NUCLEAR INNOVATION INSTITUTE™

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2024

NUCLEAR INNOVATION INSTITUTE

Annual public health and environment research report

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Introduction

Nuclear Innovation Institute

The Nuclear Innovation Institute (NII) is a member-based not-for-profit organization with a mission built on work that happens under three pillars: industry voice, skill development and industry advancement. NII's vision is a Canadian landscape where an innovative nuclear industry is celebrated as an integral part of the clean energy future.

Located in Saugeen Shores, Ontario, NII is supported by an engaged group of Founding Members, including Bruce Power, AtkinsRéalis, BWXT Canada, Cameco, E.S. Fox Ltd., Kinectrics, Power Workers' Union, and the Town of Saugeen Shores.

NII Environment

NII's Environment program is home to projects assessing the impact of energy generation on human health and the environment.

Our work focuses on three key areas:

- **Future of energy** – Advancing knowledge and practices in the nuclear industry to help the world transition to a clean energy future.
- **Future of health** – Accelerating research and advocacy for medical isotopes, from improved cancer diagnoses and treatments to expanded use in food production and industrial safety.
- **Future environment** – Researching the impact of the nuclear fuel life cycle on our water, land and air while also supporting efforts to fight climate change.

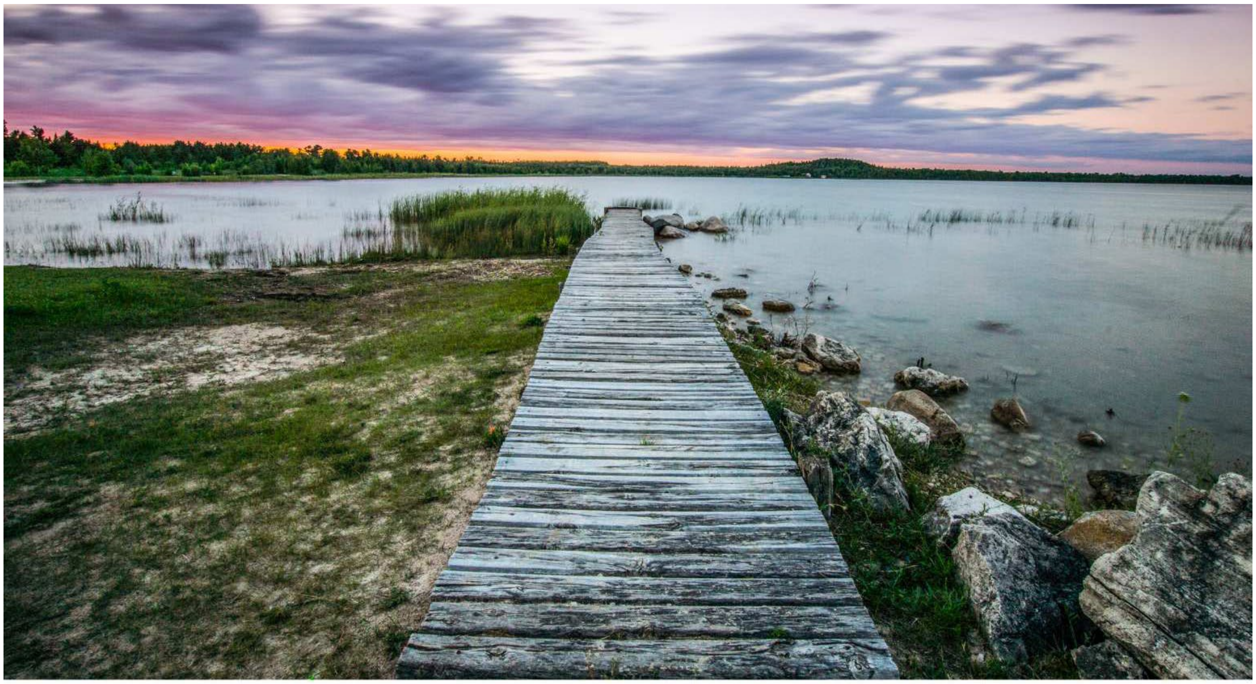
All Environment programming operates within the Bruce Power Nexus Research Centre at NII. The Centre is fully funded by Bruce Power and receives oversight from an Executive Committee comprised of representatives within Bruce Power most closely connected to its work. Additionally, Environment Programming receives input and direction on projects from Bruce Power's Research Steering Committee for Environmental Sustainability & Human Health.

The annual public health and environment research report

NII supports public health and environment research through direct funding from Bruce Power. This funding often allows researchers to secure competitive, peer-reviewed grants from federal and provincial agencies, validating the scientific rigor of the research supported by Bruce Power.

This report presents the research progress made in 2024 across NII's diverse research initiatives and provides an update on future research plans in 2025.

Project updates



The following section provides detailed updates from each of the research projects supported through NII Environment in 2024. These updates highlight key milestones, scientific progress and emerging priorities that will shape the direction of work in 2025.

Using lake sediments to understand long term environmental changes

Motivation and significance

How has Lake Huron changed over time, and what role have human activities, like industrial operations and climate change, played in shaping those changes? This research project, led by Dr. Jennifer Korosi and Dr. Joshua Thienpont at York University, aims to answer these questions using paleolimnological techniques. By analyzing sediment cores from the lakebed near the Bruce Power site, researchers can reconstruct historical environmental conditions, providing a long-term perspective on water quality, ecosystem shifts and human impact.

This work fills an important gap in our understanding of how the lake has evolved since pre-industrial times. It also supports ongoing environmental monitoring efforts and helps address concerns about cumulative effects on Lake Huron's ecosystem.

Key progress in 2024

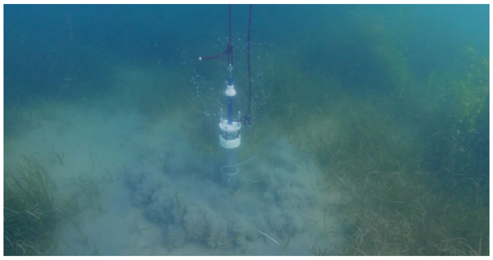
Launched in May 2024, the project has already made significant progress:

FIELDWORK COMPLETED

- In July, the research team, alongside Bruce Power staff and members of the Saugeen Ojibway Nation, collected six sediment cores from four locations, including Baie du Doré. The sites were strategically chosen to represent varying distances from the Bruce Power facility and include key areas of interest, allowing for a broad comparison of lake conditions.

INNOVATIVE SAMPLING METHODS

- NII, Bruce Power, and researchers partnered with Inspired Planet Productions, creators of the TVO documentary *All Too Clear*, to conduct sediment coring. Inspired Planet's underwater drone technology helped locate areas with material accumulation and assisted in maneuvering the corer into position.



