THESIS

SMALL GOVERNMENT, BIG PROBLEMS: CLIMATE CHANGE ADAPTATION POLICY IN NORTH AMERICAN GREAT LAKES LOCALITIES

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ABSTRACT

SMALL GOVERNMENT, BIG PROBLEMS: CLIMATE CHANGE ADAPTATION POLICY IN NORTH AMERICAN GREAT LAKES LOCALITIES

The Great Lakes region is home to 30 million people, one of the world's largest economies, and the world's largest freshwater ecosystem. These characteristics make the region uniquely vulnerable to climate change. Local governments in the area, are subject to the impacts of climate change, whether they are prepared for them or not. To explore this issue, this paper seeks to answer the question, "What is the state of local climate change adaptation policy in the Great Lakes region?" Most literature that exists on local adaptation focuses on larger cities with populations over 50,000 people. This project fills that gap by looking at climate plans from all U.S. local governments that border the Great Lakes regardless of their size. To do this, climate change adaptation plans and policies were gathered from each county and subcounty municipality (such as cities, villages, towns, and townships) in the United States that border the Great Lakes. A text analysis was performed that compared the documents to regional climate science, as well as an inductive content analysis to pull out the major topics in each plan. Findings suggest that localities in the Great Lakes Region are in the beginning stages of adapting to climate change. Only 6% sent back relevant policies. Many of them were small governments with under 20,000. Findings suggest a lack the capacity to adequately adapt to climate change, especially within the smallest governments. The degree of assistance needed from larger institutions to supplement any insufficiencies is still unclear. The results of this project capture a

snapshot of how local governments bordering the Great Lakes are (or are not) adapting to climate change. This can be used to foster intergovernmental learning on how substate governments in the region can adapt, while also providing insight into the boundaries of local action in the face of a global issue.

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DEFINITIONS AND TERMS

Anthropocentric Climate Change "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods," (UNFCCC, 1992).

Adaptation "In *human systems*, the process of adjustment to actual or expected *climate* and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects," (IPCC, 2018).

Climate change resilience "The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for *adaptation*, learning and *transformation*. This definition builds from the definition used by Arctic Council (2013)," (IPCC, 2018).

Climate change mitigation "A human intervention to reduce emissions or enhance the *sinks* of *greenhouse gasses*," (IPCC, 2018).

Great Lakes Region Any municipality, state or territory that lies within the Great Lakes Drainage Basin as defined by the EPA (EPA, Facts and Figures). For the purposes of this paper only American governments were included in the study.[1]

Municipality Cities, villages, towns, boroughs, and townships designated by the United State Census Bureau. Municipalities do not include counties. (U.S. Census Bureau, 2018)

County The highest form of local government as designated by the United States Census Bureau (U.S. Census Bureau, 2018).

Local Government Municipalities (cities, villages, towns, boroughs, and townships) and counties.

[1] A map of the Great Lakes Drainage Basin is located in the Appendix.

“The future is often stubbornly nonlinear. Expected disasters fail to materialize, and unexpected disasters arrive suddenly, seeming obvious in hindsight.” - Zach St. Georg

INTRODUCTION

If the amount of water on Earth were 100 liters, half a teaspoon of that would consist of accessible freshwater (Bureau of Reclamation, 2020). Twenty percent of that teaspoon is contained in the Laurentian Great Lakes, a large, interconnected string of lakes located in the upper mid-eastern portion of North America (Hartmann, H.C.,1990). Due to their size and location, the Lakes have a part in determining the local, regional, and global climate (U.S. Global Change Research Program, 2009; Kunkel et.al., 2000; Rouse et al., 2005; Cole et al., 2007; Nordbo et al., 2011; Scott, 1996). Their influence creates individual ecoregions (Omernik, J. M. 1987 & 1995; Host, G.E, et.al, 2005). They support one of the world's largest economies and provide resources for more than 30 million people (EPA Facts and Figures). As such, the borders of the lakes are a prominent intersection between human and natural environments. These dynamics make the area globally distinct, but also vulnerable to climate change.

Anthropogenic climate change is a global problem that spans both human and natural systems (Leemans, et.al, 2009), whose web of cause and effect does not stop at political borders. This interconnection makes creating climate adaptation policy hard for decision-makers who are limited to their jurisdictions, especially local governments. The complicated nature of climate change lends itself to global regulation by nations, NGOs or IGOs. While the scope of climate change is global, its impacts, such as fires and floods, manifest at local and regional levels. This scalar mismatch makes it difficult for any one level of government to adequately address it (Leemans, et.al, 2009; Bukowczyk, et.al, 2005). To compound this issue, scientific limitations, and the uncertainty of global emissions reductions, make predicting the scale of potential harm challenging (Pearson and Dawson, 2003; Giorgi, 2005; Lemos and Rood, 2010). How do local governments begin to approach an issue that will harm them when the power to manage the scope and severity of that harm is largely out of their reach?

Whether it be on a local, national, or global scale, there are two major strategies used to begin “solving” climate change: adaptation and mitigation. Adaptation is the effort to prepare for the inevitable effects of climate change; mitigation is the effort to reduce greenhouse gas emissions to stave off increasing global temperatures (IPCC, 2018). With such a multifaceted topic, it is imperative to understand *what* is going on at a local level, so that researchers can begin to develop theories for *why* local governments face the climate policy challenges that they do. Only then can we begin to unpack *how, if,* or *to what degree* these problems can be addressed by local governments (Eisenhardt et al., 2016).

METHODS

This paper seeks to answer the question, "What is the state of Great Lakes local climate change adaptation policy?" Answering this question clarifies the essential characteristics of local climate policies, such as their scope, avenue, and content. Instead of conducting a random sample for this study, governments that directly border the Great Lakes were chosen. This was done as an environmental consideration. The Lakes themselves create unique climates on multiple scales, meaning that the governments bordering the lakes have different climatic considerations than the governments on the interior do (Omernik, J. M. 1987 & 1995; Host, G.E, et.al, 2005). This creates a methodological trade off. Data collected from a randomized sample could be politically generalizable for the entire region, but the environmental data would be less precise. The Great Lakes region was chosen as the area of study instead of the Midwest, for the same reason. The Great Lakes are shared by the United States and Canada. Canadian governments were not included in this study to enable the paper to be grounded in theories of American public policy and politics.

Social Explorer was used to select municipalities that touch the Lakes (U.S. Census ACS, 2018). The names of counties were found using the National Center for Environmental Publications Maps of the U.S. Great Lakes Drainage Basin on the EPA's website (1990). Information requests were emailed to each local government to determine if they were adapting to climate change in any way.[2] Each request indicated that any climate change adaptation plans or preparations were of interest. It was made clear that this could come in any form (such as an initiative, resolution, regulation, etc.), that they could be nested in a policy on a different topic, and that they could come from any department. It was also articulated that mitigation plans were acceptable, as long as they also contained adaptation. The requests also defined adaptation and mitigation. Although climate change resilience and adaptation are not the same by definition, they overlap conceptually, therefore both words were included (Nelson, 2011). Requests were sent to 448 municipalities and 80 counties. 302 municipalities (67%) and 51 counties (64%) responded. Respectively, 23 municipalities and 11 counties (34 total) had relevant policies. Collectively, they contained over 5,000 pages between 46 documents.

Next, I conducted a review of climate change science literature that pertains to the Great Lakes Region. This establishes what climate challenges regional localities are facing. EcoAdapt's, *State of Climate Change Adaptation in the Great Lakes Region* (Gregg et al., 2012) was used to identify the most salient climate change risks. The assessment includes a comprehensive list of climate impacts, and it serves as the foundation for the climate science predictions included in this paper. A literature review for regional climate change research done in the past 15 years was used to supplement the information found in EcoAdapt's research.

Once the policies were received, I analyzed them in two ways. First, I compared them to regional projected climate change impacts (as outlined in the background) in order to determine how policies align with what climate scientists are forecasting. This was used as a frame of

[2] If there was an official records request form available for the government in question, this was used to submit the request. The majority of the forms were sent via email to a FOIA coordinator, a clerk or an administrator. If there was no form, the text of the request was sent in the email directly along with the necessary information to comply with each law. For this reason, the text of the records requests varied slightly depending on the law and amount of space available in the document. The standard text for each request can be found in the Appendix.

reference to give the documents context. Climate projections can vary widely, but they are one out of many essential tools needed when preparing to adapt to climate change (Lemos and Rood, 2010). To do this comparison, I conducted a text analysis in which I coded every mention of climate change in the context of air temperature, lake temperatures and ice cover, precipitation, and lake levels, their secondary impacts, and any policy implications. This yielded data on how frequently each climate change impact was discussed.

Second, I used inductive content analysis to pull out the major themes across each policy. This paints a clearer picture of what regional adaptation policies are by utilizing data abstraction to reduce information into a simplified representation. It also begins to shed light on the relationship between what climate scientists are predicting and what localities are preparing for. Categories, concepts and themes were pulled out of the policies and unnecessary components were removed in order to reduce them to their essential characteristics. First, the policies were read through once. Next, I utilized an open coding methodology to pull out common words or relevant information from each plan. This resulted in over 5000 words. These codes were aggregated to create 4355 subtopics, which were further narrowed to 725 subtopics and then again to 78 main topics. This method provides a clearer description of the policies, by eliminating their unnecessary elements and honing in on their key attributes.

LITERATURE REVIEW

Climate change adaptation is an especially challenging problem because it is complex, dynamic, and significant to large swaths of the population. (Eisenheardt et al., 2016). The way that it is defined and conceptualized is constantly evolving. At its core climate adaptation is, "the process of adjustment to actual or expected climate and its effects," (IPCC, 2014). Over time, definitions have changed to encompass complexities of the concept beyond just a measure of capacity. Such as the idea that adaptation not only includes moderating the harm caused by climate change but also exploiting its benefits (Beg et al., 2002; Scheraga & Grambsch, 1998; IPCC, 2014). Or that human action is not the only form of adaptation. Non-human communities must also adapt (Smit and Wandel, 2006; IPCC, 2014), but due to the speed of climate change, human intervention on behalf of nature is in some cases necessary (Bonn et al., 2014). There is also growing recognition that adaptation is not always a net positive. Maladaptation, while sometimes beneficial in the short term, can be detrimental and undermine broad long-term resilience (Magnana et al., 2016; Barnett & O'neill, 2010).

