



Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: [www.elsevier.com/locate/jglr](http://www.elsevier.com/locate/jglr)

## Trying hard to adapt to a chaotic world: How complex challenges overwhelmed best intentions<sup>☆</sup>

Christopher J. Orr<sup>† a</sup>, Kathleen C. Williams<sup>† b,\*</sup>, Katrina L. Laurent<sup>c</sup>, Kathryn B. Friedman<sup>d</sup>, Gail Krantzberg<sup>e</sup>, Donald Scavia<sup>f</sup>, Irena F. Creed<sup>c</sup>

<sup>a</sup> Department of Agricultural & Environmental Sciences, McGill University, Macdonald Campus, Quebec H9X 3V9, Canada

<sup>b</sup> Department of Geography, University of Wisconsin-Milwaukee, Milwaukee, WI 53201, USA

<sup>c</sup> Department of Biology, Western University, London, Ontario N6A 5B7, Canada

<sup>d</sup> University at Buffalo Regional Institute, State University of New York, Buffalo, NY 14203, USA

<sup>e</sup> Centre for Engineering and Public Policy, McMaster University, Hamilton, Ontario L8S 4L7, Canada

<sup>f</sup> School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI 48109, USA

### ARTICLE INFO

#### Article history:

Received 26 October 2013

Accepted 3 May 2014

Available online xxxx

Communicated by William D. Taylor

#### Index words:

Climate change adaptation

Environmental policy

Grassroots organization

Sense of place

Social transformation

### ABSTRACT

In this future, citizens of the Great Lakes-St. Lawrence River basin recognize their dependence upon and became united around a common vision for a thriving Great Lakes basin. However, in 2063 the environment and economy are out of balance; citizens are constantly forced to make difficult trade-offs. Climate warming, geopolitical pressures such as environmental refugees, an aging population, and a sluggish economy have overwhelmed the region's efforts to find a balance that would have ensured human prosperity without diminishing the integrity of the Great Lakes basin. This narrative illustrates the time period 2013 to 2063, depicting how the collision of multiple drivers of change cause declining social and environmental conditions, and force a gradual transformation in societal values. While society was initially complacent, the groundwork for social transformation was laid over three decades. Impacts of education programs, opposition to environmentally degrading natural resource extraction, and widespread effects of both failing social services and physical infrastructure galvanize grassroots mobilization of communities around "iceless hockey rink" meetings. These meetings act as a catalyst, translating this social movement into governance that works towards a common vision based on shared values. However, despite innovative technologies and cohesive efforts, it becomes obvious that attempts to oppose the complex and interrelated forces driving changes in the Great Lakes region are limited. These efforts come at huge economic costs, and the harsh reality forces people in the region to make difficult decisions that threaten some facets of economic, social and environmental well-being while protecting others.

© 2014 International Association for Great Lakes Research. Published by Elsevier B.V. All rights reserved.

### Introduction

The Great Lakes-St. Lawrence River basin is of vital importance to millions of Canadians and Americans because it provides for their social and physical well-being. However, planning for the future is challenging because envisioning future conditions is complex and uncertain. Scenario analysis provides a structured approach to explore highly uncertain future conditions through plausible narratives (Schwartz, 1996). Narratives that describe scenarios allow readers to suspend their disbelief in alternative future conditions and enable them to consider how

present decisions may affect the future. Careful consideration of these decisions and their potential long-term impacts enables us to better formulate informed and effective policies. The purpose of this future history is to present one of four plausible scenarios of the Great Lakes region from 2013 to 2063 as part of a collaborative process to inform policy.

This future history, "Trying Hard to Adapt," represents the scenario that occupies the lower-right quadrant of a two-dimensional coordinate plane, with the horizontal x-axis representing the human capacity for change and the vertical y-axis a balanced environment and economy (Laurent et al., in this issue). We present a plausible narrative of how the Great Lakes region came to be characterized by a strong imbalance in the desired mix of environmental and economic conditions, while society in 2063 is able to adapt, having developed a strong human capacity for change. Imbalance between the environment and economy, as defined by society, manifested in diverse ways throughout the region: society is degrading ecological services, it is trying to improve environmental conditions by limiting economic growth, or both socioeconomic

<sup>☆</sup> The Great Lakes Futures Project brought together graduate students and expert mentors from universities and institutions in Canada and the United States. Each paper required collaboration between a number of authors with many of them sharing co-leadership that we denote using a †

\* Corresponding author at: Department of Geography, PO Box 413, Milwaukee, WI 53201-0413, USA. Tel.: +1 414 303 3078.

E-mail address: [kcw2@uwm.edu](mailto:kcw2@uwm.edu) (K.C. Williams†).

and environmental conditions are relatively degraded. This narrative illustrates the social and environmental transformation experienced by residents of the Great Lakes region in five chapters.

### Scenario overview

The global context within which the Great Lakes region is situated evolved rapidly in the 50 years since 2013; human civilization needed to be agile and adaptable to keep up. Globally, climate change and human actions wreaked havoc on the world. In 2063, a struggling global economy is only one of many worries. Global sea levels rose and extreme events devastated several major coastal cities, inundating the Great Lakes region with environmental refugees. Poor living conditions and a lack of basic needs, such as food and clean water, have exacerbated geopolitical tensions and contribute to instability in an interconnected world. Global society has risen to these challenges. A restructured United Nations (UN) created the United Nations Environment Organization (UNEO), endowing it with the necessary capacities and institutional structure to initiate unprecedented global cooperation and action, something its predecessor had been incapable of achieving (Ivanova, 2005). However, these efforts have not been enough to resolve social pressures from increasing population and consumption or to allow peoples of the world to find a balance that will ensure human prosperity without diminishing the integrity and vibrancy of the world around them.

Within the Great Lakes region, citizens have been desperately trying to address economic and environmental problems in a rapidly changing regional and global context. They have been constantly trying to adapt to their changing social and physical context, but have been faced with new challenges much like the mythical Sisyphus, who was cursed to push a boulder up a hill only to repeat his toils when it would roll back to the bottom (Camus, 1955). The Great Lakes region has remained vulnerable to geopolitical, economic, demographic and climate pressures. Citizens have been unable to balance economic activity and environmental integrity within natural constraints, despite strong political will and human capacity to effect change. Citizens have been trying hard to adapt to environmental and economic changes, but the reality is that they have not been able to keep up (Fig. 1).

In this scenario, the year 2063 is characterized by a strong human capacity for change. Governments and stakeholders on both sides of the border support a binational vision of a healthy Great Lakes basin, recognizing it as the region's life support system and source for both social and economic prosperity. The result has been strong implementation of policies that further this vision. All levels of authority in both countries approach governance of the Great Lakes basin from the perspective of maintaining the ecosystem services that the lakes provide for society's physical, cultural and spiritual sustenance, rather than merely as a resource to be used and consumed for shipping, power generation, commercial fishing, agriculture and consumptive uses. Having learned from past difficulties implementing policies, the US and Canadian governments developed a cohesive approach to Great Lakes basin governance based on the need for adaptation strategies. These efforts were responsive to citizen demands, incorporating extensive consultations with local, tribal, and provincial governments.

While governance capacity has grown and matured, the economy and environment have remained out of balance. In 2063, large shocks to the economy and environment threaten to cause the entire socio-ecological system to sink further into a degraded state. Climate warming and human impacts have caused water level and growing season changes, accompanied by an explosion of invasive species (Appendix A). Degradation of the environment has created feedbacks that stress both the economy and the environment. Population pressures and increasing consumption have continued to exacerbate an already unbalanced system while technological and economic fixes have remained futile. Dedicated funding and careful planning have been insufficient for the plethora of new problems that continually emerge. These problems include the costs of adapting to the impacts

of climate change, which have been immense and have drained the economy. Severe floods and droughts, the disappearance of reliable winter snows, the drying up of harbors, and outbreaks of disease have impacted many economic sectors and features of life in the Great Lakes region. Changes have been too great and too rapid for human efforts to keep pace.