LABORATORY ANALYSIS UNDERWAY

- An undergraduate research assistant from York University has been recruited to assist with sample analysis. Sediment cores have been processed for initial examination, weighed, visually described and sub-sampled for detailed analysis. Some samples are being prepared for chemical and biological assessments, while others have been sent to Queen's University for radioisotopic dating, which will help establish a timeline of environmental changes.

The project remains on track, with the first major results expected in 2025.

Research focus for 2025

The focus for 2025 will be on analyzing the sediment cores to unlock the environmental history of Lake Huron. Key next steps include:

- **Dating the sediment layers:** Queen's University will provide radioisotopic dating results in 2025, helping researchers establish a precise timeline for past changes in water quality and ecosystem composition.
- **Chemical and biological analysis:** Researchers will analyze indicators such as diatoms (microscopic algae preserved in sediment), organic carbon content, and nitrogen isotopes to reconstruct historical environmental conditions.
- **Sharing findings:** While no publications or presentations were produced in 2024, the first research updates will be shared starting in mid-2025.

By the end of 2025, this project will provide a clearer picture of how Lake Huron has changed over time, offering valuable insights for future environmental management.

Research team and contributors

FACULTY

- **Jennifer Korosi**
  York University
- **Joshua Thienpont**
  York University

UNDERGRADUATE STUDENTS

- **Vesta Tajik**

SUMMARY

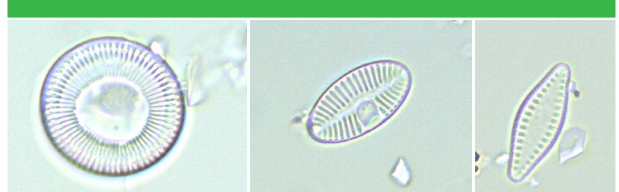
This project aims to use lake sediment analysis to reconstruct Lake Huron's environmental history and assess the long-term impacts of climate change and industrial activity. In 2024, researchers successfully collected and began analyzing sediment cores from key locations near Bruce Power. In 2025, the focus will shift to dating and chemical analysis, providing insights into historical water quality, ecosystem shifts, and pollutant trends to support ongoing environmental monitoring efforts.

What does paleolimnology mean, anyway?

Paleolimnology is the study of lakes using clues preserved in lake sediments. Over time, materials like algae, pollen, and tiny organisms settle at the bottom of a lake, forming layers of sediment in a stratigraphic manner—like the rings of a tree. By analyzing these layers, scientists can reconstruct how a lake's water quality, ecology, and climate have changed over time—from years to centuries or more.

Diatoms: Tiny time capsules in the lake

Diatoms are microscopic algae with glass silica cell walls. They're incredibly useful for paleolimnologists because different species thrive under different environmental conditions. By identifying which diatoms are present in a sediment layer, scientists can infer past lake changes to water quality, nutrient levels, and even historical climate conditions. Think of them as nature's built-in water quality monitors!



Aquatic Biota: The impacts of once-through cooling on fall and spring spawning fish

Motivation and significance

Many power plants, including Bruce Power, use once-through cooling systems, drawing water from nearby lakes or rivers to regulate reactor temperature before returning it to the environment. While effective for energy production, this process can alter local water temperatures, potentially affecting fish species that spawn in nearshore habitats or rely on stable conditions during early development.

This study examines how elevated and fluctuating temperatures impact the early development, growth, and survival of three key fish species in Lake Huron:

- Lake whitefish and round whitefish, cold-water species that are particularly sensitive to temperature shifts. Their populations are already declining in the Great Lakes, largely due to food web disruptions caused by invasive quagga mussels.
- Yellow perch, a cool water species that may be thermally sensitive. Their populations are declining in some parts of the Great Lakes, which has been linked to warming winter temperatures.

This research explores three key questions:

- How does temperature stress affect whitefish hatchlings and juveniles?
- What are the long-term effects of incubation temperature on yellow perch?
- How do whitefish and perch populations interact with nearshore spawning areas?

Figure 1. Lake whitefish.
Source: Ontario Aquaculture Research Centre.

Figure 2. Round Whitefish.
Source: Wikimedia. User LevPN.

Figure 3. Yellow Perch.
Source: Thomas Dembeck Jr.

Since 2018, this research program has provided important insights into how incubation temperature affects whitefish development. Previous studies confirmed that constant warming leads to earlier hatching, smaller body size, and jaw deformities in both lake and round whitefish. However, incorporating a fall cooling period into incubation minimized many of these negative effects, especially for round whitefish. In another scenario, lake whitefish exposed to warmer fall temperatures showed reduced length, weight, eye size, and the size of their mouth, reinforcing the idea that this seasonal shift is a critical development window.

Findings from this research will help assess the potential ecological impacts of once-through cooling and may inform sustainable fisheries management in Lake Huron.

Key progress in 2024

LONG-TERM EFFECTS OF INCUBATION TEMPERATURE ON YELLOW PERCH

- The final year of yellow perch rearing experiments was completed, with embryos incubated at 12°C, 15°C, or 18°C to assess effects on survival, development, metabolism, and thyroid function. Researchers analyzed growth rates, survival, and skeletal formation, finding that higher temperatures affected metabolism and bone development. Four manuscripts were submitted, with two now published, detailing the effects of temperature on embryonic and larval development, bone development, morphology and growth, and swimming capabilities.

MOLECULAR RESPONSE TO THERMAL STRESS

- Two experiments examined the persistent effects of incubation temperature on stress response genes in yellow perch embryos and juveniles. Researchers measured six heat shock protein genes and assessed how embryos and hatchlings responded to additional temperature stressors. A second study tested how early incubation temperatures affected the ability of yellow perch to acclimate to higher temperatures on short time scales. Researchers measured critical thermal maximum, oxygen consumption rate, and swimming speed as key metrics. One manuscript is in preparation on these findings.

WHITEFISH AND PERCH POPULATION STRUCTURE IN LAKE HURON

- Master's student Carmen Kotowich successfully defended her thesis, using compound-specific stable isotope analysis (CSIA) to study whitefish populations. Findings show that spawning-phase lake and round whitefish mix extensively in Lake Huron, supporting the idea that fish from different regions of the lake migrate to nearshore spawning areas. CSIA of yellow perch from six locations was also completed, and genetic sequencing is underway to examine population structure and genetic variation.

Research focus for 2025

The next phase of the study will focus on completing outstanding data analysis from 2024, continuing the genetic sequencing of yellow perch populations to explore how nearshore and offshore fish differ in genetic diversity, and submitting key findings for publication.

What is compound-specific stable isotope analysis (CSIA)?

Traditional isotope analysis looks at bulk tissue to determine what an animal has eaten, but it can be influenced by metabolism and other factors. CSIA takes a more precise approach by analyzing individual compounds, such as amino acids from proteins, to track an organism's diet and movement.