Adaptation research within the social sciences has the potential to bridge the intersections between environmental hazards, human vulnerability and adaptive capacity (Smit & Wandel, 2006). For this reason, research on the topic within the field is widely called for (Berrang-Ford et.al., 2015; Agrawal & Ostrom 2006). Social scientists have determined that successful adaptation across scales of government align with the pillars of public policy; effectiveness, efficiency, equity and legitimacy (Adger et al., 2005). That the globalization and rapid economic growth of an area increase that population's vulnerability to climate change (O'Brien & Leichenko, 2000). There is a push to alter the field's frame of reference. In the article, "Political

Science and Conservation Biology: A Dialog of the Deaf," Agrawal and Ostrom argue that social scientists considering social-ecological systems problems must also consider ecological vulnerability and adaptive capacity (2006).

Practitioners in subnational forms of government such as cities and states have increasingly begun to realize that that action at national and international levels is not enough to adequately address the climate crisis (Araos et al., 2016). This stems from the reality that political systems are both overlapping and fragmented (Ostrom, Tiebout and Warren, 1961). The scope of national and international actors' influence is broad, but local governments are suited to address issues on a finer scale. Theories of multilevel governance assert that autonomous cities, acting on their own behalf, are capable of, "solving diverse problems of the wider metropolitan community," (Ostrom, Tiebout and Warren, 1961). Applying climate change to this theory posits that the patchwork of power and authority existing at the local levels and beyond are in many ways assets and not hindrances to adaptation efforts. Multiple levels and spheres of government, each addressing facets of a climate change, is in theory more effective than a single monocentric government attempting to tackle the entire problem.

However, governments alone are not the only entities with the capacity to address climate change. Individuals, nonprofits, private institutions and academia can also take action. In many ways they fill in where governments are lacking. Boundary chain organizations are an example of such an exchange. They bridge the gaps between climate science and decision makers (Kirchhoff, C. J., Esselman, R., and Brown, D., 2015). A number of boundary chain organizations within the Great Lakes region have proven to be innovative and productive resources for local governments to utilize in order to navigate the complexities of climate science (Kirchhoff, C. J., Lemos, M. C., and Kalafatis, S., 2015).

Most research on substate adaptation policy is focused on large cities (those with populations at or above 50,000 people) (Meerow et al., 2016; Meerow and Newell, 2017; Hoppe et al., 2016). Research shows that you are more likely to find climate change plans in large cities as opposed to in local governments with smaller populations (Reckien et al., 2018). This could be because the barriers to climate change policies such as information, expertise, financial capability and public support are less formidable for large cities (Allman et al., 2004; Tribbia and Moser, 2008; Moser and Ekstrom, 2010, Nordgren, 2016).

In addition, local climate change adaptation policy is largely reactive instead of proactive. A survey of 441 resource managers from the Great Lakes Region, found that 30% of them gave purely reactive descriptions when asked to define climate change adaptation (Petersen et al., 2013). Limited resources put towards reactionary policies further diminishes a researcher's likelihood to find adaptation data in smaller more rural governments (Amundsen et al., 2010). Within the Great Lakes, studies show a trend where private local stakeholders acknowledge climate change and understand that they are likely to be impacted by it, but do not feel the need to take action yet (Chin et al., 2019; Morton et al., 2017). In many instances, people in the area are adapting to climate change even though they don’t realize it. Midwestern farmers have been found to change their agricultural practices in response to changing climatic patterns without considering it to be climate change adaptation (Doll et al., 2017; Morton et al., 2017).

Despite the potential for less data, research on climate change adaptation that includes smaller or more rural localities is uniquely necessary. 83% of the United States population lives in a large city, but they only account for 3% of the total land (Center for Sustainable Systems, 2021). Another 28% of land is directly controlled by the federal government (Congressional Research Service, 2020). Federalism and decentralization create a dynamic where the powers granted to the federal government and subsequently to the states have a larger sphere of influence than that of local governments (Elazar, 1987). However, if you look at climate change from a social ecological system standpoint, small local governments that comprise the majority of the nation's biodiversity, are on the front lines of climate change (Hayes & Ostrom 2005). This paper captures that dimension by looking at all local governments regardless of their size.

In the public and nonprofit spheres studies have been done to track regional adaptation work in the Great Lakes. The Great Lakes Water Quality Board conducted a study in 2017 to analyze local, state, and federal adaptation actions in the U.S. and Canada. They found that adaptation and resilience plans are not consistently found across jurisdictions; municipalities play a key role in adaptation, but that they lack capacity, leadership, and coordination (GLWQB, 2017). These struggles are in part motivated by the numerous and relatively complex impacts that climate change can have on the region. The following section begins to outline the ecosystem dynamics in the region and the impacts climate change has on them.

BACKGROUND

The American Great Lakes are in the eastern half of North America, straddling the United States and Canadian borders. They include lakes Huron, Ontario, Michigan, Erie and Superior. They make up one of the largest freshwater ecosystems in the world. The region supports 3,500 different species of plants and animals, 7% of which are globally rare or are only found in the Great Lakes region (Wuebbles et al, 2019). The basin is home to 30 million people, supporting 30% of Canada's population and 10% of the United States'. The region has a $3.1 trillion GDP, and if it were a country, it would be one of the largest economies in the world (NOAA Great Lakes, n.d.).

Climate change impacts all of these characteristics. The municipalities, states and territories that border the Great Lakes must be able to cope with that. The largest effects of climate change are on the region's air temperature, lake temperatures and ice cover, precipitation, and lake levels. These effects have a second wave of consequences, such as heat waves, which are caused by the rising air temperatures (Gregg et al., 2012). National and global changes will play a role in the secondary impacts that the region faces. Secondary impacts are what decision makers focus on when adapting to climate change.

It is important to keep in mind that while the risks presented here are arranged in a neat and tidy list, the reality is not so cut and dry. Climate modeling is not exact (McMichael, A.J. et al., 2006). Gathering climate change data on regional scales and smaller is critical because local topography such as bodies of water, mountains, rain shadows and other features can significantly affect how an area experiences climate change (Patz et al., 2005). Therefore, not every climate risk in this list will manifest equally in all localities. For instance, negative health consequences due to heat waves might be more of a concern for urban areas with less tree coverage and more heat retention than it is for townships (Bowler et al., 2010). The severity of these impacts also depends on the severity of climate change, which further depends upon global commitment to lower greenhouse gas emissions (Baule et al., 2014; Lofgren et.al, 2011). In addition, this list is not exhaustive. It creates a nearly comprehensive picture, but due to the scope of the topic, it is very possible that some Great Lakes climate change research has been left out. There are also likely to be many impacts from climate change that scientists do not foresee, especially secondary impacts (Karl et al., 2009).

The structure of the following background is adapted from EcoAdapt's, *State of Climate Change Adaptation in the Great Lakes Region* (Gregg et al., 2012). EcoAdapt's report is used as a framework because it provides a list of the primary impacts that climate change will have on the environment. These impacts are the changes in mean climatic conditions that the region will experience such as precipitation variation. Under each primary impact, it lists secondary impacts, an example is flooding that results from increased precipitation. This framework is not exact. For instance, shifting landscapes is listed as an impact of temperature changes. But that does not encompass every climactic reason for landscape changes. Drivers of change are more complex and interconnected. For landscape shifts, others include urbanization, precipitation changes, and biotic effects (Goring & Williams, 2017; Myers et al., 2009; Davis et al., 2000).

The distinction between primary and secondary impacts is important because it begins to clarify the domino effect climate change has on an ecosystem. This helps adaptation decision makers because they do not focus on addressing primary climate change impetuses such as lowering greenhouse gas emissions to maintain stable precipitation levels. Instead, they focus on addressing the secondary impacts of climate change such as how well equipped the region's infrastructure is to handle the flooding that results from increased precipitation. EcoAdapt's report is one of the only comprehensive regional climate science documents that presents impacts in a way that creates this distinction for policy makers.