### Scenario narrative

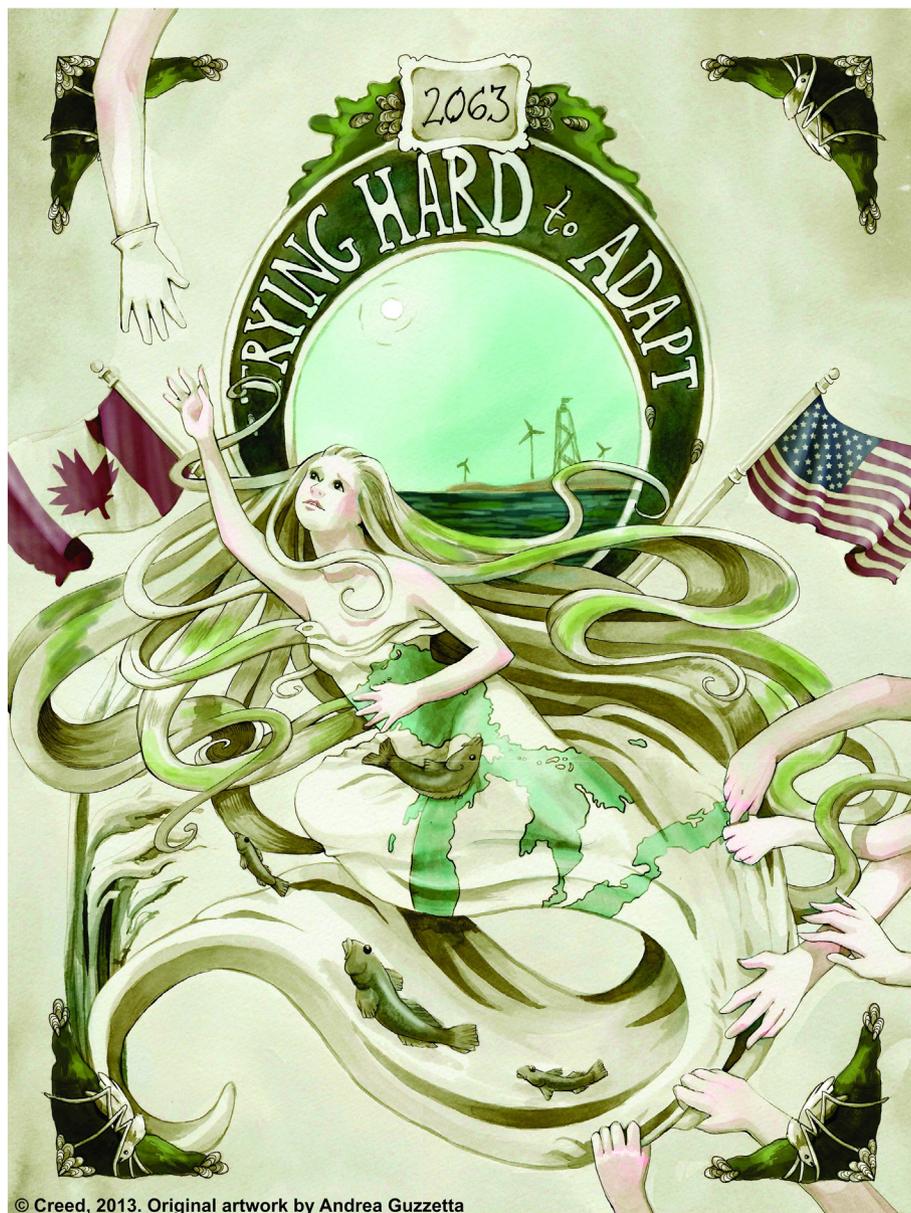
*Cracks in the foundation: how the Great Lakes region's early warning systems failed (2013–2023)*

"If you drop a frog in a pot of boiling water, it will of course frantically try to clamber out. But if you place it gently in a pot of tepid water and turn the heat on low, it will float there quite placidly. As the water gradually heats up, the frog will sink into a tranquil stupor, exactly like one of us in a hot bath, and before long, with a smile on its face, it will unresistingly allow itself to be boiled to death." – Quinn (1996, p. 258)

From the perspective of the year 2063, some might ask how we ended up in the world we live in today. Why did we not clue into what was to come fifty years ago? The answer to the second question provides some insight into the first: in 2013, we recognized that there were many problems, but we did not recognize their full extent, their interconnected nature, or the need to act. Politicians remained reactive, refusing to make policies to anticipate problems and prevent them. We kept hitting the snooze button in spite of the subtle signs of change that were all around us.

Citizens of the Great Lakes region ignored symbolic landmarks along with the rest of the world, including when the global population surpassed seven billion people and atmospheric CO<sub>2</sub> levels surged past 400 parts per million (NASA, 2013; PRB, 2012). Meanwhile, Earth's sixth mass extinction loomed like a foreboding cloud over many of the planet's diverse ecosystems, including the Great Lakes native fisheries, which threatened to disappear forever (Barnosky et al., 2011; Worm et al., 2006). Unsettling alarm bells kept going off, one after the other, but it always seemed as though we could get things back under control. For example, 2013 was a good year for maple syrup and wild rice causing us to quickly forget that both had failed in 2012 (Myers, 2012; WZZM, 2013). West Nile Virus was repeatedly found throughout the southern Great Lakes region, but was largely ignored because it affected birds far more than humans (Githeko et al., 2000; OSUE, 2008). Some places enjoyed extended skiing seasons only to be forced to plant crops a month late as a result of unseasonably late snows (Curtis, 2013). In 2017, lake water levels hit record lows for the second time in a decade (Fig. 2). Local governments began lobbying the International Joint Commission to implement a solution, although they failed to agree on what that solution should be (GLSLC, 2013). Shoreline property owners were inconvenienced but inactive, as *Phragmites* invaded the shores of the Detroit River, Georgian Bay and Green Bay, obstructing views and lowering their property values. Meanwhile, lake water levels retreated and beaches were exposed. Each time we hit the snooze button. Each time we went back to sleep.

Citizens remained unengaged while governance in the Great Lakes region was left fragmented and complacent. Although well-crafted policies held promise to protect the Great Lakes region's water resources, unfortunately, the care and attention that went into crafting policies were not translated into policy implementation. The political sensitivity and potential for failure of key policies such as the Great Lakes-St. Lawrence River Basin Water Resources Compact (the Compact) and the Great Lakes Water Quality Agreement (GLWQA) were overlooked or ignored until crises became apparent (JJC, 2012; USFC, 2008). For example, the first challenge to the Compact was an application for a water



© Creed, 2013. Original artwork by Andrea Guzzetta

**Fig. 1.** Citizens have been trying hard to adapt to environmental and economic changes, but the reality is that they have not been able to keep up. Original artwork illustrates the “trying hard to adapt” scenario for the Great Lakes-St. Lawrence River Basin in the year 2063.

diversion from Waukesha, Wisconsin submitted in 2013. Although it met the requirements for a diversion of water out of the Great Lakes basin, the issue became highly politicized and polarized. US governors who wanted to protect the region opposed the application for diversion, while others interpreted its rejection as an assault on economic growth. Polarization over the decision to not approve the diversion fomented political conflict over resource use in the Great Lakes region, resulting in negotiations that lacked political support and legitimacy.

Meanwhile, to implement the 2012 GLWQA, both national governments relied on competitive strategies such as the Great Lakes Guardian Fund and the Great Lakes Restoration Initiative to finance restoration projects in Canada and the US, respectively (Ontario Ministry of the Environment (OMoE), 2010a; USFG, 2010). The number of requests for funds far outstripped the amount of funds available, pitting communities and institutions against each other and contributing to the uneven restoration of the Great Lakes basin (Lemos and Agrawal, 2006; USEPA, 2013). Increased production of commodity crops was fuelled by demand for ethanol from corn as well as heightened global food prices. As a result, agricultural pollution began to stress the water quality of the

lakes. Fragmented US agricultural policies further exacerbated problems of water quality. As early as 2015, provisions for funding conservation practices for farmers, including conservation easements, set-asides, and other measures were dramatically reduced. The result was the increased tillage of land in sensitive areas, leading to increased nutrient loading of lakes and large algal blooms in Lake Erie. Dead zones in Lake Erie increased and reached beyond near-shore areas to cover over 775 km<sup>2</sup> (Hunt, 2013; NOAA, 2013). Ironically, on the Canadian side of Lake Erie, conservation authorities had begun implementing best management practices to control nutrient loading, but suffered closed beaches despite their efforts. This example demonstrates how environmental policies that impacted the same resource had become incongruent. US agricultural policy had reduced funding for land and water conservation, while the Government of Ontario had increased funding. Both policies impacted Lake Erie, but their effects were counterproductive, resulting in deteriorated water quality in the Great Lakes region.

While the US and Canadian governments struggled to manage environmental problems and maintain fish stocks, indigenous peoples set an

alternative example of how to manage our relationship with nature according to traditional methods that balanced human and environmental health rather than solely pursuing economic growth. By the beginning of the 2020s, Native American and First Nations communities had begun more consolidated and focused resistance to mineral extraction and conventional fisheries management practices. This resistance was based on spiritual tradition, scientific evidence, and lessons learned throughout the last decade. For example, in Northern Wisconsin near Lake Superior, a mining dispute prompted the collection and documentation of endangered plants and animals, as well as extensive wetland mapping (SWE, 2013). Much of this data, collected by biologists from Native American tribes, as well as conservation officers and scientists, was widely and publicly disseminated. Another example that spurred this movement was when First Nations on the eastern side of Lake Superior legally challenged the Canadian government on their water management practices and the resulting loss of fisheries (SooToday.com Staff, 2013). These efforts introduced different ways of thinking, demonstrating alternative approaches to resource use (contrary to resource exploitation for economic gain), as well as resource management strategies for long-term rather than short-term benefit (Appendix A).