By measuring carbon and nitrogen isotopes in specific compounds, researchers can:

- Identify whether fish originate from nearshore or offshore food webs
- Determine if populations return to the same spawning areas or mix across Lake Huron
- Provide more accurate insights into fish ecology and habitat use

For Lake Huron's whitefish and yellow perch, CSIA revealed that spawning-phase fish come from a wide range of ecological regions, supporting the idea that populations are highly mixed. This information helps guide sustainable fisheries management and conservation efforts.

Scientific outputs in 2024

Publications

- Two papers published, including studies on yellow perch development, skeletal formation, and growth at different temperatures.
- Four additional manuscripts submitted, covering topics such as swimming performance, metabolic effects of elevated temperatures, and ecological population structure of whitefish and perch.

Presentations

- Research was presented at six international and national conferences, including the Canadian Ecotoxicology Workshop, the Congress of European Comparative Endocrinologists, and the International Conference on the Biology of Fishes.
- MSc student Carmen Kotowich won a best student talk award (2nd place) for her presentation on yellow perch thermal responses.

Why does temperature matter for whitefish eggs?

Lake whitefish spawn in the fall, depositing their eggs in shallow nearshore areas where they remain stationary all winter. Unlike adult fish, which can move to find optimal conditions, whitefish embryos are completely dependent on the temperatures in their environment as they develop.

Because hatching in the spring is triggered by temperature, any warming or cooling trends can shift hatch timing, growth rates, and survival chances. If water temperatures rise too quickly, embryos may hatch too early or too small, potentially reducing their ability to compete and survive.

This research helps determine how climate change, seasonal temperature shifts, and once-through cooling systems may affect whitefish populations. This critical information can help ensure their long-term sustainability in Lake Huron.

Lake Whitefish eggs.
Source: Ellie Katz/IPR News

Research team and contributors

This project was co-funded by NSERC Collaborative Research and Development Grant and MITACS Accelerate.

FACULTY

- **Joanna Wilson**
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- **Richard Manzon**
  University of Regina
- **Christopher Somers**
  University of Regina

POSTDOCTORAL RESEARCHERS

- **William Andrew Thompson**

GRADUATE STUDENTS

- **Yuliya Shtymburska**

UNDERGRADUATE STUDENTS

- **Maxwell Hendershot**
- **Jasmine Lauzon**

RESEARCH TECHNICIANS

- **Lisa Laframboise**
- **Julee Stewart**

SUMMARY

This research provides crucial insights into how fish species in Lake Huron respond to thermal stress, with implications for ecological conservation, fisheries management, and power plant operations. Findings confirm that consistently elevated temperatures can affect early life stages, influencing growth, metabolism and survival, but a fall cooling period during incubation minimizes these effects. Analysis shoes that fish mix extensively in Lake Huron, including spawning-phase lake and round whitefish which migrate from different regions and are not a distinct population. In 2025, the focus will shift to finalizing analyses and sharing results through publications and scientific presentations.

Temperature-based modeling of whitefish egg hatching success

Motivation and significance

Lake whitefish are a culturally, economically, and ecologically important species in Lake Huron, but their early life stages are vulnerable to temperature fluctuations. Bruce Power is required to conduct a thermal risk assessment every five years to evaluate the impact of its cooling water discharge on local ecosystems. A persistent challenge has been assessing risk to whitefish eggs, as scientific studies on thermal thresholds often do not directly translate to real-world lake conditions.

This project developed a temperature-based model to estimate whitefish egg survival under different thermal scenarios, providing a standardized and consistent approach for assessing risk. By incorporating field observations, laboratory experiments, and existing thermal stress models, this research helps refine Bruce Power's environmental risk assessments, ensuring they are based on scientific evidence and regulatory best practices.

Key progress in 2024

A mathematical model was developed to predict whitefish embryo survival under different temperature conditions.

Researchers used field data and laboratory experiments to determine how long whitefish eggs incubate and how thermal stress affects embryo mortality. The model was adapted from a generalized framework developed for Chinook salmon, applying it to Lake Huron's unique conditions.

The project successfully estimated cumulative survival rates for whitefish eggs under both operational and non-operational thermal conditions, helping refine future thermal risk assessments.

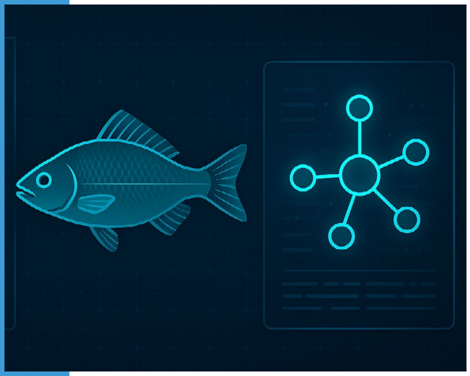
Research focus for 2025

The finalized model will be incorporated into Bruce Power's 2027 thermal risk assessment, supporting regulatory discussions and decision-making. A technical report will be submitted, documenting model design, assumptions, and results for regulatory review. The model will be applied to future assessments and operational planning.

How do scientists use models to predict environmental change?

Scientific models help researchers simulate real-world processes using mathematical equations, experimental data, and field observations. By identifying patterns and relationships, models allow scientists to predict future outcomes, test different scenarios, and guide decision-making.

In this study, researchers built a temperature-based model to estimate whitefish egg survival under different thermal conditions. By integrating lab experiments and real-world lake data, the model helps assess how temperature fluctuations impact fish populations, ensuring that environmental policies and industry practices are based on scientific evidence, not guesswork.



Research team and contributors

TEAM

- **Sarah Hasnain**
- **Katherine Gaudreau**

SUMMARY

This project successfully developed a temperature-based model to estimate lake whitefish egg survival under different thermal conditions, addressing a key challenge in environmental risk assessment. The model, which integrates field data, lab experiments, and established thermal stress models, provides a standardized approach for evaluating potential impacts. In 2025, the model will be refined and incorporated into Bruce Power's risk assessments, ensuring scientifically informed decision-making for Lake Huron's fisheries and aquatic ecosystems.

