Great Lakes Winter Science: Summary Report

A report submitted to the
International Joint Commission
Great Lakes Science Advisory Board

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Acronyms

AUVs - autonomous underwater vehicles

CSMI - Cooperative Science and Monitoring Initiative

GLWin – Great Lakes Winter Science collaborative

IJC – International Joint Commission

NOAA – National Oceanic and Atmospheric Administration

SAB – Great Lakes Science Advisory Board

USGS – United States Geological Service

Introduction & Background

A large and growing body of scientific evidence developed over several decades leaves little doubt that anthropogenic activities are changing our planet's climate, and these findings are consistent with traditional knowledge developed over millennia. Northern latitudes are particularly affected—the Great Lakes border the fastest-warming region in the United States, and average surface temperatures in Canada are warming twice as fast as the rest of the world on average. The largest lakes in the world—including the Laurentian Great Lakes—are warming at the fastest rates, and warming of lakes at northern latitudes is greatest during the winter months.

Responses of lakes to climate change are well documented during winter with increases in water temperature, loss of ice cover, alterations in distribution of freshwater fishes, and decreases in deep-water oxygen concentrations. Socioeconomic and cultural impacts from changing winter conditions are mixed. Increases in the length of the shipping season and decreased icebreaking costs due to longer ice-free conditions may confer economic benefits. Potential negative impacts include increased shoreline erosion due to decreased protection from winter storms by shorefast ice, loss of life or safety risks associated with drownings, changes in over-ice transportation, lake effect snowstorm shifts, changing recruitment patterns in valued fishery species, lost recreational opportunities, and loss of cultural identities linked to winter.

Despite winter being the season most affected by changing climate, virtually all Great Lakes monitoring, surveillance and research activities are conducted during the spring, summer and fall seasons when the lakes can be safely and reliably accessed using standard monitoring platforms. In addition to the logistical challenges associated with the specialized equipment, highly qualified personnel, and coordinated approaches needed for winter data collection, until relatively recently there was little appreciation for the abundance and diversity of ecological processes occurring under ice or in cold ice-free waters. As a result, management decisions are usually based on data and models derived from ice-free observations.

Fortunately, a small and growing number of scientists and resource managers across the Great Lakes basin and elsewhere are working to ensure winter is no longer an overlooked season. To help better understand winter science and address winter's unique and changing role in influencing Great Lakes water quality and ecological processes, the International Joint Commission's Great Lakes Science Advisory Board (SAB) undertook this project to document the state of winter science in the Great Lakes. The project developed recommendations to address research priorities that will improve our understanding of the impacts of climate change on winter and on the chemical, physical, and biological integrity of the Great Lakes.

To support its analysis, the SAB established a Work Group[1] who undertook the following tasks:

- A literature review of 151 peer-reviewed articles to synthesize new knowledge published since the completion of other recent literature reviews and workshops, and identification of persistent knowledge gaps pertaining to winter science as it impacts the Laurentian Great Lakes and their watersheds (completed March 2023);

[1] Work Group members are listed in the Acknowledgements section of this report.

- A survey of publicly available databases containing information relevant to winter and winter science in the Great Lakes (completed March 2023);

- Interviews with 12 stakeholders and rightsholders, including agency personnel, academic researchers, and members of shipping and other industries in the Great Lakes (completed April 2023); and,

- Three workshops to:
    - Identify winter science gaps, needs, and science priorities (Workshop #1, held virtually in May 2023);
    - Identify, describe, and assess research needs related to infrastructure, training, and interagency coordination (Workshop #2, held virtually in September 2023); and,
    - Derive high-priority winter science priorities with existing and future capacities and develop recommendations for sustainably meeting winter science needs (Workshop #3, held in-person in January 2024).

The contractor team has produced supporting documents for each task, as well as a project report that provides the basis for this summary report. This report provides an overview of the major winter science gaps and needs identified through the Board's analysis, and its recommendations to the governments of Canada and the United States that, if implemented by governments, will improve the management and policy relevance of ongoing and future science investments in Great Lakes water quality.

1.0 Findings

To best characterize changes occurring during winter and understand how they impact the limnology of the Great Lakes on seasonal and annual scales, winter was defined by calendar dates determined by seasonal photoperiod (December 21 to March 20). This definition is not only applicable across multiple studies but also provides transferrable benchmarks by which interannual shifts in winter phenomena and processes can be evaluated, as well as changes occurring in the fall (November to December) and spring (March to April) shoulder seasons[2].

