IAGLR
LAKES Letter

This issue explores climate change and its impact on large lakes around the world

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Responding to stresses facing the Great Lakes region in a changing climate

by **Don Wuebbles**

IT'S SUMMER TIME, beaches are open, and the Great Lakes shorelines await us. The Great Lakes are where many of us live, work, and play. And, right now, they need our help.

The science is clear: changes in climate are already having increasing impacts on the Great Lakes region. A 2019 state-of-the-science report paints a comprehensive picture of how a changing climate affects the Great Lakes and what these changes mean for public health and safety, agriculture, infrastructure, fish and wildlife, and our regional economies. Temperatures are generally increasing in the Great Lakes region, but more importantly, climate change is leading to growing concerns about heat waves, larger precipitation events, and more intense severe weather. More extreme weather events are projected across the Great Lakes: more flooding early in the year; more heat waves and drought in hotter months; and an overall decrease in snowfall, but more heavy lake-effect snowstorms.

As an important example of the impacts on the region, the warming trend has led to increased bacteria levels and exacerbated algae blooms. Both bacteria and algae blooms can make water unsafe to drink, thus significantly increasing water treatment costs. They can also make water unsafe for swimming, leading to more beach closures. Beaches, dunes, and shorelines will likewise be more vulnerable to coastal erosion as a result of changing weather patterns.

The Great Lakes have also garnered recent attention due to their at or near all-time high water levels. Although water levels fluctuate considerably over decades, high precipitation in the Great Lakes watersheds has contributed to the recent high levels. Longer-term water levels will depend on the balance between future amounts of rainfall in the watersheds and increasing evaporation in a warming climate. Both of these counteracting effects are increasing. While it is possible that higher water levels will be the new norm, the current expectation from the science community is that levels will continue to fluctuate. More definitive research studies are needed to better understand this issue.

Along with reducing the emissions driving climate change, efforts for adaptation and resiliency are crucial to planning the future of the Great Lakes region. Recommended policy solutions call for stepping up actions to achieve multiple benefits of mitigating climate change, protecting public health, and reducing stress on the Great Lakes ecosystem and our land. These include advancing green energy, improving energy efficiency, accelerating the adoption of cleaner transportation options, reducing agricultural runoff of phosphorus pollution, investing in green infrastructure, and funding to help protect fisheries, shorelines, and wetlands.

Climate change is one of, if not the biggest challenges of our time. The impacts are already being felt in the Great Lakes region, and they are likely to grow to be far-reaching and very costly. If we don't act now, the Great Lakes and all of us who enjoy and rely on our lakes for safe, clean drinking water, food, recreation, and commerce will pay an even greater price for decades to come.

Don Wuebbles is a professor of atmospheric sciences at the University of Illinois in Urbana, Ill. He is lead author of the 2019 report "An Assessment of the Impacts of Climate Change on the Great Lakes," written by 18 experts from the United States and Canada.

IAGLR 2021 Wrap-up

IAGLR's 64th annual Conference on Great Lakes Research is in the books. And while we couldn't gather in person for the second year due to the pandemic, 700 attendees from 15 countries gathered online for five days of great science. The conference featured 33 sessions with 400 oral and poster presentations around the theme *Bridging: Knowledges • Seven Generations • Land to Lake*. Ninety-six Indigenous people attended the event to share their views and understanding of the Great Lakes, including two of our three plenary speakers. The conference was hosted by Michigan Technological University. Thanks to Site Chair Noel Urban, Program co-chairs Judith Perlinger and Gord Paterson, the planning committee, and student volunteers for all their hard work to make this a successful event. Thanks also to the 82 participants of our first-ever fun run. Participants ran, walked, biked, and swam a total of 1,334 miles—enough to make it around Lake Superior—and raised $815 to support the IAGLR Scholarship.

Journal seeks papers for special sections

You're invited to submit a paper for two special sections of the *Journal of Great Lakes Research*:

- **Assigning agency: how communities, individuals, and organizations engage in environmental cleanup and revitalization.** Submissions will be accepted through September 20, 2021. View the Call for Papers for details.
- **Lake of the Woods: Five Years of Research (2016–2021).** Submissions will be accepted through December 31, 2021. View the Call for Papers for details.

It's scholarship time!

Spread the word! It's time to apply for a scholarship from IAGLR. The association offers three scholarships to support students studying large lakes of the world:

Norman S. Baldwin Fishery Science Scholarship ($3,000) for graduate research in Great Lakes fishery biology

David M. Dolan Scholarship ($3,000) for graduate research using applied mathematics to advance the quantitative understanding and management of Great Lakes ecosystems

IAGLR Scholarship ($2,000) for doctoral research making a significant contribution to the understanding of large lakes

Visit iaglr.org/awards-scholarships. Deadline: **December 1**.

State of Lake Conferences

Save the dates for two State of Lake conferences slated for next year. The State of Lake Erie Conference will be held March 16–18, 2022, in Cleveland, Ohio, and the State of Lake Michigan Conference is planned for October 24–26, 2022, in Traverse City, Michigan. We hope to see you there, in person!

What's your Twitter handle?

Are you an IAGLR member on Twitter? Let us know your Twitter handle so we can add you to our list of IAGLR members to follow. Send to lakesletter@iaglr.org with the subject line "Twitter handle."

ELLS-IAGLR 2022

IAGLR members will have the opportunity to dive into climate research at next year's European Large Lakes Symposium–IAGLR Conference. Scheduled for September 12–18, 2022, in Petrozavodsk, Russia, the conference will explore the theme *Implications of Climate Change and Human Impact on Large Lakes*. Organizers welcome your suggestions for the conference.

Petroglyphs (rock carvings) located in Onega Lake in the Russian region of Karelia. Photo by Igor Georgievski.