Bringing science into regulatory decisions

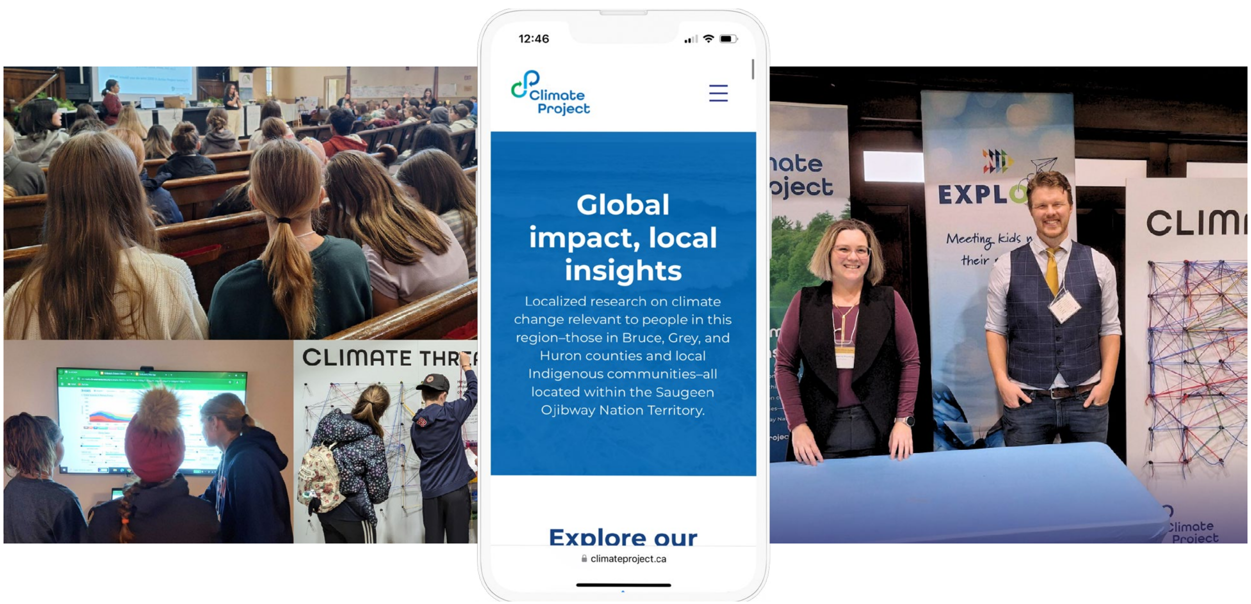
This project ensures that Bruce Power's thermal risk assessments are based on scientifically validated models, helping to provide accurate, transparent, and regulator-approved environmental impact assessments.

The Climate Project: Global impact, local insights

Motivation and significance

Climate change isn't just a global issue—it's a deeply local one. The Climate Project was launched to bring localized climate science to Bruce, Grey, and Huron counties and the Saugeen Ojibway Nation Territory, making research more accessible and relevant to the communities affected.

By translating complex data into clear, engaging resources, the project supports municipal leaders, educators, Indigenous communities, and local residents in understanding how climate change is impacting the region's air, land, and water. Through partnerships, events, and outreach, NII is positioning the Climate Project as a go-to resource for climate information in the region.



Key progress in 2024

2024 was a year of foundation-building and public engagement. The website gained traction as a key resource, community partnerships deepened, and interactive experiences helped bring climate data to life.

PUBLIC LAUNCH & WEBSITE EXPANSION

- The Climate Project officially launched in June 2024 with a fully developed website featuring scientific research, interactive tools, and Indigenous knowledge on local climate impacts. The site has been regularly updated with new content, growing into a comprehensive hub for climate information.

ENGAGING YOUTH IN CLIMATE ACTION

- Presented workshops at the Youth Climate Action Conference in Owen Sound on November 7, engaging approximately 100 students in grades 6-8 in discussions on energy and climate change.

BRINGING CLIMATE SCIENCE TO DECISION-MAKERS

- In November and December, NII presented the Climate Project to the councils of Bruce, Grey, and Huron counties, introducing it as a science-backed tool for municipal leaders. The delegations emphasized its role in supporting policy decisions, public engagement, and local sustainability efforts.

How is climate change affecting our region?

The Climate Project website tracks key climate trends in the region, showing how rising temperatures, shifting weather patterns, and environmental changes are already impacting local ecosystems and communities. Some key findings:

- **Winter traditions on thin ice:** Over the past 30 years, Grey Bruce has seen a median of 64 “ice days,” where temperatures remain below freezing all day. By the end of the century, in the most intensive warming scenario, there may be as few as 14 ice days per year. If these aren’t consecutive, it may not be cold enough for ice rinks and lakes to freeze over.
- **More lake-effect snow:** Ice cover on all Great Lakes has seen a general decrease since 1973. A warm, unfrozen lake is one of the key ingredients for lake-effect snow, since it is more easily evaporated into clouds.
- **Longer (but possibly fraught) growing seasons:** Over the past 70 years, the frost-free season in Grey Bruce has lengthened by about 19 days. By 2080, this could extend by an additional one to two months, potentially boosting agricultural productivity. However, that productivity could be offset by the challenges posed by more extreme weather events, more variable precipitation, more time for pests to grow and develop, and the possibility of increased plant diseases.

STRENGTHENING PARTNERSHIPS & COMMUNITY ENGAGEMENT

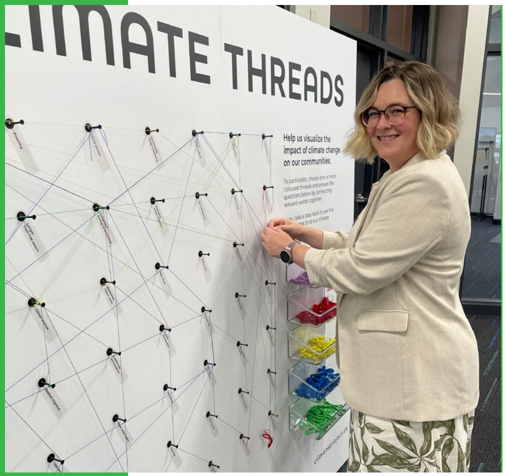
- **Métis Energy and Knowledge Symposium (June 21-22)**: Provided a sneak preview of the Climate Project at this event organized by the Métis Nation of Ontario. The conversations with MNO citizens and leaders helped shape how the project incorporates Indigenous knowledge.
- **SteelDreams Main Event (November 16)**: Participated in this major community fishing tournament and fundraiser, sharing the Climate Project with anglers and conservation groups concerned about climate impacts on local waters. The event also featured representatives from Bruce Power's environment team, Biotactic, and local outdoors clubs working on riparian restoration.
- **Climate Threads interactive installation**: Introduced this hands-on exhibit at public events and the Bruce Power Visitors' Centre, allowing participants to map their emotions—curiosity, hope, worry, anger, or motivation—onto climate-related topics.

LOCAL CLIMATE SCIENCE IN ACTION

- Showcased Indigenous-led research, lake monitoring efforts, and sustainable land management projects happening in the region, connecting scientific findings with real-world applications.

