# SCIENCE IN ACTION

Discover the world of natural sciences at the Canadian Museum of Nature!

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# THE CANADIAN MUSEUM OF NATURE IS NOT JUST A NATURAL-HISTORY MUSEUM.

It is at the leading edge of research, discovery and education, with the mission of inspiring Canadians from coast to coast to coast to connect and engage with nature through exploration and science. At the heart of this mission lies research, bridging the knowledge of the past and the predicted changes of the future to gain an understanding of how we can adapt and protect the ever-important biodiversity of the planet.

From the frigid Arctic tundra to the sweltering heat of South America, researchers at the Canadian Museum of Nature journey across the globe to investigate and uncover some of the greatest mysteries of science. Following their curiosity, these experts study fields spanning botany, terrestrial and marine biology, mineralogy and palaeontology, pushing their scientific understanding to the next level.

These researchers take their findings back to the Natural Heritage Campus in Gatineau, Quebec, where they analyze and document new scientific discoveries that highlight changes that are occurring in our world. Their additions to our collection of over 14.6 million specimens are studied by these researchers in the multi-disciplinary scientific laboratories.

Follow us through these science stories that highlight this incredible research and learn how these discoveries can be used to create a positive impact on the world around us. Ignite your curiosity as you read the scientific adventures that are contributing to a better understanding of our past and future, and engage with nature as you learn about the fascinating work being done by experts at the Canadian Museum of Nature!

## LAND ACKNOWLEDGEMENT

The Canadian Museum of Nature resides on the traditional, unceded territory of the Anishinābe Algonquin people who have stewarded this land for thousands of years.

We acknowledge that the museum's scientific research occurs across Canada—from coast to coast to coast—on the territories of the Métis and First Nations people and in Inuit Nunangat.

# MEET THE EXPERTS

**Jordan Mallon, Ph.D.**
Palaeobiologist

**Dominique Fauteux, Ph.D.**
Zoologist

**Paul Sokoloff, M.Sc.**
Botanist

**André Martel, Ph.D.**
Zoologist

**Jean-Marc Gagnon, Ph.D.**
Zoologist

**Scott Rufolo, Ph.D.**
Palaeobiologist

**Inna Lykova, Ph.D.**
Mineralogist

**Ralph Rowe, B.Sc.**
Mineralogist

**Glenn Poirier, M.Sc.**
Mineralogist

**Robert Anderson, Ph.D.**
Zoologist

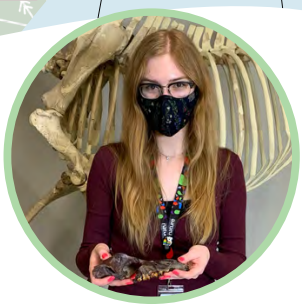
**Troy McMullin, Ph.D.**
Botanist

**Jeff Saarela, Ph.D.**
Botanist

**Roger Bull, M.Sc.**
Botanist

**Lynn Gillespie, Ph.D.**
Botanist

**Sergei Ponomarenko, Ph.D.**
Botanist



**Zoe Landry**
Ph.D. Student
University of Ottawa

**Danielle Fraser, Ph.D.**
Palaeobiologist

**Marisa Gilbert, B.Sc.**
Palaeobiologist

**Kamal Khidas, Ph.D.**
Zoologist

**Elliott Schmidt, M.Sc.**
Zoologist

**Paul Hamilton, M.Sc.**
Phycologist

**Amanda Savoie, Ph.D.**
Botanist

**Kathleen Conlan, Ph.D.**
Zoologist

**Ed Hendrycks, B.Sc.**
Zoologist

**Tetsuto Miyashita, Ph.D.**
Palaeobiologist

**Follow along as we learn about the fascinating research being done by these scientists and their teams!**

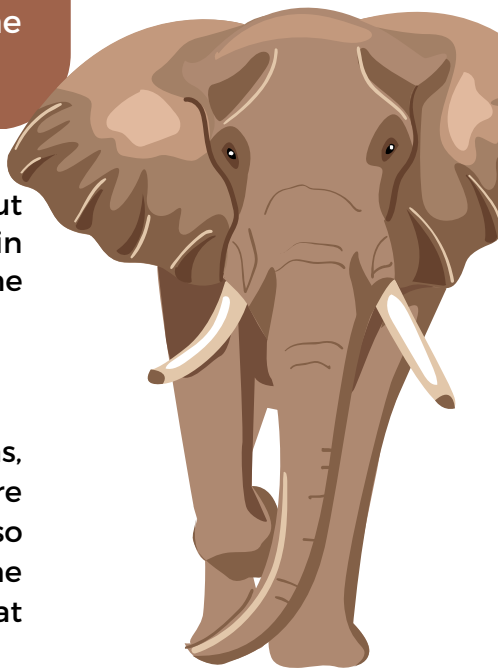
# EATING TO SURVIVE:

## What herbivorous dinosaurs can tell us about modern ecosystems

A 2021 study of dinosaur fossils found across western North America showed evidence of differences in diet between small herbivores and juvenile megaherbivores (i.e., those weighing over 1000 kilograms as adults), which would have enabled their mutual survival. Through this research, palaeobiologists take us back over 66 million years to show us how the processes that shaped dinosaur ecosystems are the same as those that shape animal ecosystems today.

Dinosaur fossils can reveal many things about the functioning of past ecosystems, which in turn can improve our understanding of the rules that govern present ones.

In modern mammal-dominated ecosystems, intensive foraging by a few large herbivore species (e.g., elephants, rhinoceros) can so alter their environment as to influence the number and types of smaller species that cohabit the area.



The dinosaur-dominated ecosystems of

**LATE CRETACEOUS NORTH AMERICA**

(about 80 to 66 million years ago) differed in that they supported an even greater number of megaherbivore species, causing scientists to wonder. . .

**. . . "WHAT EFFECTS DID THESE LARGE HERBIVORES HAVE ON THEIR COMMUNITIES?"**

# EXPERTS ON THE CASE

**JORDAN MALLON, PH.D.**

CANADIAN MUSEUM OF NATURE
PALAEOBIOLOGIST

**TAIA WYENBERG-HENZLER**

CARLETON UNIVERSITY
MASTER'S STUDENT

Taia Wyenberg-Henzler and Jordan Mallon travelled to museums across North America to collect data pertaining to the ornithischian dinosaurs—a large group that includes such familiar forms as ***Triceratops*** and ***Ankylosaurus***, as well as much smaller animals.

## 1 THE PROCESS

The team first studied key characteristics of herbivorous dinosaur teeth and skulls known to correlate with feeding habits in living animals.

## 2

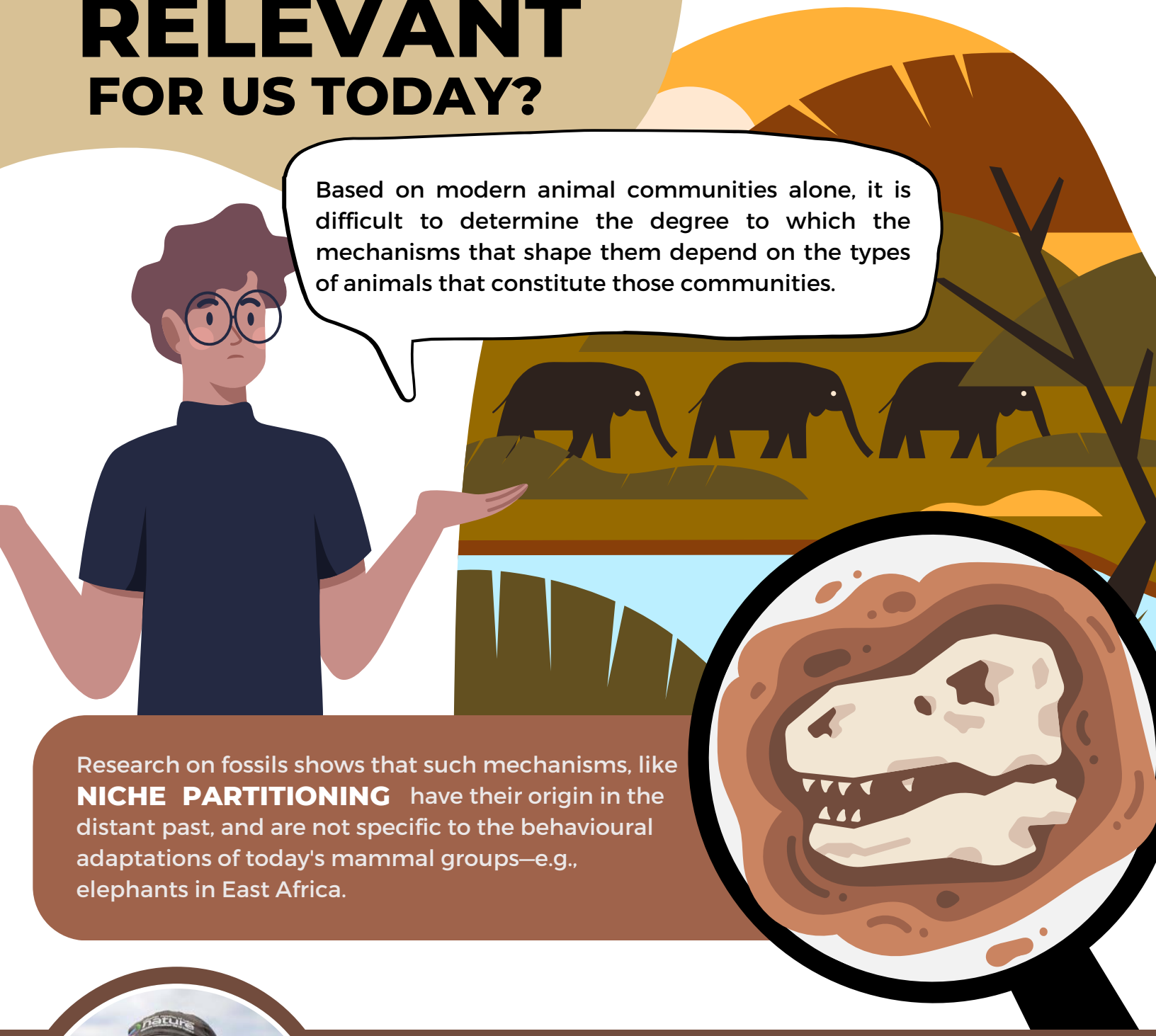
Then, they surveyed the fossil record to estimate the species' relative abundance and their associated food-intake rates on the Late Cretaceous landscape.

## THE SCIENTISTS' FINDINGS

revealed that adult duck-billed dinosaurs, in particular, would have eaten most of the available food resources, and that both young megaherbivores and small-bodied species coexisted by sharing the remaining resources of the landscape—a practice known as **"NICHE PARTITIONING".**

Precisely which dinosaurs ate which plant types is a subject of ongoing investigation in Mallon's lab.

# WHY IS THIS RELEVANT FOR US TODAY?




Research on fossils shows that such mechanisms, like **NICHE PARTITIONING** have their origin in the distant past, and are not specific to the behavioural adaptations of today's mammal groups—e.g., elephants in East Africa.

## ABOUT THE SCIENTIST

Jordan C. Mallon, Ph.D., specializes in dinosaur evolution and ecology during the Late Cretaceous of North America at the Canadian Museum of Nature.

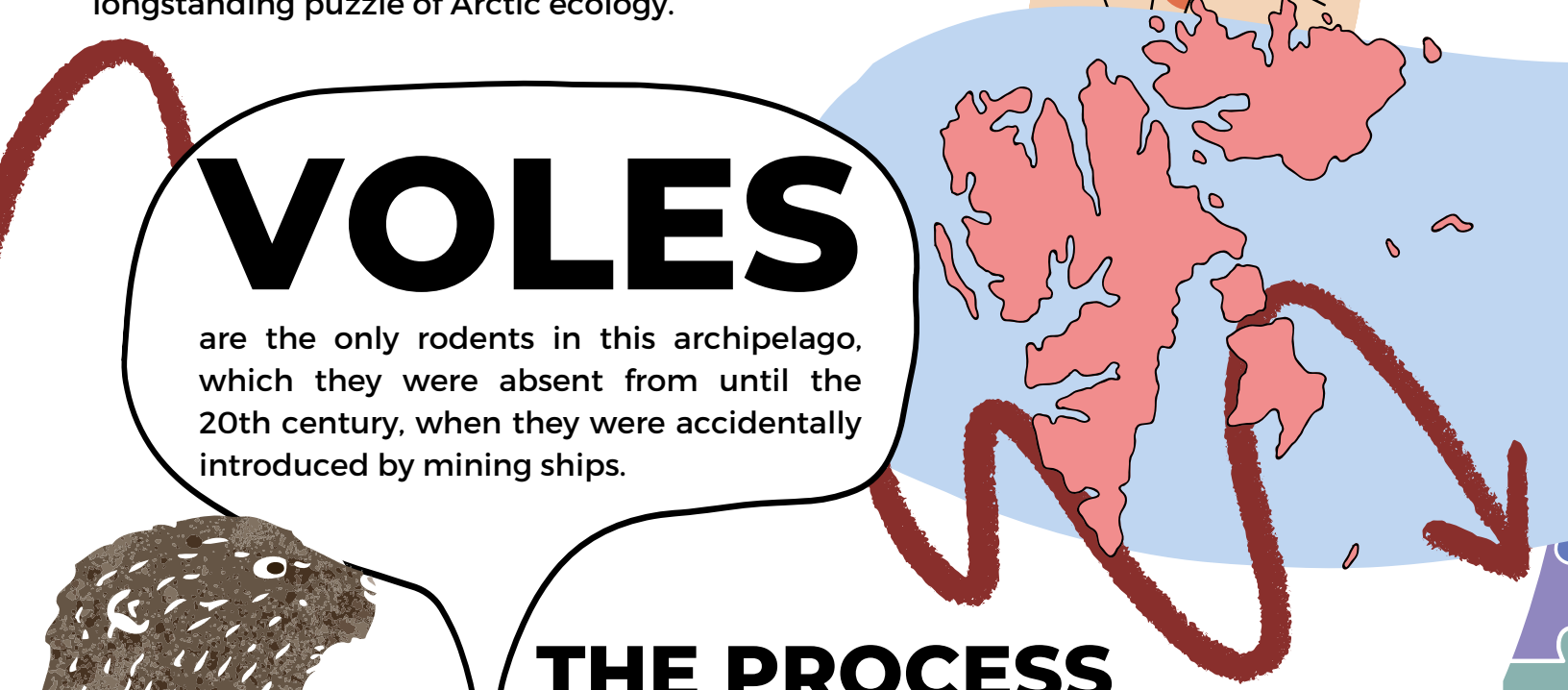
**MEET THE SCIENTIST:** Click here!

**Paper references:** Wyenberg-Henzler, T., Patterson, R.T., and Mallon, J.C. (2021). Size-mediated competition and community structure in a Late Cretaceous herbivorous dinosaur assemblage. *Historical Biology*. https://doi.org/10.1080/08912963.2021.2010191.

# A LESSON FROM NATURE:
## HOW CLIMATE CHANGE AND PREDATION CAN DISRUPT ARCTIC RODENT POPULATION CYCLES

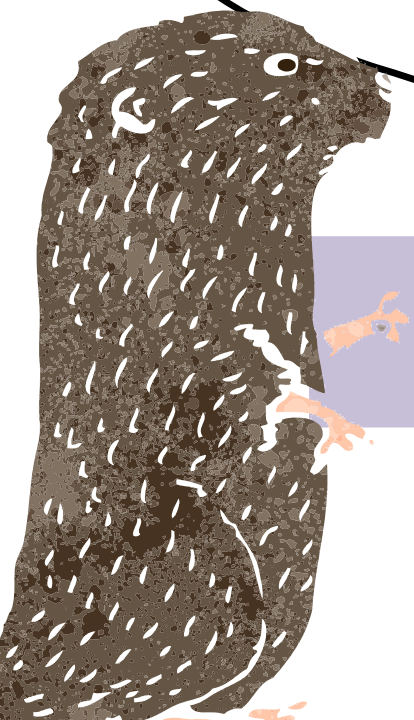
**A 17-year-long study by Canada and Norway determined how and why voles go through population cycles in the Arctic, which underscores the impact of climate change and human activities on tundra environments.**

Between 1990 and 2007, researchers analyzed the East European vole population variation in Svalbard, Norway, to determine its dynamics and investigate a longstanding puzzle of Arctic ecology.



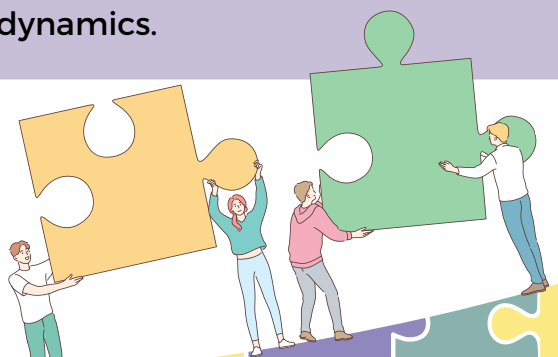
## VOLES

are the only rodents in this archipelago, which they were absent from until the 20th century, when they were accidentally introduced by mining ships.



## THE PROCESS

Scientists compared theories, model simulations and empirical data using live trapping and they contrasted winter and summer dynamics.



# THE SCIENTISTS' FINDINGS

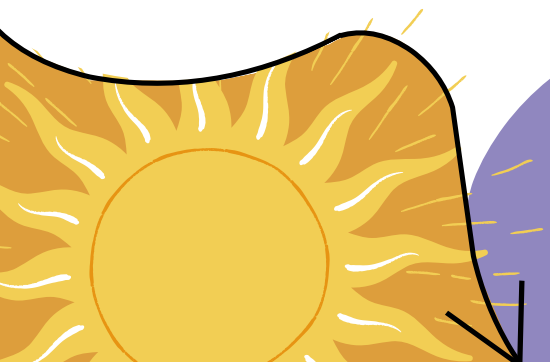
In Svalbard, they found that the unique absence of predation and unusual rain-on-snow events, which are expected to increase with climate change, led to non-cyclic population fluctuations (through which population dynamics can be understood and predicted).

## BUT WHAT DOES THIS MEAN?

Without predation, herbivores such as voles can reproduce very quickly in summer and overshoot the carrying capacity of the tundra (i.e., the maximum number of herbivores that can be sustained by the available resources), which drops significantly in winter because of the plants' withering and going dormant.




Additionally, heavy rain on snow can prevent voles from accessing food because of hardened snow or ice, resulting in extreme winter population declines.



Without such weather patterns, the authors found that voles would experience two-year cycles of abundance based on theoretical models, and not the three- to five-year cycles observed in most Nordic ecosystems.

# WHY IS THIS RELEVANT FOR US TODAY?

Voles are important small mammals because they are food for many predators, they influence other herbivores and they consume plants, thus affecting biodiversity.

In the absence of predation, small rodents may not go through the typical three- to five-year population cycles observed in small rodents in many parts of North America, Europe and Asia, emphasizing that predation is an important factor driving population cycles.

Moreover, the disruptive effects of rain on snow leading to non-cyclic dynamics in voles in Svalbard indicate that climate change will play an important role in defining future population dynamics in Northern ecosystems. The Canadian Museum of Nature's exhibitions contribute to raising public awareness of the impact of climate change on nature.