These initiatives, combined with extensive outreach and education activities, began fostering a shared identity, as well as a social connection to, and engagement with the Great Lakes as a region. NGOs, educational institutions and activists initiated a broad array of educational efforts to engage citizens of all ages. Initiatives ranged from birding and canoe trips to projects that engaged citizen scientists. Education efforts initiated through university partnerships used education to connect students to their waterways and develop capacity in teachers. Place-based education, a pedagogical approach, provided an avenue for citizens to learn about their watersheds through experience, creating understanding of, and emotional attachment to, the Great Lakes basin (Semken and Freeman, 2008). These efforts used streams and lakes as classrooms, engaging students to ask questions, collect data and present results (Fig. 2). Other educators worked in communities to bring people to their rivers through trips, lectures and citizen science training. These experiences laid the early groundwork for more widespread changes to come.

#### *Rude awakening (2023–2033)*

“Our complete negligence has been matched only by our ignorance. We have sat idly by while the walls of our home have crumbled around us. Only when drops from above dampen our mood do we glance skyward and realize that the roof is also gone.” — Winter Boisvert, Green Party of Canada 2032

The 2020s saw the collision of multiple forces and resulted in a rude awakening for citizens of the Great Lakes region. They woke up almost scalded to death, like the metaphorical frog in a pot while the heat is slowly turned up. A morass of climate change, environmental crises, demographic transition, and geopolitical pressures combined in a melting pot of disaster throughout the 2020s. For example, scientists could only watch, slack-jawed in horror during the summer of 2024 as the Arctic sea ice completely melted (Derksen et al., 2012; Fig. 2). Melting permafrost in Canada's north sent environmental refugees trickling south, as traditional native lifestyles became unviable. The Great Lakes region became one of the main destinations for those displaced within North America and from abroad. Many tried to settle in and around Lake Ontario, hoping to find employment. The economy, not yet fully recovered from the recession during the 2010s, provided few refugees with desirable jobs and local residents did not welcome increased competition for employment. At the same time, there were no provisions in the Canadian Immigration and Protection and US immigration laws to provide for environmental refugees that entered from abroad. Refugees

and governments were forced to navigate these challenges to ensure newcomers were able to integrate. While immigration policy in the 20th Century was based on economic opportunity, immigration in the 21st Century came to be based on environmental conditions such as the availability of clean water and a temperate climate (Appendix A).

Meanwhile, aging baby boomers retiring in droves became an increasing drain on the economy. A flood of retirees strained pension and healthcare systems (Echenberg, 2012; SC, 2013). As increasing numbers of individuals grew older, they began filling retirement housing beyond capacity; the Great Lakes region had failed to plan for such a large wave of retirees. At the same time, insufficient pensions and savings forced many of traditional retirement age to continue working. Expectations that high retirement rates would liberate jobs for younger generations had been overestimated as those reaching retirement age were forced to continue working to support themselves. With ominous rumblings, these examples heralded the enormity of the problems that the Great Lakes region was not prepared to face.

Governance in the Great Lakes region was particularly unprepared for the extent, the interconnectedness and the complexity of the problems it faced. Its inability to adequately deal with these problems was rooted in policy failures that haunted it from the past. Decision-makers assumed that existing policies, including the GLWQA, the Clean Water Act, and the Canada–Ontario Agreement Respecting the Great Lakes basin would be enough to protect the lakes (IJC, 2012; Ontario Ministry of the Environment (OMoE), 2006; Ontario Ministry of the Environment (OMoE), 2010b). However, continued divergence of Canadian and US policy directions, as well as divergence between each country's own levels of government, left voids in responsibility. For example, revisions to the Canadian Fisheries Act reflected a national retreat from waterways protection, while the Great Lakes Guardian Fund demonstrated Ontario's commitment to remediation and habitat restoration in the basin (GC, 2013). In the US, the Great Lakes Restoration Initiative demonstrated the federal commitment to habitat restoration, while several states gutted their environmental protection laws. These divergences between policies, combined with a lack of resources, meant that policies such as the Compact acted as legal shields, allowing inaction by appearing to address a need that they were incapable of fulfilling.

Multiple interrelated factors caused the failure of the Compact, which in turn caused cascading impacts. Starting in 2026 and continuing into the 2030s, global food prices were pushed high in response to global shortages and drought in Central and South America. Combined with warmer growing conditions, agricultural production and export became increasingly profitable across the US and in Canada's prairie provinces. However, continued withdrawals from aquifers across North America led to increasing water shortages and conflicts in the Great Plains states and provinces. Economic and political pressures to export water to these areas mounted. Although the Great Lakes Compact had protected the lakes from water exports until then, the economic case to export water to thirsty states that once relied on the Ogallala Aquifer became too strong to not pursue (Fig. 2). The Canadian government, infuriated by the sale of a shared water resource, restricted its sale of some mining products to the US, precipitating a crisis in many industries. Failure of the Compact meant not only falling lake water levels but also strained trading relationships through deliberate violation of international trade agreements.

Erratic and extreme weather events – floods and droughts – placed increasing pressure on agricultural systems and infrastructure. Changes in the US Farm Bill meant that riparian buffers of the past were long gone. Erosion and nutrient loading into Lake Erie from the US overwhelmed the effects of best management practices being implemented in Canada. Decreased lake water levels, accompanied by increases in periodic rainfall and warmer temperatures, meant the continued re-emergence of the anoxic region in Lake Erie every August. Algal blooms of 300–1000 km<sup>2</sup> became common, making it increasingly expensive to treat water in the western Lake Erie basin. Unable to

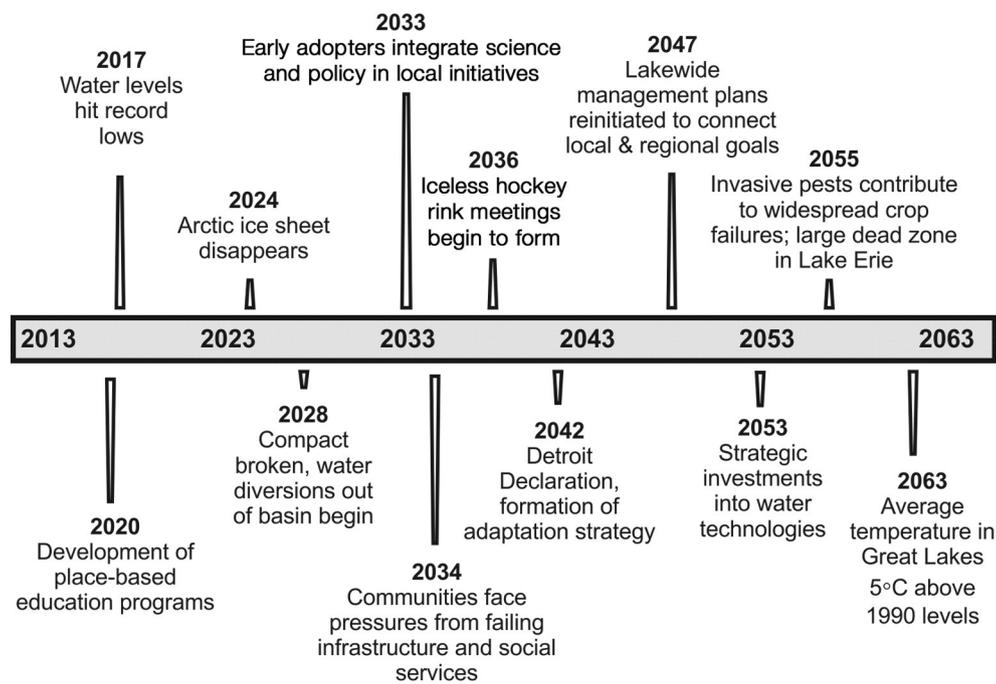


Fig. 2. Time line of the events occurring from 2013 until 2063 within the Great Lakes-St. Lawrence River basin under the “trying hard to adapt” scenario.

handle increased demands on their infrastructure, several cities' water treatment and supply systems failed, requiring boil water advisories.