IAGLR 2022 part of Joint Aquatic Sciences Meeting

IAGLR will join eight other member societies of the Consortium of Aquatic Science Societies to host a Joint Aquatic Sciences Meeting May 14–20, 2022, in Grand Rapids, Michigan. The meeting theme is *Rapid Changes ~ Collaborative Solutions*.

The consortium's societies represent more than 20,000 members, and next year's joint gathering of research scientists, educators, students, resource managers, and conservation professionals is expected to draw an estimated 3,000-4,500 in-person attendees as well as a sizeable number of virtual attendees.

Keynote and plenary speakers will be complemented by multidisciplinary sessions and events that will broaden our horizons and strengthen our connections so that we can effectively respond to the rapid changes taking place in our shared aquatic ecosystems.

IAGLR 2022 (JASM 2022) Call for Proposals

You're invited to propose a symposium, integrative event, or workshop. Workshops will be held on May 14 and 15, with symposia and integrative events starting on May 16. Proposal collaborations among societies are encouraged. **The deadline for proposals is September 24, 2021.** Let's make sure the world's large lakes are well-represented!

CASS Member Societies

- American Fisheries Society
- Association for the Sciences of Limnology and Oceanography
- Coastal and Estuarine Research Federation
- Freshwater Mollusk Conservation Society
- International Association for Great Lakes Research
- North American Lake Management Society
- Phycological Society of America
- Society for Freshwater Science
- Society of Wetland Scientists

KUDOS

Congratulations to the following IAGLR members on their accomplishments.

BOPI BIDDANDA (Grand Valley State University) for receiving a Fulbright Scholar award. In 2022, Biddanda will be a senior Fulbright core research/ teaching fellow at the University of Granada in Spain.

ELAINE HO-TASSONE (University of Waterloo) for successfully defending her Ph.D. dissertation, "Democratizing water quality monitoring processes for the lower Grand River and nearshore Lake Erie." Ho-Tassone is now completing a postdoctoral fellowship at Algoma University, developing a community-based water quality monitoring program in partnership with Garden River First Nation.

TIM JOHNSON (Ontario Ministry of Northern Development, Mines, Natural Resources, and Forestry), past IAGLR president and member since 1997, for receiving the Jack Christie/Ken Loftus Award from the Great Lakes Fishery Commission. The award recognizes significant scientific contributions toward understanding Great Lakes ecosystems and honors Johnson's exceptional work in developing and refining multi-species food web models that explore the dynamics of aquatic ecosystems.

JASMINE MANCUSO for starting a job as research lab manager for the aquatic ecology lab at Oakland University and for accepting an adjunct professor of ecology position at Rochester University in Rochester, Mich.

PAUL SIBLEY (University of Guelph) for his appointment as full-time director for the School of Environmental Sciences starting September 1.

Congratulations IAGLR 2021 Best Student Paper Presenters

RYAN GROW (Lakehead University) for being named a recipient of IAGLR's 2021 Best Student Paper Award for the presentation "Estimating Cisco *(Coregonus artedi)* density in Lake Superior using an up-looking acoustic platform."

LAUREN WELLER (University of Windsor) for being named a recipient of IAGLR's 2021 Best Student Paper Award for the presentation "Characterizing carbon complexity across the land-water interface in agricultural landscapes."

ALEXIS BROWN (Cleveland State University) for being selected runner-up for IAGLR's 2021 Best Student Paper Award for the presentation "An early alert system for harmful algal blooms in Lake Erie."

Welcome new IAGLR members

The following members joined IAGLR between May and July 2021. Welcome to IAGLR!

Richard Grosshans
Ryan Grow
Sharon Gubamwoyo
Sreecharar Gullapalli
Kristina Heinemann
Ivor Knight
Xavier Lazzaro
Madalitso Magombo Chatsika
Neema Maheshe
John Malala
Cesilia Mataba
Gerald McKenna
Joyeuse Mudagi
Aline Munundu
Alice Mutie
Fabrice Muvundja
Namakau Muyumbana
Venny Mziri
Racheal Nabwire
Dorothy Namuyiga
Musau Ntambwe
Nathan Rohrbaugh
Claver Sibomana
Janvière Tuyisenge
Ariana Uwaibi
Natalija Vojno
Mulugeta Wakjira
Michelle Woodhouse

NEW MEMBER SPOTLIGHT

Rupert Kindersley

Executive Director
Georgian Bay Association

The Georgian Bay Association is a 105-year-old umbrella advocacy organization for 18 community associations along the east and north shores of Georgian Bay in Ontario, representing around 3,000 families. We reach and influence an estimated 18,000 residents of the Georgian Bay. Our mandate is to work with our water-based communities and other stakeholders to ensure the careful stewardship of the greater Georgian Bay environment.

Accordingly, as executive director, I joined IAGLR this year to educate myself on the scientific research that is relevant to the Georgian Bay environment. I also wanted to be able to access the presentations to inform some of our committee members who had expressed interest in some of the research. GBA has 12 committees that report to the board on our various activities. There were a number of presentations that are of interest to these committees:

Water Committee: Deals with both water levels and water quality issues.

Aquaculture Committee: Advocates for moving open-net fish farms in Lake Huron into sustainable, enclosed facilities. Nutrient loading, escapees competing with wild fish stocks, and the fact that three facilities have been closed because of pollution are some of our issues.

Fisheries Committee: Is interested in wild fish health and numbers, impact and prevention of invasive species, and species at risk, among other topics.

Guardians of the Bay and First Nation Liaison Committees: Are concerned with promoting behavior and thinking that will protect Georgian Bay, not harm it. The potential for Traditional Ecological Knowledge to inform our understanding of the ecosystem and complement scientific research is of interest to us.