The SAB is encouraged by the growing understanding and widespread recognition that climate warming is affecting the Great Lakes, and the attendant winter limnology summits and work groups that have been formed to develop knowledge and inform management responses. Notable examples include the Cooperative Institute for Great Lakes Research sponsored summit 'Winter Limnology on the Great Lakes – Prospects and Research Needs' and a Chapman conference 'Winter Limnology in a Changing World' (both in 2019), as well as a growing community of practices as evidenced by the International Society of Limnology Winter Limnology Working Group, National Science Foundation supported Winter Limnology Network, and the ad hoc Great Lakes Winter Science (GLWin) collaborative, and coordinated winter sampling efforts like 2022's Great Lakes Winter Grab. Interest and participation in winter science has been steadily gaining momentum; these and other conferences and workshops, and previous literature reviews have put forth extensive efforts to summarize what is currently known about winter science and have also revealed an extensive suite of knowledge gaps pertaining to winter limnology.

During the three workshops for this project, participants considered the science gaps and needs identified in the literature through the lens of their own professional perspectives and experiences conducting science during all seasons including winter. Workshop discussions allowed an elucidation of which remaining knowledge gaps are the most pressing to address, and generated insights to inform where and how resources could be allocated within the Great Lakes region to close those gaps.

For a detailed account of winter science gaps and needs, and the infrastructure, training, and interagency coordination activities needed to fill them, the reader is encouraged to review the contractor report and associated workshop reports. A high-level and generalized summary of gaps and needs are included in Appendix 1, and major themes identified through project activities are presented below.

1.1 Science Gaps & Needs

Winter science gaps and needs were explored across their chemical, physical and biological domains, and there was broad recognition that cross-disciplinary analysis including Indigenous Knowledge, in the context of socioeconomic and cultural values, are needed to frame the pursuit

[2] Shoulder seasons present conditions where lake sampling/surveys are difficult or dangerous due to weather and ice formation and breakup, and they can vary considerably in timing and duration depending on location in the basin and year-to-year conditions.

of science activities moving forward. Key workshop insights pertained to one or more of the three themes presented below.

Monitoring & Surveillance

Of all the science gaps and needs identified by project participants, one of the most universally shared was concern about a shortage of available winter data. The capacity of the existing Great Lakes science community to collect winter observations is limited by winter science resources, including but not limited to ice-hardened vessels, ice-capable autonomous underwater vehicles (AUVs), hovercrafts, under-ice moorings, and ice-capable buoys. Investments in additional monitoring capacity would enable progress towards expanding monitoring both spatially and temporally and address a perceived paucity of biological data in comparison with chemical and physical data. Examples of needed areas for investment include more observations of currents, temperature, water quality, thermal structure, nutrients, and movement and abundance of biota, among other parameters. Winter observations would benefit from capacity building focused on training students and researchers to conduct winter sampling and research safely and effectively, standardizing winter sampling protocols and developing improved winter sampling methods.

Recognizing that an expansion of winter science capacity is likely to happen incrementally and should inform Great Lakes management across all seasons, an initial and cost-effective action could include year-round, long-term deployments of cabled observatories at strategic locations at appropriate densities throughout the basin. Year-round deployment and continuous data collection would also allow for an improved understanding of winter's shoulder seasons, which are believed to be ecologically important but are notoriously difficult to sample using conventional monitoring platforms due to dangerous conditions associated with ice formation and breakup. As additional resources for winter science are identified, other emerging technologies including remote sensing, observational buoys and sensors, and improved telemetry systems could be leveraged to help fill data gaps and populate continuous databases.

Modeling & Forecasting

A key theme that arose throughout the project was the need to update modeling methods and designs for the purpose of addressing winter science problems. Because physical modeling and forecasting is more highly evolved than biogeochemical and ecological models for the Great Lakes, participants identified immediate priorities related to forecasting annual maximum ice cover in the future, linking models with event-based water quality monitoring to better predict extreme hydrological events, improving flood risk models associated with increased winter runoff volume and changing timing, and improving model biases to increase scientific credibility of modeled outputs.

There was also recognition that coupled physical-biogeochemical-ecological models are needed, and an ensemble of approaches would be beneficial to minimize reliance on a single model and to recognize that a range of modeling approaches have been adopted by the Great Lakes modeling community.

Monitoring and modeling activities should be optimized so short- and long-term datasets can be used for improved mechanistic and correlational models to improve winter forecasts for both weather, ice cover, and lake phenomenon.

