WATER ON THE MOVE

Seiche or surge?
The Dead Sea’s salt giants
Lake turnover in a warming climate
The art of moving water
Meteotsunamis in the Great Lakes

SPRING 2024, NO. 21
Empowering Great Lakes Communities
Reflections and aspirations of incoming IAGLR President Donna Kashian

The great lakes of the world, with their vast water and rich ecosystems, remind us of the interconnectedness of our world. They are not only a source of ecological wonder, but also a symbol of the communities that thrive around them. These communities, spanning borders and cultures, share a common thread, a deep-rooted respect and commitment to the health and sustainability of these great waters.

As the incoming president of IAGLR, I am grateful for the opportunity to reflect on the role the association has played in my career and the careers of many. In this capacity, I hope to contribute to the tradition of promoting collaboration among scientists, policy makers, rights holders, and stakeholders to advance understanding of the world’s great lake ecosystems.

First, I would like to highlight the achievements of IAGLR over the past year. Jérôme Marty, our executive director, successfully guided IAGLR through a recovery period resulting from the pandemic. We welcomed Communication Coordinator Nicole Wood and witnessed Communication Director Paula McIntyre take on new responsibilities as strategy advisor. We successfully broadened our reach and impact. Our outgoing president, Neil Rooney, effectively embraced the momentum of engaging Indigenous Knowledge holders and stakeholders to advance understanding of the world’s great lake ecosystems.

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Looking ahead, I would like to expand efforts within IAGLR to continue to build our great lake communities and empower individuals, especially those at the start of their careers and from underserved populations. I hope to continue to build inclusive cultural perspectives for our collective journey of discovery, collaboration, and stewardship for the great lakes of the world with our shared goals to understand and protect these lakes and their surrounding communities.
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Meet JGLR's new lead editor

We are pleased to welcome Margaret Docker, the next lead editor of the *Journal of Great Lakes Research*. Docker will start in November for a transition phase working with outgoing editors Bob Hecky and Stephanie Guildford, and she will assume the full role in January 2025.

**Q. Tell us a little about yourself.**

**A.** I did my undergraduate and graduate degrees at the University of Guelph, and I’m now a professor in the Department of Biological Sciences at the University of Manitoba (with 14½ years of postdoc positions in between). Much of my research focuses on sea lamprey in the Laurentian Great Lakes or the use of environmental DNA to monitor fish and other aquatic species in Lake Winnipeg and its watershed. As a result, I have one foot in the Laurentian Great Lakes and one in Manitoba’s great lakes, and my work relates to both management of aquatic invasive species and conservation of species at risk.

**Q. What interested you in the role of JGLR lead editor?**

**A.** I have a long association with JGLR (as a reader, reviewer, author, and guest/associate editor), IAGLR, and the Great Lakes Fishery Commission. JGLR feels like my “community,” and I was excited about the opportunity to be lead editor of a journal that serves this community. I think we’re reaching a crisis in scientific publishing; reviewer burnout is at an all-time high, and article processing charges from “elite” journals continue to rise. Being able to ask authors, reviewers, and associate editors to entrust their work or devote their volunteer labor to a journal that serves the community rather than a for-profit publisher was important to me. I’ve always liked how JGLR and IAGLR show appreciation for reviewers and associate editors (e.g., with awards and social media posts), recognize author contributions with best paper awards (especially for students and early career researchers [ECRs]), and serve the broader community with initiatives such as the IAGLR International Travel Award.

**Q. What do you think makes JGLR different to other aquatic journals?**

**A.** I think the greatest difference between JGLR and other aquatic journals is its multidisciplinarity, not just in terms of taxonomic coverage, but by including the social sciences as well as a range of disciplines across the natural sciences. Readers are exposed to relevant topics outside their immediate area of expertise that they wouldn’t have come across otherwise, and authors have their papers brought to a much broader audience. I think this breadth and multidisciplinarity is especially important for the meaningful application of research results.

**Q. What is your vision for the journal over the next few years?**

**A.** Another reason why I was interested in the JGLR lead editor position was that the job posting specifically identified several goals that I also share. These include continuing to foster diversity on the editorial board—which serves as the “gatekeeper” of the publication process—and increasing diversity of contributions, particularly from outside of Canada and the United States. In addition to increasing geographic diversity, I want to help reduce barriers to publication for non-native English speakers and be particularly welcoming to students and other ECRs as authors and reviewers. Working with the associate editors and others on the IAGLR team, I also want to continue efforts to identify topics of interest for special sections and editorials, including recognition of the 50th anniversary of JGLR.

**Q. Any favorite JGLR articles?**

**A.** It would be hard to single out one or a few favorite articles, but—and my sea lamprey bias is showing here—the entire collection of articles in the two special issues from the Sea Lamprey International Symposium (SLIS II and SLIS III) in 2003 and 2021 would be right near the top. For sea lamprey biologists, they’re indispensable collections.
Congratulations IAGLR award and scholarship winners

**LIFETIME ACHIEVEMENT AWARD**

**STEPHANIE GUILDFORD** and **ROBERT HECKY** received IAGLR’s Lifetime Achievement Award for important and continued contributions to large lake research. Both are professors emeriti in the Biology Department and Large Lakes Observatory (LLO) at University of Minnesota–Duluth. Their colleagues note that Guildford and Hecky are “a true team in science and in life.” The couple met at the Freshwater Institute in Winnipeg and worked together there for several years. They eventually married and have been working on large lakes in North America, Africa, and elsewhere ever since.