# ABOUT THE SCIENTIST

Dominique Fauteux, Ph.D., is a zoologist who specializes in population dynamics, trophic interactions and comparative morphology of small Arctic mammals at the Canadian Museum of Nature.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Fauteux, D., Stien, A., Yoccoz, N. G., Fuglei, E. and Ims, R. A. (2021). Climate variability and density-dependent population dynamics: Lessons from a simple High Arctic ecosystem. *Proceedings of the National Academy of Sciences*, 118 (37) e2106635118. https://doi.org/10.1073/pnas.2106635118

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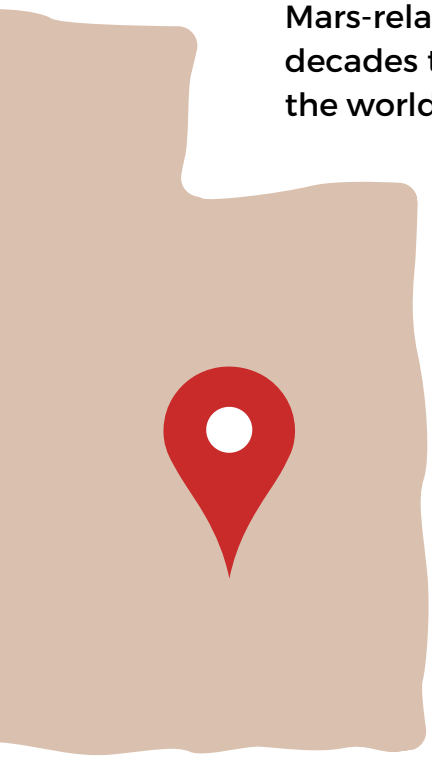
# NEW PROSPECTS FOR LIFE ON MARS

## THANKS TO A BOTANICAL EXPEDITION IN UTAH

Deserts overflow with biodiversity and spark botanists' interest in techniques that could be used in the search for life on the Red Planet.

Mars-related research has grown over the past decades thanks to various simulation facilities in the world's most extreme environments.



The oldest of these sites, the **MARS DESERT RESEARCH STATION** (MDRS), is located in the United States in a southern Utah desert, where numerous scientific, medical, journalistic and artistic crews have travelled over the years to understand and mitigate the future technical and psychological challenges of Martian exploration.

## THE SCIENTISTS' FINDINGS

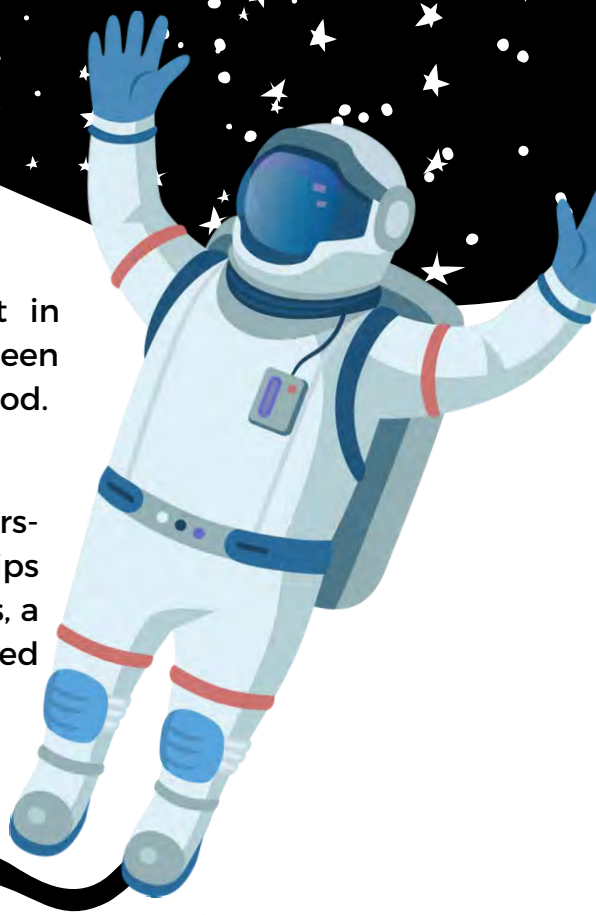
This field investigation complemented a previous study by identifying 40 additional species of vascular plants (i.e., a large group of land plants with roots and shoots) at MDRS, which brings the total number of the "Martian flora" inventory to 79 species and two additional genera (or species groups).

# HOWEVER,

the collection conditions were significantly different than before.

1 First, this study was conducted in the spring, not in November when many specimens had likely been overlooked because of the less-favourable autumn period.

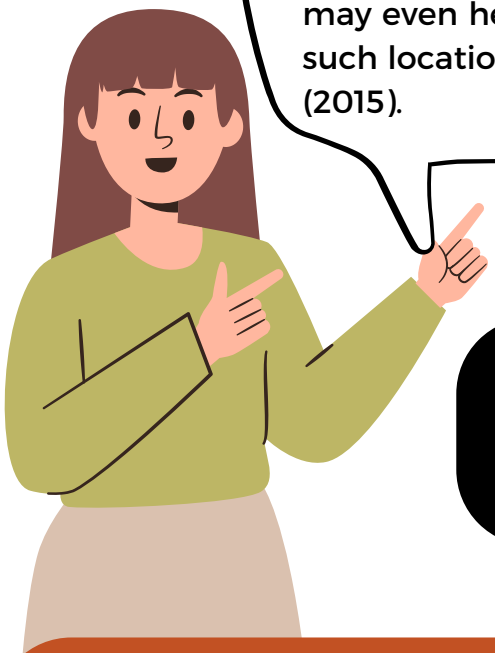
2 Second, there were no constraints related to a Mars-mission simulation, which strictly controls trips outside the MDRS (e.g., nearby pre-approved sites, a smaller team, shorter exploration time, and reduced visibility and dexterity because of spacesuits).



While this is essential to simulate a realistic Martian excursion and to learn how to undertake fieldwork on another world, it limits the number of species recorded.

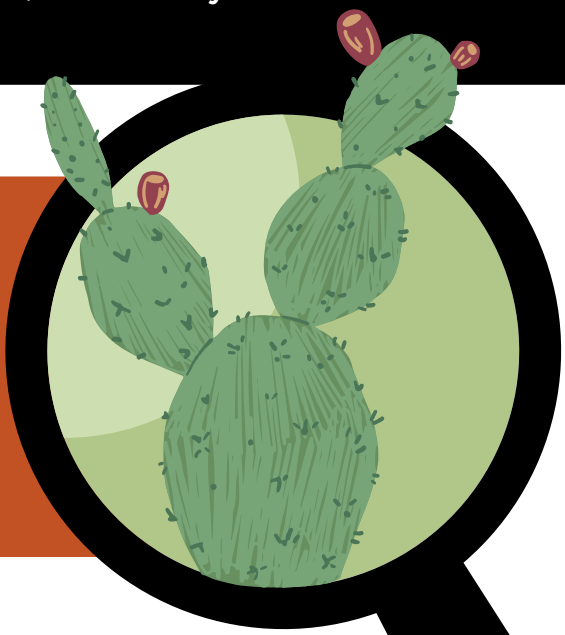
The present survey, accompanied with descriptions and photographs of the flora and its typical and observed habitat, illustrates a wider sample of the diversity around the station.

# WHY IS THIS RELEVANT FOR US TODAY?

This work is important to our understanding of plant diversity and adaptation in extreme environments. It may even help us understand how to grow plants in such locations, as depicted in the movie **The Martian** (2015).

These new records provide important information about unique species and their presence at MDRS, providing valuable insights for future crews, biodiversity researchers and conservation organizations.



Indeed, two cactus species found by the botanists happened to be endangered species and therefore were not collected, only documented. This finding helps inform crews about this area and to preserve these species. By contrast, other plants were recognized as invasive and their documentation here can help land managers with mitigation efforts.

## ABOUT THE SCIENTIST

Paul C. Sokoloff, M.Sc., is a Senior Research Assistant at the Canadian Museum of Nature, specializing in plant biodiversity and taxonomy in the Arctic and beyond.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Sokoloff P.C., Murray D.A., McBeth S.R.M., Irvine M.G., Rupert S.M. (2020). Additions to the "Martian Flora": new botanical records from the Mars Desert Research Station, Utah. *Biodiversity Data Journal* 8: e55063. https://doi.org/10.3897/BDJ.8.e55063.

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### A WORLD FIRST IN THE NATIONAL CAPITAL REGION: THE IMPACT OF

# INVASIVE ZEBRA MUSSELS ON LOCAL BIODIVERSITY

A unique 26-year-long study by the Canadian Museum of Nature underscores the recent causes and impacts of the zebra mussel invasion in the Rideau River in Ontario. It revealed a persistent upstream-downstream pattern (with larger populations downstream) and a lake-like effect halfway down the river, ideal for larvae that can jeopardize native species.

## EXPERTS ON THE CASE

**ANDRÉ MARTEL, PH.D.**
CANADIAN MUSEUM OF NATURE ZOOLOGIST

**JACQUELINE MADILL, B.SC.**
CANADIAN MUSEUM OF NATURE FORMER SENIOR RESEARCH ASSISTANT

**André L. Martel, one of Canada's leading experts on molluscs, worked with Jacqueline Madill, a former Senior Research Assistant at the Canadian Museum of Nature, to track the dazzling proliferation of the zebra mussel in Ontario's Rideau River between 1990 and 2015.**

### 1990

This highly invasive species was first recorded in Eastern Ontario in 1990 by Martel as he was examining the molluscan fauna of the Rideau River.

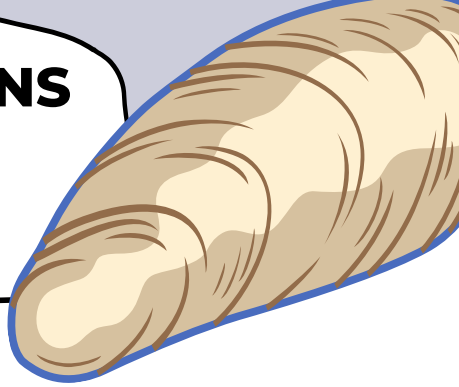
### 1995

By 1995, some specimens had reached the upstream sites, while a 100 000-fold surge was observed downstream, with a mean density going up to 500 000 mussels/m² in Ottawa!

### 2015

In 2015, upstream densities had also increased, and the zebra mussel has since spread downstream and overland (e.g., through boat traffic and transportation) from Quebec to Manitoba.

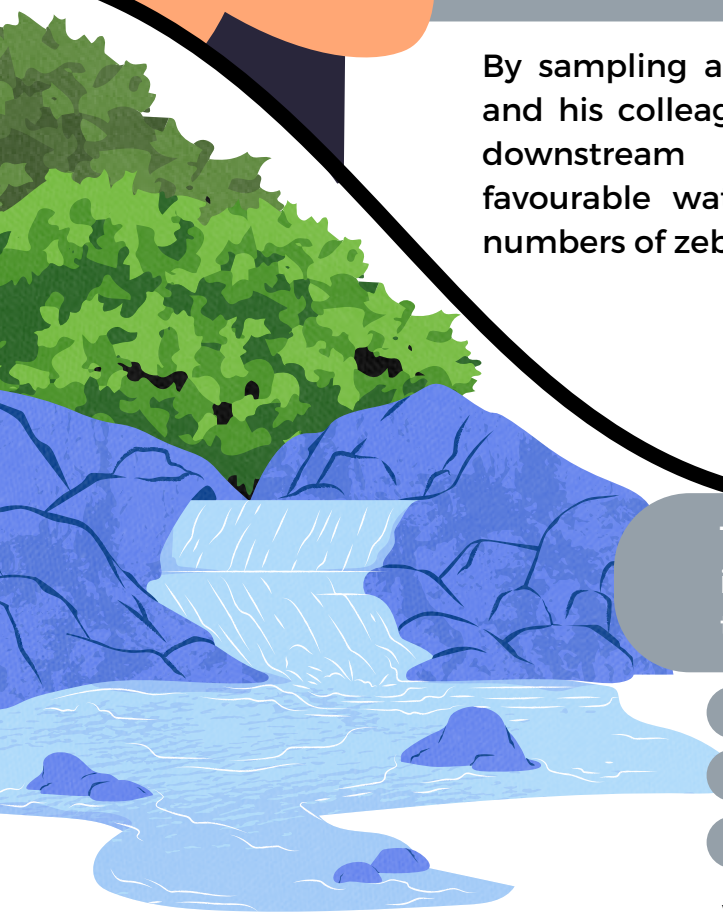
**SO WHAT ARE THE REASONS AND EFFECTS OF SUCH LONG-TERM NUMBERS?**



# THE RESEARCH

Answering this question is crucial to understanding the dynamics of the colonization and knowing why this small river is an ideal habitat for this invasive mussel.

By sampling and counting specimens over the years, Martel and his colleagues were able to identify a distinct upstream-downstream pattern: downstream sections have more favourable water chemistry that contributes to the higher numbers of zebra mussels carried by the current.



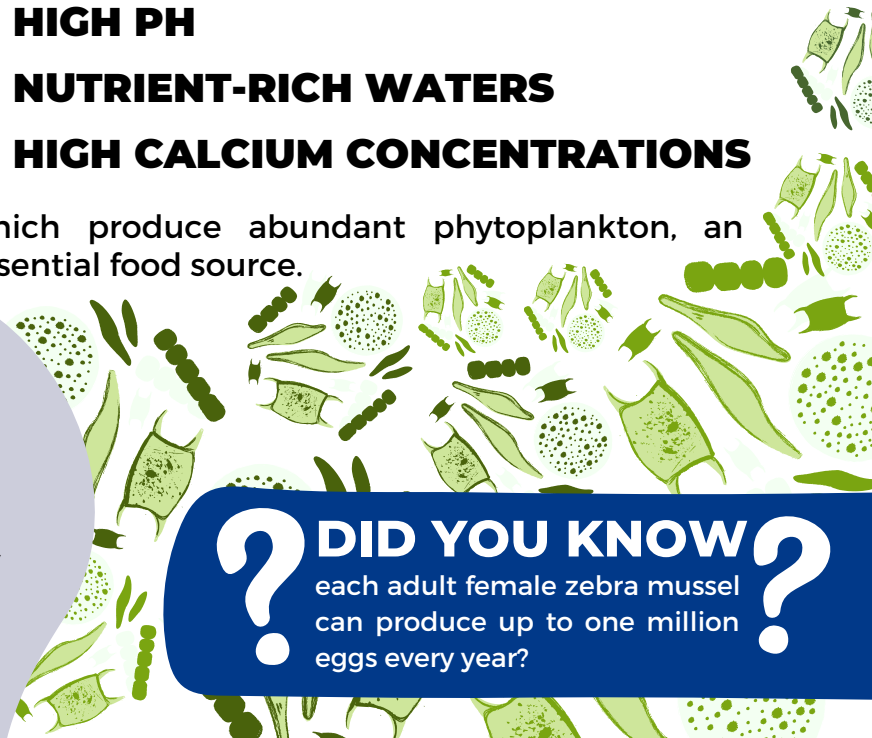
# THE SCIENTIST'S FINDINGS

The habitat is indeed critical to a population's increase, and the Rideau River happens to check all the boxes required by this species to thrive:

1. **HIGH PH**
2. **NUTRIENT-RICH WATERS**
3. **HIGH CALCIUM CONCENTRATIONS**

which produce abundant phytoplankton, an essential food source.

**Moreover, a "lake effect" can be observed mid-river, with wider, calmer bays acting like a long shallow lake and thus stimulating the growth of larvae. These elements correlate with the persistence of high population settlement downstream, even over a quarter-century.**



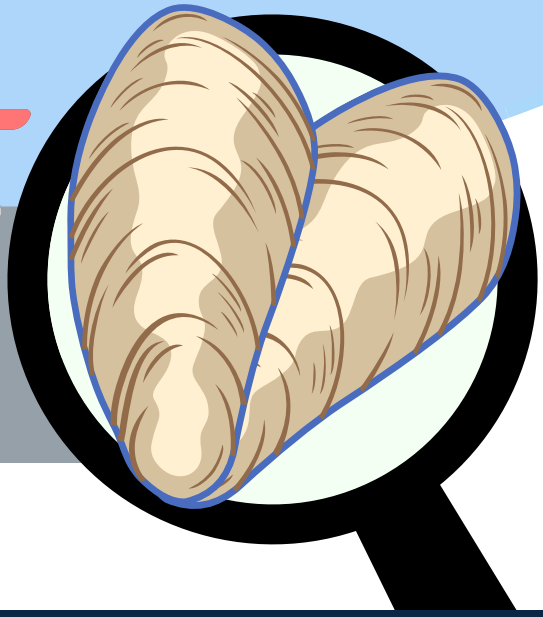
**DID YOU KNOW**

each adult female zebra mussel can produce up to one million eggs every year?

# WHY IS THIS RELEVANT FOR US TODAY?

This study fills a gap in our understanding of the population dynamics of expanding zebra mussels and their negative effects on native freshwater species, i.e., by competing with them for phytoplankton and by smothering them entirely.

Human impacts on the Rideau River and other Canadian watercourses are highlighted, because boats can be a serious risk factor for the spread of such mussel species into new habitats, which can threaten already endangered species and fragile freshwater biodiversity.



The presence of this invasive mollusc in the Ottawa-Gatineau region also has repercussions on the management of water intakes and on the cities' water-filtration systems.

## ABOUT THE SCIENTIST

André L. Martel, Ph.D., is an aquatic biologist and zoologist at the Canadian Museum of Nature. His research focuses on Canada's imperilled freshwater mussel fauna.

**MEET THE SCIENTIST:** Click here!

**Research paper reference:** Martel, A.L. and Madill, J.B. (2018). Twenty-six years (1990–2015) of monitoring annual recruitment of the invasive zebra mussel (*Dreissena polymorpha*) in the Rideau River, a small river system in Eastern Ontario, Canada. *Canadian Journal of Zoology*, 96 (10), pp. 1071–1079. DOI: 10.1139/cjz-2017-0360. https://cdnsciencepub.com/doi/full/10.1139/cjz-2017-0360?src=recsys

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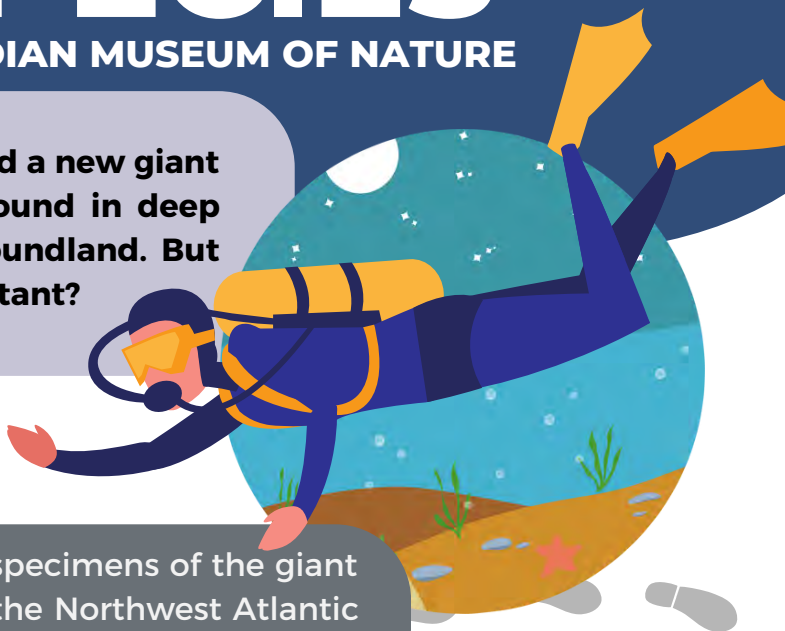
# A NEW MARINE CLAM SPECIES

## DISCOVERED AT THE CANADIAN MUSEUM OF NATURE

**In 2015, a team of Canadian researchers described a new giant file-clam species called *Acesta cryptadelphe*, found in deep waters off the coast of Nova Scotia and Newfoundland. But how did they actually do that and why is it important?**



## 1 THE PROCESS

First, they had to determine whether specimens of the giant file clam (genus ***Acesta***) collected in the Northwest Atlantic were distinct from those found in Europe.