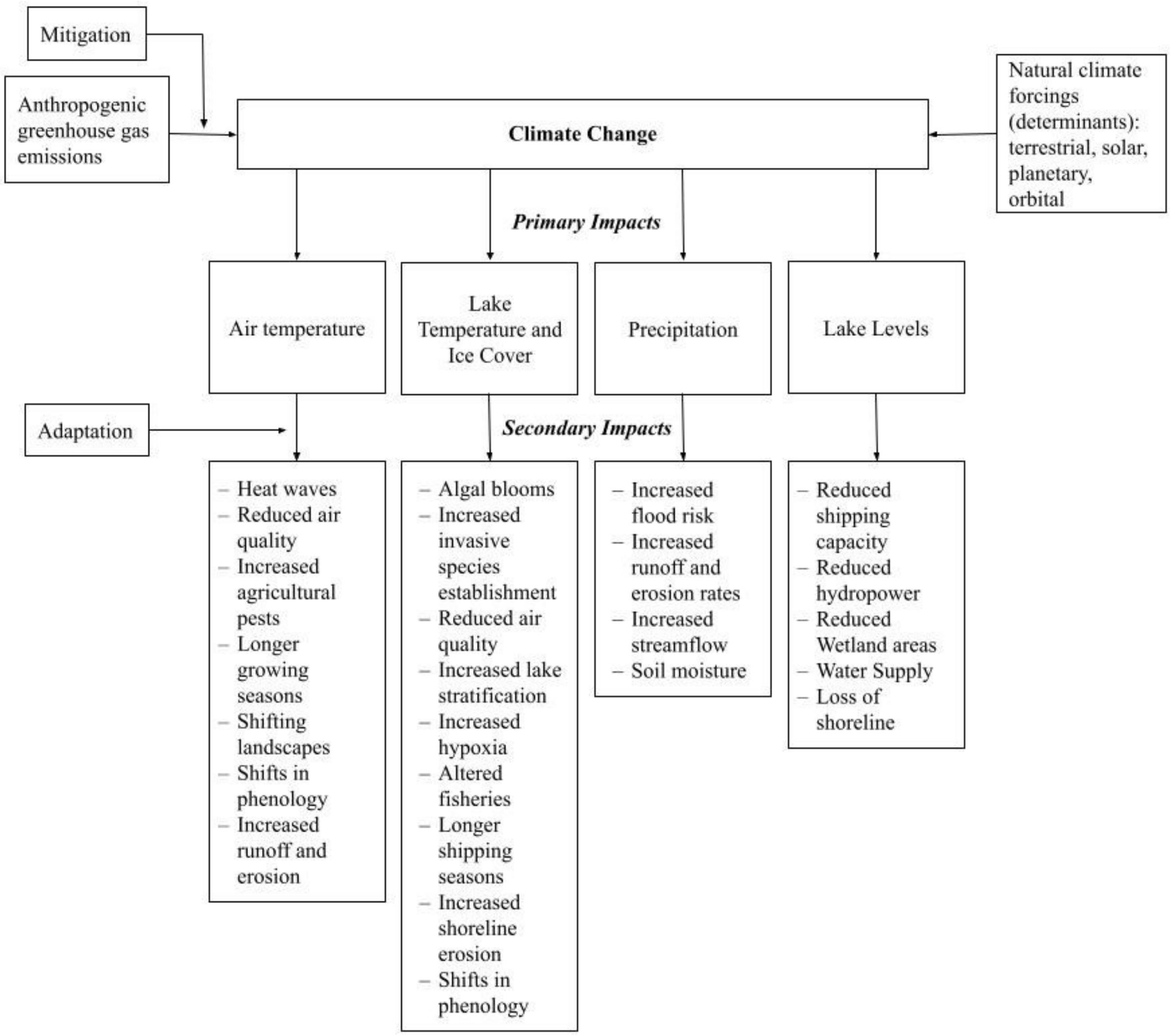

Figure 1: Climate Change Impacts Concept Map

Air temperature

Depending on the state, the region's average annual winter temperatures can range from 20°- 45° F (MDNR, 2917; Changnon et al., 2004). And average annual summer temperatures can range from 70°- 85°F (MDNR, 2917; Changnon et al., 2004). Over the past few decades, the average temperature in the region has been gradually increasing (Baule et al., 2014). By 2100 it is expected to increase anywhere from 5.5°F to 11°F depending on emissions scenarios (Baule et al., 2014; GLISA, 2021). These increases are not entirely uniform across seasons or states (Kunkel et al., 2009).

Secondary Impacts

- Increased frequency, duration, and intensity of heat waves*:* With rising temperatures, extreme heat events are expected to be more common throughout the 21st century (Byun and Hamet, 2019; Lopez et al., 2019). The Great Lakes basin has high humidity levels which are expected to trigger the onset of extreme heat events at lower temperatures (Xie et al., 2021). Areas downwind of the Lakes are expected to have a reduced number of extreme heat days (Xie et al., 2021).
- Lower crop yields*:* High temperatures can lower crop yields, especially that of soybeans and corn, two of the most widely produced crops in the region (Feng, S. et al., 2019; USGCRP, 2019). Predictions forecast soybean and corn production to decrease by 10-30% by midcentury (Wuebbles et al., 2019; USGCRP, 2019).
- Health Complications and Urban Heat Islands*:* Urban cities can exacerbate heat waves by creating 'heat islands' where less vegetation, less evapotranspiration, and a concentration of dark surfaces such as roads and rooftops lead to a concentration of excess heat (Frumkin, H., 2016). Heat waves can have especially damaging impacts on human health such as cardiovascular and respiratory illness (Vogel et al., 2019; Patz, 2005). National statistics show that heat waves have the potential to increase mortality rates, but 4% especially earlier in the summer when individuals are not adjusted to high temperatures. The elderly and those who do not have access to air

conditioning are especially vulnerable (Astrom et al. 2011; Luber & McGeehin, 2008; Hansen et al., 2011).

- Reduced air quality: How climate change affects air quality in the Great Lakes region is not heavily studied. However, national studies show that increased air conditioning use from rising temperatures can lower air quality due to elevated levels of power plant pollution. This could have implications for illnesses such as asthma, respiratory distress (Abel, D.W. et al., 2018).
- Increased agricultural pests: While further studies need to be done, increasing air temperatures and CO2 levels have shown the potential to increase the number and severity of agricultural pests such as gypsy moths. This could negatively impact agricultural production (Williams, 2003; Gregg et al., 2012).
- Longer growing seasons: With warmer temperatures, the Great Lakes Region has experienced increasingly longer growing seasons by about two weeks on average. This has been accompanied by shifts in spring frost time, where brief spring warm periods that spur initial plant growth are followed by a spring frost. This has decreased the rate of successful crop production (Baule et al., 2014). Longer growing seasons means more time for farmers to grow crops, however downsides such as early-onset budding in combination with late spring frost will most likely outweigh the benefits of a longer growing season (Wuebbles et al., 2010).
- Shifting landscapes: As temperatures shift, so too will the biotic landscape of the Great Lakes region. Plants and animals migrate with the natural climatic changes of the world, but anthropogenic climate change presents a unique challenge because of its speed (George, Z. S., 2020). For example, sessile organisms that stay in one place

for their entire lives, such as plants that rely on seed dispersal to migrate over generations, are particularly at risk of being outpaced by climate change (George, Z. S., 2020). A study of the Holocene Era found that lake effects buffered the severity of climatic changes along the shores of the Great Lakes. If future changes follow this pattern, lakeside ecosystems could provide a refuge for some plants and animals (Davis et al., 2000). At the same time the Lakes could be a barrier to the movement of plants and animals whose suitable habitats move across the water (Marrotte et al., 2020).

- Shifts in phenology*:* As the timing of seasons shift, so too will the timing of plant and animal rhythms. This can impact agricultural yields owing to an increase in spring bud damage due to frost (Zavalloni, C., 2004). It could also lead to disruptions in trophic structures. For instance, if monarch butterfly migration no longer overlaps with milkweed blossoming, this could severely cripple the survival of a key regional pollinator, thus affecting agriculture and native biodiversity (Gregg et al., 2012).
- Increased runoff and soil erosion*:* Increased air temperatures warms soil, which in turn can increase evapotranspiration rates and decrease soil moisture (Pruski et al., 2002; O'Neal et al., 2005; Wang, 2018). This can impact soil infiltration and runoff, which both affect erosion rates (Pruski et al, 2002; Wang, 2018). Increased runoff and erosion has agricultural and nonagricultural implications. Farmers' crops can suffer from a loss of soil depth and moisture, impacting the productivity of the land (O'Neal et al., 2005; Uri, 2001). Higher erosion and runoff rates transfer larger amounts of agricultural pollutants into waterways; potentially impacting water quality, water temperature, and aquatic life (Uri, 2001). They can also cause clogs in water systems

which can negatively impact infrastructure such as roads and reservoirs (Uri, 2001). Finally, wind erosion such as that of the Dust Bowl can damage the integrity of both living and nonliving entities (Uri, 2001).

Lake Temperature and Ice Cover

Lake temperatures have been increasing at a rate that outpaces warming air temperatures (Pryor et al., 2014; Mccormick and Fahnenstiel, 1999; Austin and Colman, 2007; GLISA, 2021). Just like terrestrial environments, bodies of water can also experience heat waves. Scientists expect heat waves within the Lakes to increase by 7.3% per decade, with the largest number in Lake Erie and the smallest in Lake Superior (Woolway, 2021). Ice coverage continues to be sporadic from year to year with very low and very high ice coverage possible in the future (Mason, et al., 2016).

Secondary Impacts

- Algal blooms*:* Harmful algal blooms (HABs), which are already a significant threat to the Great Lakes, are expected to be exacerbated by climate change. The HABs in the Great Lakes are largely caused by cyanobacteria that is produced from excess phosphorus and nitrogen runoff. Currently, Lake Erie, the smallest and warmest of the Lakes, has the largest issue with HABs. HABs are dangerous because they produce toxins that can create dead zones in bodies of freshwater that kill fish, can poison humans and animals, can be difficult for municipal water infrastructure to filter, can create long term ecosystem challenges, and can negatively impact economies. Climate change will exacerbate HABs though increased runoff and erosion from storms, and warmer lake water temperature. (Carmichael and Boyer, 2016; McKindles, 2020)

- Increased invasive establishment*:* Warmer lake water is expected to exacerbate existing invasive species problems and could open the door to new aquatic invasive species. Sea lamprey would benefit from warmer water, and could increase in population size (Hansen, M. J. et al., 2016). In addition, warmwater fish species from the Mississippi and Atlantic coast have the potential to invade the Great Lakes and introduce new pathogens that native fish are not immune to (Marcogliese, 2001; Rahel and Olden, 2008). Aquatic invasive species can alter ecosystems to such a degree that native plants and animals can go extinct, and biodiversity can be severely impaired (NOAA Fisheries, n.d.).
- Increased lake stratification*:* Stratification describes the separation of thermal layers in a lake. Cold weather brings about the mixing and oxygenation of the Lakes where oxygen rich water near the surface becomes denser and mixes with the oxygen poor water towards the bottom of the lake (Steward, S., 2014). Warmer air and water temperatures would increase lake stratification by delaying the onset of oxygenation. This could impact lake biodiversity and the duration of dead zones (Magnuson, J. J, 1997; Weinke and Biddanda, 2019; Lehman, 2002). Increased stratification of the Lakes could contribute to a loss of nutrients at the bottom of the Lake, impacting primary production. This intern could continue to negatively affect the food chain (Gregg et al., 2012).
- Increased hypoxia*:* Hypoxia occurs when the dissolved oxygen concentration in a body of water is too low to support plant and animal species (Hyde, 2021). Warmer

lake temperatures caused by climate change can lead to longer periods of stratification in the lakes as well as increased respiration rates (Scavia et al., 2014). In addition, predicted growth in sediment loading due to rising levels of precipitation can drive up the concentration of oxygen consuming HABs. This can further increase the Lakes chances of experiencing hypoxia (Scavia et al., 2014). This is a threat to native fish species, the fishing industry, biodiversity, and recreation among other things.