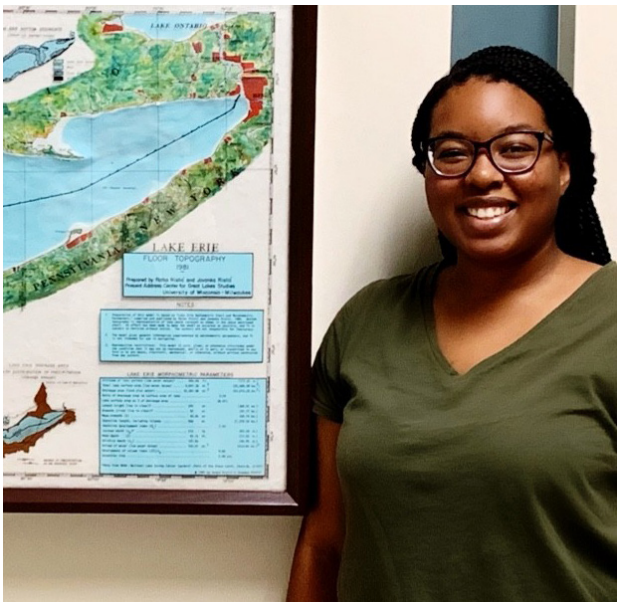
Personally, my family has been coming to a group of islands on the bay since 1881. There are now close to 200 of us!

About my Work

I am a Ph.D. candidate in the School of the Environment at Florida Agricultural & Mechanical University. I work in the Molecular Aquatic Microbial Ecology Lab with Dr. Richard A. Long and Dr. Michael Abazinge. My dissertation research is based on harmful algal blooms in Lake Erie with a focus on toxin and buoyancy genetics of *Microcystis aeruginosa* and is funded by NOAA Center for Coastal and Marine Ecosystems. This research will quantify gene expression with a genomics approach to identify the trends of buoyancy within an active bloom. It will add to the body of knowledge on bloom dynamics. I am honored to work with NOAA Great Lakes Environmental Research Laboratory and Dr. Reagan Errera to accomplish this research

Why IAGLR?

I joined IAGLR to engage in a community focused on Great Lakes research. Since I am physically located far from the Great Lakes, I find it important to be part of IAGLR to stay abreast on current knowledge. I hope my dissertation research adds to the body of knowledge on the Great Lakes and ignites future research. Following the pandemic, I hope to participate in IAGLR events and network with other scientists, students, professionals, and stakeholders in this field.



Ariana Uwaibi

Ph.D. Candidate
NOAA Center for Coastal and Marine Ecosystems
Florida A&M University

LIFETIME MEMBER SPOTLIGHT

BOB HEATH

Chair, Program Committee, Cleveland Water Alliance

Bob Heath joined IAGLR in 1985 and has been actively involved in the association over the years. In fact, he is the only person to have twice received the Anderson Everett Award for service to IAGLR. He was president of the association in 2010, program chair for the 2007 Conference on Great Lakes Research, and also served as chair of both the Conference and Endowment committees. We asked Bob about his background and his involvement with IAGLR.

TELL US ABOUT YOURSELF

My training was not in any of the traditional ecological fields. I earned a Ph.D. in biophysics from the University of Southern California, with a dissertation on the etiology of cystic fibrosis. During my postdoc in molecular biology at Caltech, I was influenced by Professor Max Delbrück, the "founding father" of modern biophysics. He encouraged me to look for new areas not yet influenced by molecular biology, as I accepted a faculty position at Kent State University.

At Kent State, I began biochemical research in aquatic ecology, specifically the role of alkaline phosphatase in P-limited plankton communities. Later my research broadened to the general role of dissolved organic matter in aquatic ecosystems. One problem—I had no background in ecology. So, my first sabbatical was with Professor Eugene P. Odum (University of Georgia), who encouraged me to explore ecosystem ecology. He told me, "you'll never be known for the work you do, you'll be known only for the ideas you generate."

WHAT ROLE HAS IAGLR PLAYED IN YOUR LIFE?

As a sailor, I greatly enjoyed conducting research from the pitch and roll of the *Lake Guardian* or the *Limnos* and introducing my students to the joy of research on these inland seas. I joined IAGLR realizing I had much to learn from colleagues familiar with these wonderful large lakes. From the first annual research conference I attended, I felt this was my home base. It was a place where new ideas were generated, and research teams could be constructed. Most importantly, it was a venue for my graduate students to present their research in a welcoming atmosphere. Among the highlights of my career are serving as president of IAGLR and aiding in establishing a solid endowment in support of student awards. Now I work with the Cleveland Water Alliance, seeking ways to establish a "water cluster" in the Great Lakes region.

IAGLR Lifetime Membership

Bob Heath is our most recent lifetime member, an option that allows someone to pay a one-time fee and become an IAGLR member for life. He joins 21 current members who have chosen this option not only to stay engaged with IAGLR on a long-term basis, but also to support the association while doing so.

Please consider doing the same when you renew your '22 membership. To learn more, visit our Membership page.

ON THIN ICE

Are lakes feeling the heat?