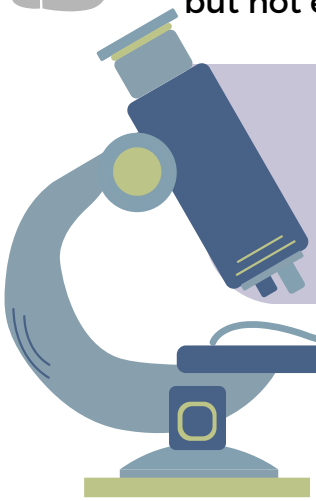
The team started by analyzing variations in their shell shape. If sufficient distinctions were observed, a new species could then be designated.

Several steps were taken to compare 13 Northwest Atlantic specimens (collected by means of manned diving excursions and remotely operated vehicles between depths of 400 m and 1241 m) with 139 others, many of which were borrowed from several natural-history museum collections.

2

The researchers were able to scan and analyze the shells with a shape-analysis methodology similar to the facial recognition methods seen in CSI TV programs.

Some differences were observed in the proportion, hinge and shape of the Northwest Atlantic clam shells, but not enough.



Knowing that most of these adult ***Acesta*** shells have few external morphological features that can be used to distinguish species, new ways of assessing similarities and variations were needed. This is where larval shells and DNA analyses came into play.

**With these, we now know that the Northwest Atlantic specimens differ significantly from others by having a distinct genetic makeup and larger larval shell size.**

# THE SCIENTISTS' FINDINGS

These findings show that while the Nova Scotia and Newfoundland specimens are similar to European ***Acesta*** clams, they are not identical to them.

Results of this study allowed the recognition of this new species from the deep marine canyons of the Northwest Atlantic:

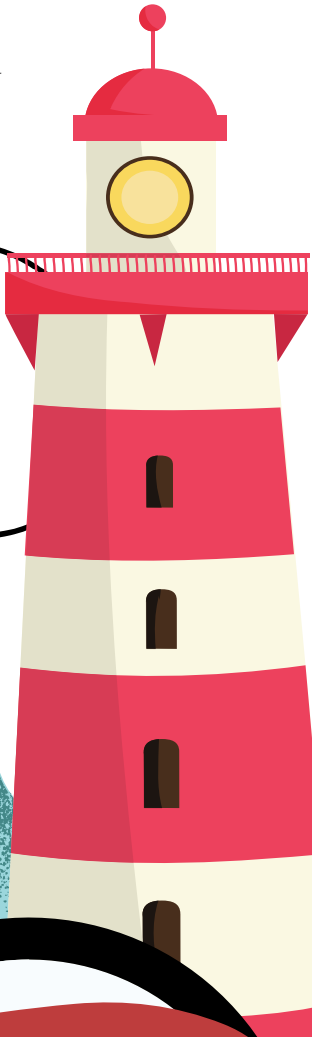
# *ACESTA CRYPTADELPHE*

(which means “hidden sibling”, in reference to the similar shell morphology that they share with their Northeast Atlantic congeners).

# WHY IS THIS RELEVANT FOR US TODAY?

In times of climate change and biodiversity loss caused by human activity, it is reassuring to know that we can identify new species that help us increase our understanding of our natural world and, hopefully, better protect it for the future. Such a discovery reminds us that science is crucial in this regard.





**“Our persistence shows that there are still discoveries to be made from deep in our oceans, and both museum collections and genetic analysis are important resources to advance this knowledge”,** said lead author Jean-Marc Gagnon.

# ABOUT THE SCIENTIST

Jean-Marc Gagnon, Ph.D., is the Chief Scientist and Curator of the Invertebrate Collection at the Canadian Museum of Nature, specializing in marine ecology and biology.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Gagnon, J.-M., Kenchington, E., Port, A., Anstey, L.J., and Murillo, F.J. (2015). Morphological and genetic variation in North Atlantic giant file clams, *Acesta* spp. (Bivalvia: Limidae), with description of a new cryptic species in the Northwest Atlantic. *Zootaxa* 4007(2): pp. 151-180. https://doi.org/10.11646/zootaxa.4007.2.1.

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# HOW MODERN KENYAN FISH

## SHED LIGHT ON THEIR ANCESTORS, THEIR ENVIRONMENT AND OUR HUMAN ORIGINS

How do we reconstruct a four-million-year-old ecosystem?

And how does that imply a pan-African river system suitable for our human ancestors?

It may not be the first answer that springs to mind, but comparing fish fossils with their modern counterparts is a part of the answer.

Canadian scientists can venture far beyond northern climes to help unlock the secrets of animal remains and understand their connection with human and Earth history.

## THE KANAPOI SITE

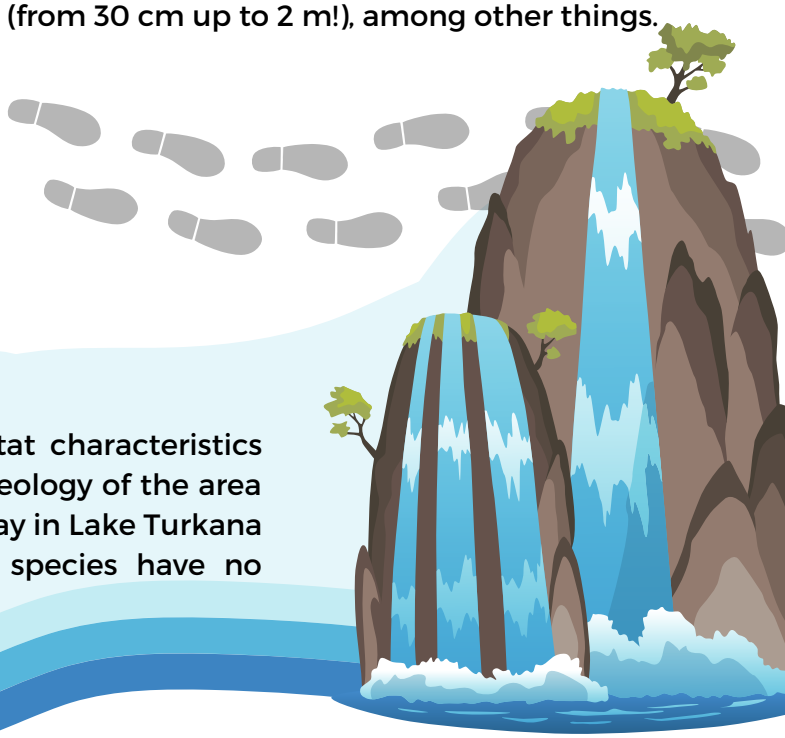
in Kenya is the theatre of various expeditions that provide invaluable data on life there 4.2 million years ago.

In a 2020 study, over 400 fossil fish specimens were identified and compared with modern fish species and habitats to reconstruct East African fish species groups and freshwater environments at the time.

# EXPERTS ON THE CASE

Researcher Scott Rufolo worked with Research Associate at the Canadian Museum of Nature, Kathlyn Stewart, to examine the fossils, whose teeth and various bones gave valuable information on the fishes' identity, diet and size (from 30 cm up to 2 m!), among other things.

**SCOTT RUFOLO, PH.D.**
CANADIAN MUSEUM OF
NATURE PALAEOBIOLOGIST



It was then possible to relate them to their habitat characteristics (river vs. lake, shallow vs. deep, etc.) based on the geology of the area and through comparison to fish species present today in Lake Turkana and its surroundings—though some of the fossil species have no modern descendants.

# THE SCIENTISTS' FINDINGS

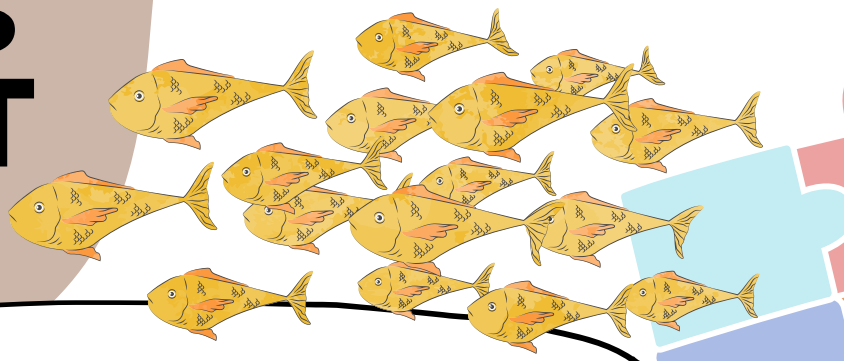
This method of equating past and present behaviours is commonly employed, but rarely tested, and it proved valid in this study. Indeed, 80% of the Kanapoi fish group and 100% of fish fossils from other Lake Turkana sites matched the lake and delta habitats of the same species groups today.

Additionally, an important geographic implication stems from the diversity of fish found at Kanapoi: a connection between the early Nile River and the Turkana Basin may have existed through a river network called the Qena system, which would explain the uniform distribution of many species across Africa 20 million years ago.

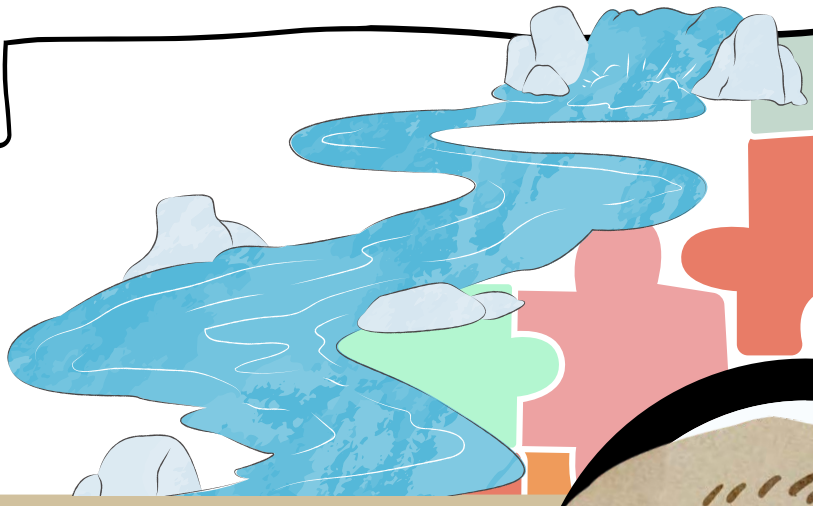
**Evidence of wet periods supports this idea because floods may have expanded lakes and rivers, leading to the migration of fish and other vertebrates across eastern and northern Africa, such as one of the earliest members of the human lineage, *Australopithecus anamensis*, whose remains are also found at Kanapoi.**

Descendants of the fish live in these regions today, although some populations have been driven out by pollution or habitat disturbance, as has happened in the Nile.

# WHY IS THIS RELEVANT FOR US TODAY?



This study tests the accuracy of the comparative method and indicates that modern fish ecosystems can be successfully linked to past environments, which implies that future changes in such ecosystems could be interpreted or predicted in current habitats.



Moreover, the environmental reconstruction and the Qena system hypothesis both contribute to a better understanding of the living conditions of our early human ancestors and the animals with which they shared the landscape.

# ABOUT THE SCIENTIST

Scott Rufolo, Ph.D., specializes in palaeontology and zooarchaeology at the Canadian Museum of Nature, studying how animals and early humans developed and coexisted millions of years ago. He collaborated on this research with Kathlyn Stewart, Ph.D., retired Research Scientist and current Research Associate at the Canadian Museum of Nature.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Stewart, K.M., Rufolo, S.J. (2020). Kanapoi revisited: Paleoecological and biogeographical inferences from the fossil fish. *Journal of Human Evolution* 140: 102452 (14 pp.). DOI: 10.1016/j.jhevol.2018.01.008.

# RESEARCH AND POLICY:

## WORKING TOGETHER TO PROTECT AND RECOVER CANADA'S IMPERILLED FRESHWATER SPECIES

**Improving the recovery of freshwater species at risk in Canada must occur in association with sound legislation and decision-making.**

**SARNET,** a government–academic research network, was made possible through the government's commitment to developing and addressing research priorities.

A key role of scientific research is to fill current knowledge gaps and provide information to prioritize future studies and effective actions for preserving species at risk.

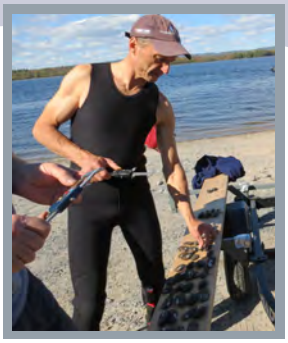
Freshwater fishes and mussels are keystone species for biodiversity and environmental health, but they have some of the highest extinction and imperilment rates worldwide, as listed by the *Species at Risk Act (SARA)*.

Policy-makers and conservation practitioners must protect these species, address their threats and support their recovery to prevent their extinction, which is largely caused by human activity. This can prove difficult because of uncertainties, lack of coordination, or funding constraints.

# SOME OF THE EXPERTS ON THE CASE

ROWSHIRA CASTAÑEDA, PH.D.

STEVEN COOKE, PH.D.



ANDRÉ MARTEL, PH.D.

ANDREW DRAKE, PH.D.

To overcome this, a collaborative research program between government and academics, the Canadian Freshwater Species at Risk Research Network (SARNET), was created through the leadership of scientists at the Great Lakes Laboratory for Fisheries and Aquatic Sciences of the Department of Fisheries and Oceans Canada.

The SARNET research program included the active participation of Rowshira Castañeda, a science coordinator at the Department of Fisheries and Oceans Canada, Steven Cooke, a professor and the Canada Research Chair of Environmental Sciences at Carleton University, André L. Martel, a research scientist at the Canadian Museum of Nature, and Andrew Drake, a research scientist at the Department of Fisheries and Oceans Canada.

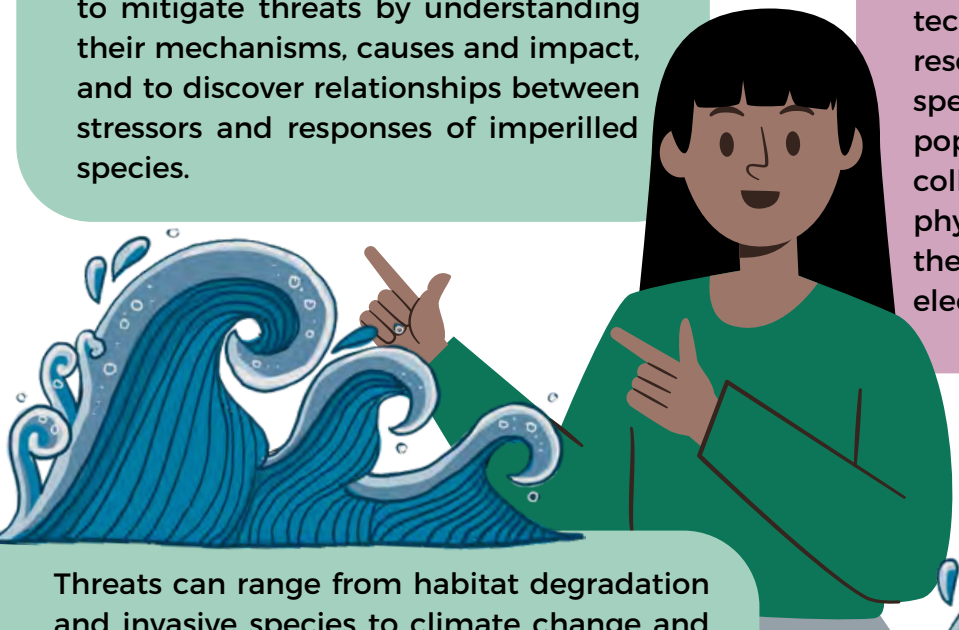
**Various SARNET applications and projects that focus on threats and recovery were targeted.**

**1**

On one hand, field, laboratory and analytical experiments were designed to mitigate threats by understanding their mechanisms, causes and impact, and to discover relationships between stressors and responses of imperilled species.

**2**

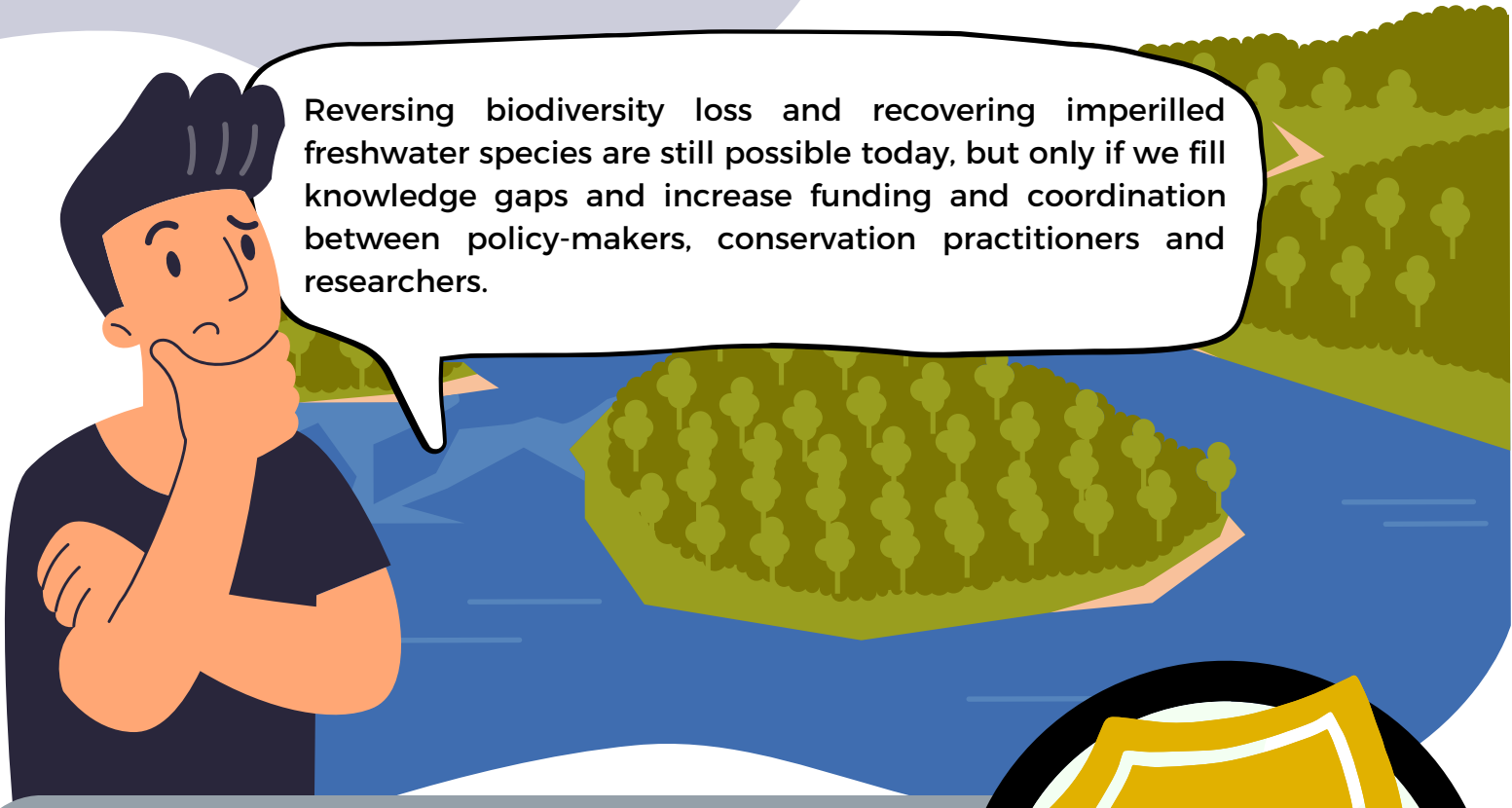
On the other hand, the development of captive breeding and reintroduction techniques through captive experimental-research populations (CERPs) or surrogate species would greatly assist in predicting population responses to stressors and collecting life-history, behavioural and physiological data without endangering them, thanks to nonlethal sampling or electronic tags, for example.