- Altered fisheries: Increased water temperature has the potential to expand the volume of water in the lakes and therefore increase habitable areas for fish in all thermal guilds (Jones et al., 2006; Lynch et al., 2010; Hokanson, 1997). However, considering the reduced lake levels that come in conjunction with warmer air temperatures, warmer water temperatures can reduce habitat area especially in the western basin of Lake Erie (Jones et al., 2006). Shifting oxygenation levels due to algae blooms could also limit the actual amount of habitat expansion (Lynch et al., 2010). Warmer lake temperature are also likely to spur fish to move into deeper and more northern waters in an attempt to find suitable habitats (Lynch et al., 2010).
- Longer shipping season: Reduced ice cover on the Lakes means that freighters and other shipping vessels can ship goods earlier in the spring and later in the fall, extending the amount of time that they can make a profit (Millerd, 2011).
- Shifts in phenology: Just like warmer air temperatures, warmer water temperatures can also change the timing of natural seasonal plant and animal rhythms. This includes fish spawning times, such as that of the yellow perch (Lyons et al., 2015), and insect maturation times and rates (Shipley et al., 2022). Shifting the seasonal

cycles of plants and animals can have significant impacts on trophic systems (Damien & Tougeron, 2019).

Precipitation

In comparison to air and lake temperatures, there is less consensus on how climate change is going to impact precipitation trends. In general scientists agree that the annual average amount of precipitation is likely to continue to increase as well as the intensity of single precipitation events (Patz et al., 2008). In addition, how precipitation is distributed across the seasons is changing (Kling et al., 2003). Researchers expect precipitation increases in the winter and spring, while the average levels in the summer and fall will remain the same or become drier (Kling et al., 2003; Baule, 2014; GLISA, 2021; Hayhoe et al., 2010). A rise in winter precipitation is expected, but due to increasing temperatures this precipitation is likely to begin to shift from snowfall to rainfall (GLISA, 2021; Wuebbles et al., 2017; Wright et al., 2013; Vavrus et al., 2013). The intensity of individual precipitation events is also supposed to increase (Baule, 2014).

Secondary Impacts

- Increased Flood Risk*:* The increase in extreme precipitation events are triggering floods throughout the region. Water infrastructure is based on past precipitation trends and cannot always handle increases in storm surge (Baule et al., 2014). Flooding can have negative effects on human health when overflowing sewer systems expose people to waterborne diseases (Patz, J.A. et al., 2008; USGCRP, 2019). Sewage overflows can also carry trash, organic compounds, heavy metals, and toxic pollutants into contact with human and natural environments. This can also cause mold contamination (USGCRP, 2019).

- Increased Runoff and Erosion Rates: A significant portion of annual soil loss is caused by only a few high erosion events (Gonzalez-Hidalgo et al., 2007; Edwards & Owens, 1991; Wang et al., 2018). As precipitation increases in frequency and severity, this will increase regional soil runoff and erosion rates (Wang et al., 2018).
- Increased Streamflow: Increased precipitation in the Great Lakes Region is increasing streamflow. As climate change continues, total runoff could increase by 7-9% (Cherkauer and Sinha, 2010; Gregg et al., 2012). The 100-year recurrence interval for peak daily streamflow could increase by 10-30% (Byun et al., 2019). The highest increases in runoff and streamflow are expected in the winter and spring months (Cherkauer and Sinha, 2010; Byun et al., 2019).
- Soil Moisture: Soil moisture is expected to increase in the winter due to precipitation increases. This, in combination with less frozen soil could reduce midwinter flooding due to an increase in infiltration capacity, but it could increase flooding in the late winter and early spring due to increased soil moisture retention (Byun et al., 2019). Soil moisture is expected to decrease in the summer and fall due to increased evapotranspiration rates, potentially impacting agricultural yields (Gregg et al., 2012; Byun et al., 2019).

Lake Levels

Higher temperatures are likely to reduce water levels in the Great Lakes, however research has predicted varying future water levels depending on the method of climate change modeling used. Scientists agree that Lake Superior, the largest and deepest of the lakes, will be the least impacted. Lakes Huron, Michigan, Erie, and Ontario are expected to see greater water level variation (Angel and Kunkel, 2010; Hartman, H.C., 1990).

Secondary Impacts

- Reduced shipping capacity*:* Lower water levels would mean that ships would have to reduce the weight of their cargo to draw less water, so that they can safely navigate newly shallow areas of the lakes. This could result in higher operation costs for shipping companies and lower profits. (Millerd, F., 2011).
- Reduced hydropower: Hydropower produces 9.1% of the power consumed in the Great Lakes basin (UNM, N.D.). Reduced lake levels would negatively impact the hydropower generation in the basin. Changnon and Glantz estimate that this could cost generators and lake shippers over $1 billion annually (Changnon and Glantz, 1996).
- Reduced wetland areas: The lower Great Lakes have lost around 71% of their wetlands due to agriculture, organization, water management, and upstream pollution (Mitsch and Hernandez, 2013). Climate change is expected to exacerbate the stress placed on an important and dwindling natural environment.
- Water supply: Climate change impacts basin runoff, overlake precipitation, and lake evaporation, changing water rates and times (Cohen, 1986). These changes will require new water management paradigms especially in light of forecasted regional population increases (Brown, Mahat, Ramirez, 2019).
- Loss of shoreline: Lake level rise has the potential to cause a loss of land and shoreline. This could impact the infrastructure as well as the natural habitats that rely on current shoreline dynamics (Gregg et al., 2012).

RESULTS AND ANALYSIS

Out of the 34 local governments whose documents were included in this study, cities made up the largest portion at 41%. Another 8% were towns, 8% were villages, 12% were townships and 32% were counties. 71% of the governments had populations under 50,000. This diversity justifies a need for research on a broad range of localities, beyond just cities, as well as research on localities that have populations under as well as over 50,000 people.

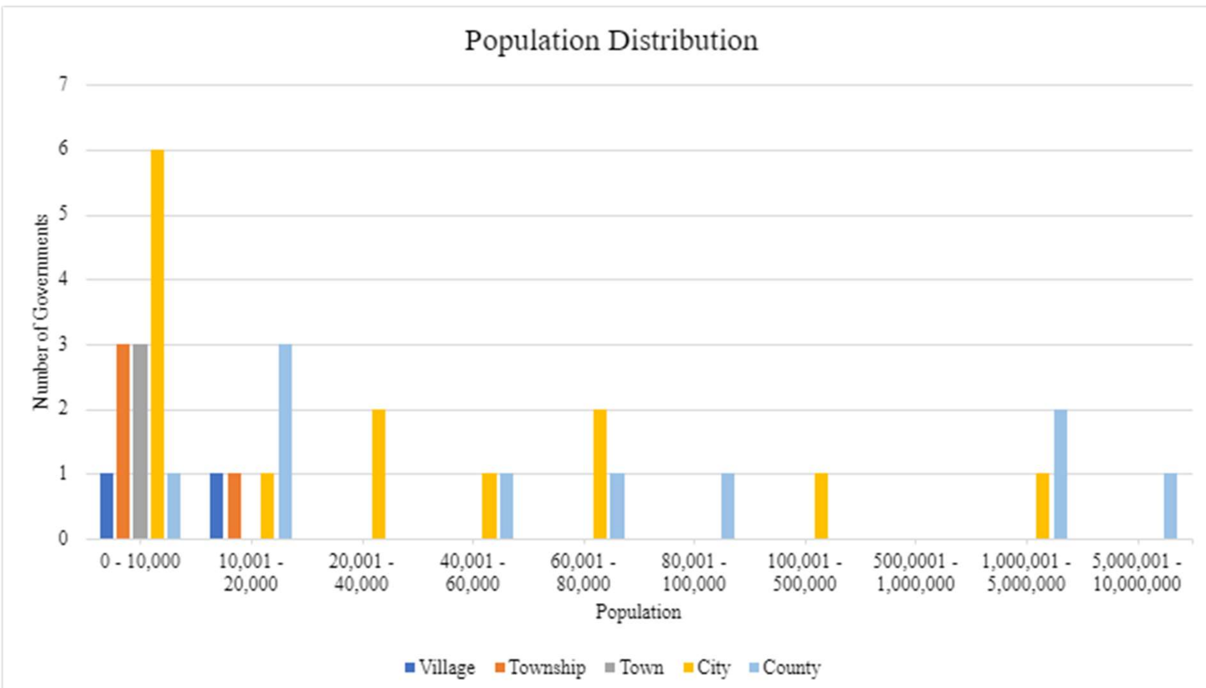

Figure 2: Population distribution across each type of local government

8 of the municipalities were from counties that also had plans, indicating that counties could play a role in the motivation for municipalities to adopt climate policy. Many of them utilized funding from outside sources, such as federal, state, or nonprofits grants and programs. The plans were all written after 2008 and 85% of them were written in the past 5 years. Almost a third of the plans indicated that they were either preliminary or were to be used as guides for future planning

processes. This, including the fact that 6% of the governments that were contacted responded with a relevant plan or policy, are indications that the localities in the region are still in the beginning stages of consciously adapting to climate change.

The plans that the local governments sent came in multiple formats. They ranged from 2 page county resolution proposals to 628 page hazard mitigation plans. 38% of the plans came from documents that were not entirely about climate change. As shown in Figure 3, they made up seven categories: hazard mitigation plans, master plans, land and water resource management plans, shoreline and coastal resiliency plans, comprehensive plans, energy plans, and conservation committee agendas.

