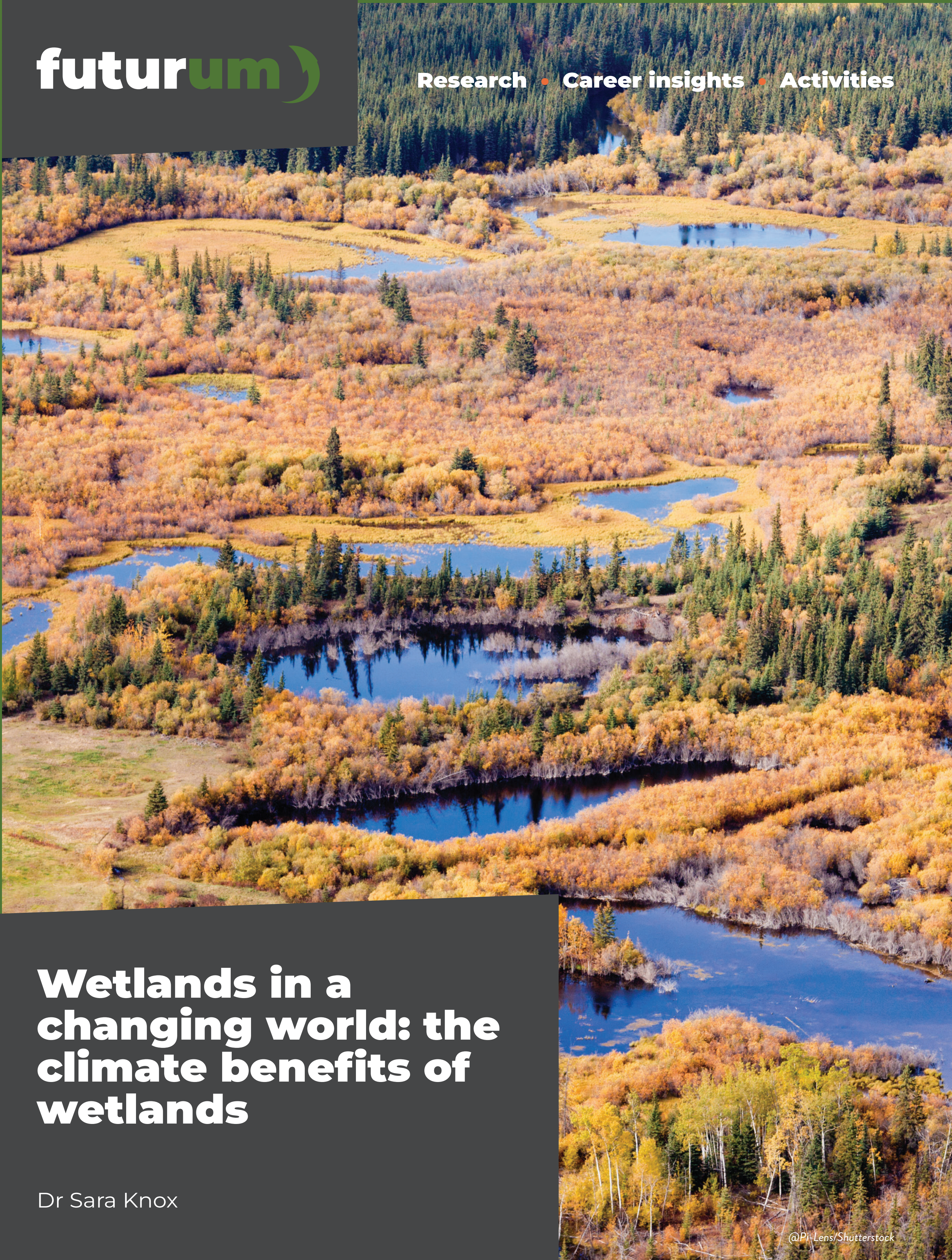

Wetlands in a changing world: the climate benefits of wetlands

Dr Sara Knox

Wetlands in a changing world: the climate benefits of wetlands

Wetlands are humid, damp environments where the boundaries between land and water become blurred. Here, you might find trees, shrubs, grasses and reeds rising out of the water, in an ecosystem that is home to many different animal and plant species. These unique environments are excellent at storing carbon and are important for human well-being; however, human activities, such as agriculture and logging, are putting them at risk. At **McGill University** in Canada, **Dr Sara Knox** is working to understand the impacts of human activities and climate change on carbon storage in wetlands.