Climate Threads: Visualizing climate emotions

Climate change affects everyone, but people experience it in different ways. The Climate Threads installation invites participants to map their emotions onto climate-related topics using colored threads that represent curiosity, hope, worry, anger, and motivation. The result provides a powerful visual representation of how climate change is shaping our communities.



Research focus for 2025

With a strong foundation built in 2024, the Climate Project is now focused on scaling its impact, deepening partnerships, and making climate science even more accessible to those who need it the most.

- **Targeted outreach for key audiences:** The Climate Project will ensure that decision-makers have direct access to science-backed resources to support climate policy and planning. It will also develop teacher-friendly materials that help educators integrate climate education into their classrooms and highlight opportunities for student-led climate initiatives. The project will continue to feature Indigenous knowledge systems and support collaborative climate research with local partners. Additionally, the Climate Threads installation will be expanded, and new interactive engagement tools will be introduced to encourage public participation in climate discussions.
- **Enhanced online engagement:** The Climate Project will diversify its social media content to reach a broader audience by incorporating local stories, climate statistics, and real-world examples that make climate science more relatable. It will also increase the visibility of community events and work to strengthen partnerships with local organizations, researchers, and advocates to amplify their work through shared storytelling and collaborative outreach.

TEAM AND CONTRIBUTORS

- **Stephanie Keating**
- **Summer Goodeve**
- **Margaux Bucher**
- **Dana Van Allen**

SUMMARY

In 2024, the Climate Project launched as a resource for localized climate science, making complex data more accessible to the communities of Bruce, Grey, and Huron counties and the Saugeen Ojibway Nation Territory. With a strong foundation in place, 2025 will focus on deepening engagement and expanding reach. The Climate Project will continue to support informed decision-making, develop teacher-friendly resources, and engage with local communities.

State of Lake Huron: A comprehensive report

Motivation and significance

Lake Huron is experiencing significant environmental changes driven by climate change, invasive species, pollution, and habitat loss. These stressors have altered water quality, ecosystem balance, and biodiversity, impacting both natural processes and human activities.

This project compiles a comprehensive State of Lake Huron report, bringing together scientific research, monitoring data, and regulatory insights into a single, accessible document. The report will serve as a foundational resource for regulatory filings, cumulative effects studies, and environmental planning, ensuring that decision-making is grounded in the latest scientific understanding. A public-facing version of the document is in preparation.

Key report findings

The report compiles and reviews existing scientific literature on Lake Huron's physical conditions, ecosystem trends, and known stressors, including:

CLIMATE CHANGE IMPACTS

- Rising air and water temperatures, reduced ice cover, and shifting precipitation patterns are affecting the lake's thermal structure and water levels. These changes impact fish spawning, nutrient cycling, and the overall stability of aquatic ecosystems.

INVASIVE SPECIES

- The introduction of zebra and quagga mussels (dreissenid mussels), round goby, and sea lamprey has disrupted the lake's food web. In particular, dreissenid mussels have contributed to declines in key prey species, reducing food availability for native fish like lake whitefish.

WATER QUALITY & POLLUTION

- While long-term phosphorus levels have declined due to regulations, some nearshore areas still experience nutrient-driven algal blooms. Chloride levels from road salt and contaminants like PFAS (polyfluoroalkylated substances) are emerging concerns for ecosystem health. PFAS are a group of human-made chemicals that do not degrade and can accumulate in the environment over time. Sources of PFAS include urban runoff, wastewater effluent, and airport drainage.

FISHERY DECLINES

- The lake's commercial and recreational fisheries, including lake trout and whitefish, have been impacted by changes in prey availability, habitat conditions, and climate pressures.

HABITAT DEGRADATION

- Wetland loss, shoreline hardening, and tributary modifications have reduced critical spawning and nursery habitats, affecting biodiversity and ecosystem resilience.

Ongoing monitoring and restoration efforts focus on habitat conservation, invasive species management, and adapting to climate-driven changes. Collaborative efforts between researchers, Indigenous communities, and conservation groups remain key to protecting Lake Huron's ecosystem for future generations.

What are cumulative effects?

Environmental changes don't happen in isolation – multiple stressors can interact over time, amplifying their impacts. Climate change, invasive species, and pollution combine in complex ways, affecting Lake Huron's ecosystem. Understanding cumulative effects helps researchers and policymakers make better-informed environmental decisions.

Why does Lake Huron matter?

Lake Huron is one of the world's largest freshwater lakes, supporting diverse ecosystems, fisheries, and communities. Changes in water quality, habitat availability, and species populations affect not just the lake itself, but the people and industries that rely on it.

Spotter buoys: Tracking Lake Huron's water data

Motivation and significance

As climate change continues to reshape weather patterns and impact natural ecosystems, having access to real-time data has never been more important. Understanding lake conditions—like temperature and wave heights—isn't just useful for safety and recreation; it's also crucial for monitoring the health of our waters and spotting early signs of environmental shifts.

In June 2024, Bruce Power deployed three state-of-the-art smart buoys along the Bruce County shoreline of Lake Huron. These buoys are already providing real-time data on Lake Huron's conditions, helping scientists, policymakers, and local communities track environmental changes. The data is integrated into Seagull, an open-access platform that compiles information from buoys across the Great Lakes, making lake monitoring more accessible than ever.

The goal of this project is to enhance environmental data collection, improve public access to lake conditions, and support long-term monitoring efforts for Lake Huron.

Key progress in 2024

SPOTTERS DEPLOYED

- Three Spotter buoys were deployed along the shoreline of Lake Huron at Lorne Beach, Inverhuron, and MacGregor Point. Developed by Sofar Ocean Technologies, the buoys are solar-powered, compact, and highly advanced. They provide continuous data on water temperature, wave height, and other lake conditions. One major advantage of real-time monitoring is that it significantly reduces the risk of missing data due to device failure or loss – a common issue with traditional data logging methods.

INTEGRATION WITH SEAGULL

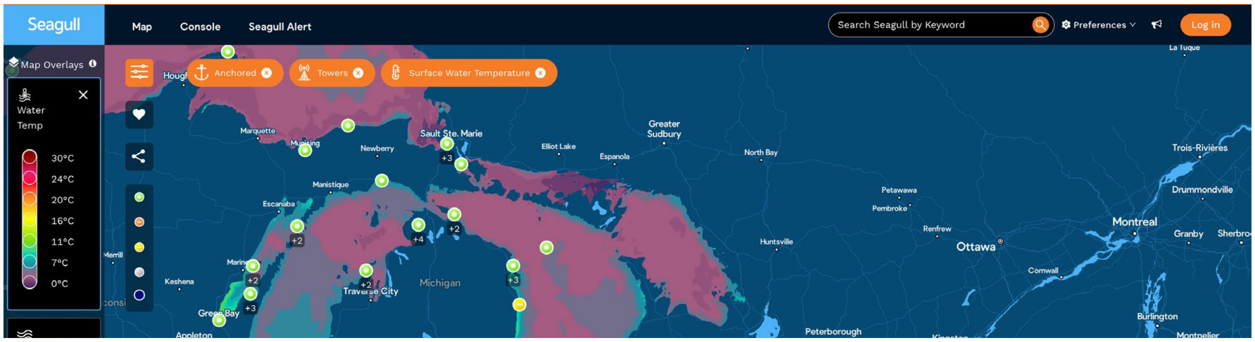
- Data from the Spotter buoys is publicly accessible via Seagull, an open-access platform developed by the Great Lakes Observing System. Seagull aggregates data from buoys and weather stations across the Great Lakes, delivering real-time updates and forecast models on conditions like currents and wind speed.