Data Management, Accessibility & Communication

Two of the most common data management concerns the SAB heard during the project are that winter data that has been collected is often not maximally utilized as there due to low awareness, and that multiple databases that include Great Lakes winter data exist, but they can be challenging to identify and access. To begin to address this need, the project developed a summary table of known monitoring programs and databases that include winter observations (see Appendix 2). Most existing programs and databases address physical characteristics and often have periods of record dating back many decades—including ice cover, temperature, precipitation, and lake levels—which is unsurprising given those data are needed for accurate weather forecasting and safety associated with navigation and hydroelectricity generation, among other uses. A growing number of available datasets address Great Lakes water quality, and many of those are associated with drinking water treatment plant intakes. Due to the year-round operation of drinking water treatment plants, and their numbers and locations throughout the coastal areas of the Great Lakes, drinking water treatment plant operators may offer particularly rich partnership opportunities to improve our understanding of physical parameters and biogeochemistry in the lakes' coastal waters during all seasons.

Another overarching science need relates to centralized, cross-disciplinary databases, data integration, and data sharing pipelines to support advancements in winter science. During workshop discussions, participants noted that through previous experiences a lot has been learned about what has not worked, including limitations of non-linked databases and the lack of a central database, lack of commitment for data management following completion of research projects, limited capacity of a single database to include multiple kinds of data (e.g., point, continuous, social science, Indigenous knowledge), and that ownership of databases or models by a single funding-depending entity can affect updates and maintenance. Conversely, there are data archiving systems for long-term data storage that have worked well, with National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information being an example that has high data quality assurance/quality control and is publicly accessible.

To address the limitation posed by lack of a central database while being mindful of lessons learned, the SAB encourages the Parties to pilot a winter science database with existing data to determine its design architecture so that it is efficiently utilized by multiple entities to inform management decision-making, before investing in a full-scale database structure. A lead organization such as the Great Lakes Observing System, or potentially a Center of Excellence proposed in the IJC's Great Lakes Science Strategy for the Next Decade, is needed to ensure overall responsibility for data management and updates. A pilot-scale effort should resolve how data are stored to meet the needs of the user (e.g., summarized data versus raw data) because there will be implications on cost (e.g., data storage), efficiency (e.g., data processing speeds), data file sharing tools (e.g., each agency has its own firewall), and utility (e.g., data for models, trend analysis, etc.).

1.2 Research Coordination Opportunities

Great Lakes water quality governance arrangements are amongst some of the most highly evolved of any region on earth, and associated science and management activities benefit from multinational coordination and alignment provided by the Great Lakes Water Quality Agreement. Starting from this enviable position, project activities assessed research needs to further improve infrastructure, training, and interagency coordination to help fill persistent winter science gaps.

Coordination & Interdisciplinarity

Project participants universally agreed that one of the single most impactful and important opportunities through which to improve winter science is high-level collaboration and coordinated, cooperative ecosystem-based management. Respondents noted a general lack of collective objectives related to winter monitoring efforts and highlighted that formalized coordination across winter science would help to unify the field. Quite simply, the winter science field can no longer afford to operate as siloed monitoring and assessment entities where the biggest roadblock to doing good work can be addressed by working better together.

There are many hopeful examples of coordination across agencies and entities to advance winter science that could be formalized and expanded. Examples include cruises of opportunity with the US Coast Guard, which has resulted in winter sample collection by crewed Coast Guard vessels and science training for Coast Guard staff and coordinated basinwide sampling by more than a dozen US and Canadian universities and agencies as part of the 2022 grassroot coordinated sampling campaign called Great Lakes Winter Grab.

Thus, immediate opportunities exist to leverage and formalize existing collaborations to improve winter sampling by equipping US and Canadian Coast Guard vessels and training staff for sample collection and storage. Additional opportunities include utilizing (or expanding) drinking water intake monitoring to access year-round nearshore data across an expanded suite of parameters and contracting/coordinating with the commercial and ice-fishing communities to increase the number and locations of offshore samples.

More broadly, fostering intentional interagency collaborations can be achieved by bringing cross-disciplinary perspectives into agency staff and research programs. Preparing joint proposals across disciplines and making interdisciplinary collaboration a priority in agency funding to universities and industry partners could be pursued, and agencies can promote interdisciplinary engagement within their staff and make this a priority when hiring new staff. Funding programs can require broader perspectives; for example, United States Geological Service (USGS) Climate Adaptation Science Centers' program proposals require clear management relevance that automatically inspires multidisciplinary approaches.

