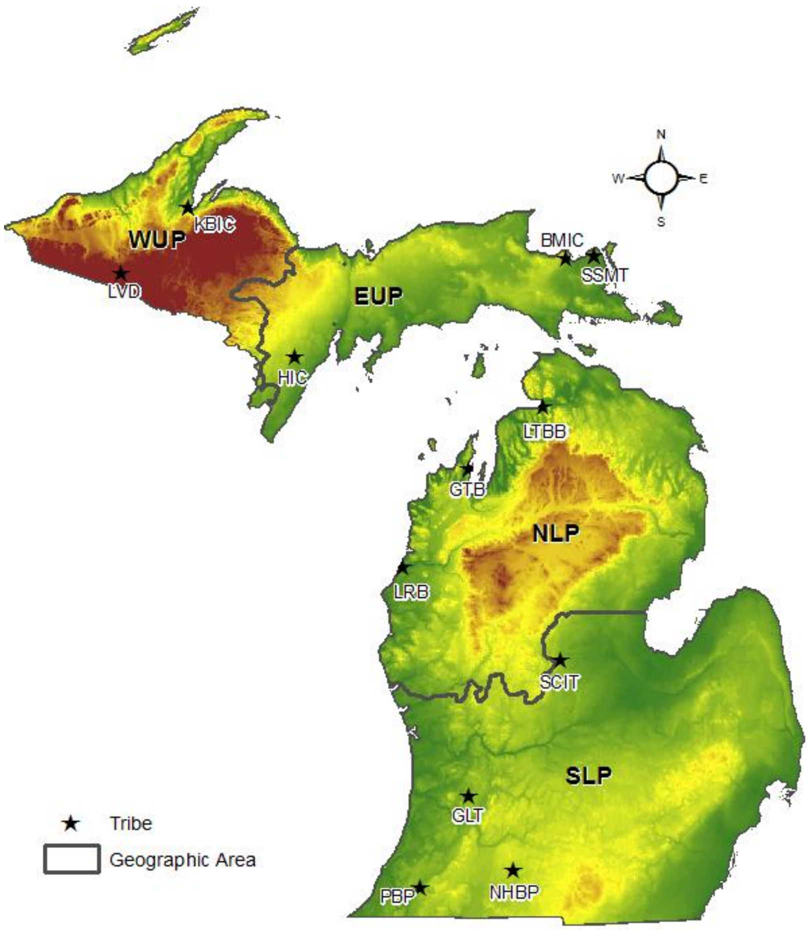


**Figure 1**. Michigan Tribes and Geographic Areas

Both historically and currently, the Anisihnaabek populate the four geographic areas included in this assessment: over 36.3 million acres spanning the northern boreal transition, with over 64,900 inland lakes and ponds (Breck, 2004). The participating Tribes' reservations, service areas, and ceded territories are geographically dispersed from the southern tip of Michigan's Lower Peninsula, with tribal lands in Indiana, to the shores of Lake Superior in Michigan's Upper Peninsula. Several participating Tribes have retained the rights to hunt, fish, and gather in territories ceded to the United States under the Treaty of 1836 and the Treaty of 1842. These Tribes exercise their treaty rights, co-manage certain ceded territory resources, and are actively involved in the protection of the natural and cultural resources across the Great Lakes region.

The climates and landscapes vary greatly among participating Tribe reservations, service areas, and ceded territories; yet, there was significant overlap in the resources identified by each Tribe under this adaptation project. This overlap is due, at least in part, to the inclusion of community and traditional knowledges. The process of identifying tribal resources was led by tribal natural resources and environmental staff. Tribal staff worked with tribal community members and cultural leaders to identify culturally and socio-economically important resources. Tribal resources were identified that: 1) are valued by tribal members and government, and 2) may be sensitive to climate change.

## Community Involvement and Outreach

Community involvement in the vulnerability assessment and adaptation planning process is vital to the quality and efficacy of climate change adaptation. Tribal communities maintain important traditional and community knowledge regarding local plants and animals, lands and waters, seasons and cycles, including recent changes in climate and impacts on natural resources. Traditional knowledge (TK) refers to the bodies of knowledge, practices, and beliefs that have been developed and shared across generations. TK is sustained today by Anishinaabek communities, with ongoing relationships with the lands, waters, and other beings of this region.

TK may inform and guide the process of climate adaptation, including understanding species and resource sensitivities, exposure, and adaptive capacities. Specifically in the case of phenological change, tribal community members may share observations made over decades and over generations, which would increase the quality and confidence in vulnerability assessments and the successful identification and implementation of adaptation strategies.

Community involvement may increase tribal leader, program, and membership support of adaptation efforts and effective action towards adaptation goals. Every step in the adaptation process presents needs and opportunities for community involvement. Involvement may take the form of community advisory committees, one-on-one conversations, formal interviews, community workshops, and community feasts. It is important to consider the rights, risks, and means of protections involved in working with community members and TK, as discussed in Guidelines for Considering Traditional Knowledges in Climate Change Initiatives (Climate and Traditional Knowledges Workgroup, 2014). Resources for community outreach and involvement are shared in Appendix C.

## Historical and Contemporary Climate Landscape

Analyses of recorded historical and current temperature and precipitation data shows that the Great Lakes region’s climate is getting warmer, with greater variability (extremes). The Great Lakes moderate coastal area temperatures, providing cooler spring and summer temperatures and warmer late fall and early winter temperatures compared to continental areas with similar latitudes (GLISA, 2016). However, the Great Lakes region has experienced, and is projected to continue to experience, greater rates of temperature increase than the global average (Girvetz et al. 2009). The overarching changes in temperature and precipitation are causing, and will continue to cause, numerous other changes in river and stream flow and associated flooding risks, ground saturation, ice cover decrease and evaporation increase, snowpack decrease, growing season changes, and geographic shifts of terrestrial and aquatic species.

Expansive ice-cover on the Great Lakes in late winter has led to larger temperature variations and lake-effect snowstorms, supporting Michigan’s characteristic winters, cool springs, and dependent northern boreal transition ecosystems. Decreases in Great Lake ice-cover may increase lake-effect snow and rain over the next 50 years, however, snow accumulation may decrease due to temperature changes (Notaro, 2014; Notaro, 2015).

### Temperature Trends

Temperature variability in the Midwest has gotten warmer over the last century by 0.059°C per decade, with a total increase of 1.16°F between 1900 and 2010 (Great Lakes Integrated Sciences and Assessments 2016; **Figure 2**). The pace of warming has increased to 0.264°C (0.475°F) per decade since the 1980’s (see gray shading in **Figure 3**).

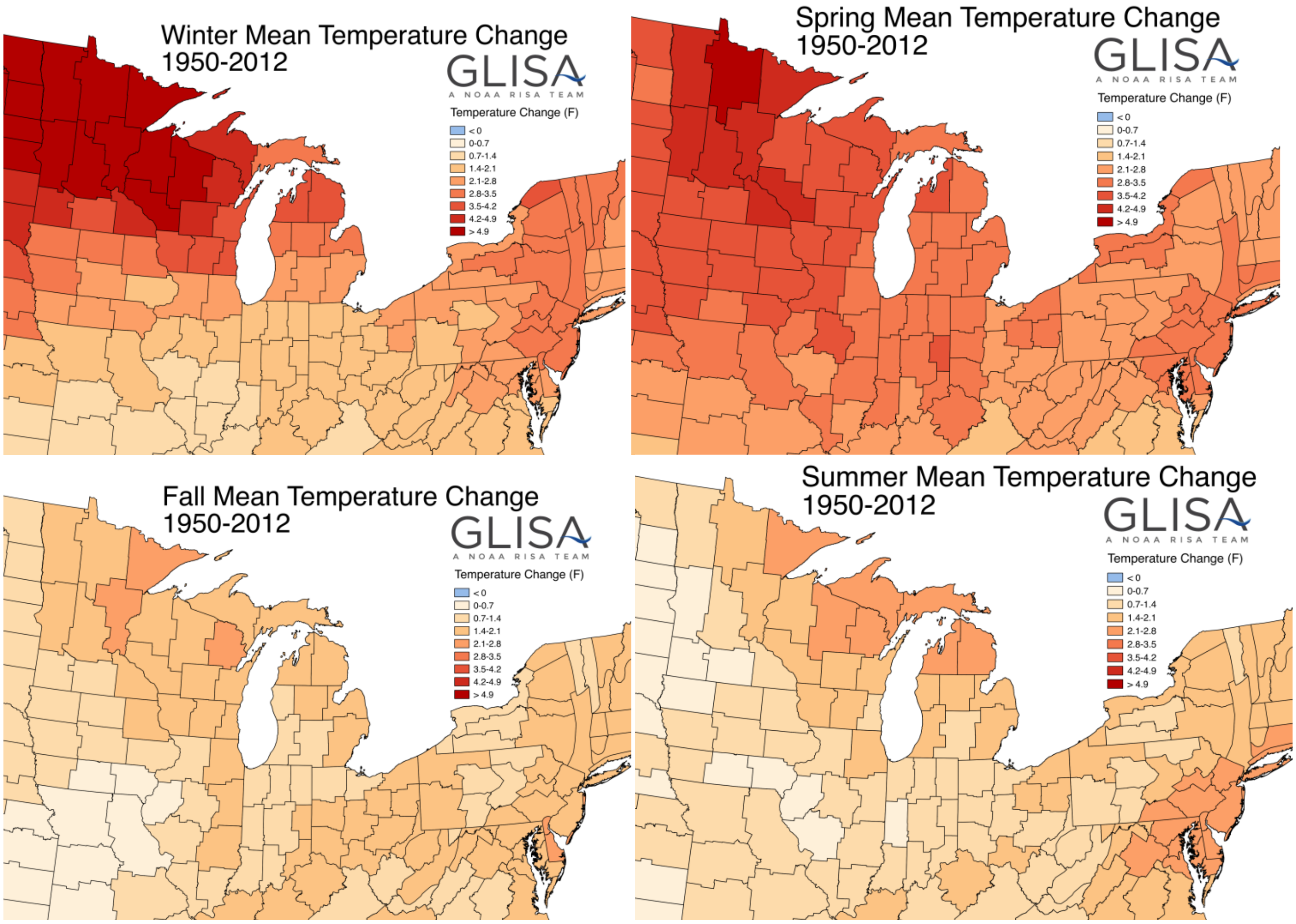


**Figure 2. Great Lakes Region Mean Temperature Changes by Season**. Source: Great Lakes Integrated Sciences and Assessments 2016