by **Sapna Sharma**

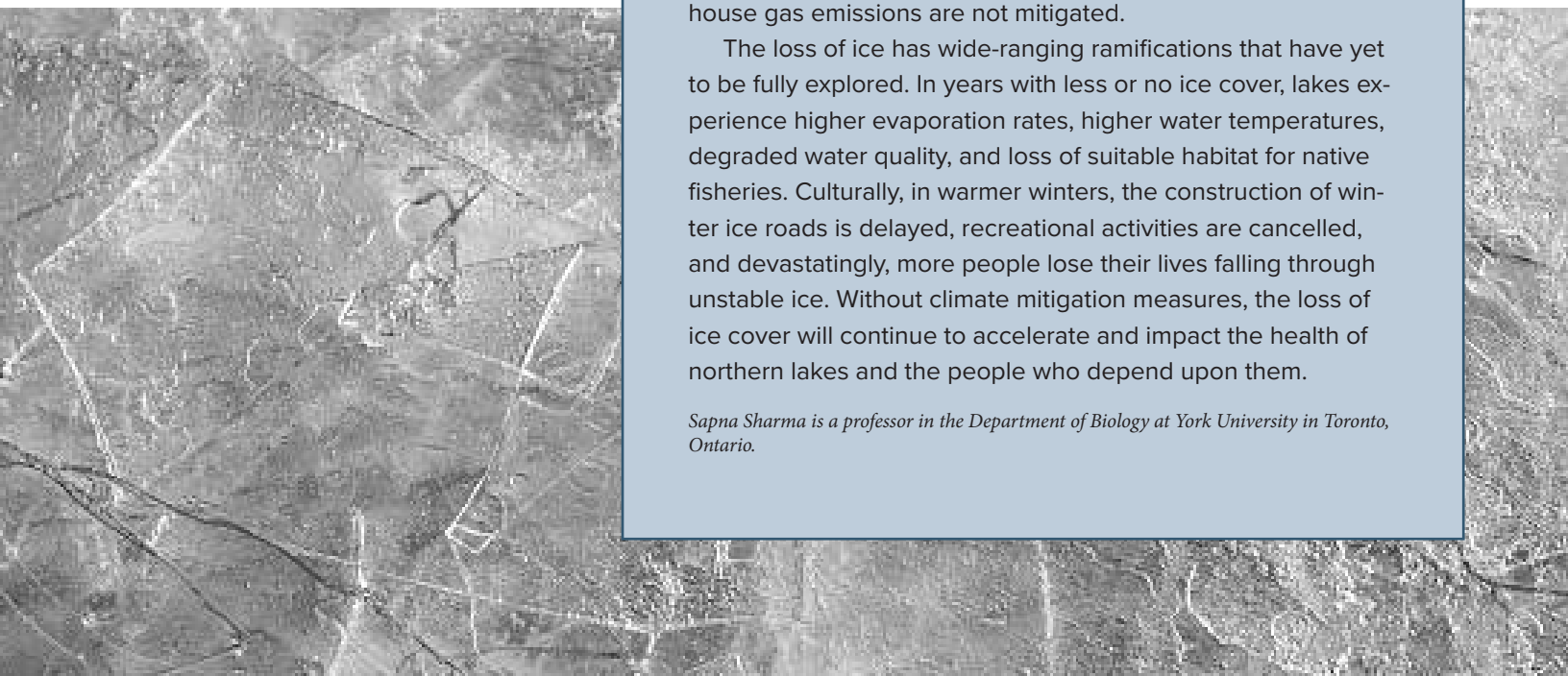
Lake Wilcox, Ontario. Photo by Sapna Sharma.

NORTHERN COMMUNITIES have relied on lake ice for centuries, as evidenced by their records of ice formation and breakup dates long before the advent of meteorological stations. Such data collection dates back to 875 AD, when communities surrounding hundreds of lakes began a long-standing tradition of documenting information on lake ice.

These data have proven to be effective indicators of climate change when compared with recent ice data. For example, data collected since at least 1443 by Shinto priests living near Japan's Lake Suwa show that the lake only experienced three ice-free years in the first 250 years of its record. However, since 1988, Suwa only froze twice per decade and is forecasted to never freeze again after the 2030s. Similarly, since 1857, Bayfield Bay in Lake Superior froze every winter until 1997, after which the bay has already had four ice-free years. As temperatures continue to warm, 215,000 lakes may no longer freeze every winter and almost 5,700 lakes may permanently lose ice cover by the end of the century. Large and deep lakes, including bays in lakes Michigan and Superior, are most likely to permanently lose ice cover as soon as the 2060s if greenhouse gas emissions are not mitigated.

The loss of ice has wide-ranging ramifications that have yet to be fully explored. In years with less or no ice cover, lakes experience higher evaporation rates, higher water temperatures, degraded water quality, and loss of suitable habitat for native fisheries. Culturally, in warmer winters, the construction of winter ice roads is delayed, recreational activities are cancelled, and devastatingly, more people lose their lives falling through unstable ice. Without climate mitigation measures, the loss of ice cover will continue to accelerate and impact the health of northern lakes and the people who depend upon them.

Sapna Sharma is a professor in the Department of Biology at York University in Toronto, Ontario.



Lowarengak Beach Management Unit offices in the northern sector of Lake Turkana destroyed by strong winds and increased lake levels. Photo by James Last.

A glance at the world's largest permanent desert lake

Climate change effects, fluctuating lake levels, and a way forward for Lake Turkana

by **Zephaniah Migeni**

LAKE TURKANA presents an acute case study of the impacts of climate change, including persistent conflicts, diminished livelihoods, reduced crop and livestock production, and damaged infrastructure, among others. The lake is one of the seven African Great Lakes and the world's largest permanent desert lake, stretching through northern Kenya before crossing into Ethiopia at its northern end. The region experiences a mean daily temperature of 30°C/86°F and less than 500 mm of precipitation per year. In this hot, arid environment, Lake Turkana supports the livelihood of more than 500,000 people and provides their most reliable source of surface water. This semi-saline lake receives more than 90% of its water from the Omo River, supplemented by rain and two major seasonal rivers: Turkwel and Kerio. Its endorheic nature, desert location, sporadic rainfall, high evaporation rates, and extreme dependence on Ethiopia's increasingly dammed Omo River for water inflow highlights the sensitivity of the system's lake level, water quality, and fauna and flora. Like other large lakes globally, it faces multiple threats and stressors.

Dust storm at Ferguson's Gulf on the west side of Lake Turkana. Photo by James Last.

Many locals have raised concerns over the rapidly decreasing lake water levels, a phenomenon which has created panic and uncertainty about their future survival in the basin. Scientific studies have reported that changes in the volume and seasonality of inflows from the Omo River—due to upstream dams and irrigation schemes—significantly influence the ecology of the basin. Further, recent studies have found that the lake level fluctuates annually with an amplitude of 1–1.5 meters, presenting an urgent need to maintain balance and increase retention ability.