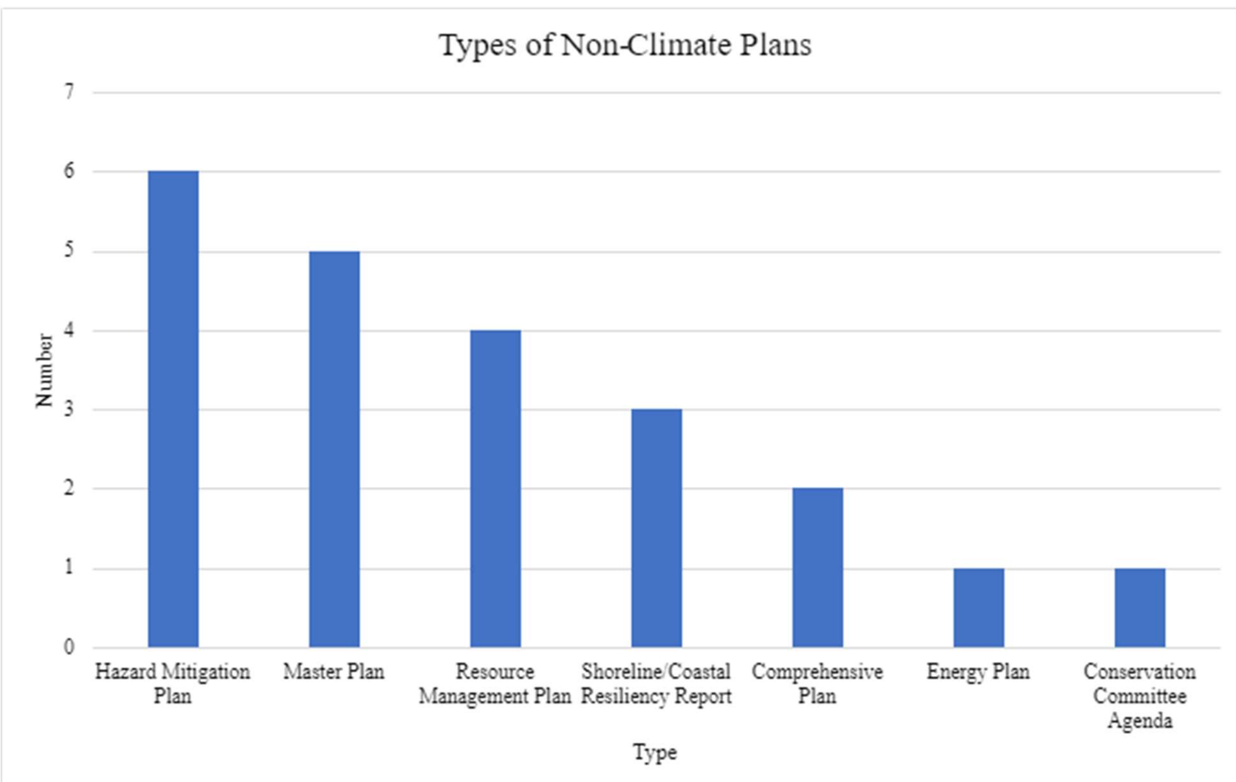

Figure 3: Type and number of non-climate change focused plans and policies

Population size, locality type, or type of plan were not good predictors of if a plan was entirely about climate change or not, but the state could be. In addition to being the two states with the most plans, 92% of the localities from Wisconsin and 73% of the localities from Michigan sent plans that were not entirely about climate change.

Plans that were entirely about climate change also took a number of formats. As shown in Figure 4, the most common plans were climate action resilience plans and climate health adaptation plans.

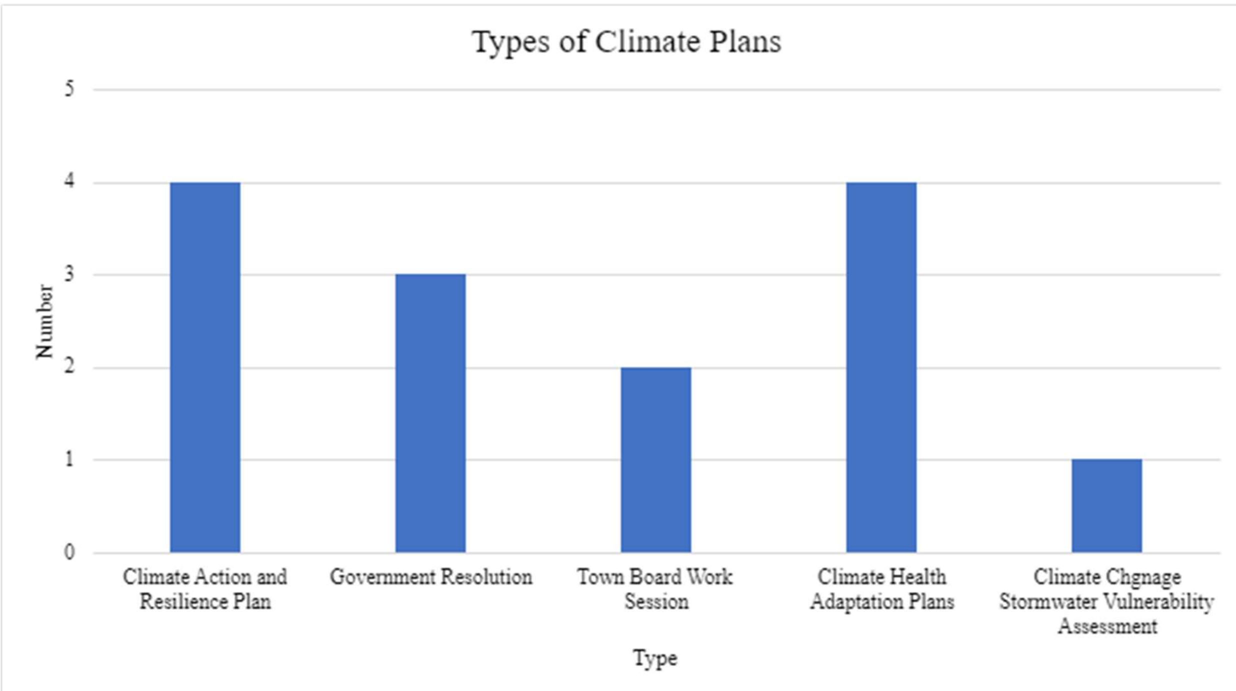

Figure 4: Type and number of climate change focused plans and policies

The distinctions in this category are less significant than that of the non-climate change plans. Hazard mitigation plans, master plans, and comprehensive plans are more common documents for local governments than those about climate change. They had more definitive structures and contents. In contrast, the climate plans lacked uniformity. They varied widely in their length, some being only 2 pages long while others were in the 200s. The number of times that climate change was mentioned and discussed in detail also varied widely. Some of the more surface level documents only mentioned climate change 12-15 times, while others discussed the word climate in great detail, mentioning it 200-300 times, irrespective of the number of pages in the document. This lack of uniformity within the types and scope of entirely climate focused plans and policies holds potential for future research on the best practices and formats for climate policy structure.

When analyzing the documents for any discussion of climate drivers and impacts[3], the number of times an impact was mentioned was used as a way to gauge a locality's level of concern for a particular topic. As you can see in Figure 5, the number of times each impact was mentioned by each locality varied widely. It is clear that cities have the highest number of climate science mentions, followed closely by counties, and then townships, and then significantly behind the rest of the localities are villages and towns. Smaller counts for towns and villages were to be expected because they represent a smaller portion of the data. Proportionally however, they make up a much smaller number. This finding could support the Great Lakes Water Quality Boards conclusion that small municipalities lack capacity, leadership, and coordination when it comes to the ability to execute comprehensive adaptation plans (GLWQB, 2017).

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[3] Refer to the background section.

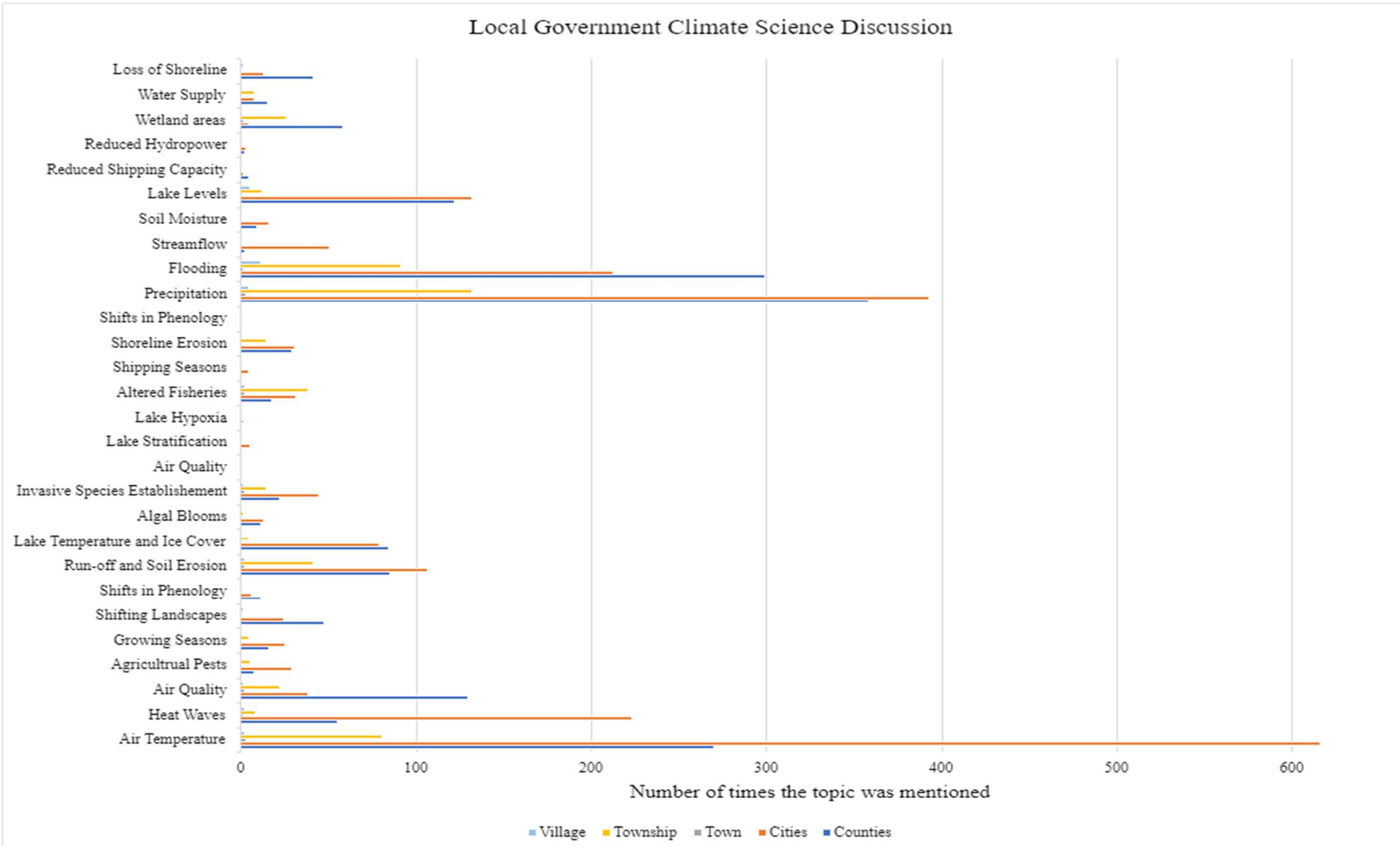

Figure 5: The number of times each climate science impact was mentioned broken down by village, township, town, city, and county