“Together, Stephanie and Bob have been trailblazers in limnology, making important contributions that furthered our understanding of diverse topics,” writes Ted Ozersky, LLO associate professor. “This work includes seminal papers about the role of nutrients in eutrophication and its remediation, how light and different nutrients interact to limit productivity in lakes and oceans, how lake food webs are connected across habitats, the impacts of anthropogenic disturbance on the African Great Lakes, and how invasive mussels have re-engineered the nutrient cycle of the Laurentian Great Lakes.”

In addition to their contributions of high-quality science, the couple has made a large imprint on the field of large lake research as mentors and team builders. In addition, since 2012, Hecky and Guildford have served as co-editors of IAGLR’s *Journal of Great Lakes Research*.

**ANDERSON-EVERETT AWARD**

**MARY GINNEBAUGH** received this award in recognition of her long-time service to IAGLR. Ginnebaugh, who is retired from Wisconsin Department of Natural Resources, joined the association in 1985. Her recent service includes a term on the IAGLR Board of Directors, where she provided an important voice in financial strategy and the hiring of a new executive director. She also took on co-chairing the Conference Committee during a critical time as we returned to in-person meetings after the pandemic. In 2013, Ginnebaugh established the David D. Dolan Scholarship in memory of her husband and continues to provide oversight and financial support to the benefit not only of the graduate students conducting the research, but to the understanding and management of Great Lakes ecosystems. Ginnebaugh and Dolan, who also served on the board, received the Anderson-Everett award jointly in 2001.

**LARGE LAKE CHAMPION AWARD**

**JENNIFER BOEHMÉ** (Great Lakes Observing System) was recognized for her committed efforts to address Great Lakes water quality and pollution issues to protect human health, collaborating across borders, organizations, and agencies. Boehmé’s dedication to linking research to policy has helped to safeguard human health and the health of the ecosystem.

**JOHN HARTIG** (University of Windsor) has championed ecosystem restoration for 45+ years, leading to some of the most successful restoration and revitalization stories in North America. Hartig helped nurture, operationalize, and implement an ecosystem approach in restoring the most polluted areas of the Great Lakes. Now ecosystem-based management is accepted in water policy worldwide. There is no better example of his impact than his work on the Detroit River. Cleaning up the river led to its economic revitalization including the award-winning Detroit International RiverWalk.

**HENRY LICKERS** (Haudenosaunee citizen of the Seneca Nation, Turtle Clan) has spent a career bridging knowledge systems and sharing stories to encourage others to recognize that science and Traditional Knowledge need each other. Lickers has been instrumental in incorporating First Nation’s people and knowledge into environmental planning and decision making throughout the Great Lakes region.
ASSOCIATION NEWS

Awards continued

JOURNAL AWARDS


ALEXANDER DUNCAN (Chippewas of Nawash Unceded First Nation, Fisheries Assessment Program) received the Elsevier Student Author Award for the article “An investigation into Saugeen Ojibway Nation-based ecological knowledge on the ciscoes (Coregonus spp.) of Lake Huron,” Journal of Great Lakes Research 49, S138-S147 (2023). Co-authors include Ryan Lauzon and Cavan Harpur.

ELAINE HO-TASSONE (NORDIK Institute/Algoma University) received the Elsevier Early Career Scientist Award for the article “Collaborative watershed analysis: A ‘groupthink’ assessment of cumulative effects,” Journal of Great Lakes Research 49, S104-S115 (2023). Co-authors include Andrew Judge, Andrew Trant, and Simon Courtenay.

EDITOR’S AWARDS

MARLENE EVANS (Environment and Climate Change Canada) received the Outstanding Associate Editor 2023 Award for outstanding support of the review process for the Journal of Great Lakes Research.

BERNARD CRIIMINS (Clarkson University) received the Outstanding Reviewer 2023 Award for outstanding support of the review process for the Journal of Great Lakes Research.

SCHOLARSHIPS

CHRISTINE ATUHAIRE (Makerere University, Uganda) received the 2024 IDEA+ Research Scholarship for the presentation titled “Remote sensing of marine plastics on Lake Victoria in Uganda” at this year’s Conference on Great Lakes Research.

RUTH DUNCAN (Trent University) received the 2024 IDEA+ Presenter Scholarship for the presentation titled “Maawanji’idiwag: Reflections on the journey of building a multi-national network to support Indigenous-led Great Lakes Research” at the conference.

JUSTIN HUBBARD (University of Toronto) received a 2024 Norman S. Baldwin Fishery Science Scholarship for research on “Predicting freshwater invasion risks under current and future conditions.”

ZACH JONES (University of Windsor) received a 2024 Norman S. Baldwin Fishery Science Scholarship for research on “Determining the effect of winter duration on a warmwater fish: using inland lakes to inform Great Lakes management.”

NUSRAT KHAN (Arizona State University) received the 2024 David M. Dolan Scholarship for research on “Deciphering dynamics with advanced statistical analysis of TKN trends in Great Lake tributaries over four decades.”

SARAH PETERSON (University of Wisconsin) received the 2024 IAGLR Scholarship for research on “Coastal geomorphological changes under fluctuating water levels in the Great Lakes.”

SAM FRANCIS SAGE (The Ohio State University) received the IAGLR Outstanding Student Paper Award (at IAGLR 2023) for research on “Combating legacy phosphorus: Phosphorus removal structures for tile-drained agricultural fields.”

JANVIÈRE TUYISENGE (IHE Delft Institute for Water Education, Delft, Netherlands) received the 2024 IAGLR International Travel Award for the presentation titled “Cage aquaculture in Lake Kivu-Rwanda: Examining the implications for water quality and greenhouse gas emissions” at this year’s conference.