Yet very little attention has been given toward research and management of Lake Turkana. There are strong calls to establish and equip a scientific research station in Omorate, Ethiopia, to facilitate consistent lakewide environmental monitoring required for making informed decisions. It is also important to strengthen the existing research station on the west side of the lake in Kalokol, Kenya, to enhance joint, coordinated, and sustained binational research and processes. Local communities and institutions should be empowered with the necessary skills to enable them to actively participate in the lake's well-being. With Lake Turkana being located in a hydrologically closed desert basin, its existence depends on maintaining a delicate balance between the fluctuating gains and losses that dominate its water budget. It therefore provides an ideal model to monitor and develop climate change adaptation strategies. Increased modeling, monitoring, and analysis of the effects of climate change on the lake ecosystem are required to help in decision making and policy formulation.

Zephaniah Migeni is the advisory groups communications facilitator for the African Center for Aquatic Research and Education.

The author acknowledges contributors Ted Lawrence and Stephanie Smith from the ACARE secretariat, and Kevin Obiero, Jeppe Kolding, John Malala, Abebe Getahun, Mulugeta Wakjira, and James Last Keyombe from the Lake Turkana Advisory Group.

Woman headed to assist in fish processing in Lake Turkana. Fishing is usually a family affair and women are the processors while men are the fishermen. Photo by James Last.

The African continent is richly diverse, with unique cultures spread throughout its varied geographies. One such example is the Turkana peoples of northwestern Kenya and south-central Ethiopia, recognized by their knotted shoulder clothes and brightly beaded necklaces, as shown above. The area is also known for the 1984 discovery of the 1.9 million-year-old Turkana Boy, the most complete skeleton of early man ever found.

Understanding climate change in the world's

ANCIENT LAKES

by **Stephanie E. Hampton**

Most lakes across the globe are less than 10,000 years old, but a small proportion are much older, from hundreds of thousands to millions of years old. In a recent review of ancient lakes—those that have persisted through at least one glacial cycle (>130,000 years)—more than half are also great lakes of the world (Hampton et al. 2018). Over their long lives, ancient lakes have experienced wet and dry periods, large-scale cycles of warming and cooling, and substantial changes in both biology and abiotic conditions. Such a history provides rich context for the effects of climate change already underway. These lakes not only record rich histories of environmental variation in their sediments, but also provide a home for a disproportionate share of the world's freshwater biodiversity and harbor high rates of endemism. From Lake Baikal's endemic freshwater seal (*Pusa siberica*) fishing the lake's frigid subarctic waters for endemic pelagic amphipods and sculpins (Watanabe et al. 2020) to the astonishing diversity of the cichlid radiations in the warm tropical East African Rift Lakes of Malawi, Victoria, and Tanganyika (Seehausen et al. 1997), the biodiversity of ancient lakes is adapted to sometimes unique conditions.

Lake Zaysan is an ancient large lake in Central Asia, where water availability is a primary concern for the region. Remote sensing has been particularly helpful in understanding lake level trends (e.g. Bai et al. 2011) but comparatively little ecological information is available. Photo by Dmitry A. Mottl - Own work, CC BY-SA 3.0.

At the same time, ancient lakes have attracted some of the earliest known human settlements, and archeologists see evidence of the resources that the lakes have long provided to humans. Archeological evidence shows that endemic fish and the Baikal seal were exploited by Indigenous people living around Lake Baikal since at least the mid-Holocene (Nomokonova et al. 2010). The Aral Sea has been home to ancient settlements going back thousands of years, and recurring reductions in water level have occurred over the past 5,000 years due to both climate and human action (Boroffka et al. 2006). This long history of anthropogenic impact may be why biodiversity in the Aral Sea has never been as high as reported in other ancient lakes, even during periods of high lake level (e.g., prior to 1960 AD). Tourism and fisheries thrive on many of the ancient lakes, supporting major economies and providing subsistence resources for local communities. The African Great Lakes support the largest lentic freshwater fishery in the world and provide a key protein source for tens of millions of East Africans, while commerce related to fishing directly supports the livelihoods of thousands more people (Bootsma and Hecky 1993). Like lakes everywhere, ancient lakes now face a suite of anthropogenic threats that may degrade their socioeconomic and scientific value. For all ancient lakes where data are available, long-term warming consistent with climate change has been observed (Hampton et al. 2018), altering physical and biogeochemical processes and posing challenges to the coldwater stenotherms of high latitude as well as endemic species of warm water that may already be living near their thermal maxima. Eutrophication is apparent for ancient lakes in some of the most populous watersheds, such as Lake Biwa, and those with large urban centers in their watersheds have exhibited the effects of more extensive pollution. For example, the Caspian Sea has 43 large urban centers (greater than 300,000 people) in the catchment, and bioaccumulation of heavy metals in tissues of economically important fishes have rendered a substantial proportion of catch unfit for purchase on the EU marketplace. For many of the ancient lakes, even those in the class of great lakes, comparatively little ecological information is available such that patterns and trends are impossible to assess (see Supplemental Information in (Hampton et al. 2018). While the threats that have precipitated recent ecological change are not unique to ancient lakes, high rates of endemism and biodiversity and long association with humans suggest that what may be lost will not be recovered, warranting more focused attention and coordinated study.

Stephanie E. Hampton is a professor and director of the Center for Environmental Research, Education, and Outreach at Washington State University in Pullman, Wash.

Ancient Great Lakes

- Aral Sea
- Baikal
- Biwa
- Caspian Sea
- Eyre
- Hovsgol
- Issyk kul
- Maracaibo
- Malawi
- Tahoe
- Tanganyika
- Titicaca
- Van
- Victoria
- Zaysan

The nerpa, or Baikal seal (*Pusa siberica*), is the world's only exclusively freshwater pinniped and the top predator on the lake. Shortening ice associated with climate change affects the seals in several ways because ice is central to both reproduction and molting (Moore et al. 2009). The Baikal seal mates, gives birth, and protects its pups in snow-ice caves on the lake ice. In years with early ice melt, the adult seals are forced back into water before their molt is complete, which is energetically costly. Photo by Sergey Gabdurakhmanov CC BY 2.0.