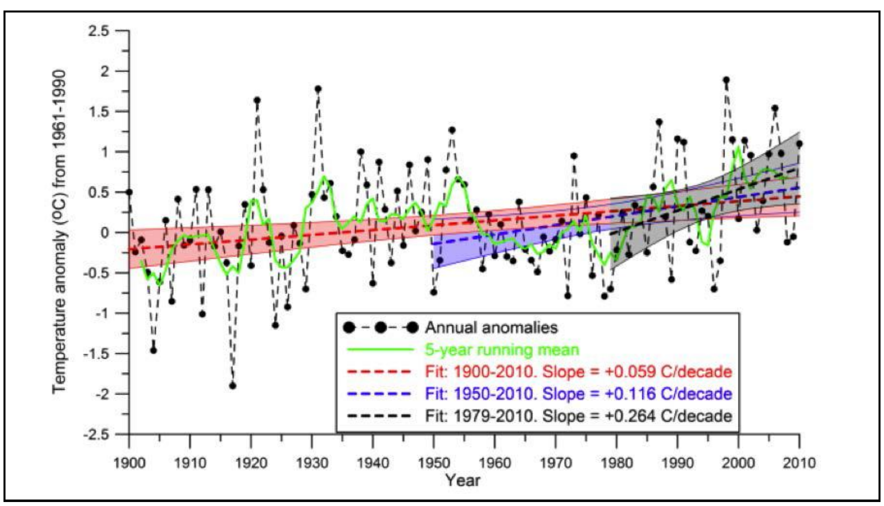


**Figure 3. Temperature Variability in the Midwest 1900 to 2010**. Source: Andresen et al. 2012

The annual mean temperatures for the four geographic areas assessed have increased over the last half-century by 2 - 2.6° Fahrenheit, with marked seasonal differences (Great Lakes Integrated Sciences and Assessments 2016; **Table 1**). The greatest increases were observed during the winter, spring, and summer months and the smallest increases were observed for the fall months. Detailed historic and contemporary temperature information specific to each geographic region assessed are included in **Appendix A**.

**Table 1. Change in Mean Temperatures from 1950 to 2012**
Percentage changes are calculated relative to 1951-1980 historical reference period.
Source: Great Lakes Integrated Sciences and Assessments 2016

| Timeframe | SLP (°F) | NLP (°F) | EUP (°F) | WUP (°F) |
|---|---|---|---|---|
| *Annual* | 2.0 | 2.3 | 2.1 | 2.6 |
| *Winter*, December-February | 2.1 | 2.7 | 1.9 | 3.1 |
| *Spring*, March-May | 2.7 | 2.8 | 2.2 | 2.6 |
| *Summer*, June-August | 1.3 | 1.8 | 2.1 | 2.2 |
| *Fall*, September-November | 1.5 | 1.7 | 1.8 | 2.1 |

Increasing ambient air temperatures in the Great Lakes region have been accompanied by Great Lakes and inland lake ice cover decreases and surface water temperature increases. From 1973 to 2010, annual average ice cover on the Great Lakes declined by 71% (GLISA, 2016), despite recent high ice winters in 2013-2014 and 2014-2015 (**Table 2**). First ice cover on inland lakes occurs 6-11 days later and ice-out occurs 2-13 days earlier compared to the middle of the 19$^{th}$ century (GLISA, 2016). At the current rate of ice cover decline, Lake Superior may have little to no open lake ice cover by mid-century (GLISA, 2014).

**Table 2. Great Lakes Ice Cover Decline from 1973 to 2010**
Source: Great Lakes Integrated Sciences and Assessments 2016

| Lake | Percentage Decline |
|---|---|
| All Great Lakes | 71% |
| Lake Ontario | 88% |
| Lake Superior | 79% |
| Lake Michigan | 77% |
| Lake Huron | 62% |
| Lake Erie | 50% |

The Great Lakes have experienced increases in surface water temperatures over the past half century, at greater rates than ambient air temperatures. Between 1979 and 2012, Lake Superior summer surface water temperatures increased by 3.2°F (**Table 3**). Shorter cold winter seasons and increased ice-free surface waters allow greater evaporation, lake-effect precipitation, and earlier lake stratification (GLISA, 2014).

**Table 3. Upper Great Lakes Temperature Change from 1950 to 2015**
Source: Great Lakes Integrated Sciences and Assessments 2016

| Lake | Temperature Change |
|---|---|
| Lake Superior | +3.2 |
| Lake Michigan | +2.7 |
| Lake Huron | +2.5 |

## Precipitation Trends

Total annual precipitation in the Great Lakes region has increased by 10.8% since 1900 (GLISA, 2014). Over the last half-century, the four geographic areas of this study experienced varied changes in precipitation, with marked seasonal differences (**Table 4**). The greatest decreases have been observed during the spring and summer months in the Upper Peninsula. The greatest increases were observed in the fall months for all geographic areas and in the spring months for the Lower Peninsula. The average annual snowfall baseline increased between 1961-1990 and 1981-2010 by 12 or more inches across each of the four geographic areas assessed (**Figure 4**), with the largest increases along Lakes Superior, Michigan, and Huron. Increased lake effect precipitation has not equated increased snow accumulation, however, as milder winters may cause snow to melt more quickly. Between 1975 and 2004, the number of days per year with snow cover over land decreased by 15 and average snow depth decreased by 5.1 cm (GLISA, 2014). Precipitation may be increasingly falling as rain during late fall, winter, and early spring precipitation events.

**Table 4. Change in Mean Total Precipitation (%) from 1950 to 2012**
Percentage changes are calculated relative to 1951-1980 historical reference period. Source: Great Lakes Integrated Sciences and Assessments 2016.

| **Timeframe** | **SLP Inches (%)** | **NLP Inches (%)** | **EUP Inches (%)** | **WUP Inches (%)** |
|---|---|---|---|---|
| *Annual* | 4.7 (+15.1) | 3.7 (+11.7) | 0.5 (+1.6) | -1.7 (-5.2) |
| *Winter*, December-February | 0.7 (+11.9) | 0.5 (+9.7) | 0.07 (+1.2) | 0.2 (+3.6) |
| *Spring*, March-May | 1.4 (+17.1) | 1.5 (+18.9) | -0.8 (-10.9) | -0.8 (-10.0) |
| *Summer*, June-August | 1.2 (+11.9) | 0.4 (+3.8) | -0.9 (-8.5) | -2.3 (-21.0) |
| *Fall*, September-November | 1.3 (+16.8) | 1.1 (+12.3) | 1.9 (+20.6) | 1.2 (+13.3) |

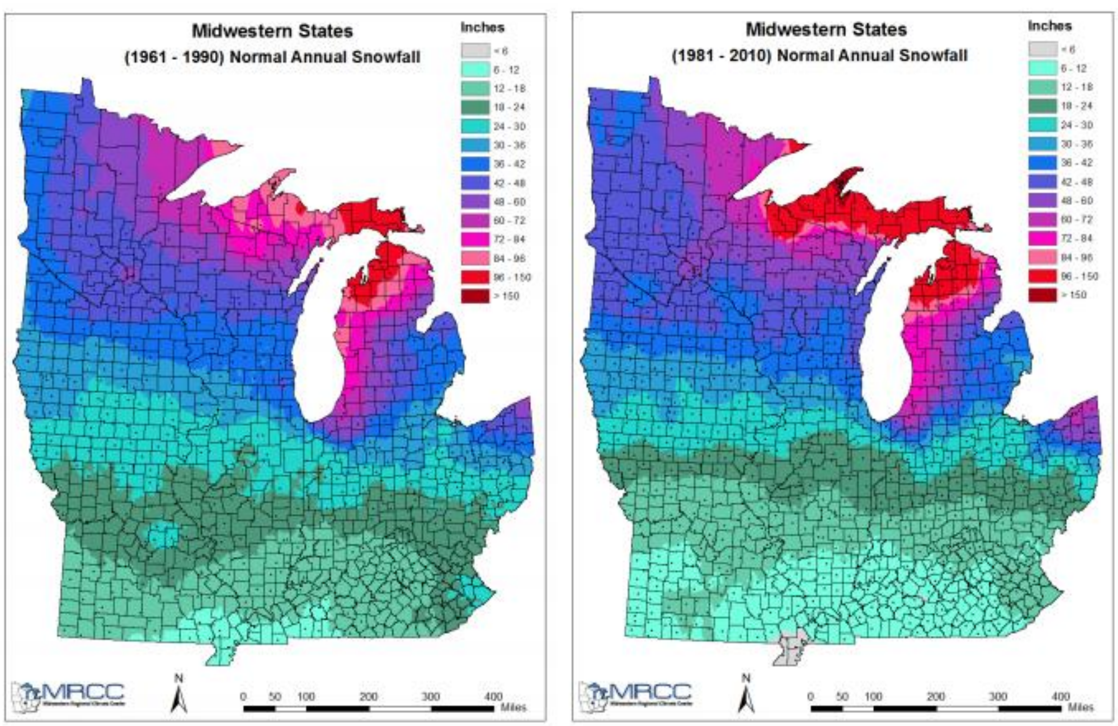


**Figure 4. Mean Snowfall in Two Recent 30-Year Time Periods**. Mean snowfall from 1961-1990 is shown on the left and 1981-2010 is shown on the right. Source: Andresen et al. 2012 Figure 8

One of the most marked climate changes in the Great Lakes region has been an increase in extreme precipitation. According to Great Lakes Integrated Sciences and Assessments (GLISA) and other leading climatologists in the region, stronger and more frequent precipitation events are occurring across the Midwest. Both the frequency and intensity of severe storms (extreme precipitation events) have increased during the last century in the Great Lakes region.

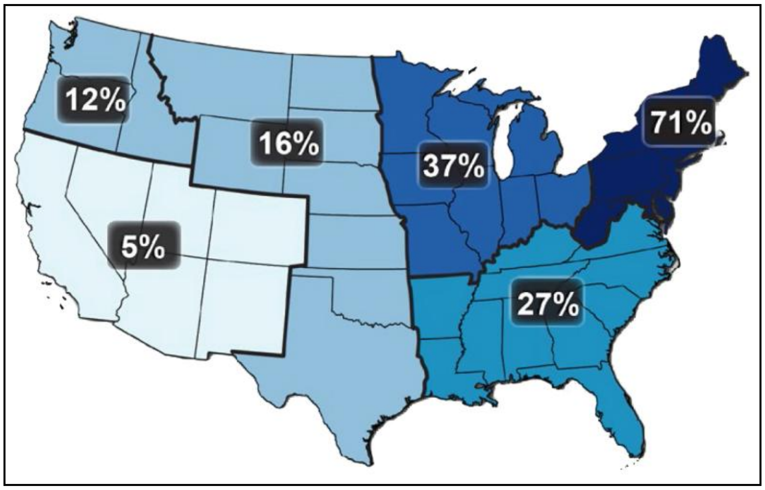


**Figure 5. Percent Increase in Heaviest 1% of Daily Precipitation Events from 1958 to 2012.** From: Third National Climate Assessment Chapter 2: Our Changing Climate, modified. Source: Great Lakes Integrated Sciences and Assessments 2016

From 1958 to 2012, the amount of precipitation falling in the heaviest 1% of storms increased by 37% in the Great Lakes region (**Figure 5**; Walsh, et. al. 2014). GLISA also reported that precipitation is 5.1% more intense and frequency has increased 23.6% when compared to 1951-1980 (GLISA, Extreme Precipitation, 2015). Heavy, multi-day wet periods have also increased in frequency over the last century (Kunkel, et. al. 1999). Severe or intense precipitation has numerous consequences that are cause for concern. Flooding and storm water runoff are priority concerns, as rain from extreme participation events has inadequate time to infiltrate the soil. Instead, it erodes land surfaces, infiltrates and damages infrastructure, and carries soils, nutrients, and/or contaminants directly to surface waters. Storm water runoff has the potential to impact natural and manmade systems and structures.