AMANDA WELSBACHER (Penn State Behrend) received the IAGLR Outstanding Student Poster Award (at IAGLR 2023) for research on “Collection of Nitellopsis obtusa and determination of eDNA signal detection limit.”

Student award winners at last week’s conference. Pictured are Ruth Duncan, Alex Duncan, Nusrat Khan, Janvière Tuyisenge, Christine Atuhaire, and Zach Jones.
Meet the newly elected members of the IAGLR Board

Welcome new and re-elected members of the 2024–2025 IAGLR Board of Directors! Newly elected members include Jada Langston, Ronald Semyalo, and Zanko Zandsalimi. Alex Maguffee was re-elected to a second term as secretary.

IAGLR Board of Directors leadership changes

With the passing of the gavel at last week’s conference, our new presidential lineup for the 2024–2025 IAGLR Board of Directors includes Donna Kashian (president, center), Paris Collingsworth (vice president, right), and Neil Rooney (past president, left). Thank you for your commitment and service to IAGLR!
Recordings available
If you missed a session or want to rewatch one, make sure to visit the conference portal. Recordings will be available soon for all registrants. If you need help logging in, please review the Virtual Access Instructions.

How did we do?
What did you think of the break on Wednesday afternoon? How were the different events? The food? What can we do better? Please let us know!

If you attended IAGLR 2024, please keep an eye out for an invitation to participate in a conference survey. We sent a link for the survey to the emails used for registration on Wednesday, May 29. Reminders will go out to folks who haven’t yet filled it out by the June 12 deadline.

Thank you in advance for taking the time to respond to the survey. Your feedback is invaluable to us in planning the conference.

Conference highlights
We had a fantastic time seeing everyone in Windsor last week for the 67th Annual Conference on Great Lakes Research. More than 800 people from 18 countries attended, either in-person or virtually, to enjoy 600+ presentations and three plenaries. Many thanks to the local team for hosting a great conference, including Site Chair Mike McKay (University of Windsor) and program co-chairs Catherine Febria (University of Windsor) and Carol Miller (Wayne State University).

Lead editor change at Journal of Great Lakes Research
Margaret Docker was announced at the conference as the next lead editor of the Journal of Great Lakes Research (see page 4 for an interview). Docker is pictured above seated at right with outgoing editors Stephanie Guildford and Robert Hecky (also seated), associate editors, and others at the Editor’s Reception last week.

MPs visit with IAGLR Board
Irek Kusmierczyk, Member of Parliament for Windsor–Tecumseh (at left) and Terry Duguid, Member of Parliament for Winnipeg South, Parliamentary Secretary to the Prime Minister and Special Advisor for Water (fourth from right) visited with the IAGLR Board to share about federal freshwater initiatives and offer advice on connecting science with Great Lakes decision making.
Welcome new IAGLR members

The following members joined the association between February and April 2024. We’re glad to have you as part of the IAGLR community!

Jeremiah Adesanya
Claire Ajambo
Khoren Avetisyan
Kerrice Bailey
Aabir Banerji
Rose Basooma
Mackenzie Beach
Happiness Beda
Kati Bell
Alia Benedict
Kezzy Besa
Huifang Bi
Cailin Bishop
Flavia Breje
Alison Bressler
Sabrina Brueggemann
Katelyn Brown
Andrew Bumps
David Burge
Sarah Burk
Lucinda Busselle
Danyka Byrnes
Soryong Chae
Mbumba Chalira
Mwayi Chirwa
Anson Chow
Emily Clark
Kristen Coleman
Abigail Comar
Colleen Cosgrove
Katie Crundwell
Haley Dalian
Erik Dean
Paul Den Uyl
Lillian Denecke
Miranda Devan
Judy Dezse
Sonja Drosdoweck
Bryce Ducharme
Hamed Ebrahimi
Devin Edge
Hana Esber
Faith Ferrato
Christopher Filstrup
Kristina Flanigan
Abraham Francis
Qiudi Geng
Adam Gillespie
Malika Gottfried
Tyler Hampton
Ethan Harrop
Lauren Hart
Libia Hazra
Zachary Hilbert
Haley Hoehn
Ebie Holst
Neve Hudson
Genna Hunt
Brendan Hunter
Peter Jobin
Deandra Jones
Yordanos Kasahun
Kat Kavanagh
Miraj Kayastha
Mitch Kehne
Ali Kheiri Mazraeh
Dustin Kincaid
Katelyn King
Corbin Kohart
Amanpreet Kohli
Benjamin Kondowe
Benjamin Kramer
Burak Kuyumcu
Jada Langston
Sean Leng
Kar Long Leung
Shai Lis
Xiaofeng Liu
Jarrod Ludwig
Zira MacFarlane
Stafford Maracle
Haley Matschke
Robin Matthews
Melissa Mattwig
Luke Mawhinney
Autumn McGowan
Zachary Mills
Natalie Minda
Ali Mokdad
Brigitte Mongane
Asmita Murumkar
Austin Nair
Reza Najafi
Allison Nalesnik
Amber Ng
Julia Obuya
Jill Olin
Sophie Orendorf
Cooper O’Rourke
Ryan Otter
Erin Overholt
Isabelle Paulsen
Kristen Pearce
Thomas Pendergast
Michael Penka
Kelly Peterson
Emma Pirie
Melika Rahimimovaghari
Riley Ralph
Margaret Rettig
Jessie Reynolds
Valerie Risch
Rylie Robinson
Hunter Roose
Liane Rosario
Aziza Said
Thomas Saleh
Phoenix Sandrock
Mithra Sankrithi
Thomas Schiffer
Maiza Saqib
Serena Schaffer
Amber Schmidt
Jacqueline Serran
Marsha Serville-Tertullien
Vinayak Shedekar
Ian Smith
Erin Smith
Mollie Sorrell
Elizabeth Spitzer
Ashlyn Stanaloni
Isabelle Staph
Heather Stirratt
Grayson Tellier
Sydney Todd
Kate Truitt
Pei-Lan Tsou
Nicole Turner
Alana Tyner
Iradukunda Valentine
Christopher Vandergoot
Zheng Wang
Christopher Ward
Grace Watson
Dillon Weik
Katelin Weitzel
Phil Wernette
Yan Jin Xu
Ruohao Zhang
Shuting Zhang
Helen Zhang
Xing Zhou
Elizaveta Zvereva
Kudos