Inadequate funding, monitoring, and regulation exacerbated problems of integration and accountability. For example, the breeding population of Asian carp that started reproducing in the tributaries of the Sandusky River in the early 2010s went unaddressed in the Great Lakes basin, becoming more established as state and federal agencies wrestled with questions of accountability. The US federal government priority for keeping navigable waterways open clashed with individual state desires to prevent the invasive fish from spreading further in the lakes. Once introduced, lack of clarity on state, provincial and federal government roles and responsibilities delayed decisions and actions to address the problem. Delay of political action allowed time for the fish to establish a breeding population.

As if sensing such widespread governance failure, and responding to the rapid deterioration of the Great Lakes basin before their eyes, there was an emergence of local engagement. Communities experienced a ‘quiet revolution,’ a further shift towards building community capacity, and recognition of the dependence of both ecosystems and society on the Great Lakes region, as well as the rivers that flow into them. These changes were driven by pull factors, such as indigenous-community partnerships that had emerged during the previous decade, as well as push factors, such as the loss of social and municipal services. Citizens began to re-examine their assumptions about the roles of state and citizens, paying closer attention to their own obligations. In many instances, municipal infrastructure had deteriorated, while funding cuts to services affected most citizens. Community volunteer groups performed stewardship, adopting parks and natural areas that had been suffering from decades of systematic under-funding. This movement, having started in isolated pockets earlier in the 2000s, gathered momentum as municipal resources evaporated. Where floods had occurred, neighbors donated time and labor, repairing homes in their communities house by house. Volunteers began contributing to experiential education programs, and networks increasingly connected people with their watersheds and neighborhoods, fostering the creation and sharing of local knowledge. Many of the services that citizens had relied on governments to provide became crowdsourced, fostering

strong community identities as a result (Zook et al., 2010). Citizens of the Great Lakes region recognized that their former connections to communities, embedded in public spaces and natural areas such as parks and the lakes, were being lost.

#### *A movement materializes: love for the Lakes (2033–2043)*

“It took us a while to clue in. When we couldn't make an outdoor skating rink anymore, it seemed to hit home. Suddenly, everybody and their neighbor got the picture. That's when the iceless hockey rink meetings started spreading like wildfire, and before you knew it we had a movement on our hands.” – Marguerite Bloom, community organizer, Cleveland 2040

In the 2030s, changes to the Great Lakes themselves – most notably the reduction of ice cover, increasingly erratic changes in lake water levels, and more frequent storms – became more visible to the citizens, municipal governments, and policy makers in the Great Lakes region. However, existing policies were inadequate to deal with the web of interconnected problems.

Disaster relief and responses to climate catastrophes boosted global and local economies. Contractors, consulting engineers, and disaster aid organizations received increased financing as a result of frequent flooding that constantly needed government intervention, but in truth no one was better off (Strömberg, 2007). Infrastructure was repaired, but costs were too high, and insurance companies began to limit their coverage. Losses became great. Homeowners, especially those who had built on floodplains and in locations once thought to be safe distances from the flooding, were left vulnerable and reliant on limited disaster relief provided by governments. Policy-makers continued to pander to specific economic interests rather than meet the needs of citizens, using scarce resources for infrastructure projects that favored industry and business needs.

As the climate warmed, the effects of climate change became visible in many places within the Great Lakes region. For example, Madeline Island, Wisconsin could no longer depend on the ice road which had been

a vital transportation route connecting Madeline Island to Bayfield, Wisconsin on the mainland. At the same time, education initiatives, such as the extensive outreach programs run by the National Parks Service in the Apostle Islands, helped residents along Lake Superior begin to understand the mechanics of climate change and what it would mean to them. Changes that would affect residents directly were made apparent: their dependence on seasonal activities would continue to change, coldwater fish species would likely decline, and the magnitude of changes would have significant economic impact (WICCI, 2011). For example, winter activities that had made up a large portion of some communities' economies threatened to virtually disappear; snowmobiling, skiing, or ice cave exploration were unlikely to be predictable, or profitable in the future (WICCI, 2011).

A few communities were examples that foreshadowed a more widespread transformation in society. These communities began integrating science and policy, and initiating education efforts in attempt to confront the hard trade-offs that they faced. Understanding the mechanics of climate change provided an important basis for making local policies. Communities around Lake Superior turned to arts and cultural resources, bolstering their economies despite the decline in many winter activities that had previously supported them. Communities also advocated increased public funding to upgrade storm water management systems since continued losses, as early as the 2010s, had forced them to consider the necessity of best management practices (Kraker, 2013). In many instances, these early-adopter communities worked with educators or were inspired by the efforts of aboriginal groups.

In other parts of the lakes, communities took longer to start discussing how to adapt to climate change. Around Lakes Michigan and Huron, climate change was most obvious in the form of increasingly unpredictable lake levels, as a result of more extreme precipitation fluctuations (Maghrebi et al., in this issue). In some years, boaters could not reach their docks because water levels were too low, while in others they sustained boat and pier damage because of high water. However, the most vocal interests were cottagers along the north shore of Lake Huron who wielded limited political force compared to other economic interests. As a result, policy-makers were slow to act. When initiated, discussions failed to connect lower lake levels to climate change and decisions were not based on a collective understanding of science.

At the eastern end of the Great Lakes region, around Buffalo, Hamilton and Toronto, more waves of environmental refugees inundated the region. By the beginning of the 2030s, global sea level had risen more than 0.2 m and places such as the Maldives and Bangladesh were forced to initiate large-scale relocations. More melting permafrost in Canada's north had similar effects, increasing pressures on urban infrastructure, local economies and social services. Discussions on what to do with environmental refugees became heated.

These problems became so widespread that they affected every community across the region; they could no longer be ignored (Fig. 2). In truth, there was no single catastrophe - just a series of small ones on every lake. Lake Superior lost or experienced reduced ice cover, winter recreation was compromised, and coldwater fish populations declined; Lakes Huron and Michigan experienced increasingly unpredictable water levels, resulting in exposed beaches and increased shoreline erosion, the loss of waterfront properties and declining property values; algal blooms led to a ban on boating and fishing in Lake Erie; and Lake Ontario faced population pressures and increases in consumptive water use.

Throughout the Great Lakes basin, biodiversity declined and the character of the landscape slowly changed. Wetlands that once consisted of diverse plants had become seas of garlic mustard and multiflora rose. Exposed shallow bays became infested by large stands of *Phragmites*. The tall reeds grew thick, blocking both views of and access to the lakes. Coldwater fish species in Lake Superior, such as siscowet lake trout, were slowly becoming less numerous, while the

populations of warmer water species, such as lean lake trout and wall-eye, increased (Cline et al., 2013). Native biodiversity was greatly reduced by pressures from climate change and pollution. While citizens had adapted to changes in their environment, they sensed that the character of the region had changed. Native species had contributed to the vitality and vibrancy of the Great Lakes region, and residents' sense of place within it.

We often do not recognize our attachment to a place until it is threatened or lost (Williams and Stewart, 1998). This happened in the Great Lakes region. The region had changed to the point where citizens felt that they were losing it. The parks, ponds, and community spaces where people met had become nearly unrecognizable. Iceless hockey rinks came to symbolize the loss of lake and landscape, love of the lakes, and a desire to act to protect them.

During the winter of 2036, outdoor rinks did not freeze along the southern shores of Lakes Ontario and Erie (Fig. 2). Meanwhile, hockey rinks in several small communities along the shores of Georgian Bay and Lake Huron were forced to shut down under tightening municipal budgets. As people began realizing how these changes affected their lives, communities began to coalesce around a common identity and vision. The birthplaces of this common identity and vision were the iceless hockey rink meetings that began in outdoor venues and community centers devoid of ice. Iceless hockey rink meetings were the incubators of a pervasive social transformation that reached into every home across the Great Lakes region. These meetings overcame the limitations of small-scale deliberations because they were integrated into governance networks that linked local and regional scales. Local organizers engaged and mobilized their communities around a common connection to and love for the lakes, communicating local concerns, but also securing commitments to solutions that required difficult trade-offs and local compromises to address both local and regional issues. Organizers gathered observations and ideas from citizens through diverse methods such as talking circles and participatory geographic information systems, and connected to each other through regional associations that aggregated the data to inform policymaking at all levels. The urgency of problems throughout the region meant that regional advocacy groups gained widespread local support and membership, and that members recognized the complex nature of local problems, as well as their connections to regional issues. Leveraging the strengths of advocacy networks and local communities, specific concerns were integrated with those of scientists and experts, and drove support from all levels of government.

This had been a long process through which both Aboriginal and local community groups had built momentum during the 2010s and 2020s. First Nations and Native American tribes had been organized and managing natural resources, nearly invisibly, for many years. Iceless hockey rinks, nurtured by the efforts of native peoples and local community leaders, provided forums to connect a strong network of advocates from both sides of the border. This network included citizens and activists, local governments and businesses, scientists and experts, as well as non-profit and indigenous groups. Intense discussions around community, but also regional planning began in earnest as towns and cities realized that many of the economic activities that had supported their livelihoods in the past had changed dramatically. People across the Great Lakes region acknowledged a need to take action.