# Projected Climate Changes

Metrological data for the Great Lakes region show climate changes that influence numerous facets of our natural and developed environments, from increasing air and water temperatures, precipitation, frequency of hard rain events, snowfall and shifts in precipitation patterns, to an overall climate marked by swings and extremes. The causes for these climate changes include regional to global phenomena: natural climate cycles and, most notably, increasing anthropogenic greenhouse gas emissions in Earth's atmosphere. The causal role of greenhouse gas emissions on current and future climate change is well established, and forms the basis of future climate change projections.

Projections of future climate change are derived from global climate models (GCMs) and regional climate models (RCMs). GCMs and RCMs are complex models that simulate atmosphere, ocean, and land processes to project changes in temperature and precipitation for a given region, from which changes in related climate parameters (e.g., lake water temperature, ice cover, wind speed over the lake, lake water levels) are derived. Scenarios are used when reliable projections of future conditions are not available, as is the case for climate change (Intergovernmental Panel on Climate Change, 2000). These scenarios are future conditions that may evolve from present conditions and are based on socioeconomic storylines or radiative forcing trajectories. The complexity of and uncertainty in climate change necessitates modeling a range of future scenarios, to capture the range of plausible future conditions.

GCMs often have relatively low spatial resolutions (i.e. 400 to 125 km or 249 to 78 mi), and downscaling methods are used to obtain projections on local and regional scales, such as those used in this report. Future climate projections are based on two datasets: the Coupled Intercomparison Project Phase 5 (CMIP5) and the Eighth degree-CONUS Daily Downscaled Climate Projections (based on CMIP3). While these data sources differ in the type of underlying scenarios, their similarities outweigh their differences, and the inclusion of a range of scenarios is valuable to adaptation planning.

**Projection Summary**

Future climate information has been projected for the Midwest using GCMs and RCMs. A summary of projected climate changes for the Midwest at mid-century (years 2041-2070) are described in **Table 5**. Global and regional climate models predict relatively consistent trends in warming temperatures at mid-century. At late-century (years 2070 – 2099), the models show greater divergence in temperature and precipitation projections.

**Table 5. Mid-Century Climate Change Projections for the Midwest**
Source: Great Lakes Integrated Sciences and Assessments

| Timeframe | Metric | Mid-Century Projections (2041-2070) |
|---|---|---|
| *Annual* | Temperature | Warming of 1.8-5.4° F |
| | Precipitation | Ranges from -7% to +12% |
| *Winter*: December-February | Temperature | Warming of 3.5-7° F with the greatest warming in the north |
| | Precipitation | Ranges from -3% to +17%. Winter precipitation falls more often as rain, considering temperature increases |
| *Spring*: March-May | Temperature | Warming of 2-7° F |
| | Precipitation | Ranges from -5% to +15% |
| *Summer*: June-August | Temperature | Warming of 2.5-9° F |
| | Precipitation | Ranges from -23% to +19% |
| *Fall*: September-November | Temperature | Warming of 3-6.5° F |
| | Precipitation | Midwest ranges from -8% to +12% changes in precipitation |
| Extremes | Temperature | Days below 32° F decrease; days above 90° F increase |
| | Precipitation | Days with greater than 1” precipitation events increase |

**Temperature Projections**

By mid-century (2041–2070), averaged climate change models project an annual average temperature increase of 3-6° Fahrenheit in the Great Lakes region (GLISA, 2016; **Figure 6**) and an annual increase in number of days with ambient temperature greater than 90° Fahrenheit of 0 to 40 days (**Figure 7**). The projected annual average temperature increase is more the result of fewer cold days than more hot days. Days in the frost free season are projected to increase by up to 35 days per year by mid-century and up to 60 days by late-century (GLISA, 2016; **Figures 8** and **9**).

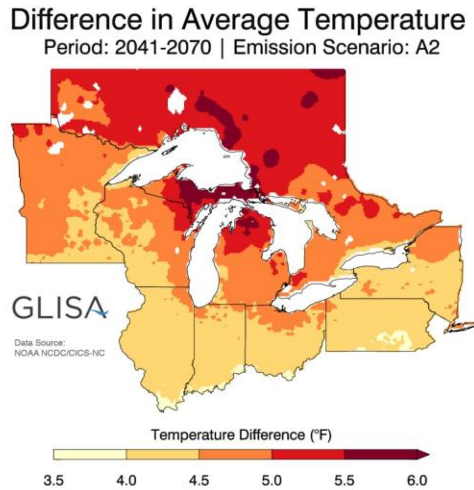


**Figure 6. Difference in Average Temperature at Mid-Century.** Image source: Great Lakes Integrated Sciences and Assessments, 2016

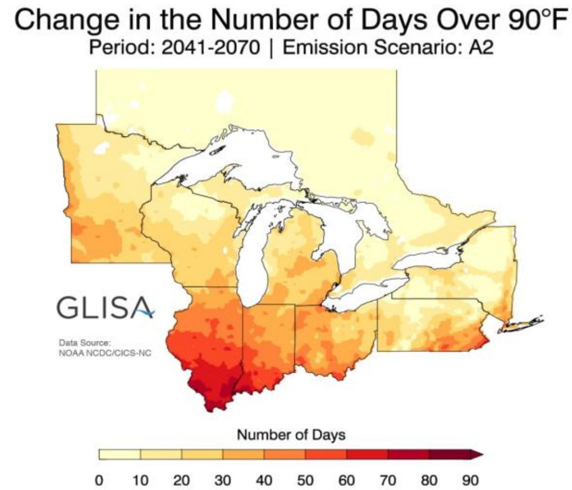


**Figure 7. Difference in Days Over 90° F at Mid-Century**. Image source: Great Lakes Integrated Sciences and Assessments, 2016

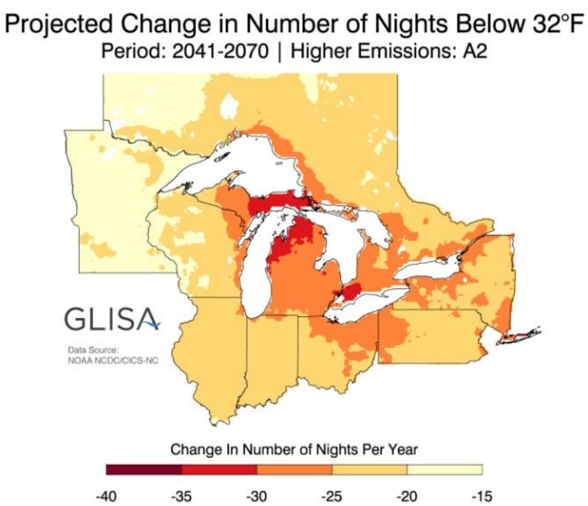


**Figure 8. Change in Nights Below 32° F at Mid-Century**. Image source: Great Lakes Integrated Sciences and Assessments, 2016

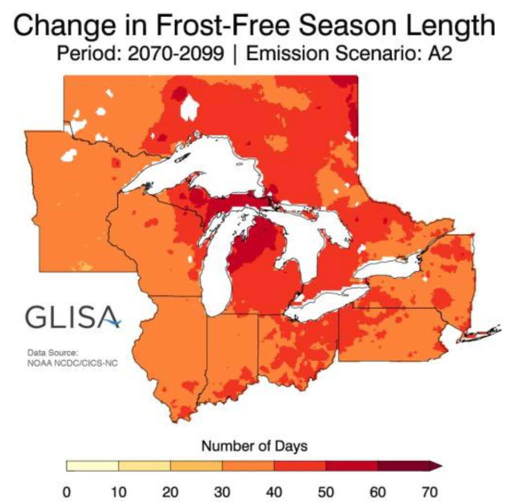


**Figure 9. Change in Frost-Free Season Length at Late-Century.** Image source: Great Lakes Integrated Sciences and Assessments, 2016

### Precipitation Projections

Precipitation projections are highly variable among models. Generally, precipitation in the Great Lakes region is projected to increase during the wet seasons and exhibit little change or decrease during the summer. **Figure 10** displays regional precipitation changes at mid-century. These changes are marked by large seasonal differences, summarized in **Table 5**. Decreasing lake ice cover will allow greater evaporation during winter and early spring months, with consequent lake effect precipitation. Winter precipitation may increasingly fall as rain due to ambient air temperature increases. While lake effect snow may increase in the short-term, snow depth is projected to decline by 20-80% by mid-century (Notaro, 2014).

An important climate impact indicator is the number of consecutive dry days, where limited (<0.01 inches) precipitation occurs. Consecutive dry days are associated with impacts on soil moisture, ecosystem structure and function, and water quality and quantity. The number of consecutive dry days is projected to remain nearly constant at mid-century, with a potential increase of up to 2 consecutive dry days per year (**Figure 11**).