The identification, protection and restoration of critical habitats would also benefit from this research.

Threats can range from habitat degradation and invasive species to climate change and warming temperatures, exacerbated by agriculture and dams. Even artificial-light pollution and changes in water flow can affect freshwater fishes and mussels.

# WHY IS THIS RELEVANT FOR US TODAY?




SARNET is dedicated to this, and many of the results and methods of artificial captive breeding can be applied to other endangered populations in Canada. Understanding threats and species reactions is a paramount step towards successful protection and it can give insights into future risks caused by human activity and climate change.

# ABOUT THE SCIENTIST

André L. Martel, Ph.D., is an aquatic biologist and zoologist at the Canadian Museum of Nature. His research focuses on Canada's imperilled freshwater mussel fauna.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Castañeda, R.A., Ackerman, J.D., Chapman, L.J., Cooke, S.J., Cuddington, K., Dextrase, A.J., Jackson, D.A., Koops, M.A., Krkošek, M. Loftus, K.K., Mandrak, N.E., Martel, A.L., Molnár, P.K., Morris, T.J., Pitcher, T.E., Poesch, M.S., Power, M., Pratt, T.C., Reid, S.M., Rodríguez, M.A., Rosenfeld, J., Wilson, C.C., Zanatta, D.T., and Drake, D.A.R. (2021). Approaches and research needs for advancing the protection and recovery of imperilled freshwater fishes and mussels in Canada. *Canadian Journal of Fisheries and Aquatic Sciences* 78(9), pp. 1356–1370. https://doi.org/10.1139/cjfas-2020-0374.

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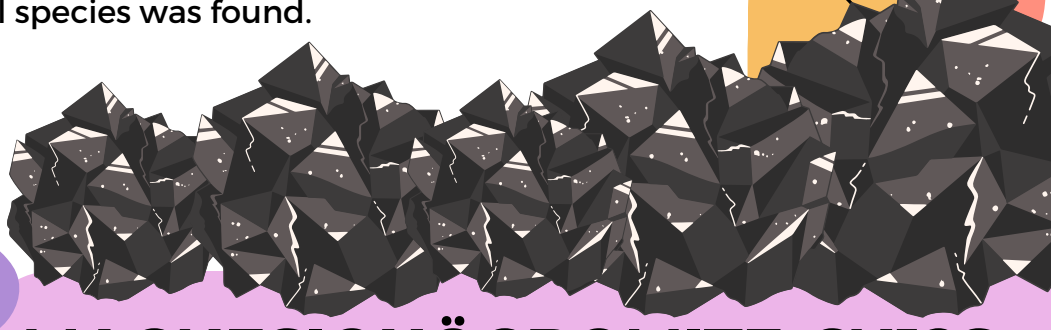
# A NEW SPECIES OF MINERALS

## HAS BEEN DISCOVERED AT THE CANADIAN MUSEUM OF NATURE!

**Just like plants and animals, minerals are also divided into groups or species. In 2021, a new species of the högbomite group was discovered in Lanark County, Ontario, opening up new perspectives on Canadian mineral richness and scientific understanding of this group of minerals.**

The DeWitts Corners occurrence, in Bathurst Township, is the location where the new mineral species was found.



### MAGNESIOHÖGBOMITE-6N12S

### $(Mg_5Al_{11}TiO_{23}(OH))$

is what this new species is called, and it forms dark brown to black crystals with brown streaks and a vitreous lustre, and is shaped like prisms, plates, or tablets up to five millimeters in size (see photo).

It is composed of

- **TITANIUM (Ti)**
- **MAGNESIUM (Mg)**
- **ALUMINUM (Al)**
- **OXYGEN (O)**
- **HYDROGEN (H)**

and was found on (or in) spinel, which is a black opaque mineral in this case.

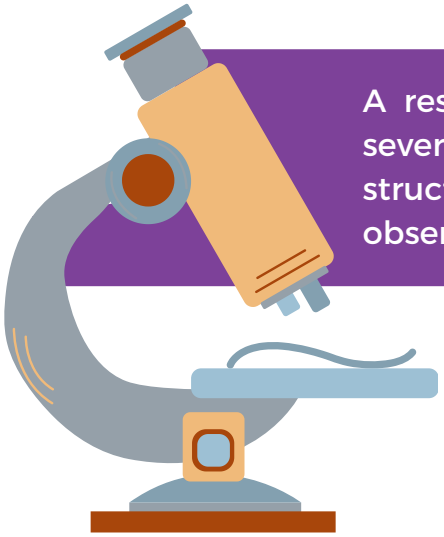
The species was found in calcite vein-dikes—unusual geological bodies with unclear origins—in Grenville Geological Province

# EXPERTS ON THE CASE

**INNA LYKOVA, PH.D.**
**Canadian Museum of Nature**
**Mineralogist**

**RALPH ROWE, B.SC.**
**Canadian Museum of Nature**
**Mineralogist**

**GLENN POIRIER, M.SC.**
**Canadian Museum of Nature**
**Mineralogist**



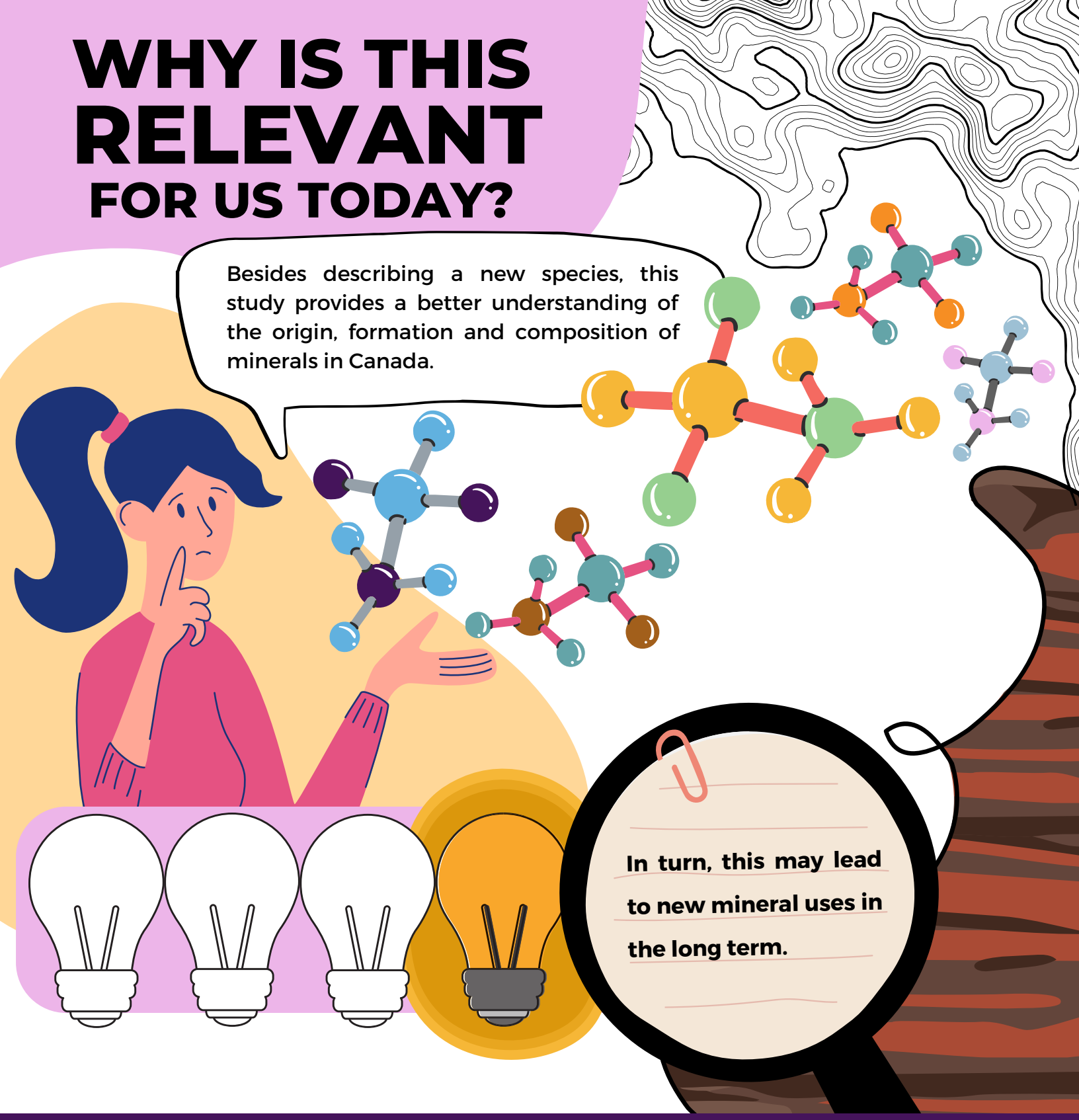
A research team from the Canadian Museum of Nature used several methods to describe, analyze and determine the mineral structure and chemical composition (e.g., electron microscope observation, X-ray diffraction analyses).

The research was conducted with the assistance of the University of Ottawa, the Canadian Conservation Institute and the Institute of Mineralogy and Crystallography of the University of Vienna, Austria.

**The specimen used to describe the new species is now part of the Canadian Museum of Nature's collections.**

# WHY IS THIS RELEVANT FOR US TODAY?

Besides describing a new species, this study provides a better understanding of the origin, formation and composition of minerals in Canada.



In turn, this may lead to new mineral uses in the long term.

# About the Scientists

Inna Lykova, Ph.D., Ralph Rowe, B.Sc., and Glenn Poirier, M.Sc., specialize in geology and mineralogy at the Canadian Museum of Nature.

**Research paper reference:** Lykova I., Rowe R., Poirier G., Giester G., and Helwig K. (2021). Magnesiohögbomite-6N12S, $Mg_5Al_{11}TiO_{23}(OH)$, a new högbomite-group mineral from the DeWitts Corners, Ontario, Canada. *Mineralogical Magazine* 85, 398–405. https:// doi.org/10.1180/mgm.2021.31.

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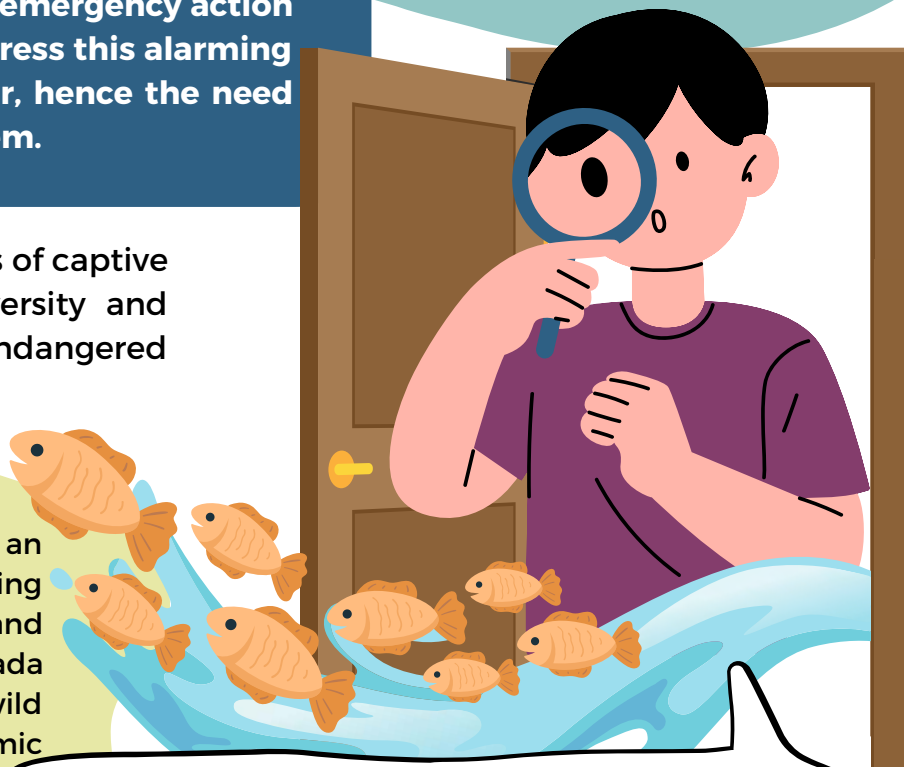
# CAPTIVE BREEDING PROGRAMS:

## A SOLUTION TO SAVE FRESHWATER SPECIES?

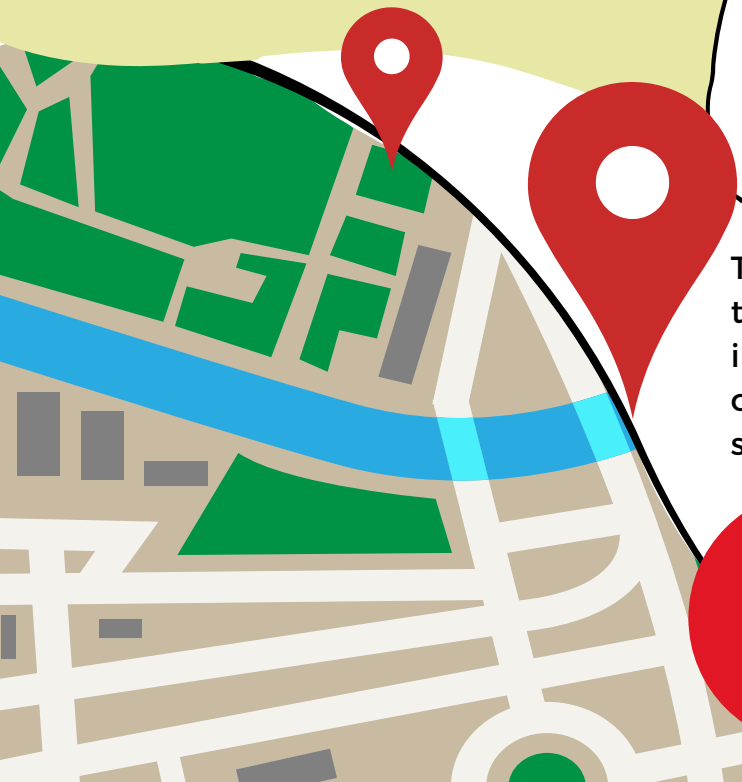
**Global freshwater biodiversity is in dire straits, having declined by 80% since the 1970s. While emergency action plans are being developed today to address this alarming situation, species continue to disappear, hence the need for immediate measures to preserve them.**

A recent study assessed the effectiveness of captive breeding programs in restoring biodiversity and achieving conservation targets for endangered freshwater species in Canada.



Captive breeding and release programs are an important tool for conserving, supplementing and reintroducing freshwater fishes and mussels, which are greatly imperilled in Canada despite their critical importance to wild ecosystems and their cultural and economic value to several Indigenous communities.

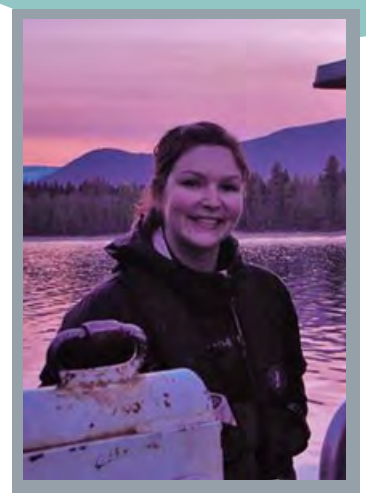
Thanks to a new systematic map created by researchers from government and academic and non-governmental organizations, knowledge gaps have been filled.



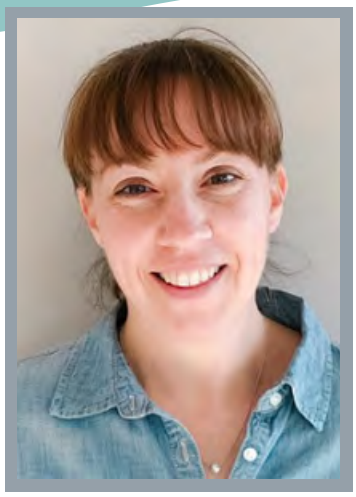
This enables decision-makers and conservationists to better protect such species from many threats, including habitat destruction, dams, pollution, overharvest, disease, global warming, invasive species, etc.

**These threats are exacerbated when the country lacks legislative preservation of natural habitats, e.g., fishery regulations.**

# SOME OF THE EXPERTS ON THE CASE



**LISA DONALDSON, B.SC.**
CARLETON UNIVERSITY RESEARCH BIOLOGIST AND LAB MANAGER



**TRINA RYTWINSKI, PH.D.**
CARLETON UNIVERSITY RESEARCH ASSOCIATE

**ANDRÉ MARTEL, PH.D.**
CANADIAN MUSEUM OF NATURE ZOOLOGIST

**STEVEN COOKE, PH.D.**
CARLETON UNIVERSITY PROFESSOR AND CANADA RESEARCH CHAIR OF ENVIRONMENTAL SCIENCES

A group of researchers teamed up under the lead of Steven Cooke, a world expert in freshwater biodiversity and conservation at Carleton University's Canadian Centre for Evidence-Based Conservation and Environmental Management.

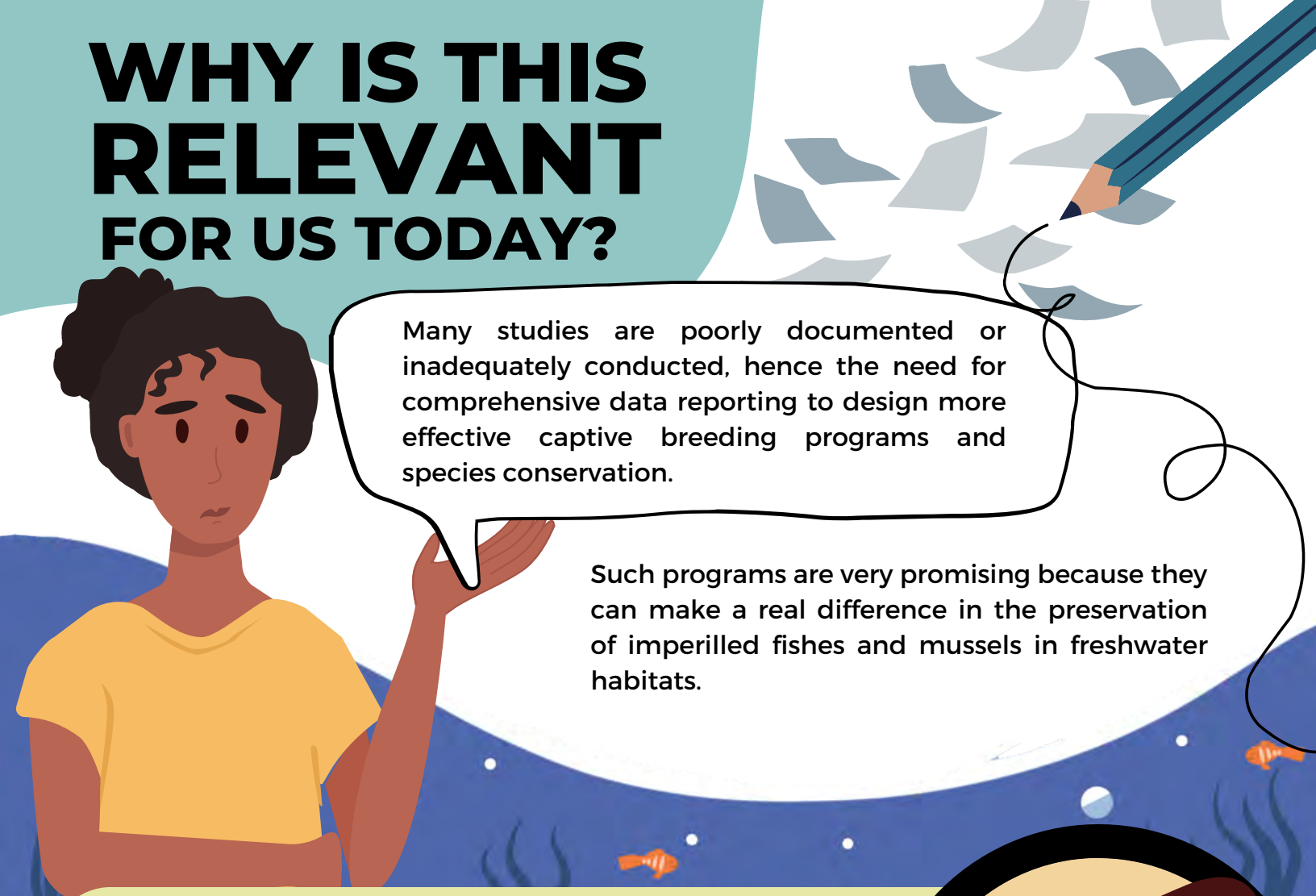
# THE PROCESS

Together with André L. Martel, a zoologist at the Canadian Museum of Nature, they reviewed 524 studies conducted between 1979 and 2018 to provide an updated global picture of existing evidence and best practices about the effectiveness of conservation-based captive breeding and release programs, with a focus on Canadian species at risk.