The impacts that were mentioned in the plans most frequently (over 100 times) were lake levels, flooding, precipitation, run-off and erosion, air quality, heat waves, and air temperature. Flooding, precipitation, heat waves and air temperature were mentioned over 200 times. This indicates that these topics are some of the most salient impacts for local governments. Table 1 breaks down the top 25% most frequently mentioned climate impacts by type of locality. One notable category was the cities' most frequently mentioned climate impact. In total air temperature was mentioned 616 times, which surpasses the next highest categories by almost twice as much. This resonates with literature that emphasizes the dangers of urban heat islands (Manoli et al., 2019; Heaviside et al., 2017), but it could also be an indication of local governments capacity. Addressing heat might be the most attainable adaptation action for cities. Towns had low climate impact counts that were relatively evenly dispersed. This indicates that they had smaller, more superficial plans. In contrast townships and counties had high impacts counts that were particularly focused on precipitation, flooding, and air temperature. Finally, villages also had relatively low climate counts, mostly ranging between 2-5, with an emphasis on flooding that was discussed 11 times. These numbers lay the foundation for more causal questions such as why localities chose to focus on these particular impacts and what causes the differentiation between the size and depth of the plans across the different types of local government.

Table 1: Top 25% most frequently mentioned climate impacts by type of local government. *N signifies the total number of mentions for all climate impacts. Refer to Appendix for a comprehensive list.

Most Frequently Mentioned Climate Impacts					
Village		Township		Town	
N = 32		N = 499		N = 17	
Impact	Count	Impact	Count	Impact	Count
Flooding	11	Precipitation	132	Precipitation	3
Lake Levels	5	Flooding	91	Air Temperature	3
Precipitation	4	Air Temperature	80	Run-off/ Erosion	2
Air Temperature	2	Run-off /Erosion	41	Altered Fisheries	2
Run-off /Erosion	2	Altered Fisheries	38	Air Quality	2
Heat Waves	2	Wetland Areas	26	Invasive Species	2
Altered Fisheries	2	Air Quality	22	Flooding	1
City		County			
N = 2105		N = 1693			
Impact	Count	Impact	Count		
Air Temperature	616	Precipitation	358		
Precipitation	393	Flooding	299		
Heat Waves	223	Air Temperature	270		
Flooding	212	Air Quality	129		
Lake Levels	132	Lake Levels	122		
Run-off /Erosion	106	Run-off /Erosion	85		
Lake Temp /Ice	79	Lake Temp/ Ice	84		

The frequency with which an impact is mentioned though can be a misleading gauge in terms of regional concern. This is because if just one or two documents out of the total are especially concerned about one particular topic, this drives up the number of times that topic is mentioned. This could erroneously convey that that topic is one of particular concern for the entire group and opposed to just one or two local governments. For this reason, an analysis was also done on the number of plans that mention each climate impact. This conveys what localities across the region view as a salient impact. The results of this analysis are displayed in Figure 6.

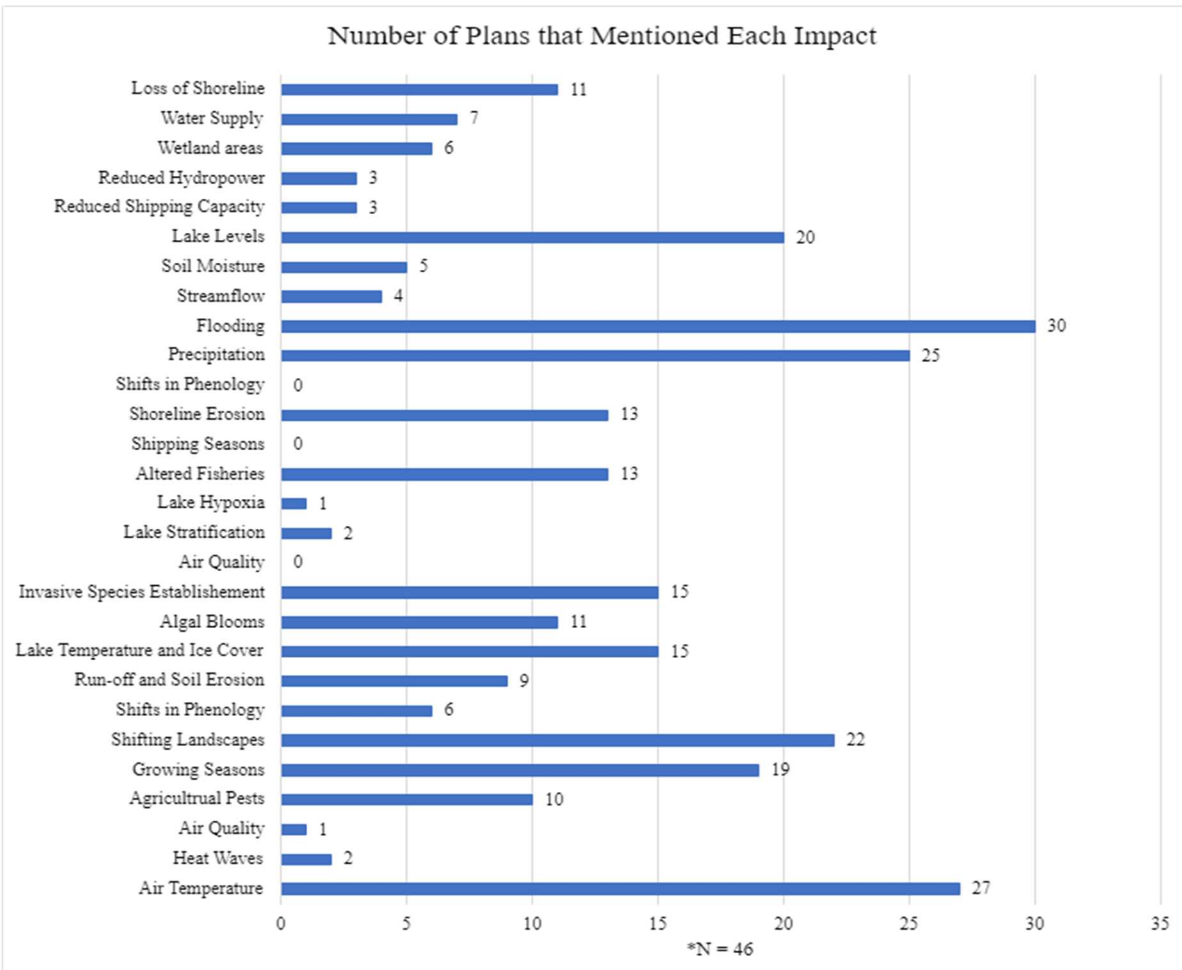

Figure 6: The number of plans that mentioned each impact out of 46 plans

Flooding, precipitation, and air temperature are not only the most frequently mentioned impacts in the plans, but they are also the greatest shared concerns across all of the local governments. Growing seasons and shifting landscapes however, while not frequently mentioned in the plans, are concerns that a large portion of the local governments included in their documents

While there was a substantial amount of discussion about impacts that were included in the climate science literature review, there were also quite a few topics that fell outside of those categories. In total, the inductive content analysis yielded 78 topics that the governments were concerned about that fell outside of the aforementioned climate science literature that was gathered. Table 2 depicts the top 50% of those topics. A full list can be found in the appendix. Seasonality, or the time of year that each of these impacts would manifest far outweighs the other topics.

Table 2: The top 50% most frequently mentioned topics from the inductive content analysis alongside the number of times each topic was mentioned

Inductive Content Analysis Topics							
Seasonality	620	Infrastructure	106	Ecosystem	64	Food	39
Forest	257	Agriculture	92	Utilities	63	Ozone	37
Recreation	161	Drought	83	Stormwater	60	Tornadoes	36
Extreme weather	147	Community	82	Wildlife	56	Power/ electricity	34
Storms	142	Respiratory problems	76	Water quality	54	Watershed	30
Vulnerable population	139	Waves	75	Human/ public health	50	Air conditioning	27
Emergency response	135	Inland bodies of water	72	Economy	50	Frozen ground	26
Fire	131	Population	71	Housing	47	Development	26
Habitat	117	Property (value/damage)	70	Vector-borne diseases	44	Schools	25
Transportation	116	Plants/ vegetation	65	Evaporation	40	Quality of life	25

This was followed by forests, recreational opportunities, extreme weather events, storms, vulnerable populations, emergency response, fires, habitat loss, transportation, and infrastructure. Each of these topics were mentioned over 100 times. The topics preceding these gradually and consistently declined in the number of times each was mentioned.

When looking at the list it is clear that not all of the topics discussed in the plans and policies that fell outside of the climate change literature do represent a gap in the literature. Many of them represent a vagueness on the part of the localities. For example, categories for plants, trees or wildlife were made up of topics that were not connected to a climate driver such as precipitation or air temperature. This indicated that while localities might have been concerned about the topic, they might not have identified a cause. Some of the topics also represent the general duties that fall within the jurisdiction of a local government that climate science might not mention, such as infrastructure, transportation, and electricity.