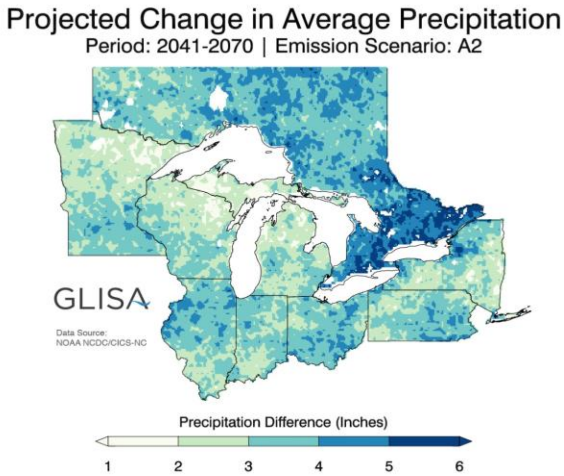


**Figure 10. Change in Average Precipitation Mid-Century.** Image source: Great Lakes Integrated Sciences and Assessments, 2016

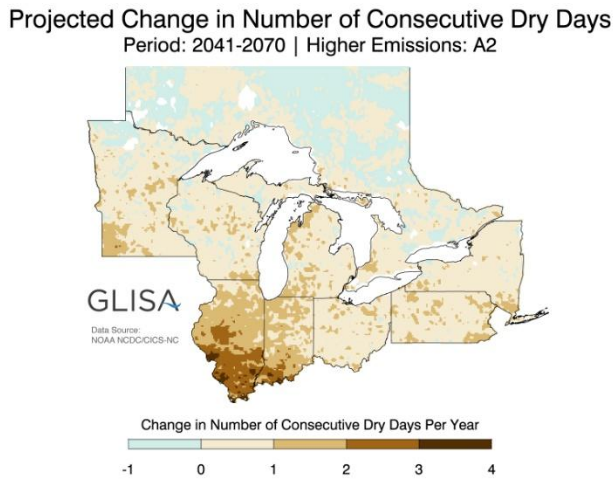


**Figure 11. Change in Consecutive Dry Days at Mid-Century.** Image source: Great Lakes Integrated Sciences and Assessments, 2016

# Tribal Resources and Vulnerability

The process of identifying tribal resources for vulnerability assessment was led by tribal natural resources and environmental staff. Tribal staff worked with tribal community members and cultural leaders to identify culturally and socio-economically important fish, wildlife, and plant species, natural features, cultural activities, human health risks, and infrastructure/community development resources. The conceptual framework for identifying these resources included qualitative assessment of: perceived vulnerability to climate change, cultural importance, economic importance, and tribal natural resource staff peer review.

The tribal resources identified for vulnerability assessment spanned individual species, whole freshwater systems, infrastructure, and cultural practices. The scope of the assessment process necessitated broad-scale vulnerability assessment tools including Nature Serve's Climate Change Vulnerability Index and geospatial analysis. The assessment addressed mid-century impacts (to the year 2050) using Nature Serve's Climate Wizard data as historical temperature and moisture metric inputs and dynamically downscaled climate projections from Dr. David Notaro, University of Wisconsin – Madison. The Climate Change Vulnerability Index was selected for use in species vulnerability assessments, as a relatively widely employed tool for rapid vulnerability assessment of multiple species, which may allow coordinated assessment and management efforts (Young et al., 2015).

Climate change vulnerability is a measure of the likelihood that climate-induced changes will have an adverse impact on a given species, habitat, structure, or condition (*part* Glick et al. 2011; Schneider et. al. 2007). Vulnerability is a function of the ***sensitivity*** of a species or system to climate changes and its ***exposure*** to those changes, considered together as ***potential impact***, along with its ***capacity to adapt*** to climate changes (Schneider et al. 2007, Williams et al. 2008). Sensitivity is a measure of whether and how a species or system is likely to be affected by a given change in climate (Schneider et al.

2007, Williams et al. 2008, Glick et al. 2011). Exposure is a measure of how much of a change in climate and associated impacts a species or system is likely to experience (Glick et al. 2011). Adaptive capacity refers to a species or system's ability to minimize or manage its sensitivity, exposure, or potential impact to climate changes (**Figure 12**; Williams et al. 2008, Glick et al. 2011).

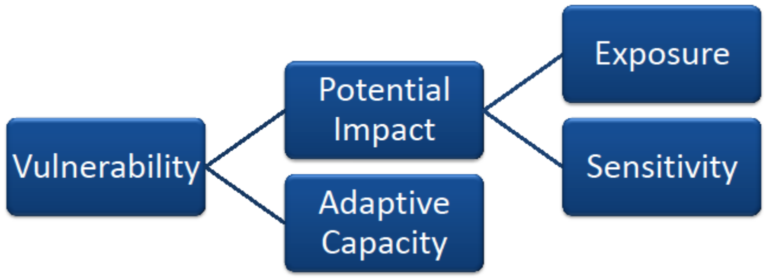


**Figure 12. Resource Vulnerability to Climate Change**. From Glick et al. 2011

The decision-matrix employed by the Climate Change Vulnerability Index (CCVI) assesses both the comparative vulnerability of species assessed and the importance of specific factors contributing to that vulnerability (Young et. al 2015). Species' sensitivity was assessed via 23 factors including indirect exposure to climate change and species-specific sensitivity and adaptive capacity. Each factor was assessed and rated for its impact on each species' vulnerability: greatly increase, increase, somewhat increase, neutral, or unknown. The working group selected multiple ratings for factors where their impact on vulnerability was less certain. Each species' exposure to climate changes was integrated into the tool as a modifier of sensitivity and adaptive capacity. The relationship between exposure, sensitivity, and adaptive capacity in the CCVI calculation of vulnerability is shown in **Figure 13**.

Species vulnerability was ranked on a scale of extremely vulnerable, highly vulnerable, moderately vulnerable, and less vulnerable. The CCVI ranks are described below:

**Extremely vulnerable** (**EV**): Abundance and/or range extent within the geographic area assessed is extremely likely to substantially decrease or disappear by 2050.

**Highly vulnerable** (**HV**): Abundance and/or range extent within the geographic area assessed is likely to decrease significantly by 2050.

**Moderately vulnerable** (**MV**): Abundance and/or range extent within the geographic area assessed is likely to decrease by 2050.

**Less vulnerable** (**LV**): Available evidence does not suggest that abundance and/or range extent within the geographic area assessed will change substantially by 2050. Actual range boundaries may change.

Uncertainty in the overall CCVI vulnerability score was partially captured in a confidence rating on a scale of Low to Very High. Confidence in the overall score was calculated within the CCVI using a Monte Carlo simulation, which considers the completeness of data entered and the proximity of a species' score to thresholds. For example, a score in the middle of the 'less vulnerable' range will have higher confidence than a score at the threshold between 'less vulnerable' and 'moderately vulnerable' (Young et al, 2015).

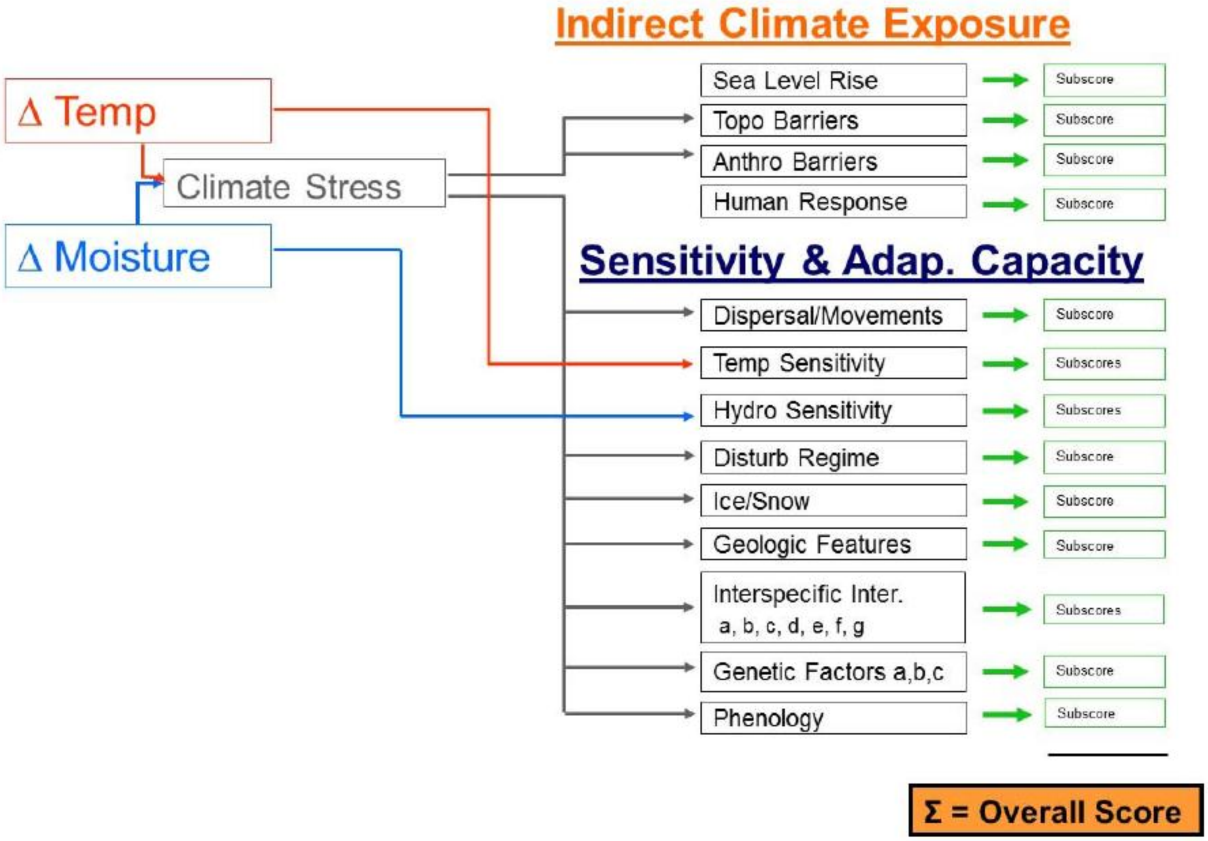


**Figure 13. Climate Change Vulnerability Index Relationships** between exposure to local climate change and sensitivity of factors. From Young, et al., 2015

Uncertainty is an important aspect of vulnerability assessment in general, and a vital aspect of broad-scale vulnerability assessments such as this. The assessment process was characterized by uncertainty, with ITCMI and tribal staff drawing from a wide variety of academic and technical literature sources, community and traditional knowledge, and local natural resource management experience. The results are intended to be updated as new information and perspectives are included in the tribal adaptation efforts.

Climate change vulnerability is one of many systemic stressors, similar to land use change and invasive species. Impacts may be cumulative over long periods of time and become apparent only after reaching certain thresholds. The presence of multiple stressors is an important issue in vulnerability assessment and associated uncertainty. For example, many of the species included on the resource list confront landscape change and habitat loss; climate change may exacerbate the process of habitat loss and/or decrease the ability of a species to move to more suitable habitat. The assessment process addresses multiple stressors that are a direct result of climate change (e.g. hydro-electric dam construction to mitigate climate change, or road-stream crossing degradation from extreme precipitation events) and significant threats to current resources and populations; however, the assessment process does not comprehensively address multiple stressors.