Place, knowledge, and change

by **Ryan Bowie**

INDIGENOUS PEOPLES have distinct cultural, spiritual, and economic relations with the Great Lakes and hold responsibilities to take care of the water. This relationship predates the arrival of settlers and is upheld in treaties, such as the Dish with One Spoon and the Treaty of Niagara. Indigenous Knowledge of the Great Lakes and surrounding regions both supports and is produced by this relationship, and is rooted in specific cultural and political contexts (e.g., Anishinabek Knowledge, Onkwehonwe Knowledge, Omushkegowuk Knowledge). Collectively, Indigenous Peoples offer a deep and nuanced understanding of the Great Lakes ecosystem essential for contemporary Great Lakes research.

Understanding the effects of climate change is a critical task for this research. The impacts of climate change are already significant and threaten potentially catastrophic consequences. It affects everyone and all environments, and therefore is a monumental challenge for Indigenous and settler peoples alike. But climate change is also part of a longer process of environmental change. Colonialism has threatened the environments, ways of life, and lives of Indigenous Peoples since Europeans began arriving. Climate change is the latest and potentially most devastating chapter of colonial history. As such, addressing climate change in a just manner is an inherently decolonizing endeavor.

Reestablishing Indigenous Peoples' roles in relation to the Great Lakes is necessary for the goal of reconciliation and for enriching the quality of research. The exclusion of Indigenous Peoples from Great Lakes research and governance colonized First Nations' responsibilities to the water, placing it largely in the hands of others. The assault on Indigenous Knowledge, epitomized by the residential school system in Canada, was intended to break Indigenous relations to their lands and waters. A result is that Indigenous Peoples are often sidelined from much of the work on the Great Lakes. The experience of First Nations in Ontario is that they are sometimes recognized, but supported largely as a peripheral add-on to the work of non-Indigenous science. However, commitments like the Great Lakes Water Quality Agreement and the Canada-Ontario Agreement have increasingly aimed to work with First Nations and other Indigenous Peoples as they aspire to be actively involved in the governance, research, and management of the Great Lakes.

The Water Declaration of the First Nations in Ontario acknowledges the leading role women have as the keepers of ceremonies to ensure waters are respected and their gift continues for future generations. The ceremonies and spiritual connections to water are essential to the purpose, planning, and conduct of Great Lakes research for Indigenous Peoples. Finding ways to address climate change will take the efforts of all involved, working together with respect for one another and the environments that support us. The return of Indigenous Peoples to the center of research and decision making about the Great Lakes will help us to understand, adapt, and mitigate the impacts of climate change in the region. This will also honor treaty relationships and decolonize research, issues that are at the very heart of the climate change problem.

Ryan Bowie is the policy analyst for the Chiefs of Ontario, Environmental Sector.

"Addressing climate change in a just manner is an inherently decolonizing endeavor."

Elizabeth Osawamick holds a copper pail and blesses the water. Photo courtesy of G. Horton-Baptiste.

Remoting sensing explores freshwater lakes' role in global carbon cycle

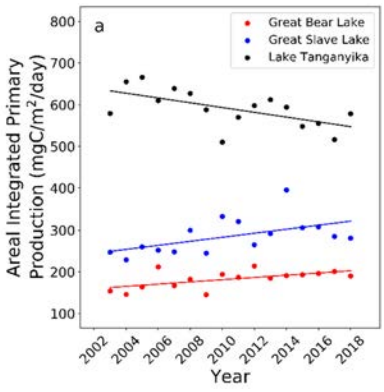
How do freshwater lakes contribute to the global carbon cycle? The vast number and size of these lakes has made answering that question a challenge. Different measurement techniques used in onsite studies also make it difficult to compare production values between lakes, or even to create lakewide assessments.

To address these challenges, researchers at Michigan Tech Research Institute (MTRI) turned to the sky. They used data collected from NASA's satellite-based MODIS sensor from 2003 to 2018 to estimate phytoplankton production in 11 of the world's largest lakes: the five Laurentian Great Lakes, three African Great Lakes, Lake Baikal, Great Bear Lake, and Great Slave Lake. MODIS views every point on Earth every one to two days, which resulted in a rich dataset of 137,161 images of the 11 lakes studied.

"Using these data, we were able to compute how much carbon is being fixed from a particular water body over a given year," says MTRI scientist Gary Fahnenstiel. "This consistent methodology allowed us to compare primary production in the world's largest lakes for the first time ever."

Their analysis revealed that three lakes showed significant trends in production over the study period. Great Bear and Great Slave lakes exhibited significant increases in production, while Lake Tanganyika experienced a significant decline. These changes appear to be related to climate change, including increasing temperatures and solar radiation and decreasing wind speeds.

The absence of climate change impacts on the other eight lakes may be due to the study's limited time period as well as interactions of other variables. For example, the study period largely misses the early mussel invasion phase in the Laurentian Great Lakes when the greatest production trends would be noted.



The study, reported in Water and at the 2021 Conference on Great Lakes Research, demonstrates how remote sensing primary production or carbon fixation models can be used for the world's large lakes. These results can be used to quantify changes in phytoplankton production, in some cases, due to climate change and anthropogenic forcing. The results also provide insights to better understand the contribution of freshwater lakes to the global carbon cycle dynamics. Researchers hope to expand the study to use other satellite platforms with higher spatial resolution so they can look at smaller lakes in the future.