The buoys and the data they provide are useful for a wide range of users. This data is crucial for scientists tracking environmental effects, such as long-term temperature changes, wave patterns, and potential climate-related impacts on Lake Huron. It also helps boaters, anglers, and swimmers check conditions before heading out on the water.

Buoys of a feather: How Seagull is revolutionizing lake monitoring

Seagull is an open-access data platform that compiles real-time information from buoys and weather stations across the Great Lakes. Anyone with an observing device—like Bruce Power's Spotter buoys—can contribute data in a standardized way, making it easier for scientists, boaters, and environmental groups to track lake conditions.

Seagull isn't just for viewing lake data, though. Users can set custom alerts to notify them when waves reach a certain height, when water temperatures change rapidly, or when conditions shift unexpectedly. This system ensures that researchers, policymakers, and the public all have access to the latest lake information, helping everyone make smarter, data-driven decisions about water use, recreation, and environmental protection.



Research focus for 2025

The buoy data will be incorporated into Bruce Power's environmental monitoring program, contributing to long-term lake health assessments. Bruce Power's environment team will expand data analysis, tracking trends in temperature, wave activity, and investigating seasonal patterns. The team is also exploring additional sensors and enhancements to the buoys.

- **Trialing year-round deployment:** While the Spotter buoys have performed well in spring, summer, and fall, there is strong regulatory and stakeholder interest in real-time winter monitoring as well. The research team is investigating the possibility of deploying Spotter buoys year-round to assess their performance under ice and extreme storm conditions. Winter data is critical for understanding how ice cover, storm activity, and lake mixing processes impact water temperature and ecosystem health.
- **Additional monitoring:** New Spotter configurations and sensors have been developed to measure water currents and other parameters in real time and are being investigated for deployment in Lake Huron.

SUMMARY

Bruce Power's deployment of three smart Spotter buoys has significantly improved real-time lake monitoring in Lake Huron. By providing continuous data Lake Huron's changing conditions, these buoys play a key role in environmental assessments, regulatory compliance, and ongoing research into climate impacts on the Great Lakes. In 2025, researchers will focus on expanding data analysis, optimizing buoy deployment, and engaging more users with this valuable tool.

Investigating the effects of sub-natural background radiation exposure

Motivation and significance

Radiation is often associated with harm, but what happens when there is *too little* of it? This project explores how biological systems respond when exposed to radiation levels below the natural background. Since all life has evolved in the presence of low levels of ionizing radiation, researchers hypothesize that removing this radiation may disrupt essential biological processes.

To test this, scientists are conducting experiments at SNOLAB, one of the deepest underground laboratories in the world. The vast amount of earth acts as a shield from cosmic radiation, allowing researchers to study the long-term responses in cells and yeast. Understanding these effects is crucial for space exploration, radiation safety, and fundamental biology.

Motivation and significance

Radiation is often associated with harm, but what happens when there is too little of it? This project explores how biological systems respond when exposed to radiation levels below the natural background. Since all life has evolved in the presence of low levels of ionizing radiation, researchers hypothesize that removing this radiation may disrupt essential biological processes.

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Key progress in 2024

Researchers advanced experiments using yeast *(Saccharomyces cerevisiae)* as a model to better understand how organisms respond to ultra-low-radiation environments.

Two primary areas of study were:

YEAST AS A LIVING RADIATION DOSIMETER

- To test whether yeast could serve as a biological radiation detector, researchers exposed desiccated (dried-out) yeast to different types of radiation, including neutrons, protons, and x-rays. They compared two yeast strains: a wild-type strain with normal DNA repair mechanisms, and a “rad51 knockout” strain, which is more sensitive to radiation due to its inability to repair DNA double-strand breaks.

How does oxygen change radiation sensitivity?

In most biological systems, oxygen makes cells more sensitive to radiation by increasing the formation of harmful free radicals. However, researchers found that oxygen had no measurable effect on desiccated yeast’s radiation response. This unexpected finding suggests that dried-out cells may be naturally protected against radiation damage in ways that hydrated cells are not.

Key findings:

- Desiccated yeast had a 3-fold increase in radiation tolerance, suggesting that the dried-out state provides significant protection.
- The relative biological effectiveness (RBE) of neutrons and protons in desiccated yeast closely matched previous results in hydrated yeast, confirming consistency across different conditions.
- Oxygen had no measurable effect on how desiccated yeast responded to radiation. This important discovery simplifies future experiments by eliminating the need for strict oxygen control.

These results validate desiccated yeast as a reliable model for radiation studies, paving the way for long-term monitoring experiments at SNOLAB.

THE IMPACT OF ULTRA-LOW RADIATION ON YEAST GROWTH

- Scientists cultured yeast for up to 100 generations in SNOLAB, where natural background radiation is nearly eliminated. Surprisingly, yeast grew up to 16% slower in this environment, suggesting that low levels of radiation may play a role in normal cellular function and growth regulation. To understand why, researchers are now analyzing gene expression data (transcriptomics) to uncover the mechanisms behind this unexpected slowdown.
- The project is on track, with major experimental milestones completed. Key findings from the project have been submitted for publication, including work on how yeast adapt to ultra-low radiation.

Research focus for 2025

In 2025, the research will expand beyond yeast to explore how ultra-low radiation levels affect human lung cells, with a focus on metabolism, DNA stability and cancer risk.

EXPLORING EVEN MORE EXTREME LOW-RADIATION CONDITIONS IN YEAST

- To push radiation exposure even lower, researchers will experiment with *potassium-40* (^{40}K) depleted yeast. Since potassium-40 is a naturally occurring radioactive isotope in all living organisms, removing it will allow researchers to further isolate the effects of radiation absence. In 2025, these low-radiation yeast cultures will be tested at SNOLAB to study metabolic changes in extreme low-radiation conditions.