### Natural Resource Vulnerability Assessment Findings

Climate change impacts the factors that influence which flora and fauna survive and thrive within the geographic areas assessed: seasonal temperatures, precipitation patterns, hydrology, pests and disease. Climate change impacts flora and fauna both directly (i.e. through heat stress, soil moisture, and snowfall) and indirectly (i.e. through habitat shifts, pest ranges, and disease). The relatively flat terrain of the Great Lakes region may inhibit species from shifting their ranges higher in latitude or altitude in time to "track" suitable climate conditions (Hall, 2012). Lack of connectivity of terrestrial and aquatic habitats will further limit species movements. The Great Lakes serve as barriers to the movement of many terrestrial species across geographic areas, most notably northward from the Northern Lower Peninsula (NLP), Eastern Upper Peninsula (EUP), and Western Upper Peninsula (WUP). Species at the southernmost extent of their range, including many of the boreal transition zone species included in this assessment, are at increased risk for habitat loss or shifting.

Natural and anthropogenic barriers, occupied range, and species' dispersal abilities were among the issues addressed in the species-level vulnerability assessment process using the Nature Serve's CCVI tool. The summarized results of these assessments are presented in **Table 6**. These relative vulnerability rankings provide an overview of the types and severity of species-level vulnerabilities within the geographic areas assessed. The vulnerability rank and confidence rankings for each species assessed in each geographic area are included in **Appendix B**. The CCVI document and a separate species notes file are available from ITCMI, which document the process and findings of the CCVI assessment. Future in-depth vulnerability assessments may: clarify the mechanisms that dictate each species sensitivity, exposure, and adaptability; investigate community-level vulnerabilities and potential future changes to community composition and function; and define thresholds for adaptation strategies.

**Table 6. Michigan Tribal Climate Change Vulnerability Index Assessment Rankings** for all species in all geographic areas assessed. Vulnerability ranks include: extremely vulnerable (EV), highly vulnerable (HV), moderately vulnerable (MV), and less vulnerable (LV).

| | **Vegetation Species** | | **CCVI Vulnerability Rank** | | | |
|---|---|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **Anishinaabemowin** | **WUP** | **EUP** | **NLP** | **SLP** |
| *Andromeda polifolia* | Bog Rosemary | Binemiiki | HV | EV | HV | EV |
| *Zizania palustris* | Northern Wild Rice | Manoomin | HV | HV | HV | EV |
| *Zizania aquatica* | Southern Wild Rice | Manoomin | MV | HV | MV | EV |
| *Fraxinus nigra* | Black Ash | Aagimaak | MV | HV | HV | HV |
| *Picea mariana* | Black Spruce | Jingwop | HV | HV | HV | - |
| *Carex scirpoidea* | Bulrush Sedge | Jika miooskoon | HV | HV | HV | HV |
| *Polygala paucifolia* | Fringed Polygala | Tikizidgiibikoons | MV | HV | HV | MV |
| *Ledum groenlandicum* | Labrador Tea | Waabashkikiibag | MV | HV | HV | HV |
| *Vaccinium macrocarpon* | Large Cranberry | Aniibimin | MV | HV | HV | HV |
| *Thuja occidentalis* | Northern White Cedar | Giizhikenh | MV | HV | HV | HV |
| *Betula papyrifera* | Paper Birch | Wiigwasaatig | MV | HV | HV | HV |
| *Mitchella repens* | Partridge Berry | Binewimin | MV | HV | HV | HV |
| *Chimaphila umbellata* | Pipsissewa / Prince's Pine | Gaagigebag | HV | HV | HV | HV |
| *Vaccinium oxycoccos* | Small Cranberry | Mashkiigimin | MV | MV | MV | HV |
| *Cypripedium parviflorum* | Yellow Lady's Slipper | Neemidi makazin | HV | HV | HV | HV |
| *Fagus grandifolia* | American Beech | Gawe'mik | MV | MV | MV | MV |
| *Ulmus americana* | American Elm | Aniib | LV | LV | LV | MV |
| *Abies balsamea* | Balsam Fir | Jingob | MV | MV | MV | MV |
| *Gaylussacia baccata* | Black Huckleberry | Miinan | MV | MV | MV | MV |
| *Salix nigra* | Black Willow | Zasgogmizh | LV | MV | MV | MV |
| *Sagittaria latifolia* | Broadleaf Arrowhead | Cijak-kadens waabiziipin | LV | MV | MV | MV |
| *Lobelia cardinalis* | Cardinal Flower | Shkotaebugonii | LV | MV | MV | MV |
| *Trillium grandiflorum* | Common Trillium | Ininiwin dibige'gun | MV | MV | MV | MV |

***LV**=Less Vulnerable* ***MV**=Moderately Vulnerable* ***HV**=Highly Vulnerable* ***EV**=Extremely Vulnerable*

| Scientific Name | Common Name | Anishinaabemowin | WUP | EUP | NLP | SLP |
|---|---|---|---|---|---|---|
| *Gaultheria hispidula* | Creeping Snowberry | Waaboozobanzh | LV | MV | MV | MV |
| *Crataegus douglasii* | Douglas/Black Hawthorn | Mine'sagawanzh | MV | MV | MV | MV |
| *Coptis trifolia ssp. Groenlandica* | Goldthread | Ozaawidjibik | LV | MV | MV | MV |
| *Schoenoplectus acutus* | Hardstem Bulrush | Jika miooskoon | MV | MV | MV | MV |
| *Tsuga canadensis* | Hemlock | Gagaagi wanzh | MV | MV | MV | MV |
| *Athyrium filix-femina ssp. Angustum* | Ladyfern | A'sawan | LV | MV | MV | MV |
| *Vaccinium angustifolium* | Lowbush Blueberry | Miinagaawanzh | LV | MV | MV | MV |
| *Caltha palustris* | Marsh Marigold | Ogitebag | LV | MV | MV | MV |
| *Acer pensylvanicum* | Moosewood / Striped Maple | Moozomizh | LV | MV | MV | MV |
| *Ilex mucronata* | Mountain Holly | Mikiminu'nimic | LV | LV | MV | MV |
| *Prunus pensylvanica* | Pin Cherry | Bawa'iminaan | LV | MV | MV | MV |
| *Cypripedium acaule* | Pink Lady's Slipper | | MV | MV | MV | MV |
| *Lycopodium obscurum* | Princess Pine | Cigona'gan | LV | MV | MV | MV |
| *Impatiens capensis* | Spotted Touch Me Not/Jewelweed | Mukikiibug | MV | MV | MV | MV |
| *Acer saccharum* | Sugar Maple | Aninaatig | MV | MV | MV | MV |
| *Asclepias incarnata* | Swamp Milkweed | Bagizowin | LV | MV | MV | MV |
| *Acorus americanus* | Sweetflag | Wiikenh | LV | MV | MV | MV |
| *Hierochloe odorata* | Sweetgrass | Wiingashk | MV | MV | MV | MV |
| *Larix laricina* | Tamarack | Pskignatik | MV | MV | MV | MV |
| *Schoenoplectus americanus* | Three-square bulrush | Jika miooskoon | MV | MV | MV | MV |
| *Pinus strobus* | White Pine | Jingwak | MV | MV | MV | MV |
| *Betula alleghaniensis* | Yellow Birch | Wiinisik | MV | MV | MV | MV |
| *Sphagnum capillifolium* | Northern Peatmoss | | LV | MV | MV | MV |
| *Sphagnum central* | Sphagnum | | LV | MV | MV | MV |
| *Myrica gale* | Sweetgale | Wa'sawasni'mike | MV | MV | MV | MV |
| *Lithospermum caroliniense* | Golden Puccoon | Odji'biknamun | LV | LV | LV | LV |
| *Tilia americana* | Basswood | Wiigobaatig | LV | LV | LV | LV |
| *Corylus cornuta* | Beaked hazelnut | Bagaanimizh | LV | LV | LV | LV |
| *Arctostaphylos uva-ursi* | Bearberry | Miskwaabiimag | LV | LV | LV | LV |
| *Populus grandidentata* | Bigtooth Aspen | Azaadi | LV | LV | LV | LV |
| *Carya cordiformis* | Bitternut Hickory | Mitigwaabaak | - | - | - | LV |
| *Caulophyllum thalictroides* | Blue Cohosh | Bezhigojiibik | LV | LV | LV | LV |
| *Pteridium aquilinum* | Bracken Fern | Waagaan | LV | LV | LV | LV |
| *Typha latifolia* | Broadleaf Cattail | Apakweshk | LV | LV | LV | LV |
| *Eupatorium perfoliatum* | Common Boneset | Sasabwaksing | LV | LV | LV | LV |
| *Equisetum hyemale* | Common Horsetail/Scouring rush | Giji'binusk | LV | LV | LV | LV |
| *Asclepias syriaca* | Common Milkweed | Ininiwa | LV | LV | LV | LV |
| *Phragmites australis* | Common Reed | Aaboojigan | LV | LV | LV | LV |
| *Medeola virginiana* | Indian Cucumber Root | Minopugodjiibik | LV | LV | LV | LV |
| *Apocynum cannabinum* | Indian Hemp | Sesabiins | LV | LV | LV | LV |
| *Lobelia inflate* | Indian Tobacco | | LV | LV | LV | LV |
| *Ostrya virginiana* | Ironwood | Maananoons | LV | LV | LV | LV |
| *Arisaema triphyllum ssp. Triphyllum* | Jack in the Pulpit | Zhaashaagomin | LV | LV | LV | LV |
| *Adiantum pedatum* | Maidenhair Fern | Makade cawdak | LV | LV | LV | LV |