Long-term NOAA GLERL dataset shows warming of Lake Michigan's deepwater temperatures, signaling the loss of winter

A study published in *Nature Communications* from NOAA's Great Lakes Environmental Research Laboratory (GLERL) reveals a warming trend in Lake Michigan's deepwater temperatures that foreshadows profound ecological change on the horizon. Using a 30-year dataset of deepwater temperature measurements, GLERL scientists investigated how Lake Michigan's seasonal mixing patterns are being influenced by climate change.

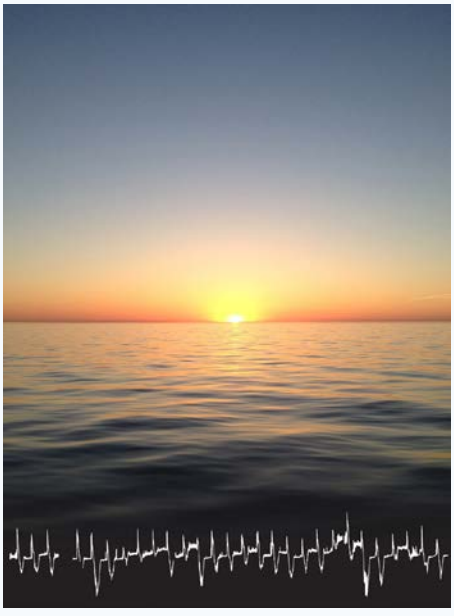
"We found that this long-term dataset not only confirms that Lake Michigan's deep waters are warming, but also shows that winter is vanishing from them," says NOAA GLERL scientist Eric Anderson. As climate change has gradually delayed the onset of cooler autumn weather over the past three decades, Lake Michigan's deep waters have reflected this change by showing shorter winter seasons.

This warming could eventually alter Lake Michigan's rate of primary productivity, which would inevitably disrupt the structure of its entire food web—a change that could have negative impacts on fisheries and recreation. "Without high-frequency long-term monitoring of subsurface waters of the world's deep lakes," says Anderson, "we will be blind to the impacts of climate change on most of Earth's fresh surface water."

Subsurface waters in deep lakes are important because they integrate conditions across years, providing a "climate memory," and can help identify the potential for ecological and physical changes throughout the lake. GLERL's continuous long-term dataset—likely the only one of its kind—was collected using a mooring that has been recording temperatures at different depths in the lake every hour almost continuously for the past three decades.

The deep-water conditions of the Earth's largest lakes are considered a missing piece of the global climate change puzzle. NOAA's work on Lake Michigan will pave the way for gaining a better understanding of this puzzle piece in the future.

Collaborators include the University of Michigan School for Environment and Sustainability and the University of Toledo Department of Environmental Sciences.



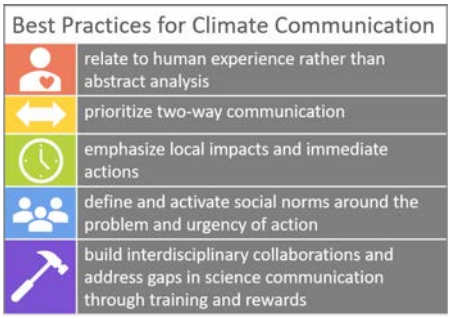
The 30-year, deep-water temperature dataset overlaying this Lake Michigan photo reveals a hidden story about how the lake's deep waters are responding to climate change.

By Gabrielle Farina, Jamison Professional Services contractor and science communications specialist at NOAA GLERL

Best practices in Great Lakes climate communication

Communicating environmental problems with slow impacts has long been a challenge because the time delay of consequences can dilute the urgency to act. We reviewed the climate change literature for best practices that could also be used in communicating other environmental threats, such as nutrient pollution, that have a disconnect in time between release into the environment and impact. Our study, recently published in *Frontiers for Environmental Science*, identified five recommended practices. As applied to communication about climate change impacts on the Great Lakes, these recommendations are as follows:

1) Relate scientific findings to human experiences rather than just providing more abstract analyses that may be difficult for people to internalize. For example, the Great Lakes are a cherished source of sustenance, spiritual value, and recreation to many residents. Highlight how these uses and values could be impacted by climate change.



2) Engage in two-way communication early in your work and throughout projects. Potential stakeholders include anyone who can affect or who would be affected by impacts from climate change. They include all levels of government, including Tribes and First Nations, nongovernmental organizations, local community members, business, and other interested parties.

3) Because the global causes and implications of climate change can overwhelm many people, emphasize localized actions for your audience and highlight the urgency of those actions. Communicate the specific potential mitigation and adaptation efforts that individuals or communities can make.

4) Define and activate social norms (community attitudes and behaviors) to mobilize around pride in the Great Lakes' environment and its role in people's communities. For example, celebrate climate adaptation projects like the development of effective task forces or restoration programs to emphasize the role and value of local action in climate resilience.

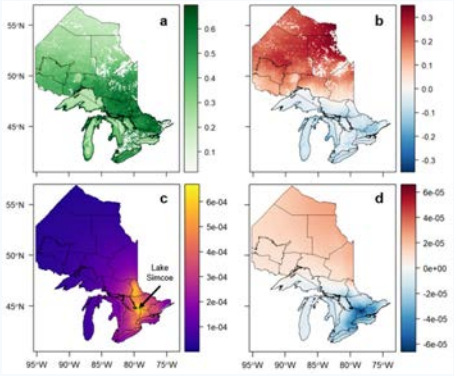
5) Build collaborations across scientific disciplines and prioritize scientific communication expertise. Effective science communication requires specific skills and takes time. Many scientists received no formal communication training yet are expected (and want!) to share their work with decision makers and the public. Budget for this in your staffing and funding of Great Lakes climate research.

By Kaytee Canfield and Kate Mulvaney, Atlantic Coastal Environmental Sciences Division, U.S. Environmental Protection Agency

Vulnerability to aquatic invasive species under human population and climate change

Aquatic invasive species (AIS) have led to fundamental changes in the structure, function, and composition of Ontario's aquatic ecosystems. Preventing the arrival of future AIS and controlling the spread of existing AIS are management priorities to protect Ontario's ecological resources. However, how climate change will affect the vulnerability of Ontario to species invasions remains uncertain. Moreover, as the effects of climate change are increasingly realized over the next several decades, other factors, such as changes in human population density, will also influence AIS arrival and spread.