Optimizing the use of winter monitoring platforms can be achieved through deliberative coordination so that a single mooring or other type of platform can host numerous sensors and serve multiple projects, experiments and agencies and universities. Similarly, a centralized inventory of winter vessels and winter sampling equipment to make sampling resources more accessible is needed and could be accomplished through additions to the Great Lakes Association of Science Ships portal.

Experiences in Canada's north, New Zealand, South America and elsewhere have demonstrated that traditional approaches to science can be considered alongside traditional knowledge systems to inform an understanding of the ecosystem and associated relationships. Workshop participants noted that it is important to engage with Indigenous communities and visit them to hear their stories about the natural world and understand how they can inform science. Further, Indigenous organizations should be supported financially to self-direct their own research based on their communal priorities, rather than simply engaging them in support of existing research programs.

Project discussions drew attention to the worrisome reality that sociocultural changes in winter recreation (e.g., ice skating, ice fishing), community celebrations, and sense of place are significant with the loss of ice, yet the social, cultural, and economic impacts of these changes on Great Lakes communities are notably understudied. A commitment to interdisciplinarity is essential to understand complex research questions, including cross-disciplinary data collection and analysis and integrating social science, economics, and traditional knowledge.

Capacity & Funding

The SAB's analysis found that funding for conducting winter science, including funding for expanded monitoring, data sharing, and interdisciplinary collaboration is a critical need. Addressing the shortage of winter data will require additional investments, in addition to optimizing activities already underway. Governments are encouraged to shift towards a culture of prioritizing data collection across all seasons by improving access to ice-hardened vessels and emerging technologies like AUVs and ensuring an adequate number of research staff and scientists who have lake access and are trained in winter science methods and safety protocols.

Winter sampling on the largest lakes on earth present unique challenges, including the need for standardized sampling approaches and training on specialized winter science methods. Safety protocols, training and equipment are essential, since ice cover and strength is increasingly less predictable and this poses new safety risks than have been historically present, including longer shoulder seasons when ice is unstable or ice-free with very cold water temperatures.

The SAB encourages the governments to draw clear connections among winter science priorities and the Great Lakes Water Quality Agreement – which does not specifically reference winter – particularly during revisions to Lake Ecosystem Objectives, Substance Objectives, and Binational Priorities for Science and Action. Bringing focus to winter science gaps may justify additional investments that are needed to inform actions and progress towards the Agreement's General Objectives.

Communication & Outreach

There is broad agreement among winter science practitioners that raising awareness about the importance of winter science is needed, and in particular the consequences if key knowledge gaps are not filled. There are multiple audiences that need to be engaged, and practitioners must consider the target audience and adjust the way that research findings are communicated. For example, journal articles are aimed at the academic community, open data are useful to modelers and statisticians, Indigenous water ceremonies are relevant for Indigenous and non-Indigenous communities alike, and infographics and social media can be used to successfully engage with the public. Outreach activities should incorporate a strong "why" or common mission statement to justify the effort to support winter science, and the implications for public safety and ecosystem services if science questions are left unanswered.

The media exhibit a high degree of interest in reporting on warming winters, and their assistance in popularizing the importance of addressing winter science needs will be required. Sustained media attention could be leveraged by developing a communications strategy that is advanced in a coordinated manner by the communications staff at partner agencies and institutions. The profile of winter science can be elevated through organized events like sled dog or snowmobile races, or science activities like Great Lakes Winter Grab which could also include a participatory science component. Raising the profile of winter science will require direct engagement with communities. Cross-disciplinary collaboration could be enhanced by organizing a Great Lakes Winter Science Forum, similar to the Mississippi River Science Forum hosted by USGS that convened stakeholders from across that basin to give talks and engage in conversation on science gaps and needs.

2.0 Conclusions & Recommendations

The project work group finds that:

1. The Great Lakes experience high variability in winter conditions, and our capacity to determine climate driven trends is improved with sufficiently long datasets.

2. Multiple databases that include Great Lakes winter data exist, but they can be challenging to identify and access, and they frequently lack interoperability.

3. There is a need to study winter ice and under-ice ecological processes not just within the open water and nearshore areas of the Great Lakes, but also in their tributaries and watersheds.

4. Lack of integration across disciplinary silos may act as a barrier to developing a holistic understanding of the current and future changes in winter in the Great Lakes.

5. Societal impacts from changing winter conditions in and around the lakes are large and include both positive and negative elements.