DISCUSSION

One of the major takeaways from this project is that 34 local governments responded with relevant policies, but that still leaves 491 that are either not discussing climate change adaptation or that didn't respond at all. As the background shows, just because climate change is not discussed, does not mean that local governments will not be impacted. Across different studies, stakeholders and decision makers in the Great Lakes region have demonstrated reactive action as opposed to proactive action (Petersen et al., 2013, Doll et al., 2017; Morton et al., 2017). If hundreds of local governments across the region are reacting to the impacts of climate change in a way that does not take climate change into account, they run the risk of using scarce resources on inadequate action.

Out of the governments that did have a relevant plan or policy most of them lacked a vulnerability assessment that could help them identify the risks that climate change poses to their specific area. It was clear that the local governments struggled to identify and address every potential risk. While the breadth of the discussions as a whole were wide, the number of topics that each locality considered tended to be narrow. Many of the plans centered around one or two impacts, such as human health or infrastructure. This could allow localities to be policy leaders for the topic that they focus on. However, it also has the potential to leave localities vulnerable to the impacts that they do not plan for.

This finding is compounded by the fact that the smallest municipal governments are severely under resourced. Many local governments in the region have less than 1000 people. When contacted for information requests, many didn't have websites or email addresses. In many instances the phone number for a government official was their home phone or their place of work. These are the same local governments, that must prepare for things like more severe fires, flooding, ice, and storms. As well as the health, economic, and infrastructural consequences of these changes.

This paper demonstrates that, while there is not a significant amount of adaptation action in the region, it is still found in unlikely places. There is not a substantial amount of literature on local adaptation in places with under 50,000 people, but counties and municipalities with less than 50,000 people made up 71% of this study. This demonstrates that despite reduced capacity, there is not a lack of interest or need on the part of small governments. This begs the question, what role do larger institutions and organizations (NGOs, IGOs, the federal government, states, nonprofits, and academia), play in helping these small governments adequately prepare for climate change.

The theories of polycentricity and boundary chain organizations could shed some light on this dynamic. The concept of boundary organizations within climate change adaptation literature suggests that these gaps might not need to always be filled by governments. Boundary chain organizations are intermediary organizations that bridge gaps between climate science and action (Kirchhoff, C. J., Lemos, M. C., & Kalafatis, S., 2015). They can be public, private, academic, nonprofit, or combination entities that help local governments translate climate science into actionable plans. Many of the plans collaborated with boundary organizations such as the MSU Extension, the Land Information Access Association, or the Lake Superior Watershed Conservancy.

While these organizations can be helpful, based on observations from this study, they can also narrow the scope of adaptation action based on what each organization specializes in. This has the potential to be either beneficial or harmful. Many local governments lacked a climate vulnerability assessment. If they do not know what climate impacts pose the greatest threat, there is a possibility that they spend valuable community resources on a specialized climate topic when there is greater need elsewhere. On the other hand, they demonstrate that addressing climate change does not need to come from one entity alone, nor do we necessarily need to reinvent the wheel to do so. Interdisciplinary and multilevel collaboration can streamline adaptation and fill gaps where capacity is lacking.

In the same sense, multilevel governance argues that overlapping jurisdictions and spheres of influence create a patchwork of services and functions as opposed to strictly monocentric forms of government (Ostrom, 1999). Incorporating climate considerations into an already existing patchwork as opposed to in one monolithic local plan could help address some of these gaps. In many ways climate change does not create completely novel issues for local governments. Rather it complicates issues that governments already address. For example, fires, floods, heat waves, utility security, or road maintenance are all issues that local governments already engage with. The Federal Emergency Management Agency and the Army Corps of Engineers and state troopers are all examples of governmental organizations that provide aid and assistance to local governments when they lack the capacity to adequately address these issues.

In the book Polycentricity and Local Public Economies, Ostrom explains that polycentric forms of government are not inherently inefficient. The FBI does not necessarily duplicate the services of state and local police, but it can supplement them (Ostrom, 1999). Even where redundancy is present, this can be viewed in some ways, as a benefit. Theoretically, when decision making centers addressing similar topics, exist at multiple levels of government, across multiple jurisdictions, the risk of institutional failure is reduced (Carlisle and Gruby, 2019). Boundary chain organizations and multilevel governance are not necessarily the only "answer" to effective climate change adaptation. Rather, these theories are examples of how local governments can begin to conceptualize and address a problem like climate change adaptation, that otherwise might seem insurmountable.

CONCLUSION

The purpose of this paper was to lay the foundation for more causal or theoretical research about municipal climate change adaptation as well as more practitioner-oriented research about Great Lakes local adaptation. After reading and analyzing each of the plans it is clear that localities use a variety of different methods to adapt to climate change. They are also concerned about a wide array of risks and impacts. This paper pulled out 107 major topics that the local governments surrounding the Great Lakes have discussed. Even with the breadth of topics discussed, the amount of action at the local level is limited. 94% of the governments contacted either did not respond or did not have a relevant adaptation plan or policy. Over half of the responses had populations under 50,000 people, and it was clear that they lack the capacity to adapt to climate change in its entirety on their own. Boundary organizations and multilevel governance are two theories that could begin to address this gap.

These findings illustrate that climate change adaptation at the local level both exists and is necessary, even within governments that have very small populations. The proper degree and format for this adaptation is yet to be determined. Future research on adaptation from the point of view of local governments could help continue to clarify their needs. In their own words, what do they need in their efforts to adapt? In addition, further research needs to be done on how resources at higher levels of government affect the ability of local governments to adapt. While it is not clear if every local government needs a full climate change adaptation plan, it is evident that they do need to begin considering the impacts of climate change in some manner. The findings in this paper illustrate that localities in the Great Lakes are adapting to climate change, but that there is also substantial room for progress.

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APPENDIX

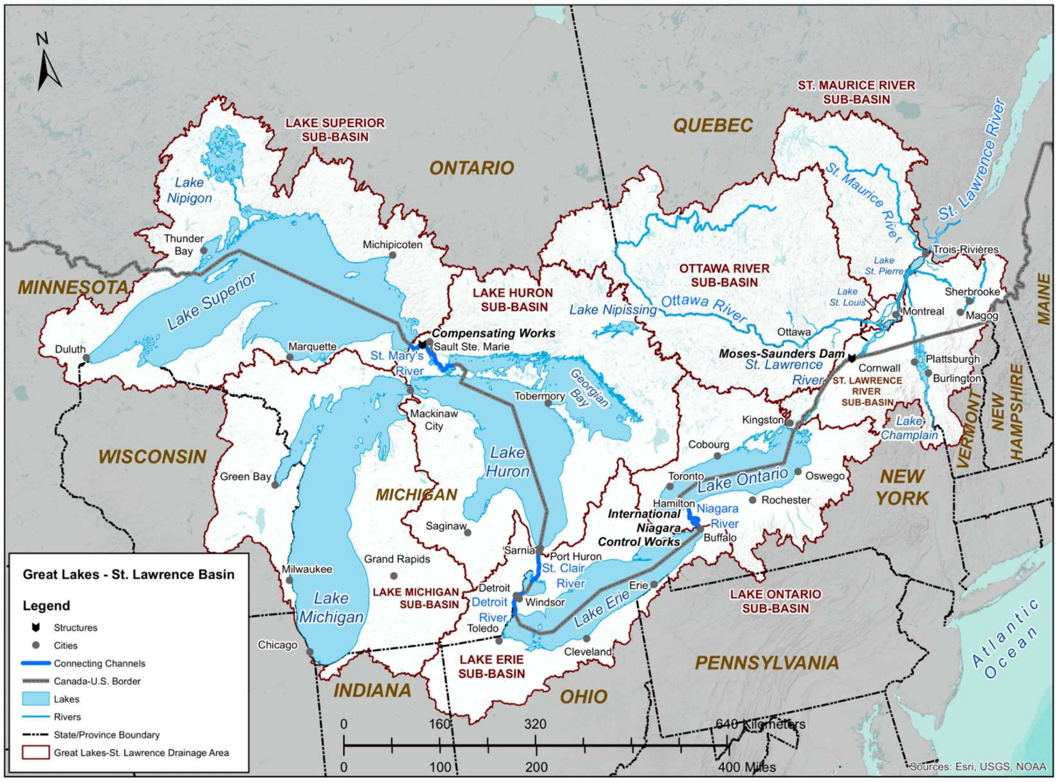

Figure 7: Great Lakes Drainage Basin

Dear (insert locality name) Clerk or appropriate official,

I would like to file a (insert name of state records request).

I am looking for town wide climate change adaptation or resilience plans and preparations. Climate change adaptation is the effort to prepare for the coming effects of climate change. Climate adaptation could also be called climate resilience. This differs from climate change mitigation which is the effort to slow the release of greenhouse gas emission into the atmosphere. The plans can be in any form including, but not limited to an initiative, regulation, resolution, framework, or assessment. The plan can come from any department. They can include adaptation and mitigation strategies if both are present.

I plan to use this information to write my graduate thesis and not for commercial

Figure 8: Copy of standard information request.