Environmental refugees were welcomed into the hockey rink meetings, as well as larger dialogues. Many came from coastal regions and recognized the importance of protecting the lakes as a vital source of their livelihoods. These dialogues helped to integrate them into their new communities and fostered shared values concerning the lakes. This united movement began to pressure policy-makers to create state, provincial, and national policies that would complement, rather than oppose local priorities.

*Turning ideas into actions: all the king's horses and all the king's men... (2043–2053)*

“What is good government? It's the same old government in a helluva fright.” — Speth, *Global Environmental Challenges: Transitions to a Sustainable World* (2004, p.171)

The social transformation of the 2030s drove an evolution in governance throughout the 2040s. Iceless hockey rink meetings were pivotal to the translation of societal values into a transformation of governance, and to the mobilization of both technological and human resources towards its end. As the number of iceless hockey rink meetings grew, the communities strengthened binational networks based on sharing information about social, economic, and ecological conditions, thus developing regional strategies.

Strong pressure from citizens, First Nations and tribal governments, as well as scientific and expert communities, inspired the Windsor–Detroit Summit, which was co-sponsored by the Canadian and US governments, as well as states and provinces. The summit scrutinized key policies, including the GLWQA and the Great Lakes–St. Lawrence River Basin Water Compact for ways to improve governance. Outcomes included the understanding of why past policies failed, namely the lack of political will to implement agreements. Although policies contained good ideas, they lacked proper mechanisms for implementation, including resources such as expertise, funding, monitoring, and enforcement. Fragmented policy that had catered to political interests during the drafting and implementation of some of the original Great Lakes agreements was no longer accepted by the engaged public participating in the process.

The Detroit Declaration (Fig. 2) laid the foundation for a comprehensive ongoing adaptation strategy for the Great Lakes region. The joint US–Canada Great Lakes Adaptation Strategies (GLASS), the series of adaptation strategies under the GLWQA, was initiated in 2047. Loadings of nutrients, metals, and toxic substances into the environment, such as mercury, were virtually eliminated under GLASS. Unlike earlier agreements that had included the reduction of contaminants of mutual concern, GLASS also included enforcement mechanisms, which gave it the teeth that earlier policies had lacked.

GLASS built on the strengths of earlier agreements. Its use of an ecosystem approach was more clearly defined to focus on ecosystem integrity, recognizing that ecosystems have benefits for society as a whole, rather than just those typically identified by stakeholders. The agreement embraced the heterogeneity of the Great Lakes, renewing the idea behind the Lakewide Management Plans (LaMPs): citizens and stakeholders around each lake would meet annually to share scientific and community learning, creating networks for data collection by engaging citizen scientists (Fig. 2; Hartig and Zarull, 1992). In contrast to the original LaMPs, GLASS redefined the roles of secretariats, articulated goals and implementation targets, required ongoing monitoring and networking, provided funding, and ensured enforcement. The secretariat provided a support function for local governments, including First Nations and Native American tribes, to ensure that they were connected to the resources and information needed to adapt to changing conditions. Secretariats also shared their experience with other communities to facilitate dissemination of knowledge and adaptation strategies.

Governance in the Great Lakes region gained renewed purpose despite continued assault from external forces. Following its restructuring, the United Nations designated the Great Lakes region a “Priority Region for Maintaining Stability.” Recognizing the Great Lakes region's irreplaceable resources, designation was accompanied by funding for climate adaptation initiatives such as GLASS. However, in return for its assistance, the United Nations required the Great Lakes region accept an increased number of environmental refugees. The region faced

increased numbers of immigration applications and pressure to accept refugees, especially from the far north of Canada and the southwestern US. These pressures threatened to overwhelm immigration and social service programs, limited the availability of jobs, increased demand for natural resources, and further taxed infrastructure that was already strained.

Networks, built through the iceless hockey rink meetings and fostered by GLASS, generated partnerships and sparked innovations in communication. Processes that facilitated collective problem definition, solution development and provided a structured series of steps to their implementation began to gain traction in the region. For example, one process involved citizens learning about community development through ongoing study and reflection, the results of which they shared with local governments. Local governments in turn, integrated citizen initiatives into regular operations (James and Lahti, 2004). Iterative processes based on mutual learning enabled improved citizen–government dialogue and allowed corporate businesses to better contribute to policy development and implementation of adaptation initiatives. In these ways, GLASS provided a forum for shared learning that sparked cross-sector innovation. Through the development of this model of adaptation strategies and the creation of forums for learning, the Great Lakes region directed investment to develop technologies that would help meet collective needs.

Collaborations attempted to address simmering challenges that were symptoms of the imbalance between the economy and environment. Although coal-fired power generation was completely phased out and green energy manufacturing was being rejuvenated, the region remained dependent on oil and natural gas from hydraulic fracturing. Sale of water out of the Great Lakes basin was stopped as a result of GLASS, but the region suffered from the loss of potential revenue. Finally, construction began on a binational high-speed rail from Montreal to Chicago in 2049, intended to significantly increase trade and tourism in the region, and help cope with rising gasoline prices. Through governance driven by a mobilized citizenry, society in the region was attempting to adapt.

*Human hubris: ...couldn't restore the Great Lakes to how they'd once been (2053–2063)*

“We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.” — Aldo Leopold, *A Sand County Almanac* (1948, p. xviii–xix)

Despite our most innovative technology and most cohesive human efforts – all the king's horses and all the king's men – it became obvious that our attempts to oppose the complex and inter-related forces driving change in the Great Lakes region were limited, or outright futile. Citizens of the Great Lakes region were faced with the harsh reality of trade-offs. Social, economic, and environmental conditions within the region had degraded to the point that making improvements to one would often be detrimental to the others. Despite good governance, new problems continued to surface, overwhelming efforts.

Strong human capacity for change gave citizens of the region the tools they needed to adapt to new problems, but not the ability stop them from occurring. Comprehensive community planning incorporated extensive consultations and enabled communities to identify and implement their own solutions to respond to regional and global threats. However, local plans were unable to anticipate or prevent these problems from occurring. These included the collapse of fisheries, lost recreational opportunities, changes in tourist seasons, compromised harbors, spreading diseases, disabling heat waves, and rising energy costs.

One example of the inadequacy of adaptation strategies was the City of Milwaukee. Having lost much of its manufacturing base early on, Milwaukee recognized a need to invest in new industries. The result was a multi-sector cooperation between the city, industry and the university, capitalizing on one of the region's best assets, Lake Michigan (Appendix A). Making strategic investments in water technologies, Milwaukee became a laboratory where green infrastructure solutions were developed, and later disseminated throughout the Great Lakes region. Although Milwaukee was held up as an example of how a vision, combined with partnerships, strategic investment, and research might succeed, the city faced crippling infrastructure problems. Its economy continued to struggle in the face of environmental conditions that progressively deteriorated. Extreme flooding caused extensive damage to sewers, roads and streams. It was impossible to upgrade infrastructure enough to protect water quality or ecosystem integrity.

This pattern of limited success was seen throughout the region. Around Lake Erie, nutrient loading was reduced through novel green infrastructure designs intended to absorb nutrients, but its dead zone persisted because agricultural inputs continued to supplement already high concentrations of nutrients in the lake (Appendix A). Around Lake Ontario, burgeoning invasive fish populations provided low-wage jobs for immigrants from Asia, including the Maldives, Bangladesh, and Vietnam, who had come from fishing cultures and had started their own businesses. Commercial fishing and processing industries resurfaced. However, in other parts of the Great Lakes region, massive fish die-offs prompted the development of an aquaculture industry. Although these changes provided food and limited employment opportunities, in light of declining human prospects and biodiversity losses, the region's vibrancy was diminished.

In other aspects, prospects looked even more dismal. Although agriculture was often thriving in the 2040s as a result of expanded ranges and a longer growing season, by the mid 2050s increased crop yields in some areas were being offset by failures in others. Conditions were aggravated by invasive pest and plant species, which caused widespread crop failures by the end of the decade (Fig. 2). The unpredictability and instability of crops exacerbated nutrient runoff. Eutrophication that had plagued the area since the late 2020s spread like a plague across Lake Erie, with algal blooms that rivaled 2011.