The project work group recommends that:

1. As part of the next Binational Priorities for Science and Action cycle, the Great Lakes Water Quality Agreement Annex 10 (Science) should perform a binational analysis to articulate the specific winter data gaps that can be met by monitoring and that are limiting policy development and lake management decision making.

2. As part of the next Binational Priorities for Science and Action cycle, the Parties should develop a coordinated binational plan to improve modeling and forecasting of ice properties for both short-term and long-term time horizons through targeted winter data validation.

3. The Parties should charge the lead coordinating agencies of the Cooperative Science and Monitoring Initiative (CSMI) with developing guidance language and programmatic approaches to include all four seasons and fill the gaps between CSMI sampling years by securing access to ice-capable vessels and other suitable monitoring platforms to support science activities on one lake and associated connecting waters per year.

4. By 2027 the Parties, including their science funding agencies, should develop an architecture for a master, open-access, winter science database that leverages artificial intelligence to consolidate information from existing databases and makes collected winter data more consistent with F.A.I.R. principles (findable, accessible, interoperable, and reusable) while ensuring data quality standards are met.

5. The IJC and the Parties should improve winter data collection through ongoing support of the nascent Great Lakes Winter Science (GLWin) Network or a similar coordination

entity, to improve winter science monitoring coordination and infrastructure (offshore, shore-based and watershed-based) and lower the barriers to winter science monitoring participation.

6. By 2027, the IJC's Advisory Boards should collaboratively guide the development of a short scoping document on the role of winter in the basinwide delivery of ecosystem services in the Great Lakes and its watershed.

7. The IJC SAB's forthcoming Great Lakes Science Plan for the Next Generation should advance supports for building winter science capacity through lowering barriers to entry by emphasizing early career training, internships, outreach, and inclusive hiring to the governments of Canada and the United States and federal science funding agencies, as well as major research institutions in the region.

The Great Lakes science and management community has developed a highly evolved suite of monitoring, surveillance and management programs that rely on data collected primarily during ice-free periods. Emerging understanding of the significant and varied biological, chemical and physical processes during winter, coupled with rapidly evolving technologies and equipment that enable safe and reliable data collection during this understudied season, hold much promise for ensuring decision making considers the influence of all seasons. The SAB hopes that the analysis and recommendations included in this report enable more impactful collaborations and help guide additional investments in winter science to inform Great Lakes policy and management decisions.

Appendix 1: Summary of Science Gaps & Needs

Topic	Expected Impacts	Major Science Gap(s)	Major Need(s)
Physical			
Ice	Each Great Lake is affected differently but on average, freeze dates are occurring later, maximum ice-cover is diminishing, ice break-up dates are occurring earlier, and interannual variability is increasing	Low temporal and spatial resolution of ice property and ice phenology measurements Lake temperature responses to alterations in ice phenology (timing of formation and breakup)	Direct measurements of lake ice characteristics, and tributary river ice observations
Coastal processes	Loss of winter shore-fast ice is impacting the erosion and morphology of Great Lakes shorelines	Changing geomorphic impacts of winter storms	Understand role of winter shore ice (or absence of ice) in coastal erosion and transport processes
Temperature	Average air and surface water temperatures are warming, and the greatest future temperature increases for the Great Lakes basin are anticipated to occur in the fall and winter seasons	Winter thermal structure for the Great Lakes with appropriate spatial, depth and temporal resolution	Depth resolved winter thermal data for all Great Lakes Coupled temperature and current datasets to understand convective processes and stratification/mixing dynamics How lake heatwave occurrences will impact aquatic species
Hydrological cycle	Timing and amount of water the basin receives in the wintertime is changing. As examples, over-lake precipitation is expected to increase for all lakes, especially in the fall, winter, and spring seasons, and more precipitation will fall as rain rather than snow	Few measurements of over-lake fluxes of water (evaporation, condensation, precipitation) and gasses to inform water budgets, lake level forecasts, and lake effect precipitation forecasts	Understand how changes in hydrological cycle influence changes in nutrient loading, mixing, and primary production
Light	Changing lake ice quality and thickness (or absence of ice) affects light penetration to the water column with impacts on wintertime ecological processes	Light climate (spectral quality and quantity) and lake ice optical properties	Understand effects of ice and snow-on-ice on photosynthetically active light and associated temperature changes
Biogeochemistry			
Greenhouse gases	Ice impacts carbon storage and timing of carbon availability to lake ecosystems, but the impacts of changing winter on these processes are unclear	Storage, transformation and cycling of carbon under ice	Understand how carbon processes in winter stimulate ice-off lake processes, and assess the consequences of shortened ice cover duration
Nutrients	More frequent winter melts and precipitation falling as rain is expected to increase winter sediment and nutrient transport to the Great Lakes	Data to accurately assess episodic nutrient export at regional scales Nutrient stoichiometry and associated processes during winter	Understand and quantify nutrient impacts on water quality and ecological processes during and following winter
Oxygen	Changing climate appears to be related to dissolved oxygen concentrations in lake environments	Data to assess dissolved oxygen and absence/presence/extent of hypoxia during winter	Understand how warming winters affect dissolved oxygen concentrations and associated ecosystem processes
Salt	Road salt (and agricultural solutes) are elevating chloride levels in tributaries and the Great Lakes	Data to assess the timing and dynamics of winter chloride loading, including impacts of changing precipitation patterns and form	Understand impacts of changing chloride loading on the Great Lakes and groundwater quality, and associated ecological processes