# THE SCIENTISTS' FINDINGS

**The results revealed areas where recovery strategies (e.g., bycatch mitigation and control of invasive species) could be implemented to restore habitat and reduce threats. Despite the significant progress made by the Canadian Freshwater Species at Risk Research Network (SARNET), a lack of funding and support hinders additional studies about freshwater-mussels monitoring.**

# WHY IS THIS RELEVANT FOR US TODAY?



Many studies are poorly documented or inadequately conducted, hence the need for comprehensive data reporting to design more effective captive breeding programs and species conservation.

Such programs are very promising because they can make a real difference in the preservation of imperilled fishes and mussels in freshwater habitats.

Preventing the extinction of these important species is vital to the ecosystems around us; for example, freshwater mussel populations are recognized as ecological indicators of ecosystem health and play a key role in filtrating water systems on which humans depend.

# ABOUT THE SCIENTIST

André L. Martel, Ph.D., is an aquatic biologist and zoologist at the Canadian Museum of Nature. His research focuses on Canada's imperilled freshwater mussel fauna.

**MEET THE SCIENTIST:** Click here!


Paper references:

Donaldson, L.A., Rytwinski, T., Taylor, J.J., Bennett, J.R., Drake, D.A.R., Martel, A.L., and Cooke, S.J. (2019). Can conservation targets for imperilled freshwater fishes and mussels be achieved by captive breeding and release programs? A systematic map protocol to determine available evidence. *Environmental Evidence* 8(16). https://doi.org/10.1186/s13750-019-0158-2.

Rytwinski, T., Kelly, L.A., Donaldson, L.A., Taylor, J.J., Smith, A., Drake, D.A.R., Martel, A.L., Geist, J., Morris, T.J., George, A.L., Dextrase, A.J., Bennett, J.R., and Cooke, S.J. (2021). What evidence exists for evaluating the effectiveness of conservation-oriented captive breeding and release programs for imperilled freshwater fishes and mussels? *Canadian Journal of Fisheries and Aquatic Sciences* 78(9), pp. 1332–1346. https://doi.org/10.1139/cjfas-2020-0331.

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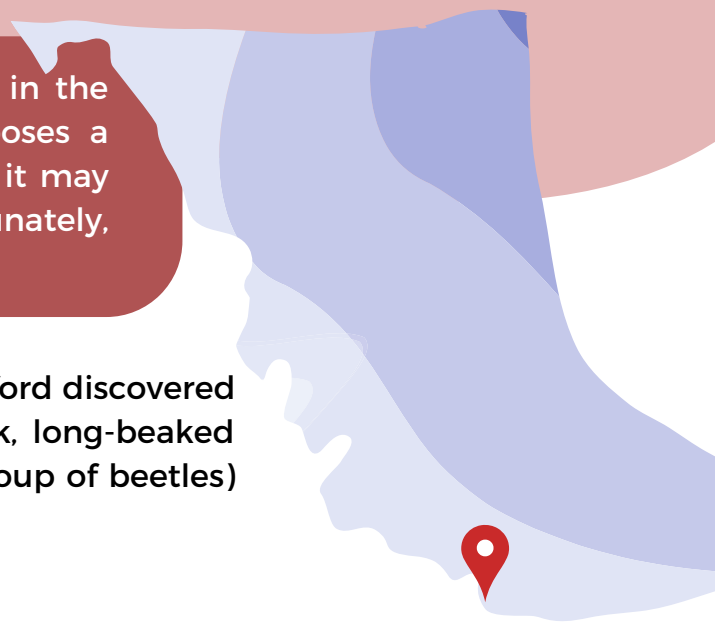
# PEST VS. CROP:

## A NEWLY RECORDED WEEVIL IN B.C. THREATENS CANADIAN STRAWBERRY PRODUCTION

A new invasive species of weevil has been found in the Lower Mainland region of British Columbia. It poses a significant risk to strawberry crops in Canada and it may spread further across the continent, but fortunately, solutions exist.

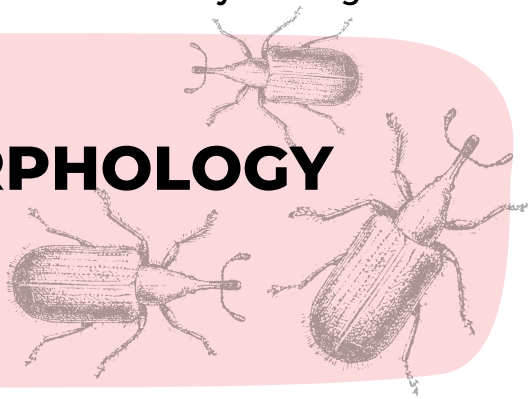
In 2019, a resident from Abbotsford discovered an unusual type of small, black, long-beaked weevil (a prolific and diverse group of beetles) in dead berry flower buds.



## EXPERTS ON THE CASE

Entomology experts—including Canadian Museum of Nature weevil expert Robert Anderson—identified it by looking at its

- **COLOUR**
- **BODY MORPHOLOGY**
- **GENITALIA**
- **DNA**



and by comparing it to other specimens in national collections, such as those of the Canadian Museum of Nature and the Barcode of Life Data System at the University of Guelph.

**ROBERT ANDERSON, PH.D.**
CANADIAN MUSEUM OF NATURE ZOOLOGIST

# THE SCIENTISTS' FINDINGS


The result was surprising: it was the first report of ***Anthonomus rubi*** in North America, a species native to Europe, Asia and North Africa. Global trade and imports may have contributed to its introduction.

The problem is that this weevil is a pest that threatens Canadian food security and agricultural production of economically significant strawberries, blackberries, raspberries and roses, in addition to native berries important to Indigenous peoples.

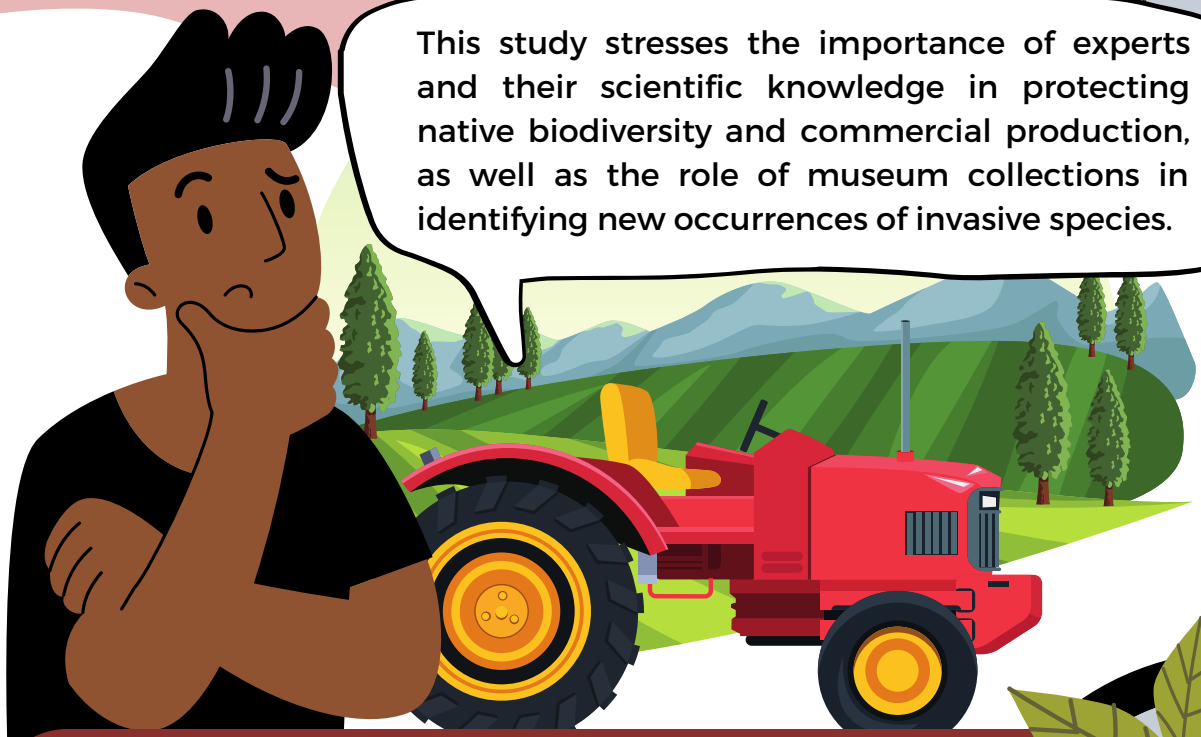
It lays its eggs in green buds and cuts the flower stalks below. Larvae grow inside of buds of both wild and cultivated plants.

A single female weevil can produce more than 150 eggs and harm 20 to 30 buds.

On a larger population scale, this could cause considerable damage. It could lead to **FRUIT YIELD LOSS** in British Columbia, which produces over 75% of the country's raspberries and 5% of strawberries.

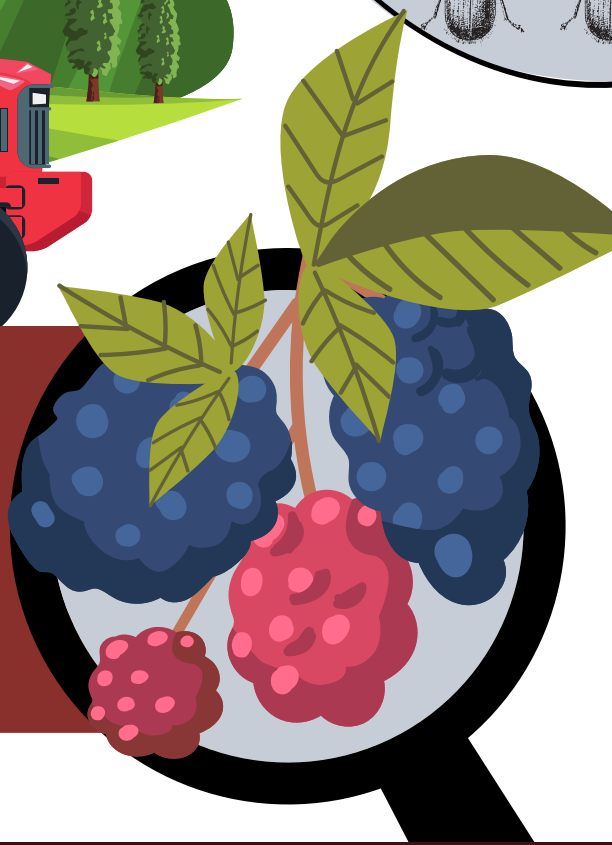
In Canada, these industries are valued at 150 million dollars annually, which is why any further spread across Canada and the United States (e.g., in northern Washington State where the species has already been found) is of great concern and must be closely monitored.

# WHY IS THIS RELEVANT FOR US TODAY?



This study stresses the importance of experts and their scientific knowledge in protecting native biodiversity and commercial production, as well as the role of museum collections in identifying new occurrences of invasive species.

International reference specimens are important, but so are collections of native species because they help researchers recognize a foreign invasive species by simply demonstrating that it is not part of such collections. Moreover, agricultural experts can use such findings to recognize pests and keep an eye out for new threats to crops.



## ABOUT THE SCIENTIST

Robert Anderson, Ph.D., specializes in biodiversity and conservation of insects and has discovered, named and classified over 250 new species of weevils—and counting.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Franklin, M.T., Hueppelsheuser, T.K., Abram, P.K., Bouchard, P., Anderson, R.S., and Gibson, G.A.P. (2021). The Eurasian strawberry blossom weevil, *Anthonomus rubi* (Herbst, 1795), is established in North America. *The Canadian Entomologist*. https://doi.org/10.4039/tce.2021.28.

## LIKENING FOREST CONDITIONS TO

# LICHENS

Old-growth forests have great ecological, cultural and aesthetic value in North America. Forest managers, conservation biologists and environmental policy-makers are charged with identifying and preserving their exceptional biodiversity, and a recent study may help them with a new perspective.

Because of intensive logging and harvesting, biodiversity that relies on old-growth forests is increasingly threatened throughout North America.

To decide on conservation priorities in the remaining old-growth forests, several steps must be taken, and the first is to delineate them.

**HOWEVER,**

the best approach is to simply assess the biodiversity directly by looking closely at what species are in the forest rather than a proxy such as the age of the trees.

Unlike many European definitions, ancient forests in North America tend to be defined based on structural characteristics, such as tree age, but this does not necessarily correspond to biodiversity.

The biodiversity in old-growth forests is affected by many other factors, such as forest continuity, i.e., the length of time an area has been continuously and extensively wooded.

# SO, WHAT IS ON THOSE TREES?

# LICHENS,

many species of which are indicators of old-growth forest conditions, have been successfully used to classify old forest ecosystems in Europe and North America.

# EXPERTS ON THE CASE

**TROY MCMULLIN, PH.D.**
CANADIAN MUSEUM OF NATURE BOTANIST

Troy McMullin, a lichen expert at the Canadian Museum of Nature, suggests that developing a comprehensive list of region-specific, old-growth-dependent lichen species would help to provide direction for conservation priorities.

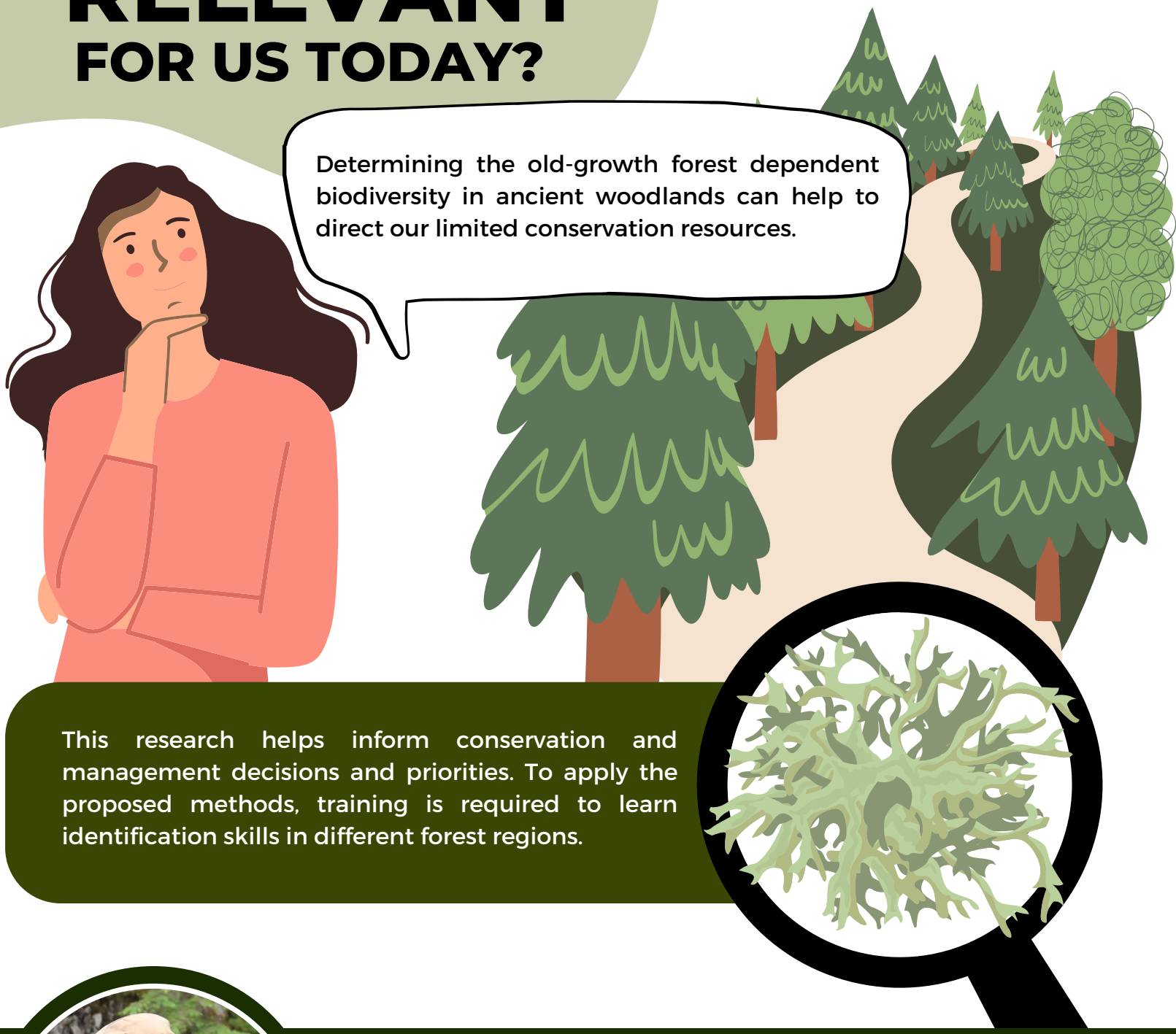
# THE PROCESS

A suite must be developed for each forest type for comparisons within a region.

Once a species list is determined, land managers and conservation biologists should be trained in species identification to create complete inventories of lichens in ancient forests.

Technologies such as DNA barcoding or image-recognition software could help them by using reference specimens in museum collections. The results will aid in determining conservation priorities in a given region.

# WHY IS THIS RELEVANT FOR US TODAY?




This research helps inform conservation and management decisions and priorities. To apply the proposed methods, training is required to learn identification skills in different forest regions.

# ABOUT THE SCIENTIST

R. Troy McMullin, Ph.D., is a research scientist who works on Canadian lichen biodiversity and conservation.

**MEET THE SCIENTIST:** Click here!

**Paper references:** McMullin, R.T., and Wiersma, Y.F. (2019). Out with OLD growth, in with ecological continNEWity: new perspectives on forest conservation. *Frontiers in Ecology and the Environment* 17(3): pp. 176-181. DOI: 10.1002/fee.2016.

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# PLANT BIODIVERSITY,
## A HOT TOPIC IN THE CANADIAN ARCTIC

The Canadian Arctic is a region of rich plant biodiversity, and Arctic vegetation is changing quickly because of climate change.

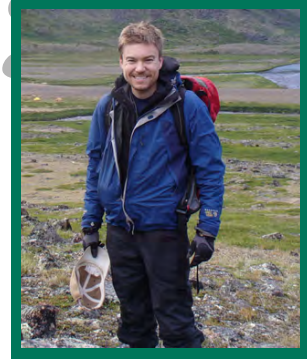
In 2020, researchers at the Canadian Museum of Nature established an updated inventory of plant species found on Victoria Island, complete with information about their known distributions, keys to identifying them, and photos.