INVESTIGATING HUMAN CELL RESPONSES TO ULTRA-LOW RADIATION

- To explore whether radiation-free environments affect cancer risk and metabolism, the team has launched new studies using human bronchial epithelial cells (BEAS-2B), a cell line commonly used in lung cancer research. Researchers will track genetic changes linked to cancer development in cells exposed to ultra-low radiation over long periods. The BEAS-2B cell line will also be used to investigate mitochondrial function to see if lung cells experience the same metabolic changes observed in yeast. The team will also study how cells respond to oxidative stress in ultra-low radiation conditions, a key factor in aging and disease.

Scientific outputs in 2024

In 2025, the research will expand beyond yeast to explore how ultra-low radiation levels affect human lung cells, with a focus on metabolism, DNA stability and cancer risk.

- **Publications** – Two papers published in *Radiation Research* and *Health Physics*.
- **Presentations** – Research shared at major conferences, including the Radiation Research Society. Annual Meeting, SNOLAB Users Meeting, and NASA Human Research Project Investigators Workshop.

What can ultra-low radiation teach us about space travel?

Astronauts face high-radiation environments in space, but they also spend time in shielded habitats where radiation levels are much lower than in open space. Research at SNOLAB is revealing that removing radiation entirely may disrupt biological processes, raising new questions about how life adapts to extreme radiation shifts. These findings could help scientists fine-tune radiation shielding strategies for long-duration space missions, ensuring that astronauts are protected without unintended effects on cellular function and health.

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SUMMARY

This project is revealing new insights into how organisms adapt to extreme low-radiation environments, with implications for radiation safety, deep-space missions, and fundamental biology. In 2025, the research will continue to push the limits of what we know about radiation and life itself.

Understanding the biological effects of radon gas exposure

Motivation and significance

Radon is an invisible, odorless, naturally occurring radioactive gas that seeps from the ground and can accumulate in homes and workplaces. It has been cited as the leading cause of lung cancer in non-smokers, yet the biological mechanisms behind radon exposure and its health risks, including the dose at which radon becomes harmful, remain poorly understood.

This project aims to determine how radon interacts with living systems at the cellular and molecular levels. Researchers are developing a custom-built radon exposure chamber to precisely control radon concentrations and study how long-term exposure affects lung tissue, the immune system, and other organ systems.

The findings will help improve public health policies by defining radon exposure thresholds that accurately reflect biological risk and will ensure that Canadian homes and workplaces are neither over- nor under-regulated when it comes to radon mitigation.

Key progress in 2024

The project is proceeding on schedule. Initial mouse experiments were successfully completed, and tissue samples are now undergoing genomic and histological analysis.*

BUILDING A STATE-OF-THE-ART RADON EXPOSURE CHAMBER

- A new radon exposure chamber is under construction in Adelaide, Australia, modeled after a successful prototype built by leading radon researchers. Engineers are upgrading the electronics and particle generator to allow precise control of radon gas flow and create a more realistic exposure profile for testing. Once completed, the chamber will be shipped to Ontario, where it will become Canada's first dedicated radon exposure research facility.

*All animal experiments were approved by the Laurentian University Animal Care Committee in accordance with the Canadian Council on Animal Care ethical guidelines for animal welfare.

FIRST ROUND OF ANIMAL STUDIES COMPLETED

- The first set of mice exposed to radon gas have completed their study period in the existing Adelaide radon chamber. Researchers selected a special strain of mice with a p53 genetic mutation, making them more vulnerable to lung cancer, to better observe the effects of radon exposure.

  Mice were exposed to differing radon levels, up to 1000 Bq/m^3, for up to six months. Tissue samples were collected from lungs, intestines, spleen, heart, kidneys, and brain, to assess radon's impact on multiple organ systems. Blood samples were taken for immune response analysis and microRNA (miRNA) studies, which could reveal early biomarkers of radon exposure.

  Scientists are now analyzing lung tissue to look for tumor formation and DNA damage. Microbiome samples from the intestines are undergoing metagenomic sequencing to determine if radon affects gut bacteria. Blood samples will be tested for immune cell changes and molecular signatures of radiation exposure.

Research focus for 2025

The coming year will focus on analyzing existing data, completing construction of the radon chamber, and expanding exposure studies.

COMPLETING RADON CHAMBER CONSTRUCTION

The chamber will be commissioned in Australia, disassembled, and shipped to Sudbury, Ontario. Once reassembled, the chamber will undergo testing and calibration, with full research operations expected to begin in 2026.

CONDUCTING SECOND COHORT OF RADON EXPOSURE STUDIES

Starting in April, the next set of mice will be exposed to radon levels up to 4000 Bq/m^3, simulating long-term residential exposure. Chronic exposure effects will be studied, with a focus on DNA damage, immune system response, and metabolic changes. Tissue analysis will compare findings from short-term vs. long-term radon exposure.

INVESTIGATING WHETHER DIET CAN MITIGATE RADON-INDUCED DAMAGE

In partnership with the MD Anderson Cancer Center in Houston, Texas, researchers will test whether an antioxidant-rich diet can reduce radon-related lung damage. This study on mice will combine dietary intervention with radon exposure and analyze lung tissue for molecular signs of damage or protection. The collaboration will help determine if nutritional strategies could be used to reduce radon's health risks.

Research focus for 2025

The coming year will focus on analyzing existing data, completing construction of the radon chamber, and expanding exposure studies.

- **Publications** – As this is the first year of the project, no papers have been published yet. However, multiple publications are expected in 2025 based on findings from the first round of animal studies.
- **Presentations** – Findings will be shared at radiation biology and public health conferences in 2025, focusing on radon exposure risks and policy implications.

What are the true effects of radon exposure on the lungs?

While radon is known to cause lung cancer at high concentrations, there are questions regarding its effects at residential and occupational levels. Scientists are conducting some of the first controlled experimental studies to understand how radon gas interacts with lung tissue. Ultimately, this research will provide a better understanding of safe levels of radon exposure, which could have wider implications for radiation protection standards.

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SUMMARY

This project is filling critical gaps in our understanding of radon exposure risks by combining cutting-edge lab technology, controlled animal studies, and real-world policy applications. With a custom-built radon exposure chamber set to be operational in Canada in 2026, this research will help inform public health guidelines, workplace safety standards, and potential mitigation strategies for radon exposure.

Developing novel methods in biodosimetry

Motivation and significance

Radiation exposure can have long-term health effects, but accurately measuring an individual's dose, especially from low-dose sources like radon, remains a challenge. Biodosimetry is the measurement of radiation exposure by analyzing biological markers, such as DNA damage or changes in gene expression, to estimate the absorbed dose. This project is developing novel biodosimetry tools to detect radiation exposure at the molecular level using microRNAs (miRNAs).

miRNAs are small, non-coding RNA molecules that regulate gene activity. They are highly stable in biological fluids, resistant to degradation, and detectable through minimally invasive techniques—making them excellent candidates for radiation biomarkers. If successful, this research could lead to faster, more precise radiation exposure assessments for applications in occupational health, environmental monitoring, and radiation medicine.