We modeled the vulnerability—potential for arrival, survival, and spread of invasive aquatic invertebrates, plants, and fishes—of Ontario's aquatic ecosystems under baseline (2018) and future (2041–2070) conditions. The assessment was based on three components: describing the spatial distribution and movement of people associated with human-mediated pathways of propagule delivery; estimating the relative suitability of recipient ecosystems for AIS survival, including changes in climatic conditions over the projection interval; and estimating natural dispersal as a function of habitat suitability.



Habitat suitability for known and potential invasive baitfish (a) is expected to decrease in the south and increase in the north in the future (2041-2070, b). Under a scenario of initial release by boat-based fishers near Lake Simcoe (c), future vulnerability is expected to increase in the north and decrease in southern Ontario due to the combined effects of not only changing habitat suitability but also shifts in angler distribution and activity patterns.

We found that the locations of greatest pathway activity (i.e., aquarium and water-garden ownership, boat-based fishing, and all recreational boating) were spatially concentrated toward the most populous areas of Ontario. In areas currently supporting the most activity across the projection interval, propagule pressure from these pathways was likely to increase. With projected climate change, habitat suitability was also likely to increase, though not uniformly, and the location and magnitude of increase was less predictable across Ontario. Taken together, the baseline (2018) and future vulnerability of Ontario's landscapes to AIS showed strong spatial patterning and differed by pathway, indicating that prevention management necessitates a pathway- and species-specific focus.

Copies of the full report are available (tim.johnson@ontario.ca). Authors of the report include Jeff Buckley, Len Hunt, Jenny Rodgers, and Tim Johnson of the Ontario Ministry of Northern Development, Mines, Natural Resources, and Forestry; and Andrew Drake of the Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada.

New Open Access Data Platform Comes to the Great Lakes

DataStream is coming to the Great Lakes and Saint Lawrence region this fall. Once Great Lakes DataStream goes live, millions of water quality observations collected by dozens of organizations across sectors and jurisdictions will be available and easy to find.

With three other regional hubs operating across Canada, DataStream provides data sharing infrastructure and hands-on support to help organizations of all sizes publish their data online. This easy-to-use platform features map-based search, data visualization tools and multiple ways to download and access the data. On DataStream, data are stored in a standardized format in line with that of the U.S. Water Quality Portal.

With enormous potential to support scientific advances and informed decision-making in the Great Lakes and Saint Lawrence region, DataStream is now actively working with monitoring groups and researchers across the basin to facilitate the open sharing of monitoring results.

If you have water or sediment quality data you would like to share, or if you would like to learn more please visit greatlakesdatastream.ca or contact datastream@gordonfn.org.

By Carolyn DuBois, Executive Director, DataStream

Connect with and inspire young learners through Sea Grant's Students Ask Scientists video chat program

Scientists need little reminding that the importance of their work is amplified through outreach. Yet young learners, grades 5-12, are a potentially overlooked audience with much to gain from exposure to current Great Lakes research. To help bridge this gap, Sea Grant educators from the Center for Great Lakes Literacy (CGLL) host Students Ask Scientists (SaS): Great Lakes Video Chats, which connects Great Lakes researchers with classrooms across the basin. These virtual meetings have been taking place since 2013 and feature experiences such as a live tour of a research vessel, a targeted presentation, or a question-and-answer session with scientists. SaS video chats provide students a chance to see real-world applications of topics they're learning in the classroom.

After a recent call between a veteran SaS scientist and a 5th grade classroom from Ohio, the teacher commented that the call "was a PERFECT way to conclude our 5th grade unit on ecosystems. It reviewed so many of the concepts we have been discussing, applied them to a local ecosystem, and extended their understanding of how non-native species impact food webs."

The benefits of participating aren't just seen by students and their teachers. Participating SaS scientists have found the program to be personally rewarding when students' excitement shines through the screen. SaS scientists also enjoy collaborating with Sea Grant staff to workshop presentation skills, enhance student engagement, streamline PowerPoints, and simplify visual aids, like graphs. For some, this program may also be an antidote to the burnout so many of us experience in our careers, by igniting the fire in your belly to continue doing the work that you love.

Sea Grant educators are always looking for scientists who are eager to share their research with curious teachers and students. Interested Great Lakes scientists are encouraged to learn more about the program on the CGLL website and from the IAGLR 2021 conference presentation recording and reach out with questions. For those ready to dive in, there is a SaS scientist sign up form at go.illinois.edu/SaSscientist.

By Allison Neubauer, Illinois-Indiana Sea Grant; Susan Daniel, SUNY Buffalo State; and Kristin TePas, IISG

Nitrogen Fixation RCN looking for interested participants

The goal of the newly formed Aquatic N2-Fixation Research Coordination Network (ANF-RCN) is to cultivate a new paradigm of the fundamental, yet understudied, role of N2-fixation in ecosystem processes across the freshwater to marine continuum. Right now, we are trying to reach as many potential participants as possible for future workshops, special sessions (we'll be at JASM 2022!), and synthesis efforts to occur over the next five years. If you are interested, you can find more information about the ANF RCN on our website and Twitter. You can also sign up to be part of the future communications about RCN activities. Please join the network or share this information with others you think would be interested.

By Amy Marcarelli, Michigan Technological University

Lakes Letter is published quarterly by the International Association for Great Lakes Research, a scientific organization made up of researchers studying the Laurentian Great Lakes, other large lakes of the world, and their watersheds, as well as those with an interest in such research.

Edited by Paula McIntyre, IAGLR Communications Director, with assistance from Jessica Ives, Lakes Letter Editorial Team