**VICTORIA ISLAND,** located in the western Canadian Arctic Archipelago and spanning Nunavut and the Northwest Territories, has been explored by many scientists over the decades.

They have documented and characterized the island's flora to develop lists of species, contributing to a better understanding of the biodiversity and ecology of the Canadian High Arctic.

Based on fieldwork conducted by generations of researchers between 1850 and 2019, museum researchers compiled 7031 unique collections from Victoria Island. The resulting annotated checklist describes the 383 species known on the island, including many new species occurrence records.

# EXPERTS ON THE CASE



Jeffery M. Saarela, Ph.D.

Paul C. Sokoloff, M.Sc.

Roger D. Bull, M.Sc.

Lynn Gillespie, Ph.D.

Sergei Ponomarenko, Ph.D.

To enrich previous records and fill species diversity and distribution knowledge gaps, a research team led by Canadian Museum of Nature scientists inventoried the flora of seven regions of Victoria Island (four on the western part and three on the southern part) as well as the Cambridge Bay, Nunavut, area by exploring many habitats on foot and by helicopter.

# THE PROCESS

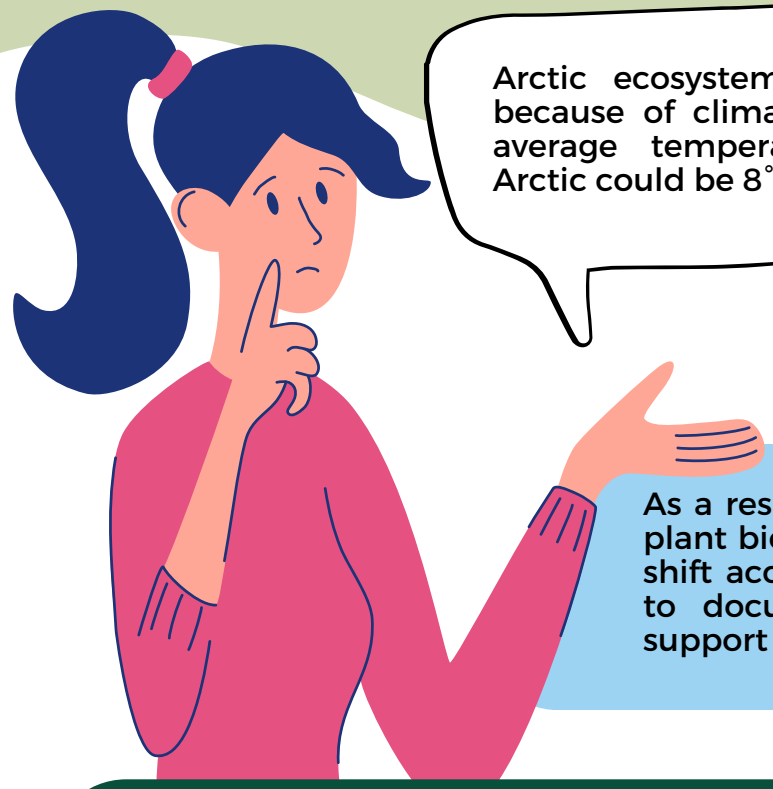
Botanical specimens were dried, pressed and deposited in the National Herbarium of Canada and the National Biodiversity Cryobank of Canada (both are part of the Canadian Museum of Nature).

# THE SCIENTISTS' FINDINGS

The botanists found that there are few non-native vascular plant species (i.e., with roots and shoots) on Victoria Island, and none that is invasive.

However, areas such as Cambridge Bay and Ulukhaktok, Northwest Territories, should be regularly monitored for possible introduction and persistence of such species. It is likely that other native species occurring on Victoria Island have not yet been discovered, as many parts of the island have not yet been surveyed.

# WHY IS THIS RELEVANT FOR US TODAY?



Arctic ecosystems are changing rapidly because of climate change. By 2100, the average temperature in the Canadian Arctic could be 8˚C warmer than today.

As a result of rapid climate change, vascular plant biodiversity in the Arctic is expected to shift accordingly, so there is an urgent need to document plant biodiversity today to support future research and conservation.

This study emphasizes the importance of field exploration combined with careful herbarium research, which is greatly facilitated by current digitization efforts. The goal of this research program is to document the Arctic flora, which will serve as a new baseline of knowledge and contribute to a better understanding of Canada's natural heritage.

# ABOUT THE SCIENTISTS

Jeffery M. Saarela, Ph.D., Paul C. Sokoloff, M.Sc., Roger D. Bull, M.Sc., and Lynn Gillespie, Ph.D., are botanists at the Canadian Museum of Nature. They collaborated with Sergei Ponomarenko, Ph.D., Research Associate at the Canadian Museum of Nature, on this research. These scientists specialize in plant biodiversity, taxonomy, species discovery and evolution in the Arctic and beyond.

**Paper references:** Saarela J.M., Sokoloff P.C., Gillespie L.J., Bull R.D., Bennett B.A., and Ponomarenko S. (2020). Vascular plants of Victoria Island (Northwest Territories and Nunavut, Canada): a specimen-based study of an Arctic flora. *PhytoKeys* 141: 1–330. https://doi.org/10.3897/phytokeys.141.48810.

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# YOU ARE WHAT YOU EAT—AND SO ARE WOLVES!

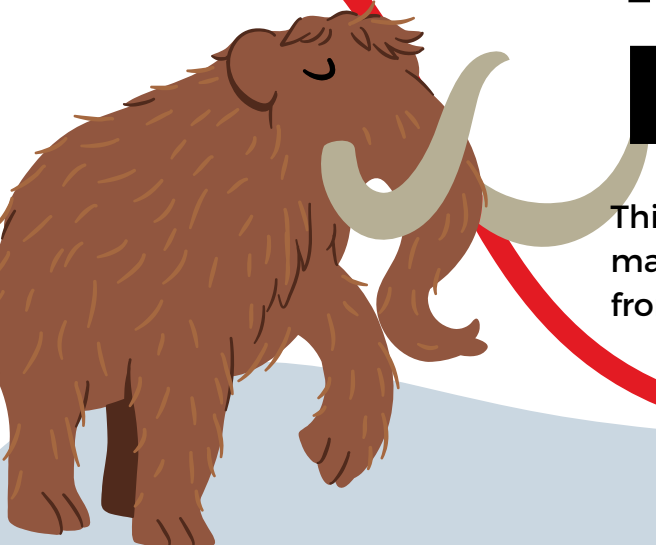
Grey wolves are among the few large predators that have survived since the late Pleistocene (129 000 to 11 700 years ago). Today, they are increasingly threatened by climate change, human activities (e.g., hunting), loss of habitat and decreasing prey abundance, especially in the Canadian Arctic and northern boreal-forest ecosystems.

**BUT CAN WOLVES ADAPT TO SUCH CHANGING CONDITIONS?**

**HOW DID THEY DO IT IN THE PAST?**

After the arrival of humans in North America over 20 000 years ago and a shift in the climatic and ecological environment, animal diversity decreased, leading to the

## QUATERNARY MEGAFAUNAL EXTINCTION



This was when 72% of large-bodied mammals (such as mammoths and horses, i.e., the megafauna) disappeared from the continent.

This extinction had vast ecological consequences for landscapes, and surviving species had to adapt their diet—but to what extent?

# EXPERTS ON THE CASE

**ZOE LANDRY**
**University of Ottawa**
**Ph.D. Student**

**DANIELLE FRASER, PH.D.**
**Canadian Museum of Nature**
**Palaeobiologist**

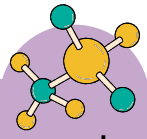
**MARISA GILBERT, B.SC.**
**Canadian Museum of Nature**
**Palaeobiologist**

# THE PROCESS

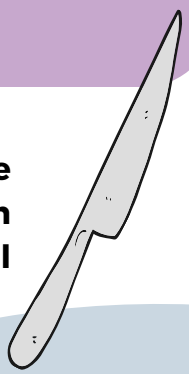
To find out, researchers at the Canadian Museum of Nature compared tooth wear and the presence of oxygen, carbon and nitrogen in the bones of wolves dated from about 50 000 years to 20 000 years ago and their present-day Yukon counterparts to determine their main prey.

# THE SCIENTISTS' FINDINGS

Dental microwear analysis revealed some small pits and scratches, indicating the type of food preferred by the wolves. Ancient and modern wolves seem to be similar in this respect, meaning that there was no substantial change in carcass-use behaviours and feeding strategies.

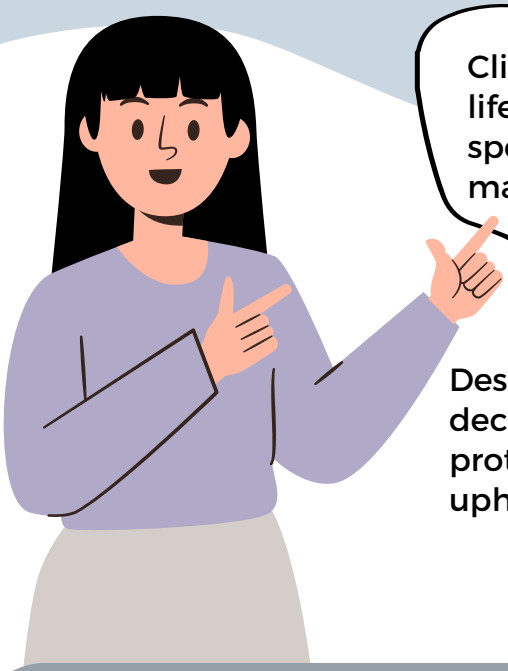


However, the three chemical traces did show some differences: the extinction of megafaunal species caused a change in diet as horse populations declined and moose and caribou became their new primary food source for survival.



**In sum, Yukon grey wolves have remained predators that feed on large herbivores for thousands of years, but they have had to alter their diet in response to environmental changes, demonstrating a degree of ecological flexibility. This can give us precious insight into the future of the species.**

# WHY IS THIS RELEVANT FOR US TODAY?



Climate change will reach far beyond our lifetime, so knowing whether Northern species will adapt to it over the long term may be tricky.

Despite some degree of diet flexibility, grey wolf populations may decline over time if their major food source (e.g., caribou) is not protected from human-induced impact and the current ecological upheaval.

If this were to happen, species interactions, competition and other disruptions could result in severe changes to ecosystems in Yukon and elsewhere. The fossil record is a valuable resource for understanding past species' responses to global change. Patterns of extinction, resilience or evolution in the past can guide us on the path to long-run protection of today's wildlife and its habitat.

# ABOUT THE SCIENTIST

Zoe Landry is a Ph.D. student at the University of Ottawa, working on palaeoecology and the evolution of past and present mammals at the Canadian Museum of Nature with Danielle Fraser, Ph.D., and Marisa Gilbert, B.Sc.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Landry, Z., Kim, S., Trayler, R.B., Gilbert, M., Zazula, G., Southon, J., and Fraser, D. (2021). Dietary reconstruction and evidence of prey shifting in Pleistocene and recent gray wolves (*Canis lupus*) from Yukon Territory. *Palaeogeography, Palaeoclimatology, Palaeoecology* 571 110368. https://doi.org/10.1016/j.palaeo.2021.110368.

### IDENTIFYING THE HABITATS OF PREHISTORIC TURTLES BY...

# THEIR FINGERS!

The origins and evolution of turtles have been a subject of longstanding debate among palaeontologists. One of the most frequently asked questions is ...

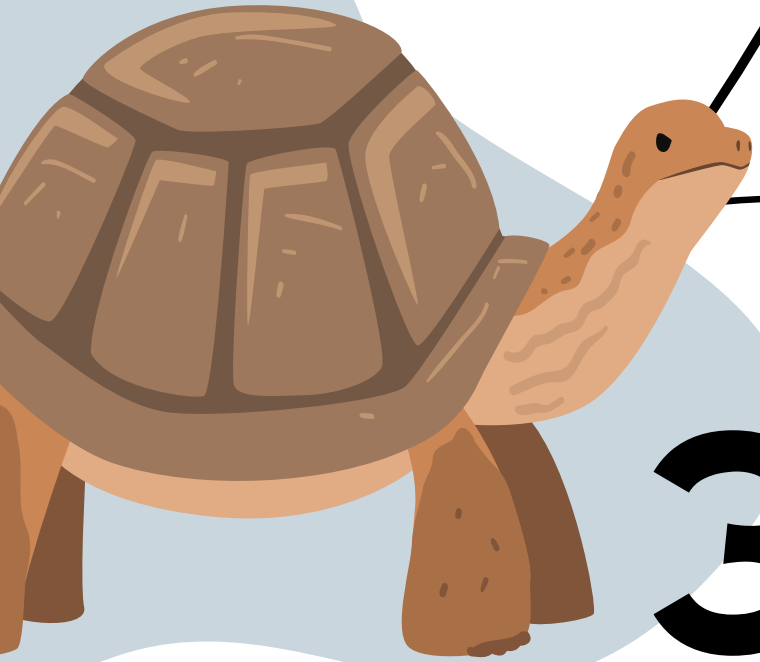

## EXPERTS ON THE CASE

To answer it, students from Carleton University created a new way to reconstruct the ancient habitats of fossil turtles based on their **"finger" bones**.

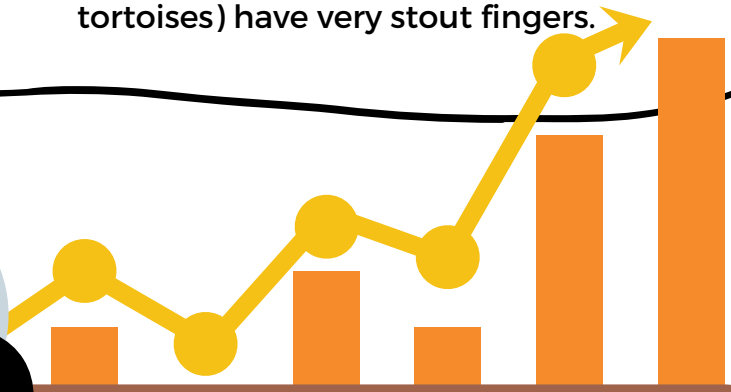
## THE PROCESS

**1** The team worked to determine whether it was possible to predict the habitat of a turtle solely from the proportions of its finger bones, which are frequently preserved as fossils.

**2** To do this, they created a large database of hand-bone measurements of living turtles, and statistically assessed the degree to which those measurements correlated with known turtle habitats.



As it turns out, hand proportions are an excellent predictor of habitat: aquatic turtles tend to have very long finger bones, while those of land-dwelling species (such as tortoises) have very stout fingers.



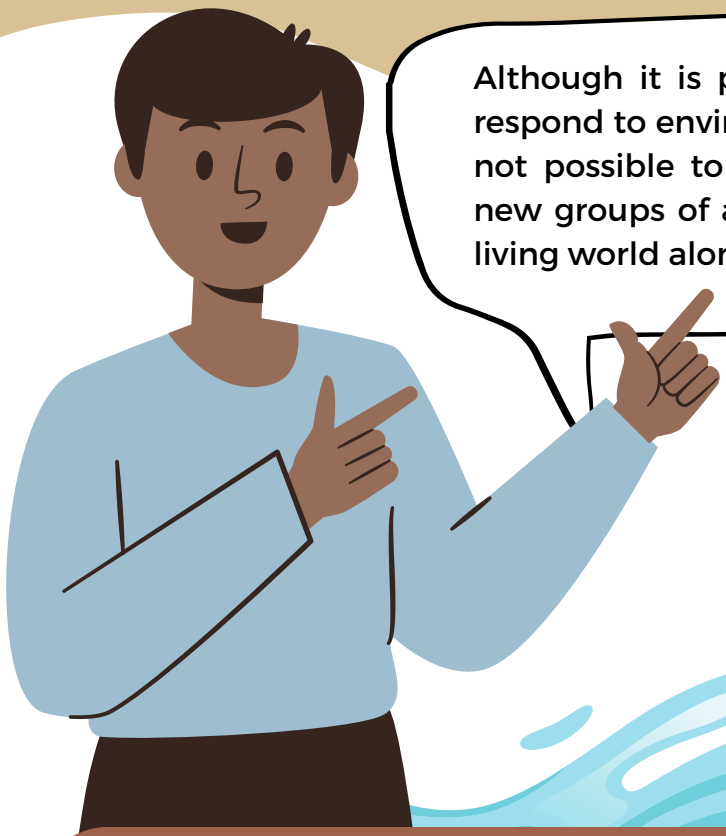
**3** The team then used the predictive power of their statistical model to deduce the habitats of ancient turtles.

# THE SCIENTISTS' FINDINGS

They found that the earliest turtles probably had a terrestrial lifestyle—which runs contrary to some recent studies suggesting otherwise—but that, overall, prehistoric turtles lived in a variety of habitats, much like modern turtles do.

# WHY IS THIS RELEVANT FOR US TODAY?

Recent discoveries, reinterpretations and analyses of the fossil record have enabled scientists to get a clearer picture of turtles, their early ancestors and their primitive habitats (terrestrial vs. aquatic).



Although it is possible to study how living species respond to environmental change in the present, it is not possible to understand the evolution of whole new groups of animals (like turtles) by studying the living world alone, hence the role of palaeontology.

**By understanding the conditions under which new animal groups evolved, we gain insight into how future environmental change will shape the evolution of life.**

# ABOUT THE SCIENTIST

Jordan C. Mallon, Ph.D., specializes in dinosaur evolution and ecology during the Late Cretaceous of North America at the Canadian Museum of Nature.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Dudgeon, T.W., Livius, M.C.H., Alfonso, N., Tessier, S., and Mallon, J.C. (2021). A new model of forelimb ecomorphology for predicting the ancient habitats of fossil turtles. *Ecology and Evolution* 11, 17071–17079. https:// doi.org/10.1002/ece3.8345.

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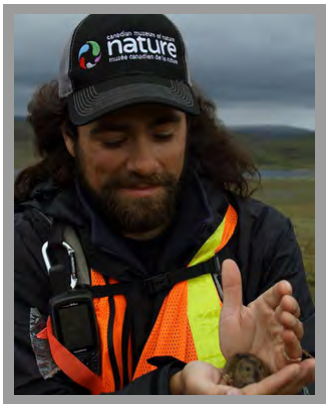
# THE MYSTERY BEHIND ARCTIC COLLARED LEMMINGS

A team of researchers from the Canadian Museum of Nature compared and analyzed the variation of skulls and molars in species of collared lemmings to put the complex diversity puzzle back together and detect differences and relationships between species.

## EXPERTS ON THE CASE


**KAMAL KHIDAS, PH.D.**
Canadian Museum of Nature
Zoologist



**DOMINIQUE FAUTEUX, PH.D.**
Canadian Museum of Nature
Zoologist

**ELLIOTT ANDREW SCHMIDT, M.SC.**
Canadian Museum of Nature
Zoologist


## LEMMINGS

are small rodents living in Arctic areas such as the Kivalliq Region, Nunavut. In this location, two collared lemming species coexist on the same territory, which may have brought them closer together and blurred species differentiation.