Congratulations to the following IAGLR members!

**LUCINDA JOHNSON** (University of Minnesota Duluth) for receiving the 2024 Environmental Stewardship Award from the Society for Freshwater Science. The award recognizes her career spent leading multidisciplinary teams and focused research on freshwater ecosystem management, rehabilitation, and conservation. This background has allowed her to forge engagements at the nexus of ecosystem studies, natural resource management and policy. Her advisory roles on top-tier boards and committees have been impactful in informing public policy and management decisions. And her university role as an educator and mentor to many up-and-coming freshwater scientists leaves an impressive legacy.

**DONNA KASHIAN** (Wayne State University) for being named a Leader in Sustainability by *Crain's Detroit Business*. Kashian was recently named director of the United Nations Regional Centre of Expertise on Education for Sustainable Development at Wayne State.

**DEBORAH LEE** (NOAA Great Lakes Environmental Research Laboratory) for receiving the American Society of Civil Engineers Environmental Water Resources Institute's 2024 Lifetime Achievement Award.

**NICHOLAS MANDRAK** (University of Toronto Scarborough) for receiving the 2024 Career Achievement Award from the Invasive Species Centre. The award honors those with 20+ years of significant contributions to invasive species prevention and management in Canada.

**MICHAEL RENNIE** (Lakehead University) for being named a new associate editor of the *Journal of Great Lakes Research*.

**REBECCA ROONEY** (University of Waterloo) for being awarded the 2024 Invasive Species Centre Leadership Award for pioneering research on invasive *Phragmites australis* and its control in Great Lakes coastal wetlands.

After an illustrious career spanning more than 33 years, Great Lakes Ecologist **TODD HOWELL** from the Ontario Ministry of the Environment, Conservation and Parks will be hanging up his “Cladofedora.” Todd is one of the foremost experts on nearshore ecology, benthic algae and monitoring in the Great Lakes. His innovative approach to monitoring the nearshore of the Great Lakes has been widely adopted by many colleagues over the years and in lakewide studies that spanned international waters (*Makarewicz and Howell, 2012*). Todd’s scientific contributions have informed policies such as the Great lakes Protection Act and the Canada-US Great Lakes Water Quality Agreement. We, Todd’s colleagues, are grateful to have been provided the opportunity to work closely with him, to learn from him, and to have shared in his enthusiastic curiosity over the years. Congratulations Todd!

by Nadine Benoit and Ryan Sorichetti

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**IN MEMORIAM**

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by Nadine Benoit and Ryan Sorichetti

**BRIAN EADIE**

The Great Lakes scientific community lost a beloved mentor and widely respected research program leader in Brian Eadie, who died of heart failure on January 13, 2024, at the age of 79. His work in biogeochemistry began early in his academic career, and he published works covering a wide range of topics. He spent most of his career at the NOAA Great Lakes Environmental Research Laboratory, from 1974 to 2006. Eadie also served on the IAGLR Board of Directors from 1985 to 1988.

Eadie was well known for his work on sediment resuspension, chemical fluxes, and contaminant cycling in the Great Lakes. Perhaps his greatest contribution was his ability to bring people with different expertise together for large inter-agency research programs such as the Episodic Events Great Lakes Experiment and Nutrient Enhanced Coastal Ocean Program. Eadie was not only a great leader of science, he was a mentor and builder of careers for young scientists at every level. His calm demeanor, the willingness to listen, and to provide guidance on the science, administration, and personal development of scientists resulted in the growth and recognition of the Great Lakes Environmental Research Laboratory as a world-class organization.

Tribute gifts in his honor may be made to the IAGLR Scholarship Fund.
The terms *storm surge* and *seiche* are frequently used interchangeably, especially in the press and on social media following large surge events. While these phenomena are related, they are distinct. This is not just a matter of semantics; if you consider the equations of motion that determine the behavior of water in a lake, the dynamical balances that describe these phenomena are fundamentally different. While this may seem like splitting hairs to some, these should not be used interchangeably, any more than a fisheries biologist would use *Cisco* and *Siscowet* interchangeably. So how do we define these two phenomena?