Topic	Expected Impacts	Major Science Gap(s)	Major Need(s)
Biology			
Fish	Expected to be variable depending on fish guild thermal preferences, with negative impacts on cold-water species; exposed shallow spawning regions are adversely affected by reduced ice cover that protects them from wind disturbance.	Data to assess winter fish ecology including food availability, spawning timing, recruitment success, metabolism, and invasive species abundance	Understand how changes in winter conditions and timing will impact the life cycles of various fish species, and associated implications for food webs
Phytoplankton	Changing winter and especially changes in ice cover is expected to cause shifts in phytoplankton community composition and biomass	Data to assess the prevalence of wintertime phytoplankton blooms and their importance to lake-wide primary production	Understand phytoplankton community composition and biomass in the water column, in ice, and in tributary watersheds, and their influence on subsequent seasonal dynamics
Zooplankton	Implications of a shortened ice-covered season on zooplankton is poorly understood	Data to assess diel migration under ice and contributions to the lakes' biological pump	Understanding spatial and temporal patterns of zooplankton ecology during the winter
Food webs	Delayed ice-onset is associated with cross-seasonal cascading food web effects	Data to assess spatial and temporal scales of primary productivity, and winter food web structures at regional and lake-wide scales including timing of changes to the food web	Understand the influence of changing winter on food webs during the winter and on subsequent seasons
Socioeconomic & Cultural Services			
Ecosystem services	There are many ecosystem services, and most are expected to be impacted by changing winter. For example, winter tourism and recreation (e.g., snow sports, ice fishing) seasons will be shorter and experience greater variability, and ice cover reduces lake-effect snow	Data and approaches to accurately value winter ecosystem services	Improved understanding of the social, cultural and economic impacts of changing winter
Shipping	Shorter duration of seasonal ice cover is expected to lengthen the shipping season	Data to inform impacts on winter spawning aquatic species, and wintertime acoustic impacts on select species	Coupled social-ecological analyses to evaluate impacts of a lengthened shipping season on select species
Human wellbeing	Impacts of changing winter on human wellbeing are not well understood, but the body of knowledge is growing (e.g., winter drowning data)	Data on a range of human wellbeing metrics including winter drownings, ice road transportation, and recreational activities (e.g., snowmobiling, ice fishing)	Evaluation of the socioeconomic and cultural impacts of changing winter on Great Lakes communities