***LV****=Less Vulnerable* ***MV****=Moderately Vulnerable* ***HV****=Highly Vulnerable* ***EV****=Extremely Vulnerable*

| Scientific Name | Common Name | Anishinaabemowin | WUP | EUP | NLP | SLP |
|---|---|---|---|---|---|---|
| *Quercus rubra* | Northern Red Oak | Mashkode-miizhimizh | LV | LV | LV | LV |
| *Anaphalis margaritacea* | Pearly Everlasting | Waabigwan | LV | LV | LV | LV |
| *Acer rubrum* | Red Maple | Zhiishiigimiiwanzh | LV | LV | LV | LV |
| *Cornus sericea* | Red Osier Dogwood | Miskwaabiimizh | LV | LV | LV | LV |
| *Vitis riparia* | Riverbank Grape | Zhawiminagaawanzh | LV | LV | LV | LV |
| *Onoclea sensibilis* | Sensitive Fern | A'nana'ganuk | LV | LV | LV | LV |
| *Ulmus rubra* | Slippery Elm | Ozhaashigob | LV | LV | LV | LV |
| *Alnus incana Rugosa* | Speckled/Tag Alder | Wadoop | LV | LV | LV | LV |
| *Eupatorium maculatum* | Spotted Joe Pye Weed | Maeskwanakukbugisowin | LV | LV | LV | LV |
| *Nymphaea odorata* | White Water Lily | Anaang pikobiisae | LV | LV | LV | LV |
| *Ilix verticillata* | Winterberry/Michigan Holly | Animoshi'min | LV | LV | LV | LV |

| | Wildlife Species | | CCVI Vulnerability Rank | | | |
|---|---|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **Anishinaabemowin** | **WUP** | **EUP** | **NLP** | **SLP** |
| *Castor canadensis* | Moose | Mooz | EV | EV | - | - |
| *Lepus americanus* | Snowshoe hare | Waaboos | EV | EV | EV | EV |
| *Castor canadensis* | American Beaver | Amik | MV | MV | MV | MV |
| *Martes americana* | American Marten | Waabizheshi | MV | MV | MV | MV |
| *Martes pennanti* | Fisher | Ojiig | MV | MV | MV | - |
| Gavia immer | Common Loon | Maang | LV | MV | MV | MV |
| *Bonasa umbellus* | Ruffed Grouse | Baabaashki | LV | LV | LV | MV |
| *Falcipennes canadensis* | Spruce Grouse | Mashkodese | LV | MV | - | - |
| *Tympanuchus phasianellus* | Sharp-tailed Grouse | Agaasak | LV | LV | MV | - |
| *Taxidea taxus* | American Badger | Misakakojiish | LV | LV | LV | LV |
| *Ursus americanus* | American Black Bear | Makademkwa | LV | LV | LV | LV |
| *Neovison vison* | American Mink | Zhaangweshi | LV | LV | LV | LV |
| *Lynx rufus* | Bobcat | Gidigaa-bizhiw | LV | LV | LV | LV |
| *Canis latrans* | Coyote | Wiisagi-maengan | LV | LV | LV | LV |
| *Sylvilagus floridanus* | Eastern Cottontail Rabbit | Mzhwe | LV | LV | LV | LV |
| *Cervus elaphus* | Elk | Omashkooz | - | - | LV | LV |
| *Canis lupus* | Gray Wolf | Maengun | LV | LV | LV | LV |
| *Erethizon dorsatum* | North American Porcupine | Gaag | LV | LV | LV | LV |
| *Lontra canadensis* | North American River Otter | Nigig | LV | LV | LV | LV |
| *Odocoileus virginianus* | White-tailed Deer | Waawaashkesh | LV | LV | LV | LV |
| *Haliaeeetus leucocephalus* | Bald Eagle | Migiizi | LV | LV | LV | LV |
| *Anas discors* | Blue Winged Teal | | LV | LV | LV | LV |
| Branta canadensis | Canada Goose | Nika | LV | LV | LV | LV |
| *Ardea herodias* | Great Blue Heron | Zhashagi | LV | LV | LV | LV |
| *Anas platyrhynchos* | Mallard | Ininishib | LV | LV | LV | LV |
| Grus canadensis | Sandhill Crane | Ajijak | LV | LV | LV | LV |
| Meleagris gallopavo | Wild Turkey | Mizise | LV | LV | LV | LV |
| *Chrysemys picta* | Northern Painted Turtle | Miskwaadesi | LV | LV | LV | LV |
| *Chelydra serpentina* | Snapping Turtle | Mikinaak | LV | LV | LV | LV |

***LV****=Less Vulnerable* ***MV****=Moderately Vulnerable* ***HV****=Highly Vulnerable* ***EV****=Extremely Vulnerable*

| Fish Species | | | CCVI Vulnerability Rank | | | |
|---|---|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **Anishinaabemowin** | **WUP** | **EUP** | **NLP** | **SLP** |
| *Acipenser fulvescens* | Lake Sturgeon | Name | MV | EV | MV | HV |
| *Sander vitreus* | Walleye | Ogaa | MV | MV | HV | MV |
| *Salvelinus fontinalis* | Brook Trout | Maazhemegoons | MV | MV | MV | MV |
| *Lota lota* | Burbot | Mizay | GL: MV | | | |
| *Salvelinus namaycush* | Lake Trout | Namegos | GL: MV | | | |
| *Coregonus artedi* | Cisco/Lake Herring | | GL: MV | | | |
| *Coregonus clupeaformis* | Whitefish | Atikameg | GL: MV | | | |
| *Esox lucius* | Northern Pike | Ginoozhe | LV | LV | LV | LV |
| *Perca flavescens* | Yellow Perch | Asaawe | LV | LV | LV | LV |
| *Osmerus mordax* | Smelt | | GL: LV | | | |
| *Esox masquinongy* | Muskellunge | Maashikinooshe | LV | LV | LV | LV |
| *Pemoxis nigromaculatus* | Black Crappie | | LV | LV | LV | LV |
| *Lepomis microchirus* | Bluegill | | LV | LV | LV | LV |
| *Catostomus commersonii* | White Sucker | Namebin | LV | LV | LV | LV |
| *Catostomus catostomus* | Longnose Sucker | Namebin | LV | LV | LV | LV |
| *Micropterus salmoides* | Largemouth Bass | Ashigan | LV | LV | LV | LV |
| *Micropterus dolomieu* | Smallmouth Bass | Ashigan | LV | LV | LV | LV |

***LV****=Less Vulnerable* ***MV****=Moderately Vulnerable* ***HV****=Highly Vulnerable* ***EV****=Extremely Vulnerable*

Of the vegetation species assessed, manoomin (Northern and Southern wild rice species: *Zizania aquatic & palustrus*) and binemiiki (bog rosemary: *Andromeda polifolia*) were ranked as high as Extremely Vulnerable. Aagimak (black ash: *Fraxinus nigra*), jingwop (black spruce: *Picea mariana*), jika miooskoon (bulrush sedge: *Carex scirpoidea*), tikizidgiibikoons (fringed polygala: *Polygala paucifolia*), waabashkikiibag (Labrador tea: *Ledum groenlandicum*), aniibimin (large cranberry: *Vaccinium* macrocarpon), giizhik (Northern white cedar: *Thuja occidentalis*), Wiigwasaatig (paper birch: *Betula papyrifera*), Binewimin (partridge berry: *Mitchella repens*), gaagigebag (pipsessewa: *Chimaphila umbellata*), mashkiigimin (small cranberry: *Vaccinium oxycoccos), and* neemidi makazin (yellow lady's slipper: *Cypripedium parviflorum)* were ranked as Highly Vulnerable. Thirty-three vegetation species were ranked as Moderately Vulnerable. Bog and wetland species are at greater risk from changing hydrology, especially those species requiring specific hydrologic systems and water chemistries. Several canopy and subcanopy tree species were identified as Highly or Moderately Vulnerable. Significant losses in these species across the landscape may increase local forest community susceptibility to invasive species, pests, and disease. Disturbances such as flooding and wildfire can open forest canopies, expose mineral soil, and reduce tree cover, providing greater opportunities for invasive species introductions (Ryan and Vose, 2012). Once established, invasive species can also limit regeneration of native plant species through increased competition and alter entire ecosystems.

Of the animal species assessed, mooz (moose: *Alces americanus*) and waaboos (snowshoe hare: *Lepus americanus*) were ranked as Extremely Vulnerable. Amik (beaver: *Castor* Canadensis), waabizhishi (marten: Martes Americana), ojiig (fisher: Martes pennant), maang (loon: Gavia immer), baabaashki (ruffed grouse: Bonasa umbellus), mashkodese (spruce grouse: Falcipennes canadensis), and agaasak (sharp-tailed grouse: Tympanuchus phasianellus) were ranked as Moderately Vulnerable. The Extremely Vulnerable ranking for mooz and waaboos, which are at the southern extent northward-moving ranges, consider climate-related decreases in occupancy and population size. Other species at the southern extent of their range include waabizhishi, ojiig, maang, and maengun. Many of these vulnerable species are clan animals and maintain vital roles in Anishinaabek ways.

Of the fish species assessed, name (lake sturgeon: *Acipenser fulvescens)* was ranked Extremely Vulnerable in the EUP and Highly Vulnerable in the SLP. Ogaa (walleye: *Sander vitreus*) was ranked

Highly Vulnerable in the NLP and Moderately Vulnerable in the SLP, EUP, and WUP. In both Great Lakes and inland fish species, the predominant impacts of climate change include changes in: 1) water temperature, as a result of changes in ambient air temperatures, ice-cover duration and extent, and numerous feedback loops, 2) water quantity, as a result of changes in precipitation patterns, and 3) water quality, as a result of runoff from extreme precipitation events and biotic response to surface water temperature increases, among other processes. These phenomena may alter food sources, locations, and abundance; suitable habitat locations and extent (i.e. lake depths or stream temperatures); timing and duration of spawning; and stress fish via decrease dissolved oxygen levels and increased metabolic rates. Understanding current and projected exposure and resilience of these fish species necessitates further site- and species-specific investigation. Projected changes in the Great Lakes are characterized by extreme uncertainty, due to the dynamics and complexity of the Great Lakes hydrologic system.

**Infrastructure, Public Health and Socio-Economic Vulnerability Assessment**

Climate change impacts the qualities of, and demands on, infrastructure, public health, and socio-economic systems across the geographic areas assessed. Changes in seasonal temperatures and precipitation patterns impact these sectors both directly (e.g. road stream-crossing damage from flooding or hospitalizations due to heat stress) and indirectly (e.g. revision of transportation/snow-removal departments and budgets). Existing stressors include aging infrastructure, limited funding for tribal health care and housing, and reliance on limited economic bases.

The assessment process for these sectors should be undertaken specific to each Tribe's community, locality, and resource base. Factors addressed in infrastructure, public health, and socio-economic vulnerability assessments are discussed below. For the purposes of this project, infrastructure includes all of the following: roadways, transportation, houses, buildings, businesses, utilities, and energy use. Relative vulnerability rankings may be established in consideration of the unique characteristics of each Tribe. Numerous frameworks are available for use with infrastructure, public health, and socio-economic vulnerability assessment; in contrast to the CCVI tool, qualitative assessment frameworks facilitate subject matter expert and community-led assessment. Tribal transportation, community health, economic development, natural resource, other department staff, and community members may use these tools to assess vulnerabilities together, drawing from intimate and long-standing knowledge of the systems assessed. One such framework was developed by the Northern Institute for Applied Climate Science and is described in **Appendix C**.

Initial vulnerabilities of the infrastructure, public health, and socio-economic resources identified by participating Tribes are described below. Future in-depth vulnerability assessments and adaptation planning efforts may: clarify the mechanisms that dictate each resources sensitivity, exposure, and adaptability; investigate and quantify risks for risk analysis and cost/benefit ratios; and define thresholds for adaptation strategies.

**Roadways and Transportation**. Roadways and paved infrastructure are the primary means of transportation. The projected warming climate will cause accelerated asphalt deterioration and with more frequent heat waves, pavement buckling may become a growing issue. Also, extreme precipitation events will increase flows in streams and accelerate wear and tear on bridges and culverts. In contrast, the possibility of milder winters and less snow fall may reduce the cost and effects of snow removal (Schwartz et al. 2014). Seiches and storms have become more relevant in recent years and have shown to flood marina areas as well as the parking lot, causing wear and tear on paved infrastructure.