Lake Erie pounds the pier as a strong northeast wind picks up at Luna Pier, Michigan, September 1, 2017. The Blade/Andy Morrison.
A storm surge is a response of a lake to external atmospheric forcing; typically a strong wind along the axis of a lake, pushing water to one end, or a large difference in atmospheric pressure across the lake, causing one end of the lake to get deeper and the other shallower (there can also be setup due to incident breaking waves, which we won’t consider here). For the wind-driven response, the size of the difference is inversely proportional to lake depth, so wind-driven storm surges are larger in shallower lakes; hence shallow Erie being the home of the most dramatic, damaging, and deadly surges. The response to atmospheric pressure gradients is often referred to as the inverse barometer effect, where the atmosphere pushes down harder on one end of the lake than the other, causing the high-pressure end to be shallow and the low-pressure end to be deep relative to the unforced case. The relative importance of these varies between the lakes; Lake Erie is dominated by wind forcing; the response in deep Lake Superior is dominated by atmospheric pressure gradients.

In contrast, a seiche is the oscillatory response of a lake that results from that forcing. (Lakes in seismically active regions, such as Crater or Tahoe, can have seiches set off by seismic activity; that’s not such a big deal in the Laurentian Great Lakes.) Once the external forcing is removed, the lake relaxes back toward its equilibrium state (i.e., a level surface), but overshoots, resulting in a reversal of which side of the lake is highest. This process of relaxation and overshoot results in periodic sloshing back and forth, first formally called a seiche by Forel in 1890 based on observations of Lake Geneva. This process continues until another wind event occurs or the energy associated with the seiche is dissipated by bottom friction. The exact same dynamics govern coffee sloshing back and forth in your coffee cup, or water sloshing back and forth in a bathtub; only the scales are different.

By analogy, storm surge can be thought of as a guitar string being pulled to one side by a guitarist’s finger; once the force is released, the string will oscillate back and forth with no external forces applied, analogous to the seiche. A fundamental feature of both a vibrating guitar string and a seiche is that the period (or, equivalently, frequency) of the resulting oscillation is a function of the geometry of the scenario, but independent of the forcing. No matter how hard the wind blows, the period of a seiche will always be a function of the length and depth of a lake. Likewise, the frequency of a plucked guitar string is a function of the characteristics of the string (specifically, tension, linear density, and length), not how hard it is plucked. For Superior, the primary seiche period is about eight hours; for Erie, about 16. Both the guitar string and a seiching lake will also have higher frequency oscillations, often referred to as harmonics, but most of the energy is typically in the lowest, fundamental frequency.

When there are high water levels in, say, Buffalo or Toledo, it is almost always due to the initial storm surge; any resulting high water level 16 hours later because of the subsequent seiching behavior typically results in much smaller water level displacements, as energy is dissipated from the system. While high water levels pose the obvious threat of coastal flooding, low water levels can cause problems too. During a strong storm surge event on Lake Erie in December 2022, water levels near the Davis-Besse Nuclear Power plant near Toledo became low enough that there was concern that the cooling water intakes could be exposed, nearly leading to a shutdown of the plant. The threat to coastal communities from these displacements of water is real, regardless what word we use for them, but as limnologists, it is worth noting that there are two distinct processes that we should be careful to distinguish between.

Jay Austin is a professor at the Large Lakes Observatory, University of Minnesota Duluth.
OUR TEAM has been conducting field observations and numerical studies in the Dead Sea to gain insight into the formation of kilometer-thick so-called salt giants that have been identified in the sedimentary sequences of Earth’s crust. At present, the Dead Sea is the only deep hypersaline lake on Earth that allows us to study the coupled heat and salt transport processes that create such large salt deposits. As a terminal lake, its surface level has been declining at a rate of one meter annually due to the diversion of freshwater inflow from the Jordan River and evaporation from industrial ponds. This has led to a dramatic increase of the Dead Sea’s salinity—now about 10 times that of the ocean—and as a result has led to the formation of salt crystals that settle onto the lake floor where they have formed a salt deposit of about four meters thick since around 1980.
The formation of these salt deposits is governed by so-called instabilities of the water column, which allow tiny disturbances to grow into large-scale flows. Particularly important in the Dead Sea, the double-diffusive instability occurs when warm and salty surface water exists above cooler and less salty water below. This situation exists during summers, when intense sunshine heats up the surface water and causes it to warm and evaporate leaving the salt behind so that it becomes warmer and more concentrated. When the lake surface is disturbed by waves or other motion, tiny parcels of warm water enter the cooler water below. Since heat diffuses more rapidly than salt, this warm water parcel cools rapidly. Colder water can hold less dissolved salt, and hence some of this parcel’s salt precipitates out and forms crystals that sink to the bottom. This instability amplifies centimeter-scale disturbances and causes them to grow into meter-size salt fingers of warm and salty brine that descend to the cooler lower layers of the lake, where they lose heat, become supersaturated, and precipitate salt crystals that “snow” onto the lakebed. As these salt fingers grow larger and stronger, they develop yet another instability, which can lead to the emergence of thermohaline staircases, across which the temperature and salinity of the water jumps by a large amount over a very short distance. During winter, on the other hand, the entire water column is well mixed. Hence salt fingers do not form, but since the water is still supersaturated, it now produces fine salt crystals at all depths that form a smooth deposit (see photo on previous page). Salt chimneys (pictured, top right) form around discharges of underwater springs; the mixing of spring water with Dead Sea brine results in mineralization of aragonite and gypsum that form vertical chimneys, which are coated externally by halite through contact with the supersaturated Dead Sea brine.

At present, the Dead Sea is the only water body on Earth that is salty and deep enough to produce the salt fingers that generate this salt snow. Consequently, it represents a unique opportunity for researchers to study the mechanisms that create and shape thick salt deposits, such as the one that formed below the Mediterranean Sea about five million years ago when the Strait of Gibraltar closed off, cutting off the supply of water from the Atlantic Ocean, thereby creating an inland sea similar to the Dead Sea today.