Appendix 2: Great Lakes Winter Science Databases

Name/Title	Link	Responsible Agency	Description
Precipitation			
MQTBrowser - Snowfall Observation Site (NWS Marquette, Michigan)	https://www.ssec.wisc.edu/lake_effect/mqt/	University of Wisconsin-Madison Space Science and Engineering Center	Charts for reflectivity, fall speed, particle size, and particle density (of snow). The user can view the available data for a selected day
ECCC Data Catalogue search results for "Snow"	https://catalogue.ec.gc.ca/geonetwork/srv/search?keyword=Snow	Environment and Climate Change Canada (ECCC)	Search resulted in 17 records, including databases for specific regions in Canada or specific experiments, as well as general Canadian snow data such as snow depth and snow cover
Homepage - no title	https://www.cocorahs.org/	Community Collaborative Rain, Hail & Snow Network (CoCoRaHs)	Homepage for CoCoRaHs, which is a volunteer-driven network that measures and maps precipitation in the US Homepage shows an interactive, timestamped US map of 24-hour precipitation
Water			
Winter grab database	https://doi.org/10.6073/pasta/25b45064d0e2fd8578aad055609c0ca3	N/A - Multi-Organization Effort	Data Package for the 2022 Great Lakes Winter Grab that contains the results from a multi-institutional winter limnology sampling campaign on the Laurentian Great Lakes. Researchers from 19 institutions sampled 49 locations in all five of the Great Lakes over a period of 24 days in February-March 2022. This dataset contains information on diverse physical, chemical, and biological parameters
Great Lakes Water Level Data > Monthly mean lakewide average water levels	https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Information-2/Water-Level-Data/	US Army Corps of Engineers (USACE)	Charts showing daily average and monthly mean water levels by individual Great Lake
NOAA-GLERL Data > Water Temperature and Ice Data	https://www.glerl.noaa.gov/data/#watertemp	NOAA GLERL	Links to water temperature data collected from buoys and people deploying instruments from research vessels. GLERL also predicts Great Lakes water temperatures using NOAA scientific models
NOAA-GLERL Data > Biological and Water Quality Data	https://www.glerl.noaa.gov/data/#biological	NOAA GLERL	Links to GLERL datasets for water quality and biological resources, including benthos & invasive species, biological identification (Great Lakes Water Life), long-term ecological research (Muskegon Transect), water quality, and zooplankton
NOAA CoastWatch Great Lakes Node	https://coastwatch.glerl.noaa.gov/	NOAA	Homepage for CoastWatch, the NOAA program within which GLERL operates. From the homepage the user can navigate to other pages, such as Sea Surface Temperature Imagery, Great Lakes Surface Environmental Analysis, Ice Data, Surface Temperature Contour Maps, etc. Contact information is provided on this page

Name/Title	Link	Responsible Agency	Description
Water Continued			
USGS Water Data for the Nation	https://nwis.waterdata.usgs.gov/nwis	US Geological Survey (USGS)	Links to water-resources data collected across the United States, including data on surface water, groundwater, water quality, and water use
USGS Science Data Catalog	https://data.usgs.gov/datacatalog/data/USGS:64834dfbd34ef77fcafcd657	USGS Great Lakes Science Center	Data for DO sensors coupled to GLATOS receivers in Lake Erie
Great Lakes Connecting Channels Monitoring and Surveillance Data	https://data-donnees.az.ec.gc.ca/data/substances/monitor/great-lakes-water-quality-monitoring-and-aquatic-ecosystem-health-data/great-lakes-connecting-channels-monitoring-and-surveillance-data/	ECCC	Year-round water quality data for 7 sites located within Huron-Erie corridor, Niagara River and St. Lawrence River
Provincial (Stream) Water Quality Monitoring Network	https://data.ontario.ca/dataset/provincial-stream-water-quality-monitoring-network	Ministry of the Environment, Conservation and Parks Environmental Monitoring and Reporting Branch	Links to spreadsheets with stream water quality monitoring data for several parameters, including total and dissolved nutrients, metals, and chloride, for rivers and streams across Ontario. Available datasets date from 1964 through the end of 2021
Safe Drinking Water Information System	https://sdwis.epa.gov/ords/sfdw_pub/r/sfdw/sdwis_fed_reports_public/200	USEPA	Federal Data Warehouse of all public water systems, violation information, and enforcement information
Lake water quality at drinking water intakes	https://data.ontario.ca/dataset/lake-water-quality-at-drinking-water-intakes	Ministry of the Environment, Conservation and Parks	Links to spreadsheets with sampling locations, water chemistry, and chlorophyll collected at 18 locations in the Great Lakes-St. Lawrence River and 4 locations in Lake Simcoe. Available datasets date from 1976-2019
Lake water quality at drinking water intakes – All Ontario Great Lakes	https://files.ontario.ca/moe_mapping/downloads/2Water/GLIP/All_Lakes_GLIP.csv	The Great Lakes Intake Program	Great Lakes and Lake Simcoe water chemistry and chlorophyll data since 1976
2022 Drinking Water Quality for Charter Township of Michigan	https://cms2.revize.com/revize/washingtonmi/DPW/2023_DPW/2022%20CCR.pdf	Charter Township of Washington	Water Quality Report highlights the performance of GLWA and the Charter Township of Washington (Lake Huron water intake)
Great Lakes DataStream	https://greatlakesdatastream.ca/en/	The Gordon Foundation	An open access platform for sharing information on freshwater health. It brings together water quality datasets collected by monitoring groups throughout the Great Lakes and St. Lawrence River Basin
Lake Superior moored temperature and currents, Sep 2005-May 2015	https://conservancy.umn.edu/handle/11299/222317	University of Minnesota Duluth, Large Lakes Observatory	Temperature data is presented in two different forms. First, individual, raw temperature records are presented in directories corresponding to individual mooring deployments. In addition, a separate directory includes hourly, gridded data from each individual mooring deployment, which are likely of more interest to investigators. Acoustic Doppler Current Profiler data is presented in raw form. All data is presented in MATLAB format