Climate change was undeniably upon us. Extreme events had begun to pummel the region and temperature within the Great Lakes region had increased by nearly 5 °C above 1990 levels (Fig. 2, Appendix A). Almost no winter ice covered the lakes except intermittently on Lake Superior. Still more environmental refugees fled to the Great Lakes region. Across the Great Lakes region, shallow bays and coastal areas dried up, damaging critical marshland habitats (Appendix A). Fish populations plummeted as shallow spawning areas disappeared. Regulations implemented to protect native fish species attempted to prevent overharvesting of the small remaining populations.

Impacts to people were no less severe. Some towns lost access to their harbors and many waterfront property owners complained that water levels dropped so much they were no longer waterfront properties. More frequent heavy storms added to the amount of sediment entering the lakes. Shallow shipping channels and harbors combined with lower water levels resulted in increased dredging costs. Both the shipping industry and coastal communities faced economic hardships because there was less water. One benefit was that lower lake levels exposed beaches, and rising temperatures meant there was a longer summer tourist season. A longer summer tourist season almost compensated for the loss of winter recreation opportunities including skiing, snowshoeing and sledding.

In 2063, environmental, geopolitical, demographic, and economic pressures continue to disrupt and overwhelm the region's best, most ambitious efforts. Numerous problems drain economic resources, while environmental changes continue to impede economic stability, let alone provide for a healthy economy (WB, 2012). While economic

and environmental conditions are not compromised everywhere, the hopeful instances represent a 'silver lining' within a larger picture of a degraded environment and economy, neither of which is able to support the betterment of itself or the other.

## Conclusion

Upon reflection, education measures and adaptation strategies implemented in the 2040s and 2050s were too little too late. The 50 years since 2013 taught citizens of the region that avoiding past mistakes was not enough. Education and policy strategies are not normative; they are effective only insofar as they are guided by moral principles and values. An ethic of compassionate retreat incorporates two considerations: First, we have moral obligations to the home we inhabit, along with respect for what makes that home, not only inhabitable, but a place to cherish. The need for a compassionate approach embodies respect and reciprocity for both human and nonhuman species' needs to survive. Second, within this home, nature has limits, many of which may have already been surpassed (Rockström et al., 2009). An attitude of humility recognizes that we may have already surpassed the limits of nature to provide for human demands and that our only option is to retreat (Brown and Schmidt, 2010). To incorporate an ethic of compassionate retreat, governance solutions should carefully consider the diversity of local, regional, and community problems, embracing the need to weigh both facts and moral considerations (Ostrom et al., 2007; Brown and Schmidt, 2010).

Incorporating values into everyday practices and institutions may have sounded idealistic in 2013. However, values are always embedded in decisions, whether implicitly, or articulated explicitly. Aboriginal culture provides a prime example of how values can be embedded within management practices and daily activities while still adhering to accurate knowledge and understanding of the world. Some First Nation and Native American hunting and fishing practices incorporate moral considerations, including humility towards and respect for nature based on an understanding of how other species provide for their livelihoods (Berkes, 2008). When the values that guide our decisions no longer match our understanding of the world, the ideals of society may be transformed through gradual social movements shaped by many interconnected internal and external forces, as illustrated throughout this scenario.

In this light, it seems obvious that societal values guide governance and implementation. In 2063, people in the Great Lakes region recognize that it is imperative to change, not only their policies and actions, but also the values that define their relationship with nature. Although they possess immense capacity to define how they live on this world, its complexity and uncertainty mean that limits exist to human understanding and control. Acknowledging human limitations requires that they approach this relationship with humility and openness to alternative beliefs, local conditions and local communities, recognizing the needs of both human and nonhuman species alike.

## Acknowledgments

We would like to thank the Transborder Research University Network, the funding Universities of the GLFP, Environment Canada, Michigan Sea Grant and New York Sea Grant. Furthermore, we would like to acknowledge the financial assistance from the Canada Research Chair (950-228034) and Canadian Network of Aquatic Ecosystem Services (417353-2011) grants held by Dr. Creed that funded the original artwork of Andrea M. Guzzetta and the engagement of her staff member J. Miller who assisted in editing this article. We would also like to acknowledge the invaluable contributions of numerous Great Lakes stakeholders who participated in the Great Lakes Futures Project workshops and seminars, as well as the many students involved in the project who provided their comments throughout preparation of this paper.

## Appendix A. Drivers of change

**Table A1**

The state of each driver of change for the Great Lakes region in 2063.

Driver	Description
Aquatic invasive species	Ranges of vector-borne diseases have expanded northwards into the Great Lakes region. Climate stress on native plants has resulted in the invasion of many non-native species. Quagga mussels and Asian carp are prevalent.
Biological and chemical contaminants	Anoxic region caused by nutrient loading persists in Lake Erie. Increased temperatures and extreme weather facilitated accelerated toxin circulation, such as mercury, through the environment.
Climate change	Global surface temperature is + 3 °C above the 1990 levels and in the Great Lakes region the temperature is + 5 °C above 1990 levels, resulting in frequent and intense droughts and floods.
Demographics	Population is 67 million, older and more diverse. Growth is uneven throughout the region. Canadian cities on Lakes Erie and Ontario grew quickly through the immigration of environmental refugees.
Economy	Growth is slow and the economy continues to degrade the environment. Manufacturing, agriculture and services are the most important sectors.
Energy	Demand has increased despite increases in efficiency and diversification of energy sources. Hydraulic fracturing supplies a large proportion of energy; coal was eventually phased out. Renewable energy comprises a greater proportion.
Governance and geopolitics	Binational cooperation and a common vision drive policy. Pressures from environmental refugees and demand to export water are met with binational, cooperative strategies rather than the divergence of policies of the past. All stakeholders are involved in decision-making. Policy integrates public values and is based on science.
Societal values	A vision of a healthy Great Lakes region is based on the recognition of human and ecological interdependence, and an understanding that humans are a part of nature, not separate.
Water quantity	Water levels are low and fluctuate widely. Ships are forced to carry lighter loads. New waterfront property exists in some places, but has been lost in others because of receding waters.
Technology	Technology advancements are insufficient to solve problems caused by an economy at odds with the environment. While not one of the initially identified drivers, it was an important influence.

### A.1. Drivers of change in the year 2063

#### A.1.1. Aquatic invasive species

A decline in native species has been accompanied by northward range expansion of disease vectors and invasive species (WICCI, 2011). Increased temperatures stress many native plant species, but have brought hospitable conditions for invasive species from warmer climates; it is impossible to control most invasive species. The West Nile Virus is ubiquitous, and sporadic outbreaks of malaria occur during hot, wet summers (Pachauri and Reisinger, 2007). Ballast water regulation has been effective at limiting invasions of new species from Europe and Asia, while the biggest threat is live trade. Meanwhile, species such as Quagga mussels and Asian carp have long since invaded the Great Lakes basin (Pagnucco et al., in this issue).

#### A.1.2. Biological and chemical contaminants

Dealing with biological and chemical contaminants in the Great Lakes basin has been an uphill battle; natural processes have overwhelmed human efforts. Warmer waters and a longer growing

season have increased the speed through which contaminants move through biotic and abiotic systems (Cornwall et al., in this issue).

#### A.1.3. Climate change

In 2063, the worst climate predictions by the Fifth Intergovernmental Panel on Climate Change (IPCC) released in 2013 have become a global reality. To date, average global temperature has risen by 3 °C above 1990 levels and sea level has risen 0.45 m (Bates et al., 2008; Pachauri and Reisinger, 2007). Changes within the Great Lakes region have been less catastrophic than changes on a global scale. However, the average temperature in the Great Lakes region has increased by more than 5 °C (Bartolai et al., in this issue); the region has benefited from a longer growing season, but suffered from ice cover loss (GLISA, 2012).

#### A.1.4. Demographics

The population in the Great Lakes region is now 67 million, up from 48.5 million in 2013 (Méthot et al., in this issue). In the US, population grew moderately, from 31 to 40 million, while population on the Canadian side grew at a proportionally larger rate, from 18 to 27 million. The population is considerably older and more diverse while the number of people over the age of 65 has doubled since 2013 (Méthot et al., in this issue; USCB, 2012).

#### A.1.5. Societal values

In the 2010s and 2020s, values were competitive and individualistic. The values of Native Americans and First Nations became more influential, especially in resource management (Berkes, 2008). By the 2030s, mounting climate, economic, geopolitical and demographic pressures had propelled a dramatic shift in values towards recognizing our shared identity, interdependence and vision of a healthy Great Lakes region. A loss of the sense of place in the Great Lakes region drove this transformation in values (Williams and Stewart, 1998).

#### A.1.6. Economy

Growth is slow or nonexistent, with manufacturing, agriculture and services the most important sectors (Campbell et al., in this issue). Manufacturing has reached low but stable levels following the green energy boom during the 2040s. Trade had declined because falling lake levels have reduced shipping capacity, while increased fuel prices have made truck transport less profitable (Miller, 2007).