Given the widespread presence of radon in homes and workplaces, a key goal of this project is to identify miRNA signatures specific to radon exposure, helping to clarify its biological effects and potential health risks.

Key progress in 2024

The project has now successfully set up both x-ray and radon exposure models for rodents, allowing experiments to proceed as planned.*

ESTABLISHING A BASELINE: MIRNA RESPONSE TO X-RAY EXPOSURE

- To validate miRNA as a radiation biomarker, researchers conducted a pilot study in rodents to examine how miRNA expression changes after x-ray exposure. Samples were collected at 6 hours post-exposure from animals that received no dose, 100 mGy, or 2 Gy doses. Analysis identified several miRNAs that showed dose-dependent changes, confirming that radiation alters miRNA expression in a measurable way.

*All animal experiments were approved by the Laurentian University Animal Care Committee in accordance with the Canadian Council on Animal Care ethical guidelines for animal welfare.

- Building on this, a second round of experiments expanded the dose range and extended the sampling timeline: Plasma samples were collected 48 hours post-exposure from animals receiving no dose, 100, 300, or 2000 mGy doses. These samples are now undergoing next-generation miRNAome profiling, which will map changes across the entire miRNA network to identify radiation-specific molecular signatures.

INVESTIGATING MIRNA CHANGES IN RESPONSE TO CHRONIC RADON EXPOSURE

- To assess how long-term exposure to radon gas affects miRNA expression, researchers launched a new chronic exposure study in rodents. Animals were exposed to 4000 Bq/m^3 of radon for 8 hours per day over 12 weeks, mimicking real-world chronic exposure scenarios. Blood serum samples were collected and will be analyzed to determine whether miRNA expression differs between radon-exposed and control animals. The next phase of this study will include lower chronic radon doses to better replicate residential and occupational exposure levels.

Research focus for 2025

Upcoming research will deepen the understanding of how radiation affects miRNA expression, with particular emphasis on radon exposure.

IDENTIFYING MIRNA BIOMARKERS FOR ACUTE AND CHRONIC RADON EXPOSURE

- miRNA analysis will be expanded to include lower-dose chronic radon exposure conditions. Researchers will compare short-term vs. long-term miRNA expression changes to determine whether radon exposure leaves a lasting molecular signature.

PROFILING MIRNA CHANGES ACROSS DIFFERENT RADIATION DOSES AND TIME POINTS

- Continued miRNAome profiling of plasma and serum samples to track miRNA responses over time. Researchers will test whether miRNA changes follow a clear dose-response pattern, which would strengthen their use as reliable biodosimetry tools.

INVESTIGATING SEX DIFFERENCES IN MIRNA RESPONSE

- Male and female subjects may respond differently to radiation exposure, a factor that has not been well-studied in biodosimetry. 2025 experiments will compare miRNA changes between male and female rodents, helping to determine whether sex-specific biomarkers should be considered in radiation risk assessments

EXPANDING THE STUDY TO REAL-WORLD EXPOSURE SCENARIOS

- Researchers will explore miRNA signatures associated with lower chronic radon exposures, bringing the study closer to actual exposure conditions in homes and workplaces.

Scientific outputs in 2024

- **Publications** – Two manuscripts in preparation, including a literature review on miRNA and radiation exposure.
- **Conference presentations** – Findings presented at the Radiation Research Society 2024 Annual Meeting in Tucson, Arizona.

How do we measure past radiation exposure?

Unlike radiation dosimeters, which only measure exposure at the time of detection, biodosimetry allows scientists to analyze biological changes long after exposure has occurred. This research is working toward a molecular fingerprint of radiation exposure, which could be used to assess long-term health risks in radiation workers, astronauts, and even cancer patients.

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SUMMARY

This project is pioneering a new approach to radiation exposure assessment by using miRNA biomarkers to track biological responses at the molecular level. With promising initial results and a growing focus on radon exposure, 2025 will be a pivotal year in determining whether miRNAs can serve as accurate, minimally invasive biodosimetry tools for both research and real-world applications.

MicroRNAs: Small molecules with big potential

MicroRNAs (miRNAs) are incredibly small: each one is only about 7 nanometers long, or 10,000 times smaller than the width of a human hair. Despite their tiny size, they play a huge role in gene regulation, helping cells turn genes on and off in response to environmental changes, including radiation exposure. Because miRNAs are stable in blood and resistant to degradation, they are being explored as biomarkers for detecting radiation exposure, offering a potential non-invasive way to assess radiation risk in the future.

NEUDOSE: Paving the way for future space science

Motivation and significance

The NEUtron DOSimetry & Exploration (NEUDOSE) mission was a satellite project designed and built by researchers at McMaster University, Bruce Power, and the Nuclear Innovation Institute to study the effects of neutron radiation on human health in space. Launched in 2023, NEUDOSE featured a novel radiation detector capable of distinguishing neutron exposure from other types of space radiation – critical data for astronaut safety in deep space missions.

While the NEUDOSE project has concluded, its technology and expertise have led to several exciting new initiatives. Although these new projects are not funded by Bruce Power or NII, they build on the foundation established by NEUDOSE:

- **ISS-NEUDOSE (2027):** The mission's radiation detector, CNP-TEPC, will be deployed on the International Space Station in 2027 for a long-duration experiment. This test will validate its performance and assess its readiness for lunar missions.
- **PRESET CubeSat (2026):** Building on lessons from NEUDOSE, McMaster researchers are developing their own satellite components for the PRESET CubeSat mission, including a custom radio, deployable antenna, altitude control system, and onboard computer. This work aims to create a scalable satellite platform for future scientific missions.

These projects highlight how Bruce Power and NII's early investment in space radiation research has contributed to the expansion of Canada's space science capabilities. More details on these ongoing efforts can be found at mstri.ca.

Conclusion

In 2024, NII Environment helped drive critical research into pressing environmental and health challenges, from understanding how climate change is shaping Lake Huron to developing cutting-edge radiation safety tools. These projects have expanded our scientific knowledge, contributed to policy discussions, and provided practical insights for industries, researchers, and communities alike.

Looking ahead, 2025 will focus on expanding the impact of this research, with key priorities including:

- Advancing our understanding of Lake Huron's health through continued monitoring, modeling, and ecosystem studies.
- Exploring the long-term effects of radiation exposure using novel biodosimetry techniques and experiments at SNOLAB.
- Providing science-backed insights for decision-makers, ensuring that research findings translate into real-world applications.

By supporting independent, high-quality research, Bruce Power and NII are shaping a future where science drives better policy, stronger environmental protections, and healthier communities.