The rapid lake level decline of about one meter annually also exposes vast areas of newly formed beach every year (pictured above right, bottom image) and provides lessons regarding the stability, erosion, and protection of arid coastlines under sea level change. It offers opportunities to study the natural formation of beach berms and the transport and sorting of gravel that enters the Dead Sea via seasonal streams that discharge flash floods. These transient streams display strong meandering behavior as they incise deeply into the newly exposed beach areas, and they form knickpoints as a result of the sea level fall. The setting of the Dead Sea allows us to determine the migration velocity of such knickpoints, and to test measures for protecting coastal infrastructure from their impact.

Interested readers can find additional information in an upcoming review in Annual Review of Fluid Mechanics.

Left: Layers of salt (halite) and sediment (mud) deposited in the past four decades. Annual layers are of ~0.1 meter thick. Top right: Salt chimneys up to 20 meters in size. Top right, bottom image: Coastline showing annual steps of about one meter due to lake level fall.
How might the thermal stratification in Lake Ontario change as the climate warms?

by MATHEW WELLS
University of Toronto Scarborough

THE WATER TEMPERATURE in the middle of Lake Ontario during the winter of 2023–24 was likely the warmest it has ever been, and the resulting changes in the thermal stratification and mixing cycles may give an indication of what is in store as the climate warms. The thermal regime of the Great Lakes is important for many reasons—it determines local weather patterns and influences the quality of drinking water. Temperature is also an abiotic master factor that affects virtually all biochemical, physiological, and life history processes in fishes. Most previous research studies have focused on summer conditions with the winter period (roughly October through April) being greatly undersampled. To address this knowledge gap, Tim Johnson (Ontario Ministry of Natural Resources and Forestry) and I used funding from the Great Lakes Observation System to measure the temperature profiles in Lake Ontario over the last three winters.

Preliminary satellite observations by NOAA suggest that the surface waters in the center of Lake Ontario never cooled below 4°C this last winter. This is important, as water has its maximum density at 4°C, and further cooling, somewhat counter intuitively, results in less dense water. In typical winters, historic records between 1936 and 1986 suggest that the temperatures in the center of the lake were 2°C and rose to 2.5°C between 1993 and 2023. There was variability in these temperatures, and 2012 was possibly nearly as warm as last winter. With a warming climate, the conditions experienced last winter may become the norm rather than the exception. While a 2°C increase in winter temperature may seem small, it likely signals a profound change in circulation dynamics compared to 50 years ago.

The figure on the next page summarizes the annual cycle of mixing in Lake Ontario during a colder winter and a warmer winter. The main difference between them is the timing and duration of the mixing and stratified periods. In both cases, during late fall when air temperatures are dropping and water temperatures are well above 4°C, convective cooling combined with strong winds can homogenize the water column. This is the well-known fall overturn. Cooling occurs fastest in the shallow edges of the lakes, and these are regions where ice potentially first forms, as shown above. During early winter, when temperatures drop below 4°C, further cooling could lead to a stable inverse stratification whereby colder water is actually lighter. However there is a competition between the tendency for wind to mix the water column and the stabilizing influence of cooling below 4°C. In fall and winter, the mechanical mixing from winds blowing over Lake Ontario usually dominates, resulting in vertical homogenization of the water column, so that we rarely see any substantial, sustained winter inverse stratification.

During late winter and spring, when waters are below 4°C, an important source of mixing is paradoxically from solar heating, as the days become longer. Heating water that is...
below 4°C actually makes the water denser, so that it sinks and mixes the water column. Surprisingly this so called radiatively driven convection can actually be more effective than wind-driven mixing in homogenizing the water column. In particular, as we move from winter to spring, there is a point where the water column warms past 4°C (the maximum density of water), at which point the whole water column must mix. This spring overturn is very important in redistributing oxygen and nutrients through the water column. After the water column has warmed above 4°C, it can now start to develop thermal layering (stratification), whereby the warmer, lighter waters float above the colder, denser waters. This stratification greatly limits the vertical mixing between the surface and the bottom of the lake. This stable summer thermal stratification typically forms between May and June, but in a warmer winter could occur in April or even earlier.

While the waters of Lake Ontario are usually well-mixed vertically during winter, there are important lateral gradients in temperature across the lake. The shallow regions of the lake that are less than 50 meters in depth cool down more quickly in the fall and warm up fastest in the spring. The deeper regions of the lake that are 100–200 meters deep have a larger thermal mass and a slower response time. In typical cold winters, the center of Lake Ontario can be above 4°C in January while the shallow edges have cooled to near freezing so that ice can form nearshore, and then in April or May the edges of the lake may have warmed above 4°C, while the middle of the lake is still 2–3°C. Similar (but warmer) gradients would likely be set up in fall and winter in a warmer climate.

The warmer climate of the future implies that Lake Ontario may never again cool below 4°C in the deep center, and we expect the duration of the winter mixing period to shorten. The biggest change would be that there is no longer a sustained period of solar-driven radiation homogenizing the water column in spring as the water warms from below 4°C. Rather only the wind could drive vertical mixing, and the winter overturn will be reduced to an extended period of fall overturn driven primarily by mechanical mixing from the strong westerly winds that blow over the 300-kilometer length of Lake Ontario. These changes in the duration and timing of the mixing periods and thermal stratified periods will have profound effects on the food available for fish to eat and when they reproduce, how dissolved oxygen is mixed from the atmosphere to the lake bottom, and where phytoplankton would grow within the water column.