#### A.1.7. Energy

In 2063, the energy sector is searching for new forms of energy. Demand increased despite improved efficiency and diversification of energy sources (Kelly et al., in this issue). Hydraulic fracturing continues to supply much of our energy needs. A green energy boom combined with research in renewable energy technologies during the late 2040s helped the region transition away from fossil fuels and completely phase out coal. More efficient energy storage and transmission hold promise, but overreliance on fossil fuels early in the century both depleted water supplies and suppressed valuable research opportunities.

#### A.1.8. Governance and geopolitics

Citizens, businesses and governments have found new ways to live, work and make decisions together based on a common vision and an understanding of shared resources and natural limits (Adger and Jordan, 2009). Historically opposed interests have become engaged in data collection and policy development, fostering trust and lending legitimacy to scientific findings (Lemos and Morehouse, 2005). Citizen science is important for connecting experts and communities (Bonney et al., 2009). Public involvement in understanding problems and monitoring interventions has resulted in improved scientific models, and continued support for research.

The Great Lakes region faces external geopolitical pressures, but is stable within. Historical divergence of policies between the US and

Canada has been replaced by binational cooperation (Sandlos, 2013). Immigration of environmental refugees inundates the Great Lakes region. Meanwhile, the region faces pressure from the Great Plains states to export water. The United Nations is active in climate adaptation measures following its restructuring (Ivanova, 2005). The Great Lakes Compact remains together but under intense debate – it was broken in the 2020s and reinstated in the 2040s (Jetoo et al., in this issue).

#### A.1.9. Water quantity

Lake levels have repeatedly fallen to record lows in recent decades, while water levels are not always low, they do reach lower lows. In some parts of the Great Lakes-St. Lawrence River basin, shallow bays and coastal areas have dried up, damaging critical marshland habitats (Fracz and Chow-Fraser, 2013). Fish populations have plummeted as their shallow spawning areas have disappeared. Both the shipping industry and coastal communities face economic hardships (Millerd, 2007).

#### A.1.10. Technology

Society has made incredible advancements but technological fixes remain insufficient to solve problems caused by an economy at odds with the environment. Water conservation and waste removal technologies developed in Milwaukee have been adopted throughout the Great Lakes region and have helped minimize human impact on water and fisheries (Schmid, 2009, 2013). Some former manufacturing facilities have been transformed to green energy facilities. New technologies for creating biomass energy from some invasive species were developed (Zimmerman, 2013).

## References

- Adger, W.N., Jordan, A., 2009. *Governing Sustainability*. Cambridge University Press, Cambridge, UK.
- Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G.O., Swartz, B., Quental, T.B., Marshall, C., McGuire, J.L., Lindsey, E.L., Maguire, J.L., Mersey, B., Ferrer, E.A., 2011. Has the Earth's sixth mass extinction already arrived? *Nature* 471 (7336), 51–57.
- Bartolai, A., He, L., Hurst, A., Mortsch, L., Paehlke, R., Scavia, D., 2014. Climate change as a driver of change in the Great Lakes St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P. (Eds.), 2008. *Climate Change and Water: IPCC Technical Paper VI*. IPCC Secretariat, Geneva.
- Berkes, F., 2008. *Sacred Ecology*. Routledge, New York, NY.
- Bonney, R., Cooper, C.B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K.V., Shirk, J., 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* 59 (11), 977–984.
- Brown, P., Schmidt, J., 2010. *Water Ethics: Foundational Readings for Students and Professionals*. Island Press, Washington, DC.
- Campbell, M., Cooper, M., Friedman, K.B., Anderson, W., 2014. The economy as a driver of change in the Great Lakes-St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Camus, A., 1955. *The Myth of Sisyphus, and Other Essays*. Knopf, New York, NY.
- Cline, T.J., Bennington, V., Kitchell, J.F., 2013. Climate change expands the spatial extent and duration of preferred thermal habitat for Lake Superior fishes. *PLoS ONE* 8 (4), e62279.
- Cornwell, E.R., Goyette, J.-O., Sorichetti, R.J., Allan, J.D., Kashian, D.R., Sibley, P.K., Taylor, W.D., Trick, C.G., 2014. Biological and chemical contaminants as drivers of change in the Great Lakes St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Curtis, M., 2013. Cropping off to record late start. Accessed online 08-30-2013 at: <http://www.wisfarmer.com/leadstories/205806721.html>.
- Derksen, C., Smith, S.L., Sharp, M., Brown, L., Howell, S., Copland, L., Mueller, D.R., Gauthier, Y., Fletcher, C.G., Tivy, A., Bernier, M., Bourgeois, J., Brown, R., Burn, C.R., Duguay, C., Kushner, P., Langlois, A., Lewkowicz, A.G., Royer, A., Walker, A., 2012. Variability and change in the Canadian cryosphere. *Clim. Chang.* 115 (1), 59–88.
- Echenberg, H., 2012. Canada's aging population and public policy: 7. The Effects on Community Planning. No. 2012-02-E. Library of Parliament, Ottawa, ON.
- Fracz, A., Chow-Fraser, P., 2013. Impacts of declining water levels on the quantity of fish habitat in coastal wetlands of eastern Georgian Bay, Lake Huron. *Hydrobiologia* 702 (1), 151–169.
- Githeko, A.K., Lindsay, S.W., Confalonieri, U.E., Patz, J.A., 2000. Climate change and vector-borne diseases: a regional analysis. *B World Health Organ* 78 (9), 1136–1147.
- Government of Canada (GC), 2013. Fisheries Act, RSC 1985, c F-14. Accessed online 10-25-2013 at: <http://canlii.ca/t/524r4>.
- February 15, 2013 Great Lakes – St. Lawrence Cities Initiative (GLSCI), 2013. Letter to Federal Governments. Accessed online 07-25-2013 at: <http://www.glsicities.org/news/news/FINAL%20President%20Obama%20and%20Prime%20Minister%20Harper%20-%20Water%20Level%20Letter%20-%20GLSLCI.pdf>.
- Great Lakes Integrated Sciences and Assessments (GLISA), 2012. Climate change in the Great Lakes region. Accessed online 08-30-2013 at: [http://www.glsa.msu.edu/docs/fact\\_sheets/GLISA\\_climate\\_change\\_summary.pdf](http://www.glsa.msu.edu/docs/fact_sheets/GLISA_climate_change_summary.pdf).
- Hartig, J.H., Zarull, M.A., 1992. *Under RAPs: Toward Grassroots Ecological Democracy in the Great Lakes Basin*. University of Michigan Press/Regional, Ann Arbor, MI.
- Hunt, S., 2013. Algae bloom in Lake Erie closes Canadian beaches. July 19, 2013, The Columbus Dispatch (online) (Accessed online 07-25-2013 at: <http://www.dispatch.com/content/stories/local/2013/07/19/algae-bloom-closes-canadian-beaches.html>).
- International Joint Commission (IJC), 2012. The Great Lakes Water Quality Agreement, 2012. International Joint Commission, Windsor (Accessed online 02-28-2014 at: [http://www.ijc.org/en/Great\\_Lakes\\_Water\\_Quality](http://www.ijc.org/en/Great_Lakes_Water_Quality)).
- Ivanova, M., 2005. Assessing UNEP as Anchor Institution for the Global Environment: Lessons for the UNEO Debate. Yale Centre for Environmental Law & Policy. Yale University, New Haven, CT (Accessed online 09-01-2013 at: <http://www.yale.edu/gegdialogue/uneo-wp.pdf>).
- James, S., Lahti, T., 2004. *The Natural Step for Communities: How Cities and Towns can Change to Sustainable Practices*. New Society Publishers, Gabriola Island, B.C.
- Jetoo, S., Thorn, A., Friedman, K.B., Gosman, S., Krantzberg, G., 2014. Governance and geopolitics as a driver of change in the Great Lakes St. Lawrence River Basin. *J. Great Lakes Res.* (in this issue).
- Kelly, B., Keeler, B., Helm, G., Krantzberg, G., Lyon, T., Friedman, K., Mabee, W., 2014. Energy as a driver of change in the Great Lakes-St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Kraker, D., 2013. Flood-ravaged Duluth, Northeast Minnesota, Still Recovering One Year Later. Accessed online 08-30-2013 at: <http://www.mprnews.org/story/2013/06/18/weather/duluth-northeast-minnesota-flood-anniversary>.
- Laurent, K.L., Scavia, D., Friedman, K.B., Krantzberg, G., 2014. Critical forces directing the future: how two highly important and highly uncertain axes of analysis can frame alternative futures for the Great Lakes-St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Lemos, M., Agrawal, A., 2006. Environmental governance. *Annu. Rev. Environ. Resour.* 31, 297–325.
- Lemos, M., Morehouse, B., 2005. The co-production of science and policy in integrated climate assessments. *Global Environ. Chang.* 15 (1), 57–68.
- Leopold, A., 1948. *Forward to a Sand County Almanac*. In: Schwartz, C.W., Leopold, A. (Eds.), *A Sand County Almanac: With Essays on Conservation from Round River*. Ballantine Books, New York.
- Maghrebi, M., Nalley, D., Laurent, K.L., Atkinson, J., 2014. Water quantity as a driver of change for the Great Lakes-St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Méthot, J., Huang, X., Grover, H., 2014. Demographics and societal values as a driver of change for the Great Lakes-St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Millerd, F., 2007. Global climate change and Great Lakes international shipping. Accessed online 04-30-2013 at: [http://ntl.bts.gov/lib/32000/32100/32145/sr291\\_millerd.pdf](http://ntl.bts.gov/lib/32000/32100/32145/sr291_millerd.pdf).
- Myers, J., 2012. Minnesota wild rice harvest hurt by June flooding. Duluth News Tribune. Accessed online 08-30-2013 at: [http://www.twincities.com/ci\\_21399725/minnesota-wild-rice-harvest-hurt-by-june-flooding](http://www.twincities.com/ci_21399725/minnesota-wild-rice-harvest-hurt-by-june-flooding).
- National Aeronautics and Space Administration (NASA), 2013. NASA Scientists React to 400 ppm Milestone. Accessed online 08-30-2013 at: <http://climate.nasa.gov/400ppmquotes>.
- National Oceanic and Atmospheric Administration (NOAA), 2013. NOAA, partners predict significant harmful algal bloom in western Lake Erie this summer. Accessed online 10-17-2013 at: [http://www.noaanews.noaa.gov/stories2013/20130702\\_lakeeriehabs.html](http://www.noaanews.noaa.gov/stories2013/20130702_lakeeriehabs.html).
- Ohio State University Extension (OSUE), 2008. Frequently asked questions about West Nile virus. Accessed online 08-30-2013 at: <http://ohioline.osu.edu/wnv-fact/pdf/1000.pdf>.
- Ontario Ministry of the Environment (OMoE), 2010a. Great Lakes Guardian Community Fund. Queens Printer of Ontario (Accessed online 02-28-2014 at: [http://www.ene.gov.on.ca/environment/en/funding/great\\_lakes\\_fund/index.htm](http://www.ene.gov.on.ca/environment/en/funding/great_lakes_fund/index.htm)).
- Ontario Ministry of the Environment (OMoE), 2010b. Keeping the Great Lakes Great. Her Majesty the Queen in Right of Canada, represented by the Minister of the Environment. Queens Printer of Ontario (Accessed online 02-28-2014 at: [http://www.ene.gov.on.ca/environment/en/subject/great\\_lakes/STDPROD\\_096902.html#1](http://www.ene.gov.on.ca/environment/en/subject/great_lakes/STDPROD_096902.html#1)).
- Ontario Ministry of the Environment (OMoE), 2006. Clean Water Act, 2006. Queens Printer of Ontario (Accessed online 02-28-2014 at: [http://www.e-laws.gov.on.ca/html/statutes/english/elaws\\_statutes\\_06c22\\_e.htm](http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_06c22_e.htm)).
- Ostrom, E., Janssen, M.A., Anderies, J.M., 2007. Going beyond panaceas. *Proc. Natl. Acad. Sci. USA* 104 (39), 15176–15178.
- Pachauri, R.K., Reisinger, A., 2007. Climate change 2007: synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change (Accessed online 10-21-2014 at: [https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr\\_frontmatter.pdf](https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_frontmatter.pdf)).
- Pagnucco, K., Maynard, G., Fera, S., Yan, N., Nalepa, T., Ricciardi, A., 2014. Aquatic invasive species as a driver of change in the Great Lakes St. Lawrence River basin. *J. Great Lakes Res.* (in this issue).
- Population Reference Bureau (PRB), 2012. PRB's World Population Clock. Accessed online 08-30-2013 at: <http://www.prb.org/Publications/Datasheets/2012/2012populationclock.aspx>.
- Quinn, D., 1996. *The Story of B. Bantam Books*, New York, NY.
- Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin III, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J., 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecol. Soc.* 14 (2), 32.