Limited roadways during an extreme event can also leave the community vulnerable. Many tribes in Michigan have limited roadways within their reservations and the communities are susceptible to being trapped during an extreme weather event or natural disaster. For example, one particular Tribe only has two paved exits on their reservation, heading east or west, along with two dirt road exits that head west and southwest; one of which may be difficult to be driven on with a small car and/or a two wheel drive vehicle.

**Housing and Buildings**. Pre-existing housing and buildings may begin to take direct damage due to flooding and severe precipitation events as well as instability due to erosion and possible changes in the water table. These pre-existing infrastructures are especially vulnerable because they were possibly constructed without the consideration of the changing climate (Bates et al. 2008). Tribal communities in Michigan have already started to notice increases in damages; particularly in mold growth in homes and buildings; loss of cultural areas due to erosion; as well as severe erosion near some housing.

**Energy Use and Utilities**. The amount of energy use in climates that require winter heating and summer cooling will change, but the decrease in energy use in winter and increase in energy use in summer will be comparable (Li et al. 2012). Demand of electricity will increase with the increase of temperatures which may consequently increase the cost of electricity as most cooling systems run off of electricity. Additionally, the increase in severe weather events may cause more frequent interruptions within the electric grid (Melilli et al. 2014). Furthermore, increases in the energy use of cooling systems and other electrical utilities may demand a greater energy output which will increase the output of air pollutants from coal-fueled power plants (Luber et al. 2014).

**Tourism**. Michigan Tribes have invested in tourism and local tourist-based businesses for revenue. Based on projections of summer climate attractiveness (projections are based on maximum daily temperature and minimum daily relative humidity, average daily temperature and relative humidity, precipitation, sunshine, and wind speed), some Tribes are likely to see a minor to major difference by 2050. Unfavorable summer conditions begin to extend northward into the southern parts of the Midwest region. Summer conditions within the southern areas of the Lower Peninsula of Michigan begin to shift from very good and good to just acceptable tourist conditions based on the U.S. Tourism Climatic Index (Hales et al. 2014).

Some Michigan Tribes also rely on tourism through the winter months. Many people travel to areas with snow to enjoy activities such as snowmobiling, cross-country skiing, and snowshoeing, among others. The change in climate during winter months may decrease winter-related tourism activities, as the average temperature is projected to rise 6° F and the frost-free season length is expected to increase by 50-60 days (Great Lakes Integrated Science Assessments, 2014). A decrease in winter tourism could result in less revenue for Tribes during the winter months. In contrast, the increased duration of warmer weather may extend the summer tourist season.

**Commercial Fishing**. Tribal commercial fishing has the potential to suffer key species losses, such as lake herring, walleye, lake trout, due to increases in water temperature, changes in dissolved oxygen, increases in sedimentation and nutrient loading from extreme weather events, habitat degradation from fluctuating water levels, and the spread of invasive species. Drying of ephemeral wetlands on lake margins may adversely affect the food web that supports fish communities, as well as the spawning areas that fish depend on for reproduction. Commercial fishing may also be impacted by marina and harbor destruction from severe and frequent storms and fluctuating water levels (Ficke et al. 2007; Melilli et al. 2014). These impacts may result in reduced yields of traditional commercial fish and significant income loss for Tribal commercial fishing.

**Public Health**. Climate change is predicted to increase the number of extreme weather events and also decrease our air quality which will impact human health and disease in many ways. With the projected increases in temperature and frequency of extreme weather events, data suggests ground level ozone and particulate matter will increase which causes many problems including decreased lung function, increase in asthma attacks and increase in premature deaths. Also with the increase in frost-free days and warmer seasonal temperatures, allergenic plants are projected to have longer pollen seasons, affecting people with allergies. Buildings may also have increases in mold growth due to increased temperatures and precipitation. Doctors may have a harder time aiding people with allergies and asthma in the future (Luber et al. 2014). In addition with these health risks, the projected increase in temperature may increase heat-related illness including heat exhaustion, heat stroke and death. Human health impacts from insect-borne diseases may become more prevalent as well.

**Pests**. Plant and animal pests and diseases may become more prevalent as temperatures, seasons, and precipitation patterns change. One pest in particular that would have a large negative impact on jack pine stands in Michigan would be the mountain pine beetle, which has been expanding its range north and east from the west coast due to warming conditions; they were typically controlled by cold winter conditions (Safranyik, 2010). Pests also affect human health. Many of the participating Tribes are located in rural areas, with communities that pursue outdoor cultural and recreational activities often. These communities may experience greater interactions with insects such as ticks and mosquitoes, increasing risks of Lyme's disease and the West Nile Virus (Hales et al. 2014).

### Prioritizing Tribal Resources

In addition to using vulnerability assessments, prioritizing resources for adaptation action may involve the assessment of risks, costs, and feasibility. Risk assessment contributes baseline information to the prioritization process and may assist Tribes in identifying high, medium, and low priorities in adaptation planning. **Table 7** offers a tool to assess risk to tribal resources, based on the *probability* of negative impacts from climate change and the severity of *consequences* of those impacts. For example, two road-stream crossings may be considered highly vulnerable to climate change, with similar probabilities of experiencing the negative impact of washing out during storms (probability: high). However, one road-stream crossing is vital to travel in and out of the reservation, the loss of which would prohibit travel from reservation homes to the health clinic and grocery store (consequences: high). The other road-stream crossing is one of two routes to the tribal recreation center, the loss of which would increase travel time to the recreation center (consequences: low). In this scenario, the risk to the Tribe associated with the first road-stream crossing would be considered *high*, while the risk associated with the second road-stream crossing would be considered *medium*. The first road-stream crossing may then be prioritized higher than the second road-stream crossing in tribal adaptation planning.

**Table 7. Risk Assessment Matrix.** From Institute for Tribal Environmental Professionals, 2013

| | | **PROBABILITY** | | |
|---|---|---|---|---|
| | | **HIGH** | **MEDIUM** | **LOW** |
| **CONSEQUENCES** | **HIGH** | HIGH | MEDIUM-HIGH | MEDIUM |
| | **MEDIUM** | MEDIUM-HIGH | MEDIUM | MEDIUM-LOW |
| | **LOW** | MEDIUM | MEDIUM-LOW | LOW |

## Strategic Adaptation Planning

The Intergovernmental Panel on Climate Change defined adaptation as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (2007). Climate change will present both challenges and opportunities in tribal resource management. The previous sections of this report summarized historic, current, and projected climate information and the findings of brief vulnerability assessments for key tribal resources. With this information, tribal managers may strategically adapt to climate change by working to: 1) reduce the negative impacts of climate change on the health or integrity of existing resources and 2) facilitate the most optimal impacts of climate change on existing, changing, and new resources.

The data shared in this report is subject to uncertainties and limitations, which necessitate an adaptive approach throughout the adaptation planning process, with mechanisms for monitoring, feedback, and adjustment of management strategies. Adaptive management is the framework by which managers learn from past management actions and develop new management actions based on the best available information (Williams et. al. 2007). Through adaptive management, management actions are modeled to estimate future impacts, monitored to estimate effectiveness, and then adjusted, along with the original model, to increase efficacy on an ongoing basis (Walters, 1986). Adaptive management is an especially appropriate framework for climate change adaptation, where models, projections, and resource impacts are dynamic and characterized by uncertainty. With this framework in mind, tribal resource managers may access a rich variety of tools and strategies in adaptation planning (**Figure 14**).


**Figure 14**. Climate Adaptation in an Adaptive Management Framework

The climate data, vulnerability assessment tools, and findings shared in previous sections of this report address numerous phases in Figure 15: Assess issue and objectives, assess knowledge and relationships, and identify uncertainty. The next step for participating Tribes may be to tailor these data, tools, and findings to their unique locations and resources, identify gaps, and adaptation goals, options and strategies.

### Adaptation Options & Strategies

Adaptation efforts may contribute to existing resource management goals, as identified in tribal management plans and processes, the revision of existing resource management goals, and/or new management goals. For the purposes of this report, emphasis is on adaptation options and strategies, which may both define and carry-out resource management goals.  Adaptation *options* include the broadest category of adaptation actions, including foundational concepts, whereas adaptation *strategies* include broad responses that consider both ecological conditions and overarching management goals (Swanston and Janowiak, 2012).

The most fundamental adaptation options include the concepts of resistance, resilience, and response (Millar et. al. 2007).  **Resistance** actions either increase a resource's defense against anticipated changes or defend against climatic change to maintain unchanged conditions.  This may be an effective short-term option; however, resistance requires greater resources in the long term as climate changes increase.  **Resilience** actions accommodate some change, yet aim to return to prior conditions after disturbance either through natural processes or management.  **Response** actions purposefully accommodate change and enable ecosystems to adaptively respond to new conditions, such as with translocating species northward to suitable habitat in preparation for local habitat losses.  These influence the ways that ecosystems adapt to future conditions.

Adaptation strategies encompass the ways that adaptation options may be employed.  Modeling and monitoring are key strategies for adaptation planning and management under the framework of adaptive management.  Both modeling and monitoring are useful in assessing the impacts of climate change and reducing the risk of negative impacts on identified tribal resources.  Monitoring of ecosystems and species at-risk may provide current data for tribal resource managers to use in planning and implementing effective adaptation actions.

Potential adaptation strategies were identified for the resources included in this assessment, which address resistance, resilience, and response.  These strategies include land and water management strategies for the benefit of specific species, ecological communities, natural features, or infrastructure; new or modified policies; new or modified technologies; and community engagement and outreach.  Limits in funding, time, and other barriers necessitate the consideration of benefit-cost ratios for each adaptation strategy (**Appendix D**).

### Natural Resource Adaptation Strategies

Climate change may exacerbate existing vulnerabilities to current stressors, such as invasive species, habitat loss and fragmentation, and disease.  Reducing current stressors may indirectly increase species and ecological community resilience to climate changes (per resistance and resilience adaptation options).  Michigan Tribes may pursue several related adaptation strategies for prioritized flora and fauna, including but not limited to:

1. Improve and protect specific native species populations and habitat
2. Improve and protect diverse ecological communities and habitat types
3. Maintain or increase connectivity among habitats
4. Maintain or restore ecosystem services and processes, i.e. water and energy balances
5. Identify and protect climate refugia
6. Translocation of future climate adapted species

**Habitat**.  Adaptation strategies for the identified species may include habitat improvement in support of increased species populations, fitness, genetic diversity, and decreased exposure to climate changes.  Habitat improvement may decrease the likelihood of extreme losses in native species, ecological communities, and ecosystem services.  Both terrestrial and aquatic species are impacted by the combined impacts of changing land cover and hydrology.  Vegetated land cover may mitigate the impacts of extreme precipitation events, whereas impervious surfaces and barren, eroding land covers may increase runoff and promote flooding, which are current stressors to species and ecosystem integrity (Mao and Cherkauer 2009; Mishra et al 2010). Limiting forest fragmentation and clear-cuts may increase forest resilience to invasive species (Ryan and Vose, 2012).