“With a warming climate, the conditions experienced this last winter may become the norm rather the exception. While a 2°C increase in winter temperature may seem small, it likely signals a profound change in circulation dynamics compared to 50 years ago.”
The Art of Moving Water

Living near the Great Lakes instills in us a deep affinity for the water. It evokes a desire to either glide atop its surface or plunge beneath it. Avid photographer and sailor Christopher Lamb can often be found aiming his camera at the lakes. He captured the cover photo as well as the images on this and the following page. Lamb also shares a favorite story of a memorable sailing race when the water was on the move.

Photos by CHRISTOPHER LAMB

Top left, clockwise: An evening at Lake Michigan’s Point Betsie lighthouse. Sunset at Fisherman’s Island State Park on Lake Michigan. A stormy Lake Superior at Tettegouche State Park, Minnesota. Point Betsie, a welcoming lighthouse during the Mackinac Race, as seen from the air. Bottom: North pier lighthouse, Frankfort, Michigan.
I’VE HAD THE PRIVILEGE of participating in numerous Chicago to Mackinac sailboat races, a course that extends from Chicago 333 miles north to the top of Lake Huron, terminating at Mackinac Island. This year marks my 20th race, having served as both captain and crew. The lakes possess their own unique temperament, with each year bringing radically different conditions. It’s not uncommon for the lakes to conjure their own weather, influencing sailors and navigators across their vast expanses as they sail northward.

Among the many races etched in my memory, 2018 stands out for its demonstration of the lakes’ intriguing nature. A powerful northerly wind pattern whipped across Lake Michigan, generating waves that continued to build over its entire length of nearly 310 miles, culminating in a tumultuous start to the race and tragically, the loss of life for the second time in its history.

During summer, Lake Michigan’s surface water is warm, while its depths grow progressively colder. However, this race presented a unique scenario where warm surface water had been displaced to the southern reaches of the lake, essentially being “pushed” from the north all the way to the Chicago area. Enduring 35 hours of being doused with warm water wasn’t the most pleasant experience, even for seasoned sailors with great gear. This displacement, known as upwelling, brought colder water to the surface of northern Lake Michigan, ushering in its own weather dynamics including stiff winds and unexpected fog as we headed north.

The sight of other sailboats was reduced to mere silhouettes gliding through the thick fog, an eerie yet incredibly unique spectacle from our vantage point on the sailboat’s rail. The colder waters brought with them chilly air, catching many off guard with rapidly changing conditions.

To label Lake Michigan simply as a “freshwater lake” would be accurate but insufficient. The Great Lakes are better described as inland oceans, deserving our respect.

by CHRISTOPHER LAMB

South Manitou Island, as taken during the Mackinac race while sailing through northern Lake Michigan’s Manitou Passage in the evening. Photo by Christopher Lamb.
Meteotsunamis in the Great Lakes

by ERIC ANDERSON
Colorado School of Mines

METEOTSUNAMIS HAVE ALWAYS BEEN THERE, but it wasn’t until recently that their place amongst the different types of Great Lakes waves was recognized. The term is a combination of meteorological and tsunami and aptly fits both their wave characteristics and mechanism by which they are generated. Technically speaking, meteotsunamis are long waves with periods between roughly two minutes and two hours, which in the wave spectrum is situated between the more commonly observed wind waves and the large, standing waves known as seiche.

However, unlike seismic tsunami waves, which are generated by earthquakes or landslides, meteotsunamis are initiated by a few specific combinations of atmospheric conditions. The most recognizable forms of these weather conditions are what we would call thunderstorms (mesoscale convective systems) or squall lines, but generally speaking, they are any fast-moving system that has a sharp change in air pressure, and at times, wind speed. A key ingredient comes in the speed at which these atmospheric conditions move over the Great Lakes, wherein if the storm propagation speed is close to the underlying (water) wave speed, a resonance is achieved, and the atmosphere can efficiently transfer its energy into the lake below. This process results in the generation, growth, and sustainment of the meteotsunami wave in the lake. However, it is only as the wave reaches shore, where depths decrease dramatically and wave shoaling occurs, where the wave can be amplified to a level that becomes hazardous to the public.

The first Great Lakes meteotsunami appropriately attributed as such occurred on May 27, 2012, in Lake Erie. This event swept swimmers into the lake, swamped marinas, and capsized boats nearshore, and it also served as the commencement of meteotsunami research within the Great Lakes. From that point forward, several notable historical events were then reclassified as meteotsunamis, with perhaps the most famous case having occurred in Chicago in 1954 when eight people were killed.

Over time, our understanding of meteotsunami generation and occurrence matured, and the Great Lakes community joined a growing international scientific field that was starting to recognize meteotsunamis as a global phenomenon. In the Great Lakes, it has been determined that many meteotsunamis occur each year; however, most go unnoticed, as hazardous episodes only occur every few years at best. Yet, in recent years, we have also seen that even small, benign meteotsunamis can play integral roles in sediment resuspension, contaminant transport, and coastal hydrology.

Even if rare, meteotsunamis can pose a risk to beachgoers and property owners along the Great Lakes, just like the more commonly recognized wind waves and seiches. However, unlike these types of waves, no forecast exists for meteotsunamis. Researchers have been working on developing meteotsunami forecasts for the past several years, and while there has been success in recreating specific events, operational forecast systems are still unable to provide advance warning of their formation. In part, this is because weather forecast models struggle to predict thunderstorm characteristics.