Dr Sara Knox

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Fields of research
Biogeochemistry, micrometeorology, ecosystem ecology, climate change, wetlands

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Talk like a ...

biogeochemist

Carbon cycle — the natural process by which carbon moves between the atmosphere, the Earth's surface and subsurface, and living organisms

Carbon sink — any natural environment which can absorb carbon dioxide from the atmosphere

Eddy covariance — a technique for measuring the exchange of gases and energy between the Earth's surface and the atmosphere

Flux — the rate at which gases or energy travel between the Earth's surface and the atmosphere

Flux tower — a scientific instrument that continually measures the exchange of gases between the Earth's surface and the atmosphere

Greenhouse gas — a gas, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), that prevents heat from escaping the Earth's atmosphere, therefore contributing to the greenhouse effect and climate change

Wetland — an area of land saturated in water, either permanently or for a significant amount of the year, forming a distinct ecosystem which is home to plants that are adapted to wet conditions

From the marshes of the Florida Everglades in the US, to the bogs and fens of the Hudson Bay lowlands in Canada, the mangroves of the Sundarbans in India and Bangladesh, and the swamps of the Amazon River Basin in South America, wetlands cover roughly 10% of our planet and are excellent carbon sinks. "Wetlands can act as nature-based climate solutions, addressing the dual challenges of climate change mitigation and adaptation, while protecting biodiversity and supporting human well-being," says Dr Sara Knox, of McGill University. However, human disturbances are damaging wetlands, leading to the release of carbon into the atmosphere.

To tackle this, Sara is measuring the movement of carbon between wetlands and the atmosphere, helping us to understand how best to protect and manage these vital habitats.

What are wetlands?
"Wetlands are areas of land that are covered with water or have waterlogged soils for at least part of the year," explains Sara. "They can be freshwater, saltwater or a mix of both, and they often support a wide variety of plants and animals that are specially adapted to wet environments." Wetlands are often found in low-lying areas or near bodies of water like rivers, lakes and coasts. They play an important role in the environment by filtering water, providing habitat for wildlife and protecting against floods.

Eddy covariance tower measuring greenhouse gas fluxes from a restored peatland, Burns Bog, near Vancouver, British Columbia, Canada.

Wetlands also play a vital role in the global carbon cycle by capturing and storing carbon dioxide (CO_2) from the atmosphere. Sara explains, "Their waterlogged, oxygen-poor soils slow down the decomposition of plants and organic matter, preventing carbon from being released back into the air." In the cooler climates of the Northern Hemisphere, peatlands (a form of wetland) can be formed from the accumulation of dead plants. "Peatlands are especially effective at storing carbon for thousands of years," says Sara. Unfortunately, peat is a popular resource, used as fuel and in gardening and industry. "When peat is removed, the stored carbon is released into the atmosphere, contributing to climate change," continues Sara.

Other human activities also threaten wetlands. For example, they are often drained to create agricultural land, or cleared to make way for new roads, homes and industrial areas. Logging, which is a common activity across the globe, can also be particularly destructive in wetlands. "In wetland forests, drainage and cutting down trees disrupts the natural water balance, often leading to drier conditions," explains Sara.

Measuring the impact of human disturbance on wetlands

"To understand the health of natural and disturbed wetlands, we measure the exchange of carbon and water between wetlands and the atmosphere," says Sara. Carbon and water transfer between wetlands and the atmosphere in three-dimensional, rotating air flows, called eddies, and the rate at which they travel is called the flux. Sara takes measurements using the 'eddy covariance technique', which involves a tower equipped with high-frequency sensors that capture rapid changes in wind and gas concentrations. "This method gives us continuous, direct measurements of how much carbon wetlands absorb or release, and how disturbances affect their carbon and water balance," she says. "Healthy, undisturbed wetlands usually act as carbon sinks, storing more carbon than they release. However, disturbances can turn them into carbon sources, releasing carbon into the atmosphere."

Long-term monitoring of a wetland's net carbon balance helps researchers like Sara assess how changes impact its ability to store carbon and maintain other natural functions. "It also helps us understand how they recover after restoration and respond to climate change," says Sara. These data are crucial for creating effective conservation strategies and ensuring wetlands continue to provide important ecosystem services.

Using data to manage wetlands

Wetlands can store CO_2 while still emitting other greenhouse gases such as methane and nitrous oxide, so these are included in Sara's work. "This information shows whether wetlands are overall greenhouse gas sinks or sources, and how disturbances like drainage and climate change affect this balance," she explains. "Our models show that a restored peatland absorbs less carbon under warmer, drier conditions. However, the models also highlight the benefits of wetland restoration. While rewetting bogs may temporarily increase greenhouse gas emissions, it ultimately helps restore peatlands and strengthens their long-term ability to act as carbon sinks. The data show how wetlands recover and adapt; our research supports better restoration strategies and helps design policies that enhance the climate benefits of wetlands, ensuring they continue to play a vital role in carbon storage and climate change mitigation."