**Diversity**. Improving and protecting diverse ecological communities (biodiversity) and a variety of habitat types may also decrease the likelihood of extreme losses, due to the presence of functional redundancies and multiple energy pathways. For these reasons, diversity in ecological communities may also result in decreased susceptibility to invasive species, pests, and disease.

**Connectivity**. Improving and protecting habitat connectivity and species movement corridors may enhance species dispersal abilities and permit the maintenance of adequate ranges despite landscape or hydrologic change. Establishing and protecting hydrologic connectivity, such as replacing perched culverts or installing fish passages on dams, will enhance aquatic species dispersal abilities. Forest and riparian corridors are especially high value for natural species dispersal and movements. Protecting and/or increasing forest cover along stream habitats may decrease exposure among cold water fisheries in inland rivers and streams (Steen et. al. 2010).

**Ecosystem Services**. Maintaining and restoring ecosystem services may be an outcome of habitat improvements and increasing biodiversity and habitat connectivity; however, this strategy involves planning to maintain hydrologic systems, soils, and nutrient and energy cycling. Maintaining or restoring adequate forest cover, forested and non-forested wetlands, and vegetative buffers around surface waters will contribute to surface water, groundwater, and nutrient management. Pathways for nutrient and energy flow may be maintained through land use planning that minimizes road networks, forest and wetland conversion, and ensures adequate storm water management through green building practices and updating infrastructure/culverts to accommodate increased peak flow. In addition, biodiversity is associated with increased pathways for nutrient and energy flow, functional redundancies, and resilience in ecosystem services.

**Translocation**. Species translocation is an adaptation strategy whereby species are transported by resource managers to a new location. Long practiced by fish and wildlife agencies, species translocation has shown differing degrees of success. Translocation of forest canopy tree species to higher latitudes in Michigan is an active area of research among Michigan Tribes seeking to increase diversity in forest ecosystems for the long-term. In extreme cases where an endemic and highly threatened species cannot disperse to suitable habitat, translocation may be vital to ensuring the preservation of that species or gene pool.

**Infrastructure, Public Health and Socio-economic Adaptation Strategies**

**Roadways and Transportation**. The predicted extreme heat and more frequent extreme weather events will cause accelerated asphalt deterioration, pavement buckling, and deterioration of bridges and culverts. Strategies include vulnerability assessments on roadways, bridges and culverts; continued monitoring of roadways, bridges and culverts; transportation and land use planning; emergency response development (Schwartz et al. 2014). Continued monitoring will allow immediate response to any degrading changes in infrastructure stability. Pre-vulnerability assessments and transportation and land use planning should be employed before construction of new streets or roads to aid in infrastructure stability and resilience. Also, having a disaster management plan in place that includes a point of emphasis on available roads to use to exit the community during or after an extreme weather event or disaster event would support community resilience in these circumstances.

**Housing and Buildings**. Housing and buildings may begin to take direct damage due to flooding and severe precipitation events as well as instability due to erosion and possible changes in the water table. Another problem that could occur in rural areas is the likely increase in wildfires. Pre-existing structures are particularly vulnerable because they were most likely built without the idea of a changing climate

(Bates et al. 2008). Some adaptation strategies for housing and buildings include making sure insulation and window seals are properly installed and maintained to decrease heat loss and reduce heat gain particularly if the energy grid is interrupted in the winter season or summer season respectively. In addition, solar panel systems will promote housing and building resilience if severe weather events disrupt the electricity grid. Promoting effective landscaping and planting vegetation that will soak up excessive precipitation and will store water will reduce the possibility of water buildup on properties and foundations and also reduce erosion. Buildings with flat roofs should possibly incorporate vegetative roofing which will collect rainwater while reducing storm water runoff, reduce heat consumption and naturally cool the building. Applying heavier roofing material to buildings in areas with frequent high wind events can decrease the chance roofing materials becoming detached. The adoption of sprinkler systems (even outdoor, hose-connected systems) for housing and buildings could be a great strategy for a last resort defense against a wildfire that is burning towards or through a community. Elevating or flood-proofing housing and building, although expensive, will greatly reduce the chances of severe damage from flooding. For new construction, communities should develop resilient building guidelines to promote long lasting construction with climate change implications (Senick 2014).

**Energy Use and Utilities**. Energy use within the geographical area is projected to change from climate change; less energy to heat during the winter months, but more energy to cool during the summer months. Also, more frequent severe weather events may cause interruptions within the electric grid more often. The most beneficial adaptation strategy is alternate energy sources. The less the community is reliant on the electrical grid and other energy sources, the greater the communities' adaptive capacity to climate changes. Environmentally friendly energy sources including solar panels and wind turbines would increase the communities' adaptive capacity and resilience to climate change while also lessening the impacts and rate of climate change. Another strategy would include the installation of energy efficient heating and cooling systems within structures (Li et al. 2012; Melilli et al. 2014).

**Commercial Fishing**. Tribal commercial fisheries may be affected by climate change. The greatest strategy to reduce the impacts of climate change on the fishery is to try to eliminate any stressors on the fishery that can be managed to create more time for fish to adapt to their changing environment. There are many projections that are expected to change water temperature and chemistry, and increase the amount of invasive species. Some strategies to reduce these impacts and assist the fishery include invasive species management; reduce or eliminate deforestation by near shore areas and along streams; increase riparian habitat in near shore areas and on streams; avoid overexploitation of fish species; and avoid unfavorable land use changes near lakes and streams. Any management to reduce the impacts of runoff, invasive species, critical habitat destruction, changes in water temperature and changes in water chemistry will allow fish more time to adapt to the changes in climate (Ficke et al. 2007; Melilli et al. 2014).

**Tourism**. Tourism is greatly relied upon by Michigan Tribes to generate revenue. Based on climate change projections, summer months in central and upper Michigan should not become unfavorable to tourists by 2050; the southern edge of Michigan may begin to see unfavorable conditions. However, winter months may become unfavorable to tourists that travel to northern Michigan for winter activities. Communities like most Tribal communities that rely on hotels/resorts, casinos and attractions have low adaptive capacity with tourism changes. Due to low awareness and implementation done on climate change and tourism, there are not many strategies to reduce climate change on tourism. It is suggested to collaborate with tourism stakeholders and brainstorm alternative technologies, management practices and policies to reduce climate change impacts on tourism (GLISA Change in Frost-Free Season Length. 2014; Hales et al. 2014; Simpson et al. 2008).

**Pests**. Climate change may increase attacks on plants and animals by pests and make vector-borne and zoonotic diseases increasingly prevalent, including the West Nile Virus from mosquitoes and Lyme's disease from ticks. Presently, the most effective strategies include chemical/pesticide application and the avoidance of exposure. Future efforts and strategies may focus on creating environmentally friendly pesticides that target specific species, creating natural repellents, and creating disease-targeting vaccines (Portier and Tart, 2010). Other pests are expanding their ranges, including the mountain pine beetle expanding north and east from its previous range in the Rocky Mountain area. Prevention is the best strategy to prohibit pest expansion.

**Human Health Adaptation Strategies**. It has been well documented that human health is affected by ground level ozone, particulate matter and allergens. Climate change is projected to increase the health risks of asthma and decreased lung function, allergies and heat-related illnesses. Reducing carbon pollution and using cleaner methods for electricity production would decrease the amounts of air pollutants and would also decrease the effects and magnitude of climate change (Luber et al. 2014). Also, providing the community with an early warning method for extreme weather events and low air quality may be a good initial strategy to assist individuals with upper respiratory problems and decrease the chances of heat exhaustion and heat stroke. Data including ground ozone levels and particulate matter from air monitoring sites in Michigan can be found at http://www.deqmiair.org/.

The spread of diseases and viruses from insects and parasites such as mosquitoes and ticks may increase with climate change. Presently, there is no significant strategy to deal with mosquitoes without the use of harmful chemicals, avoiding exposure or decreasing the amount of stagnant water, which is difficult for tribal communities because most are surrounded by surrounded by open water, streams and wetlands. Ticks are becoming more prevalent within areas and there is also no significant strategy to deal with them without the use of harmful chemicals or avoiding exposure. Future efforts and strategies may need to focus on creating an environmentally friendly pesticide that targets specific species, creating natural environmentally friendly repellents, and creating disease-targeting vaccines (Portier and Tart, 2010).

### Moving Forward with Climate Change Strategies

In a 'perfect' world, and as increasingly required for federal program funding, climate change adaptation goals and strategies should be mainstreamed into tribal resource management operations, policies, and procedures. Identifying over-arching strategies that can guide tribal resource management options, policies, procedures, and the development of site-specific management actions may increase the effectiveness of adaptation efforts.

Potential strategies that address ecologic, infrastructure, public health, and economic resources are listed in **Appendix D**. A selection of these strategies is listed below, as well:

- *Routine monitoring of native species and ecological communities*: increase understanding of species and community life history, abundance, location, vigor, and response to climate or other changes, such as phenological change

- *Address invasive species*: maintain native species diversity, reduce entry points for potential invasive species (i.e. nurseries, landscaping, GL and inland boats)

- *Increase riparian habitat*: protect and increase crucial habitat for an extensive amount of species, while also aiding in the control of temperature fluctuations in streams and rivers

- *Increase green infrastructure*: protect and increase forests and wetlands around surface waters, update combined sewer and storm water handling systems

- *Routine monitoring of infrastructure*: decrease the probability of emergency actions due to unforeseen infrastructure failure by continuously monitoring infrastructure within the community

- *Implement alternate energy*: increase community resilience from climate change by obtaining cleaner energy sources that will reduce long term costs and reliance of the increasing demand in electricity and other energies, and also decrease the amount of carbon and particulates emitted in the atmosphere

- *Increase community awareness*: perform outreach and education to diverse age groups (youth, elders, college students, etc.) on climate change, adaptation, and mitigation actions at the individual and community levels

## Conclusions

The effects of climate change are already evidenced in historic and current climate data and the changing populations and phenology of native flora and fauna across the tribal lands assessed in this project. Projected future changes include risks to native species, tribal resource infrastructure, and current ways of life, as well as opportunities for social, economic, and cultural resilience and growth. This report is intended to provide a foundation for tribal resource managers as they incorporate climate change considerations in decision-making, moderate the risks, and proactively adapt to climate change for the benefit of current and future generations.

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