However, a recent Lake Michigan event revealed that all is not lost. In 2018, a meteotsunami was created by an atmospheric gravity wave, or essentially a large air pressure disturbance that rolled over the lake. It just so happens that these type of weather conditions are better predicted by existing weather forecast models. While they may only be a fraction of the types of weather systems that create meteotsunamis in the Great Lakes, it has become the first sign that a forecasting system may be within reach.
Coastal wetlands provide essential ecosystem services that enhance nearshore water quality by regulating biogeochemical processes (e.g., phosphorous dynamics). As water moves through a coastal wetland, nutrients, especially phosphorus, are reduced by sedimentation and uptake / assimilation into aquatic communities reducing their delivery to the coastal zone of the Great Lakes.

However, coastal wetlands can periodically be inundated with lake water from seiche (also known as standing wave) events. Seiches occur when strong winds and changing atmospheric pressure during storm events force large-scale lake water movement. As such, little is known about how seiches affect nutrient dynamics and fate in coastal wetlands, including net loadings to the coastal zone. Generating accurate estimates for nutrient loadings into Lake Ontario is essential for a fulsome understanding of potential nutrient sources, especially under the Great Lakes Water Quality Agreement (Annex 4).

An alternative process-based statistical model was created and identified that weather-induced seiche events and increased water movement amplified phosphorous loadings to the coastal zone of Lake Ontario. As water moves into coastal wetlands during seiche events, resuspension of sediments can occur like a tidal bore. Nutrients, such as phosphorus, sequestered in sediments are then released into the water column. When the water reverses flow direction, the resuspended nutrients are transported into Lake Ontario. As a result, this hydrological phenomenon impacts the nutrient retention capacity of coastal wetlands. With climate change intensifying the frequency of storm events across the Great Lakes Basin, seiche-induced inundation of coastal wetlands will pose a greater concern for nutrient processing and fate, facilitating localized phosphorous inputs to the coastal zone (Harrow-Lyle et al. 2023).
Observing surface water currents and plastic pollution transport using GPS-tracked drifters

by Patricia Semcesen, University of Toronto Scarborough, in collaboration with Georgian Bay Forever

To safeguard the near-pristine waters of Lake Huron’s Georgian Bay from plastic pollution, Georgian Bay Forever began the “Tagging Trash Trips” project, which used GPS-tracked bottle-drifters to understand where and how water currents transport floating plastic pollution in Nottawasaga Bay, Georgian Bay. Nottawasaga Bay provides drinking water to local municipalities and is a travel destination for over 1.5 million visitors annually who inevitably produce plastic pollution. With time, waves and rocky shorelines break plastic pollution into smaller pieces that are less feasible to capture and become more harmful to organisms (Bucci and Rochman 2022) like the near-threatened Piping Plover that nests on Wasaga Beach. To date, there is little to no existing scientific empirical knowledge on Georgian Bay’s water currents (Greenwood and Sherman 1983; Bennett 1988; Elbagoury et al. 2023), and how these water currents are involved in transporting plastic pollution (Belontz et al. 2022). Our objectives were to understand how water currents transport plastic pollution and to inform where limited resources should be prioritized for the capture and diversion of plastic pollution to minimize adverse consequences.

We enclosed GPS-trackers in plastic bottles that float half-submerged in water to emulate real floating plastic pollution. From the release of our drifters, we learned that most drifters entering Nottawasaga Bay were retained and had traveled tens of kilometers before reaching shore within several days. An apparent near-shore water current transported two drifters out of northern Nottawasaga Bay. This demonstrated that plastic pollution can be quickly transported into rocky areas of Georgian Bay, facilitating plastic fragmentation and reducing cleanup feasibility. Inertial motions of surface water currents caused by Earth’s rotation (Coriolis effect) were observed as the clockwise spiraling motion of drifter paths when winds were weak. An animation of observed drifter tracks can be viewed online. Due to being half-submerged in the water, drifters directly interacted with winds and demonstrated wind-dependent transport, which contributed to drifters travelling twice as fast as would be expected from water currents alone. The use of drifters allowed us to identify spatial patterns of transport and accumulation to inform conservation efforts. The insight and methods of this research can be applied to other waterbodies to learn about surface water currents and plastic debris transport.
Ending an 11-year stint of thoughtful and deliberate leadership, Bob Lambe retired as executive secretary of the Great Lakes Fishery Commission in February 2024. During his tenure, he built bridges among partners and mended fences when needed. He focused on appropriations, infrastructure, and strengthening the relationship between the commission and the Great Lakes Restoration Initiative. He saw potential in each staff member at the commission and structured its programs in ways that took full advantage of what every individual had to offer. Bob’s time at the commission is the culmination of a career replete with achievements. Before the commission, he was director of the Canada-Ontario Invasive Species Centre, a position he took on after his first “retirement,” from the Department of Fisheries and Oceans where he served as regional director general and in various capacities with the Canadian Coast Guard. And, as we all appreciate, he served for many years as a Canadian Commissioner.

Bob led the organization with tremendous skill and vision, and greatly enhanced its ability to do its job in this modern era of restoration. However, while we will miss Bob’s singular leadership, we are delighted to welcome Marc Gaden into the executive secretary role. Marc brings decades of experience in Great Lakes policy, and nearly 30 years of leadership at the commission. He came to the commission in 1995 as the first communications and legislative affairs specialist, a position he held until he became the deputy executive secretary in 2022. Marc has a deep understanding of Great Lakes fishery governance and of the rationale behind the structures that are in place to ensure sound science, cooperative research, and collaborative fishery management.

Thank you, Bob; Welcome, Marc!

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