- Sandlos, J., 2013. Nature's nations: the shared conservation history of Canada and the USA. *Int. J. Environ. Stud.* 70 (3), 358–371.
- Save the Water's Edge (SWE), 2013. Updates August 29 2013. Accessed online 09-08-2013 at: <http://www.savethewateredge.com/update-march-30-2013.html>.
- Schmid, J., 2009. U.N. names Milwaukee a water technology hub. *Journal Sentinel Online*. Newspaper. Accessed online 05-30-2013 at: <http://www.jsonline.com/business/43835922.html>.
- Schmid, J., 2013. Warehouse's rebirth reflects Milwaukee's rise in water technology. *Journal Sentinel Online*. Newspaper. Accessed online 05-30-2013 at: <http://www.jsonline.com/business/former-warehouses-rebirth-reflects-milwaukees-rise-in-water-technology-4t952us-198867041.html>.
- Schwartz, R., 1996. *The Art of the Long View: The Path to Strategic Insight for Yourself and Your Company*. Second edition. Doubleday, New York.
- Semken, S., Freeman, C.B., 2008. Sense of place in the practice and assessment of place-based science teaching. *Sci. Educ.* 92 (6), 1042–1057.
- SooToday.com Staff, 2013. Batchewana first nation seeks millions for loss of river fishery. Accessed online 09-08-2013 at: <http://www.sootoday.com/content/news/details.asp?c=52702>.
- Speth, J.G., 2004. *Red Sky at Morning: America and the Crisis of the Global Environment*. Yale University Press, New Haven, CT.
- Statistics Canada (SC), 2013. Population Projections for Canada, Provinces and Territories: Tables. Accessed online 05-01-2013 at: <http://www.statcan.gc.ca/pub/91-520-x/2010001/tablesectlist-listetableauxsect-eng.htm>.
- Strömberg, D., 2007. Natural disasters, economic development, and humanitarian aid. *J. Econ. Perspect.* 21 (3), 199–222.
- The World Bank (WB), 2012. Turn down the heat: why a 4 C world must be avoided. Accessed online 04-30-2013 at: [http://climatechange.worldbank.org/sites/default/files/Turn\\_Down\\_the\\_heat\\_Why\\_a\\_4\\_degree\\_centrigrade\\_warmer\\_world\\_must\\_be\\_avoided.pdf](http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf).
- United States Federal Government (USFG), 2008. Great Lakes-St. Lawrence River Basin Water Resources Compact. Accessed online 02-28-2014 at: <http://www.cglg.org/projects/water/CompactImplementation.asp>.
- United States Federal Government (USFG), 2010. Great Lakes Restoration Initiative Action Plan. FY 2010–2014. Accessed online 07-24-2013 at: <http://glri.us/index.html>.
- US Census Bureau (USCB), 2012. National Population Projections. Accessed online 05-01-2013 at: <https://www.census.gov/newsroom/releases/archives/population/cb12-243.html>.
- US Environmental Protection Agency (USEPA), 2013. Great Lakes National Program Office. July 15, 2013. Great Lakes Restoration Initiative Request for Applications. Accessed online 05-01-2013 at: <http://www.epa.gov/greatlakes/fund/2013rfa01/glri-2013-rfa-mod2.pdf>.
- Williams, D.R., Stewart, S.I., 1998. Sense of place: an elusive concept that is finding a home in ecosystem management. *J. Forest* 96 (5), 18–23.
- Wisconsin Initiative on Climate Change Impacts (WICCI), 2011. *Wisconsin's Changing Climate: Impacts and Adaptation*. Nelson Institute for Environmental Studies, University of Wisconsin–Madison and the Wisconsin Department of Natural Resources, Madison, WI.
- Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science* 314, 787–790.
- WZZM, 2013. Michigan maple syrup businesses recovering after bad 2012. Accessed online 08-30-2013 at: <http://www.wzzm13.com/news/article/246858/2/Michigan-maple-syrup-businesses-recovering>.
- Zimmerman, G., 2013. Weedy grasses as pellet fuel feedstock: research update. Accessed online 08-30-2013 at: <http://greatlakesphragmites.net/blog/weedy-grasses-as-pellet-fuel-feedstock-research-update/>.
- Zook, M., Graham, M., Shelton, T., Gorman, S., 2010. Volunteered geographic information and crowdsourcing disaster relief: a case study of the Haitian earthquake. *World Med. Health Policy* 2 (2), 7.