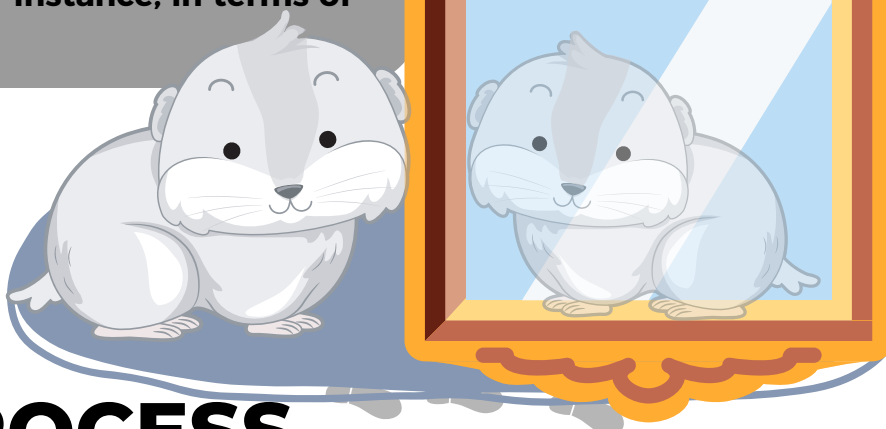
This might not have been the case previously, as glaciations and ice barriers dating back

**700 000 YEARS**

isolated them, thus preventing them from interacting.

**This separation eventually differentiated them from one another (a process called speciation)—for instance, in terms of molar development.**

However, these two collared lemming species remain hard to distinguish and may have naturally hybridized because of their close contacts and their natural reproductive barriers now being disrupted.



# THE PROCESS

To help distinguish the various groups, the skulls and upper molars of 156 lemmings collected across seven areas of the Canadian Arctic between 1925 and 1978 were analyzed and compared.

# THE SCIENTISTS' FINDINGS

**THE RESULTS REVEAL A TWIST...**

Collared lemmings from the Kivalliq Region—the zone of overlap between the two species—display significant differences in the shape of the skull and molars compared to reference specimens from the region, which are preserved in the Mammal Collection of the Canadian Museum of Nature.

This means that they should have the status of a distinct new species. This potential wild hybrid lemming is a surprise and a novelty because previous lab experiments had produced only sterile hybrids.

Additional analyses, such as looking at their genetics, ecology and range distribution must be conducted to confirm this. What is certain are the environmental, geographic (e.g., isolation or overlapping territories) and cross-species influences on the skull shape.

# WHY IS THIS RELEVANT FOR US TODAY?

This study reveals how changes in frozen landscapes from climate can create or remove physical barriers between populations, which can then lead to speciation or possible hybridization over large time periods.

**With the rapid climate change, Arctic ecosystems will continue to change and shape new species interactions and isolations.**

This work, like many others, was made possible thanks to museum collections and the reference specimens of the Canadian Museum of Nature, which are preserved in the Natural Heritage Campus, Gatineau, Quebec.

Combined with fieldwork, the specimens can reveal unexpected, novel information on how species evolve over time and the relation to environmental changes.

# ABOUT THE SCIENTISTS

Kamal Khidas, Ph.D., is Curator of the Vertebrate Collection and conducts research on Canadian mammals at the Canadian Museum of Nature. He collaborated with colleagues Dominique Fauteux, Ph.D., and Elliott Andrew Schmidt, M.Sc., on this study.

**Paper references:** Khidas, K., Schmidt, E.A., and Fauteux, D. (2020). Comparative 2D-shape analyses of collared lemmings in the zone of possible sympatry between *Dicrostonyx groenlandicus* and *Dicrostonyx richardsoni* (Rodentia, Arvicolinae). *Arctic Science* 6(4): 423–436. https://doi.org/10.1139/as-2019-0023.

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# WHEN MICROALGAE REVEAL LARGE-SCALE IMPACTS OF CLIMATE CHANGE AND MINING

Direct human impacts and resource exploitation greatly affect Northern regions and ecosystems including lakes. Climate change also threatens these critical freshwater refugia and biodiversity hotspots. Together, these impacts mark the Anthropocene.

Reconstructing the past history of lakes can be useful in assessing and predicting their natural responses to current and future environmental changes.

## DIATOMS

are microscopic algae found in aquatic systems across the world, including lakes. The potential of hundreds of thousands of diatom species constitute key organisms for oxygen production and primary energy in the food web.

Moreover, they can be used as a proxy to indicate water quality and changes in the biology of the lake because they are sensitive to surrounding conditions.

**IN SHORT, THEY ILLUSTRATE THE INTERCONNECTED NATURE OF BIOLOGICAL LIFE AND ITS ENVIRONMENT.**

# EXPERTS ON THE CASE

A team led by Paul Hamilton, a scientist at the Canadian Museum of Nature, has studied the connection between fossil diatoms and the ecological evolution of a small subarctic lake near Yellowknife, Northwest Territories, over the last 2800 years.

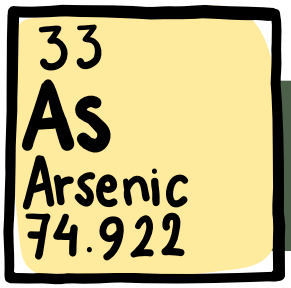
**PAUL HAMILTON, M.SC.**

CANADIAN MUSEUM OF NATURE PHYCOLOGIST

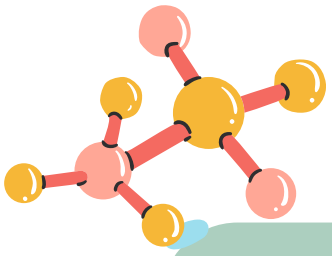
## THE PROCESS

By analyzing fossil diatoms, sediments and geochemistry in Pocket Lake, researchers were able to link diatom responses to climate variation, metal concentrations and the corresponding age of the lake.

## THE SCIENTISTS' FINDINGS




Recently, Pocket Lake has been heavily contaminated by arsenic, antimony and gold-smelting waste from the nearby Giant Mine that operated between 1948 and 1999.

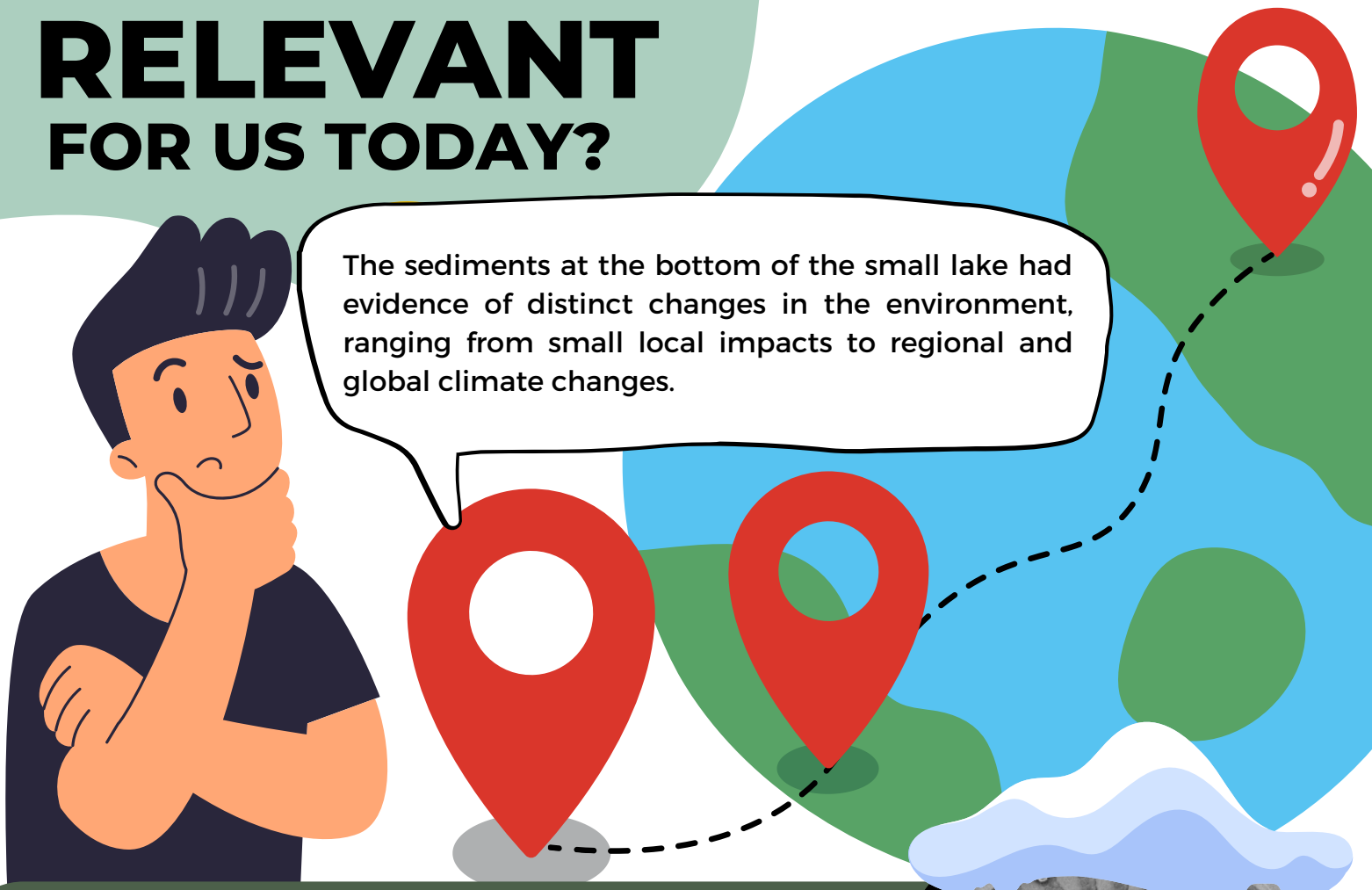


**Through diatom composition, scientists noticed that the lake had naturally aged until human intervention, which impacted the development of diatom species.**

Clear changes occurred in water composition from solar radiation, local chemistry, climate change, snowmelt and rainfall.

In addition, volcanic eruptions from western North America, and possibly as far as Iceland and Papua New Guinea, have caused a shift in diatom communities.

# WHY IS THIS RELEVANT FOR US TODAY?




This highlights the utility of using long historical records of water conditions as indicated by fossil diatoms, which are both robust and sensitive hydroecological indicators of change. As such, we can evaluate the state of lakes and their fragility before and after human activity. Climate change is an important factor here because large differences in snowpack may lead to the release of metals into Pocket Lake and to the decline of diatom diversity.

## ABOUT THE SCIENTIST

Paul B. Hamilton, M.Sc., is a senior research assistant at the Canadian Museum of Nature. He focuses on climate, ecosystem stability, biological diversity and species discovery in aquatic systems and polluted waters with direct links to how microorganisms develop in these systems.

**MEET THE SCIENTIST:** Click here!

**Paper reference:** Hamilton, P.B., Hutchinson, S.J., Patterson, R.T., Galloway, J.M., Nasser, N.A., Spence, C., Palmer, M.J., and Falck, H. (2021). Late-Holocene diatom community response to climate driven chemical changes in a small, subarctic lake, Northwest Territories, Canada. *The Holocene*, 31(7), 1124–1137. https://doi.org/10.1177/09596836211003214.

# ARCTIC SEAWEED:

## A CLIMATE-CHANGE WHISTLE-BLOWER OR SILVER LINING?

The Canadian Arctic is the epicentre of the global climate crisis. It is warming at three times the global average, and the greatest loss of sea ice, not to mention human activities, is affecting coastal ecosystems.

Within a few decades, these factors are expected to significantly influence marine vegetation, such as kelp—a type of algae that forms important marine habitats.

## BUT TO WHAT EXTENT?

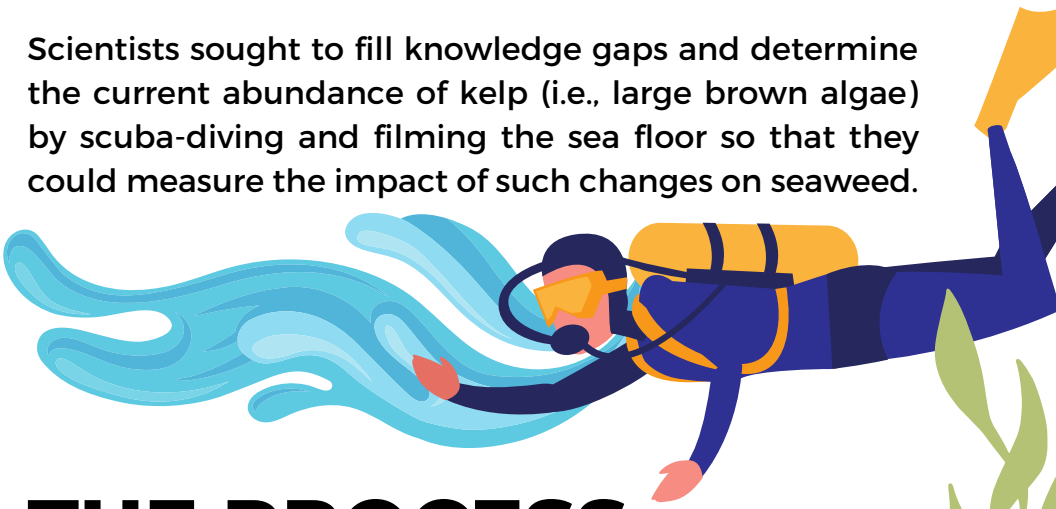
**The most extreme scenario predicts that the Arctic will be ice-free each summer before 2050 without climate policies.**

By 2100, increasing greenhouse-gas emissions are projected to raise median temperature by 4.9˚C compared to pre-industrial levels, which would put marine ecosystems at great risk.

# EXPERTS ON THE CASE

**AMANDA SAVOIE, PH.D.**
**Canadian Museum of Nature**
**Marine Botanist**

Scientists sought to fill knowledge gaps and determine the current abundance of kelp (i.e., large brown algae) by scuba-diving and filming the sea floor so that they could measure the impact of such changes on seaweed.



# THE PROCESS

Over the past decade, they sampled four dominant species along the Eastern Canadian Arctic coastline (around Hudson Bay), with additional data provided by biodiversity databases and records from the National Herbarium of Canada at the Canadian Museum of Nature.

**The researchers conducted tests and models to project results into the future under extreme scenarios.**

# THE SCIENTIST'S FINDINGS

Several interrelated factors were found to predict the future distribution of kelp (currently underestimated at about 2 000 000 km²), including

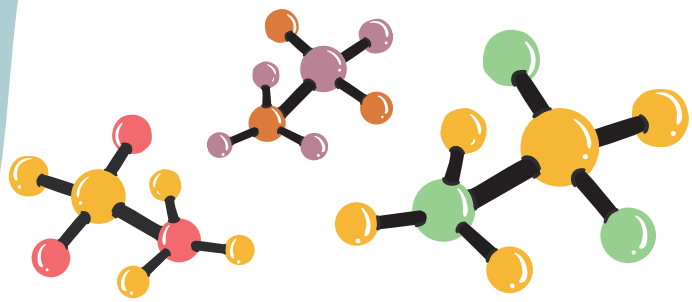
- **HIGHER SEA TEMPERATURE**
- **LOWER SALINITY**
- **REDUCED ICE THICKNESS**
  (resulting in greater light exposure).

These stressors are likely to expand the range and habitat availability of some species such as ***Agarum clathratum***, which may gain 39 000 km² by 2100 and move northward.

**By contrast, the cold-adapted species *Laminaria solidungula* will probably lose 212 000 km² (79%) of suitable habitat by the same time and may eventually become extinct.**

**In short, overall habitat suitability is expanding in the Eastern Canadian Arctic, but local drivers of kelp abundance are predicted to display a more mixed response to climate change.**

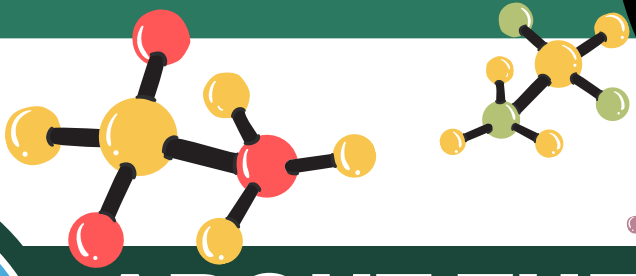
# WHY IS THIS RELEVANT FOR US TODAY?

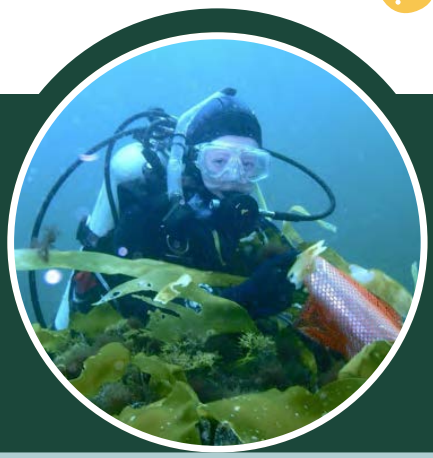


As Arctic coastal environments are rapidly changing, it is important to assess their current state before substantial changes occur. Understanding new ecosystems and anticipating their progression is a key priority for future conservation actions.

Climate change will affect kelp forests, which are widespread and essential members of Arctic ecology: they provide habitat, food and breeding grounds for fish, and they filtrate nutrients and carbon, thereby protecting coastlines.

Because of temperature shifts, non-native species might invade future temperate regions and overwhelm established communities. Research, fieldwork and museum collection records are therefore crucial to interpret, predict and mitigate future changes.





# ABOUT THE SCIENTIST

Amanda Savoie, Ph.D., studies Canadian seaweed species diversity, biogeography and taxonomy at the Canadian Museum of Nature.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Goldsmit J., Schlegel R.W., Filbee-Dexter K., MacGregor K.A., Johnson L.E., Mundy C.J., Savoie A.M., McKindsey C.W., Howland K.L., and Archambault P. (2021). Kelp in the Eastern Canadian Arctic: Current and Future Predictions of Habitat Suitability and Cover. *Frontiers in Marine Science* 18 (742209). DOI: 10.3389/fmars.2021.742209.

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# USING PREHISTORIC SPECIES INTERACTIONS AS A PREDICTOR OF RESPONSES TO FUTURE CLIMATE CHANGE

**Palaeontology is a great source of information about evolutionary and ecological changes. It provides valuable insights into how modern animals can respond to potential extinctions caused by ongoing global change.**

The long-term repercussions of these ecological changes can be mitigated by understanding how human activities are upsetting interspecies relationships.

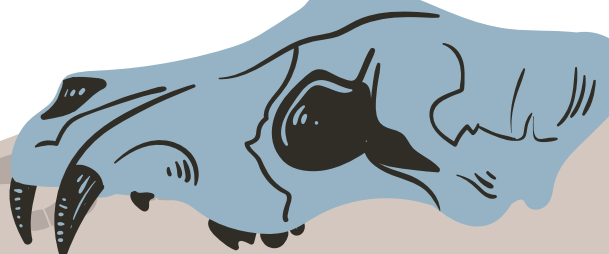
## BIOTIC INTERACTIONS

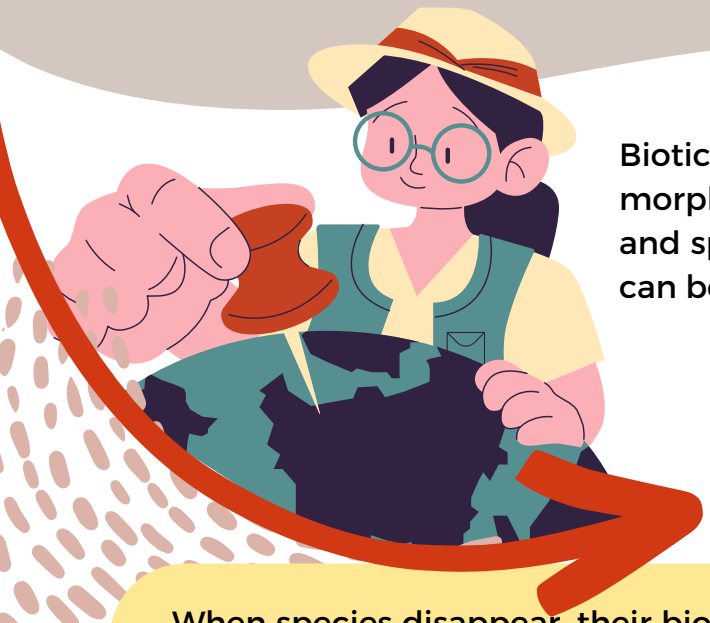
happen when organisms living in the same community directly or indirectly influence each other (e.g., through predation, competition for resources, or mutual benefits such as food sharing and protection).