Name/Title	Link	Responsible Agency	Description
		Water Continued	
Lake Superior moored temperature and currents, Spring 2015 to Spring 2021	https://conservancy.umn.edu/handle/11299/226963	University of Minnesota Duluth, Large Lakes Observatory	Temperature data is presented in two different forms. First, individual, raw temperature records are presented in directories corresponding to individual mooring deployments. In addition, a separate directory includes hourly, gridded data from each individual mooring deployment, which are likely of more interest to investigators. Acoustic Doppler Current Profiler (ADCP) data is presented in raw form. All data is presented in MATLAB format
Seagull	https://glos.org/priorities/seagull/	Great Lakes Observing System (GLOS)	Platform used to connect people to data collected by GLOS, which supports real-time, historical, and predictive observing data from the five Great Lakes and the watershed. GLOS supports physical data (e.g., wind, waves, underwater environment, etc.), biogeochemical data (e.g., chlorophyll, oxygen, toxins, etc.), and biological data (e.g., fish, algae, etc.)
BCO-DMO	https://www.bco-dmo.org/	Biological and Chemical Oceanography Data Management Office	Query 'winter' and 'great lakes' and users will come across datasets featuring water quality data (including ice and some phytoplankton) related to US NSF projects between 2012-2020
Ontario water and weather monitoring stations	https://data.ontario.ca/dataset/ontario-water-and-weather-monitoring-stations	Government of Ontario	Point locations of water and weather monitoring stations used by the Surface Water Monitoring Centre to assess flood and drought conditions across Ontario
		Other	
National Survey of Fishing, Hunting, & Wildlife - Associated Recreation (FHWAR): 2016	https://www.census.gov/library/publications/2018/demo/fhw-16-nat.html	United States Census Bureau	The National Survey of FHWAR collects data from US residents about fishing, hunting, and wildlife watching. The link provided is for the 2016 report, but trend information is also available by comparing against earlier survey reports using similar methodologies
GLATOS	https://glatos.glos.us/	Great Lakes Acoustic Telemetry Observation System (GLATOS)	Homepage for GLATOS, which tracks fish movement in the Great Lakes through implanted transmitters. From the homepage the user can view maps, publications, recent projects, and photos
The North American CORDEX Program	https://na-cordex.org/	World Climate Research Programme (WCRP)	Homepage for the WCRP North American CORDEX (Coordinated Regional Downscaling Experiment) Program, which provides global coordination of regional climate downscaling for improved climate adaptation and impact assessment. The user can download data from the CORDEX search page
Audubon Christmas Bird Count	https://netapp.audubon.org/cbcobservation/	Audubon	Audubon's Christmas Bird Count website allows the user to view historical counts and current year results either by species or by count
Waterborne Commerce Statistics Center (WCSC)	https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center-2/	USACE	Information on vessels, tonnage, commodity, origin, and destination from vessel operating companies
Provincial Groundwater Monitoring Network	https://www.ontario.ca/page/map-provincial-groundwater-monitoring-network	Government of Ontario	Groundwater level and chemistry data from monitoring wells that are part of the Provincial Groundwater Monitoring Network (PGMN) Program. Precipitation data (rain) is also available for some PGMN sites

Name/Title	Link	Responsible Agency	Description
Other continued			
Environmental Response Management Application	https://response.restoration.noaa.gov/esi_download#GreatLakes	NOAA	Web-based Geographic Information System (GIS) tool that assists both emergency responders and environmental resource managers in dealing with incidents that may adversely impact the environment. ERMA integrates and synthesizes various real-time and static datasets into a single interactive map
TRCA Open Data Portal: Aquatic Monitoring and Management	https://data.trca.ca/	TRCA	This dataset contains the species fish caught using boat electrofishing along the TRCA Lake Ontario shoreline from 2000 to 2018
limno.io	https://limno.io/	LimnoTech	Links to real-time monitoring stations in Lake Michigan, Lake Huron, and Lake Erie