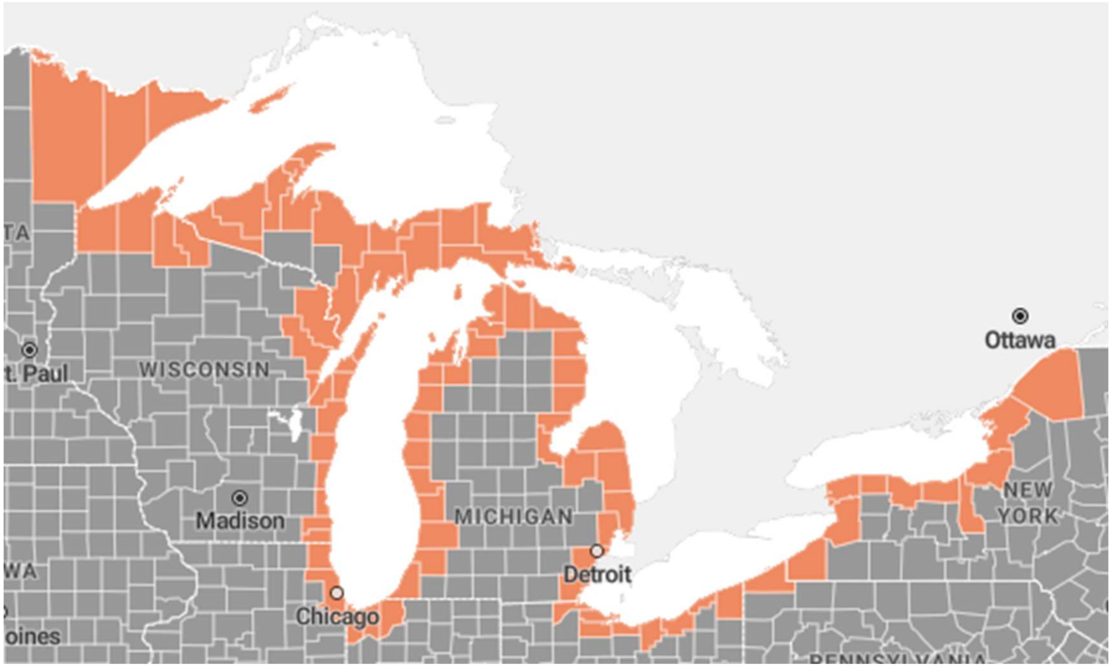

Figure 9: Counties that received information requests for this study

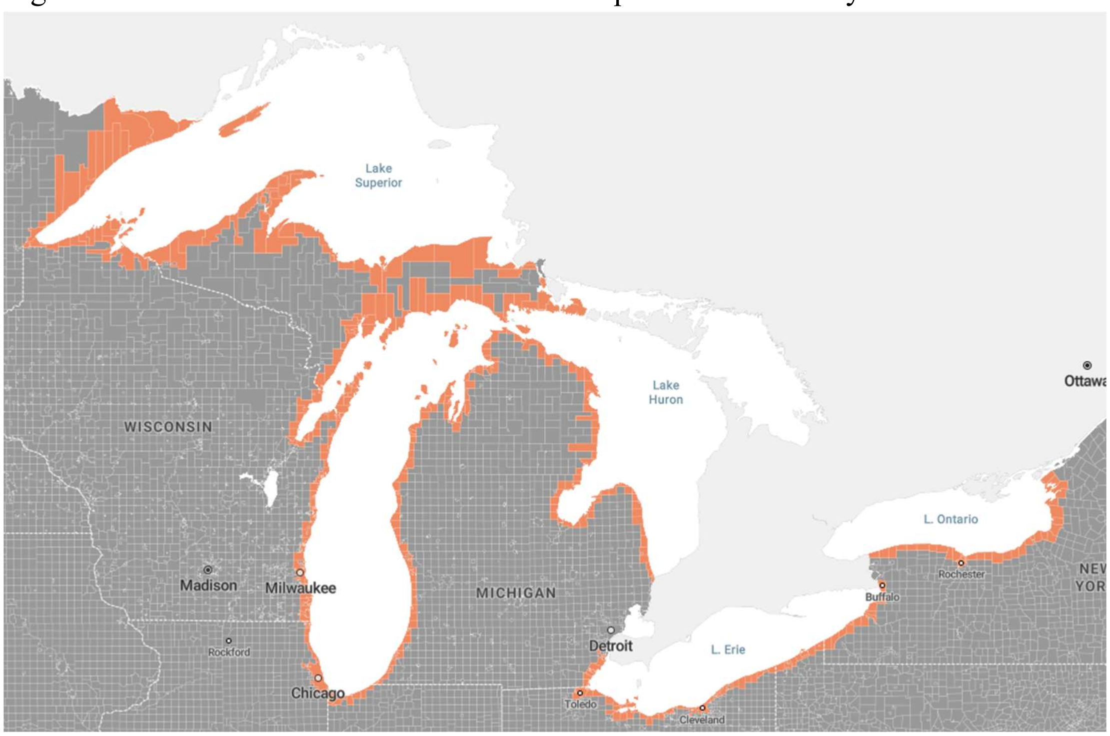

Figure 10: Municipalities that received information requests for this study

Table 3: Local government climate Adaptation Policy and Population Data

Local Government Climate Policy Data						
Government	**Type**	**State**	**Policy Type**	**Policy Date**	**Climate Document?**	**Population**
Chicago	City	IL	Climate Action Plan	2008	Yes	2,718,555
Evanston	City	IL	Climate Action and Resilience Plan	2018	Yes	75,157
Ashland	City	WI	Land and Water Resource Management Plan	2020	No	7,963
Baileys Harbor	Town	WI	Comprehensive Plan	2012	No	1,059
Sturgeon Bay	City	WI	Comprehensive Plan	2020	No	8,907
Superior	City	WI	Hazard Mitigation Plan	2020	No	26,346
Shorewood	Village	WI	Conservation Committee Agenda	2021	No	13,344
Racine	City	WI	Comprehensive Energy Plan	2020	No	77,576
Grand Marais	City	WI	Climate Action Plan	2019	Yes	1,201
Lakewood	City	OH	Resolution	2019	Yes	50,553
Toledo	City	OH	Climate Change Vulnerability Assessment for Stormwater	n/a	Yes	278,193
Sodus	Town	NY	Climate Smart Communities Pledge Resolution	2015	Yes	8,116
Williamson	Town	NY	A Work Session of the Town Board	2015	Yeos	6,772
Baraga	Township	MI	Master Plan	2017	No	3,671
Bridgman	City	MI	Master Plan	2020	No	2,534
Hancock	City	MI	Master Plan	2018	No	4,577
Marquette	City	MI	Master Plan	2018	No	20,932
Marquette	Township	MI	Climate and Health Adaptation Vision	2020	Yes	3,921

Pere Marquette	Township	MI	Shoreline Land Use and Resiliency Plan	2021	No	2,557
Grand Haven	City	MI	Coastal Resiliency Report	2017	No	10,974
Grand Haven	Township	MI	Coastal Resiliency Report	2014	No	16,625
South Haven	City	MI	Master Plan	2021	No	4,341
Sebewaing	Village	MI	Resiliency Plan	2017	Yes	2,786
Cook	County	IL	Proposed Resolution	2019	Yes	5,223,719
Marquette	County	MI	Climate and Health Adaptation Guidebook	2018	Yes	66,939
Cook	County	MN	Lake Superior North: One Watershed, One Plan	2017	No	5,311
Lake	County	MN	Lake Superior North: One Watershed, One Plan	2017	No	10,569
Marinette	County	WI	Marinette County Natural Hazards Mitigation Plan	2020	No	40,537
Ozaukee	County	WI	Ozaukee County Hazard Mitigation Plan Update	2020	No	88,284
Racine	County	WI	Racine County Hazard Mitigation Plan Update	2017	No	195,398
Kenosha	County	WI	Kenosha County Hazard Mitigation Plan	2017	No	168,330
Ashland	County	WI	Ashland County Land and Water Resource Management Plans	2020	No	15,712
Bayfield	County	WI	Bayfield County All-Hazard Mitigation Plan	2020	No	14,992

Table 4: The number of times each climate impacts was mentioned by type each type of local government

Climate Impact	County	City	Township	Town	Village
Air Temperature	270	616	80	3	2
Heat Waves	55	223	8	1	2
Air Quality	129	38	22	2	1
Agricultural Pests	7	29	5	0	0
Growing Seasons	16	25	4	0	0
Shifting Landscapes	47	24	0	0	1
Shifts in Phenology	11	6	0	0	0
Run-off and Soil Erosion	85	106	41	2	2
Lake Temperature and Ice Cover	84	79	4	0	0
Algal Blooms	11	13	1	0	0
Invasive Species Establishment	22	44	14	2	1
Air Quality	0	0	0	0	0
Lake Stratification	0	5	0	0	0
Lake Hypoxia	0	1	0	0	0
Altered Fisheries	17	31	38	2	2
Shipping Seasons	0	4	0	0	0
Shoreline Erosion	29	30	14	0	0
Shifts in Phenology	0	0	0	0	0
Precipitation	358	393	132	3	4
Flooding	299	212	91	1	11
Streamflow	2	50	0	0	0
Soil Moisture	9	16	0	0	0
Lake Levels	122	132	12	0	5
Reduced Shipping Capacity	4	1	0	0	0
Reduced Hydropower	2	3	0	0	0

Wetland areas	58	4	26	1	0
Water Supply	15	7	7	0	0
Loss of Shoreline	41	13	0	0	1

Table 5: Inductive content analysis topics and number of mentions

Inductive Content Analysis Topics					
Seasonality	620	Housing	47	Surface water damage	12
Forest	257	Vector-borne diseases	44	Institutions	11
Recreation	161	Evaporation	40	Pollution	11
Extreme weather	147	Food	39	Tourism	11
Storms	142	Ozone	37	Technology	11
Vulnerable population	139	Tornadoes	36	Storm surge	10
Emergency response	135	Power	34	Phytoplankton	10
Fire	131	Watershed	30	Waste management	9
Habitat	117	Air conditioning	27	Downscaled	8
Transportation	116	Frozen ground	26	Water resources	7
Infrastructure	106	Development	26	Water distribution system	7
Agriculture (crop damage, crop yields)	92	Schools	25	Beaches	7
Drought	83	Quality of life	25	Land management	6
Community	82	Emissions	23	Growing degree days	6
Respiratory problems	76	Permeable surfaces	22	Zoning	6
Waves	75	Bluffs	21	Sustainability	6
Inland water (streams, rivers, inland lakes)	72	Groundwater	20	Labor	6
Population	71	Land use	20	Species	5
Property (value, loss, damage)	70	Hardiness zones	18	High elevation	4
Plants/ vegetation	65	Humidity	16	Fog	4
Ecosystem	64	Urban areas	15	Animal heat stress	3
Utilities	63	Industry	15	Natural systems	3

Stormwater	60	Coastal Conditions	14	Ramifications of climate impacts	2
Wildlife	56	Hydrologic cycle	14	Midwest and Appalachia	2
Water quality	54	Conservation	13	Human migration	2
Human/ public health	50	Resource management	13		
Economy	50	Adaptation	12		