## EXPERTS ON THE CASE

Danielle Fraser, a palaeontologist at the Canadian Museum of Nature, has demonstrated the potential of biotic interactions by showcasing new methods and findings in a recent study conducted with other research partners, such as the Evolution of Terrestrial Ecosystems Working Group, that indicate that climate change is not the only driver of biodiversity evolution.

**DANIELLE FRASER, PH.D.**
CANADIAN MUSEUM OF NATURE
PALAEOBIOLOGIST





Biotic interactions also shape large-scale patterns of morphological changes or changes in abundance, diversity and spatial distribution, and the effects of these interactions can be detected over large spatiotemporal scales.

**If a given species reaches peak abundance or is not competitive enough, or if a higher taxon reaches peak diversity, its population may decline or eventually become extinct.**

When species disappear, their biotic interactions also vanish, which can cause lasting disruption to the ecological networks around them and extinction cascades following the loss of a keystone species interplaying with many others.

**Biotic interactions thus shape the trajectory before, during and after extinctions.**

Lastly, a major, wide-ranging predator has prompted such extinctions and affected relationships among animal and plant species since its global dispersal over 50 000 years ago:

# THE MODERN HUMAN *(Homo sapiens)*

Our contacts with numerous species through large-scale domestication, agriculture and hunting have had tremendous and under-studied ecological impacts on the interactions between non-human flora and fauna.

**In a few thousand years, humans—who are shaping the climate—have altered natural mechanisms and interaction networks that had otherwise persisted for 300 million years (Tóth et al., 2019).**

# WHY IS THIS RELEVANT FOR US TODAY?

The rich data found through the fossil record can be used to unravel the changing influence of biotic interactions on species' fate and evolution.

Recent major advances can help researchers estimate the likely diversity and extinction trends in modern communities, so that future strategies can be identified to avoid such events and maintain ecosystem functions.

## ABOUT THE SCIENTIST

Danielle Fraser, Ph.D., is a palaeoecologist and evolutionary biologist at the Canadian Museum of Nature. She is interested in understanding how and why mammal communities form and might change under ongoing global change.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Fraser, D., Soul, L.C., Tóth, A.B., Balk, M.A., Eronen, J.T., Pineda-Munoz, S., Shupinski, A.B., Villaseñor, A., Barr, W.A., Behrensmeyer, A.K., Du, A., Faith, J.T., Gotelli, N.J., Graves, G.R., Jukar, A.M., Looy, C.V., Miller, J.H., Potts, R., and Lyons, S.K. (2020). Investigating Biotic Interactions in Deep Time. *Trends in Ecology & Evolution* vol. 36, issue 1, pp. 61–75. https://doi.org/10.1016/j.tree.2020.09.001.

# HOW DO SMALL CRUSTACEANS HOLD SUCH AN IMPORTANT PLACE IN THE ARCTIC FOOD WEB?

**Many aquatic species in the Canadian Arctic are considered sentinels of change and are essential food resources for Indigenous communities.**

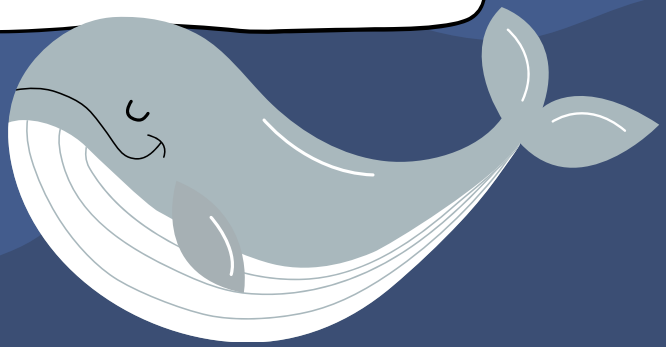
The complex ecosystems around them are teeming with life, including some tiny animals that have a big role in the larger food web. Meet one of them:

## THE PECULIAR AMPELISCID

**Ampeliscids are small, shrimp-like crustaceans living at the bottom of the ocean that interact with marine animals such as fish, crabs and seabirds.**

Some of these tiny amphipods have four eyes and can withstand starvation for more than five months!

They thrive wherever there is lots of plankton to eat, and they are a food source for large predators such as seals and grey whales.



# EXPERTS ON THE CASE

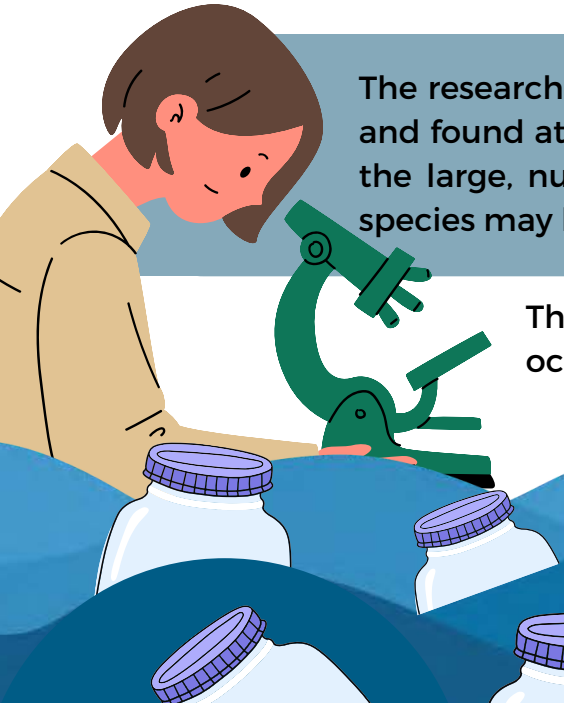
**KATHLEEN CONLAN, PH.D.**
CANADIAN MUSEUM OF NATURE
ZOOLOGY RESEARCH ASSOCIATE

**ED HENDRYCKS, B.SC.**
CANADIAN MUSEUM OF NATURE
ZOOLOGIST

A “hotspot” of ampeliscid life was discovered by Canadian Museum of Nature scientists Kathleen Conlan and Ed Hendrycks while they were studying the sea-floor animals of the Beaufort Sea in the Canadian Arctic.

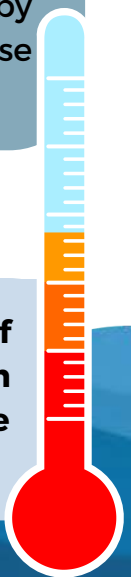
With the help of their colleagues, they were able to work out why the Arctic Ocean supported such high numbers of ampeliscids and whether the Beaufort Shelf was a worthwhile destination for Pacific grey whales.

# THE SCIENTISTS' FINDINGS



The researchers analyzed 412 samples collected between 2002 and 2009 and found at least eight ampeliscid species in the hotspot, dominated by the large, nutritious ***Ampelisca macrocephala.*** Three of these species may be new to science.

They are all sensitive to water temperature, as none of them occurred in water warmer than 0.41˚C.



**Ampeliscids were abundant on the Beaufort Shelf because the strong winds there upwell cold, rich water from the deep onto the shelf and provide the ampeliscids with abundant plankton to eat.**

# WHY IS THIS RELEVANT FOR US TODAY?

The scientists were surprised to find so many ampeliscids in the Beaufort Sea Shelf, an area known for oil and gas exploration.

Human activity, warming waters and low sea ice levels could disrupt the future proportion and distribution of these crustaceans and their habitats, therefore impacting the predators that depend on them, such as whales.

As Kathleen Conlan explains, **"Everything is connected. We need to study Arctic marine invertebrates as a key part of the food web, but we also need to think beyond for a complete picture of ocean biodiversity and change".**

# ABOUT THE SCIENTISTS

Kathleen E. Conlan, Ph.D., and Ed A. Hendrycks, B.Sc., study Arctic biodiversity and marine crustaceans known as amphipods at the Canadian Museum of Nature.

**Paper references:** Conlan, K.E., Hendrycks, E.A., and Aitken, A.E. (2019). Dense ampeliscid bed on the Canadian Beaufort Shelf: an explanation for species patterns. *Polar Biology* 42, 195–215. https://doi.org/10.1007/s00300-018-2417-z.

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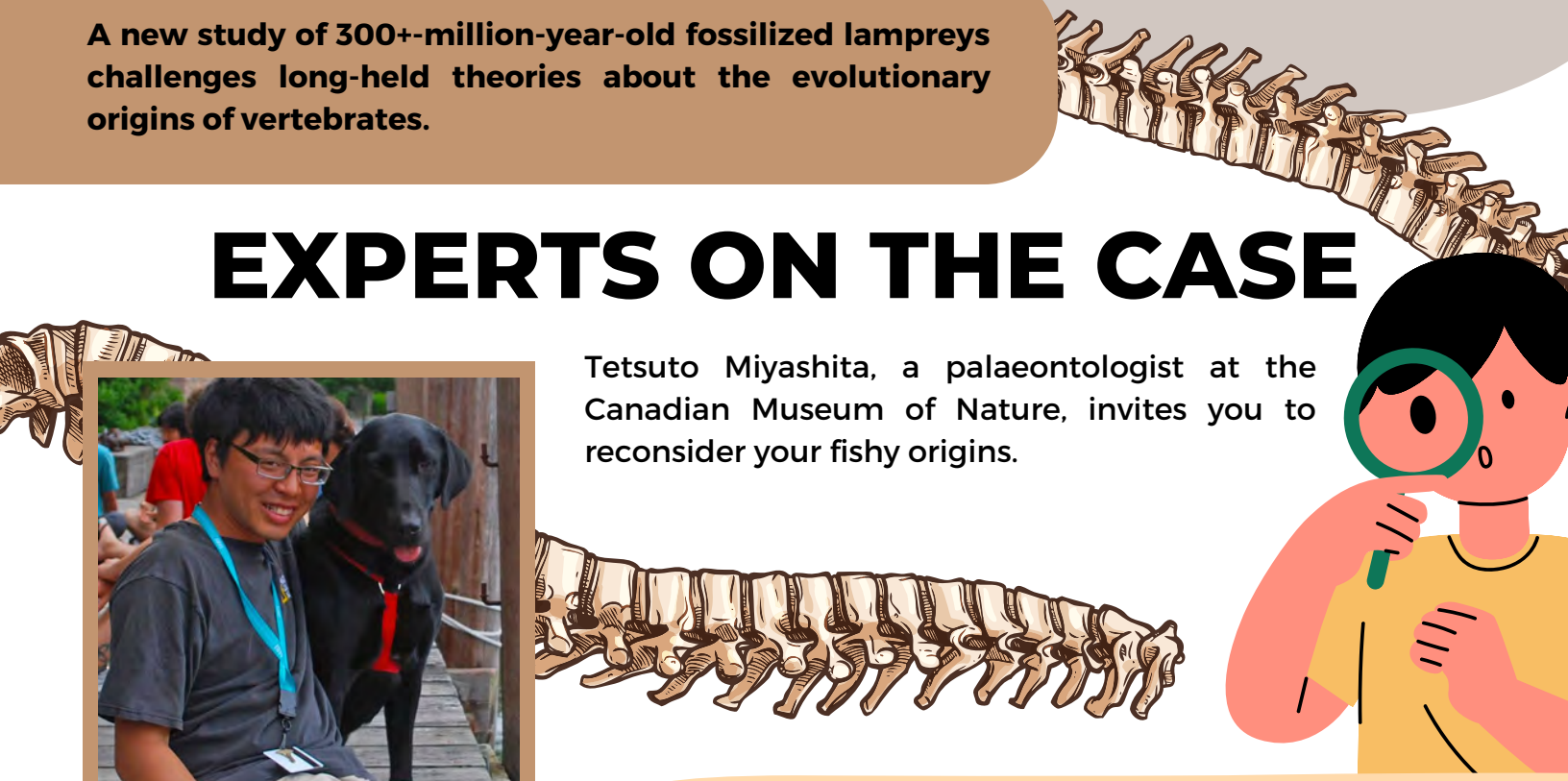
# EVOLUTION AND REVOLUTION

## WHEN FOSSIL LAMPREYS REWRITE HISTORY

**A new study of 300+-million-year-old fossilized lampreys challenges long-held theories about the evolutionary origins of vertebrates.**



## EXPERTS ON THE CASE



Tetsuto Miyashita, a palaeontologist at the Canadian Museum of Nature, invites you to reconsider your fishy origins.



**DR. TETSUTO MIYASHITA**
CANADIAN MUSEUM OF NATURE PALAEOBIOLOGIST

**All vertebrates (animals with a backbone, including humans) share a common ancestor dating back more than half a billion years, from which descendants later evolved into various forms**

## LAMPREYS

(i.e., jawless, eel-like fishes; one of the oldest branches of vertebrates) have long provided insights into this process because their life cycle was thought to repeat the ancestral stages of all vertebrate animals (as a larva).

**THEY GROW FROM BLIND, FILTER-FEEDING LARVAE TO AN ADULT FORM WITH PROMINENT EYES, GILLS, A FEEDING APPARATUS WITH SOFT TEETH AND A SKULL TO ENCASE ITS BRAIN.**

**"Once hatched, the larvae of modern lampreys bury themselves in a riverbed and filter feed before eventually metamorphosing into blood-sucking adults", explains Miyashita.**

**"The larvae are so different from adults that scientists originally thought they were different species. Even after finding out they are just an early phase in the lamprey life cycle, scientists saw the image of our distant ancestors in these seemingly primitive larvae".**

# THE SCIENTISTS' FINDINGS

However, new findings reveal that their fossil ancestors hatch out of the eggs essentially as a miniature version of their adults: four extinct species from South Africa and the United States illustrate that ancient lamprey larvae (barely 15 mm long) already had large eyes and a toothed sucker.

**This difference could be explained by the fact that ancestors of modern lampreys migrated from marine to freshwater environments. The "primitiveness" of modern lamprey larvae turned out to be a newly evolved lifestyle to survive in new habitats.**

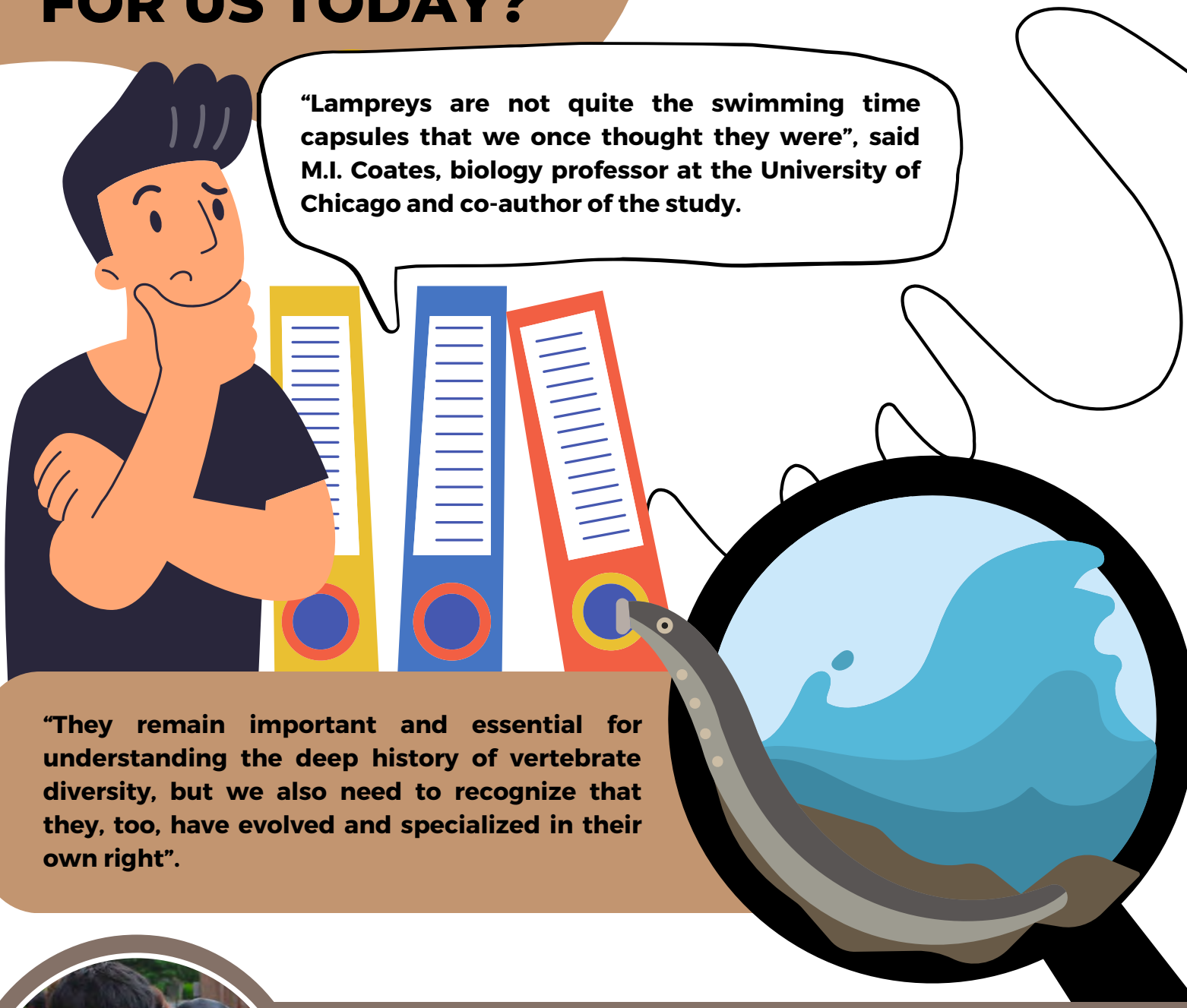
These results overturn the 150-year-old theories that lamprey larvae preserve the common ancestor's characteristics for half a billion years.

**Miyashita adds that "we've basically removed lampreys from the position of the ancestral condition of vertebrates. So now we need an alternative".**

Extinct armoured fishes known as ostracoderms may instead represent better candidates for the root of the vertebrate family tree, while modern lamprey larvae are a more recent evolutionary innovation.

# WHY IS THIS RELEVANT FOR US TODAY?

Researchers say that this is the kind of discovery that can rewrite textbooks.



**“Lampreys are not quite the swimming time capsules that we once thought they were”, said M.I. Coates, biology professor at the University of Chicago and co-author of the study.**

**“They remain important and essential for understanding the deep history of vertebrate diversity, but we also need to recognize that they, too, have evolved and specialized in their own right”.**

# ABOUT THE SCIENTIST

Tetsuto Miyashita, Ph.D., is a research scientist and palaeobiologist at the Canadian Museum of Nature.

**MEET THE SCIENTIST:** Click here!

**Paper references:** Miyashita, T., Gess, R.W., Tietjen, K., and Coates, M.I. (2021). Non-ammocoete larvae of Palaeozoic stem lampreys. *Nature* 591, 408–412. https://doi.org/10.1038/s41586-021-03305-9.

The research described throughout these stories exemplifies the essential work being done by scientists at the Canadian Museum of Nature. It is important to note that while these stories highlight new findings and discoveries that took place between 2015 and 2021, research is an ongoing process that continues to evolve as the world around us does.

Scientists are continually digging deeper to uncover and solve new mysteries about our changing planet. As the understanding of our scientific world expands, so will the research that enables this understanding, thereby creating new stories that form a path we can follow to predict and prepare for the future!

Keep up with the ever-evolving research being conducted at the Canadian Museum of Nature by following along as these science stories are updated!

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