Having an impact

Policymakers across Canada are using Sara's findings to support nature-based climate solutions that help cut emissions and protect biodiversity. "Protecting wetlands is central to this," explains Sara. "By providing data on how wetlands store and release greenhouse gases, my work informs policies focused on wetland restoration and protection. These efforts align with strategies to preserve ecosystems, reduce Canada's carbon footprint and enhance biodiversity."

Sara is now turning her attention to an even more ambitious project. "The CARBONIQUE project will be the largest and most comprehensive field study of wetland carbon dynamics in Canada," she says. "A network of eddy covariance towers is being established in Quebec, and this will provide critical data to evaluate how wetlands can help mitigate climate change. We aim to quantify the role of wetlands in nature-based climate solutions and support their integration into Quebec and Canada's climate strategies."

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About *biogeochemistry*

Biogeochemistry is a multidisciplinary field that studies the interactions of the biological, geological and chemical processes that influence the natural environment, and how these may change. It plays a vital role in monitoring the health of ecosystems and seeking solutions to environmental challenges such as climate change. "Biogeochemistry examines how elements like carbon, nitrogen, sulphur and phosphorous cycle through ecosystems, organisms and the atmosphere," explains Sara. "My focus is on the carbon cycle, and what I find most rewarding is the interdisciplinary nature of the field. It offers the opportunity to collaborate with experts from various disciplines, including hydrology, soil science and physics, allowing us to develop a comprehensive understanding of complex environmental systems and their responses to both natural and human-driven factors."

Biogeochemistry offers the opportunity to make a real difference to how scientists, policymakers and environmental organisations address the most challenging environmental problems. "The next generation can investigate how ecosystems respond to climate change, including shifts in carbon and nutrient cycling due to rising temperatures and altered precipitation patterns," says Sara. "Maintaining a focus on nature-based climate solutions is important, as the restoration, conservation, and management of wetlands, forests and soils can enhance carbon sequestration and support climate goals, even though they are not a substitute for reducing greenhouse gas emissions."

The use of artificial intelligence to support the work of environmental scientists has been steadily increasing over recent years. Sara explains, "I collaborate with computer scientists and data scientists to analyse large and complex datasets. By integrating expertise across these disciplines, we can develop more comprehensive models, uncover patterns in environmental data, and improve our understanding of ecosystem dynamics in response to climate change and other disturbances. This collaborative approach not only advances scientific knowledge but also informs more effective environmental management and policy decisions."

Pathway from school to *biogeochemistry*

Mathematics, physics, biology, chemistry and computer science will give you a strong foundation for specialising in biogeochemistry.

At college or university, study courses in physical geography, such as hydrology, atmospheric science, soil science and geology.

Sara says, "Gaining practical experience through internships or volunteer opportunities with universities, government agencies or environmental organisations is a great way to build skills. For those who enjoy working outdoors, field-based research offers hands-on experience in data collection and ecosystem monitoring. If you are less inclined towards field-based research, you can explore opportunities in computational research, focusing on data analysis, environmental modelling or using artificial intelligence to interpret large datasets."

Explore careers in *biogeochemistry*

Learn more about the work of Sara and her colleagues in the Department of Geography at McGill University (**mcgill.ca/geography**), and explore the website of McGill University's Office of Science Outreach (**mcgill.ca/science/outreach**) where you will find information about exhibitions, workshops, online presentations and podcast episodes.

Explore the websites of the Canadian Geophysical Union (**cgu-ugc.ca**), the Ecological Society of America (**esa.org**) and the European Geosciences Union (**egu.eu**) to read about the latest research taking place, and to find information about internships and careers. You could even consider becoming a student member of one of these organisations, giving you access to networking opportunities, events and conferences.

Sara says, "Staying informed through sites like NASA Earthdata (**earthdata.nasa.gov**) or the climate website of the US National Oceanic and Atmospheric Association (**noaa.gov/climate**) can deepen your understanding of global environmental issues."

Dr Sara Knox and her students (from right: Christina Mace, Marion Nyberg and Aylin Apodaca) conducting field work at Burns Bog.

Meet *Sara*

Biogeochemistry combines my love of the outdoors with my passion for science. Additionally, my love for math and science is fulfilled as biogeochemistry integrates elements of physics, biology, chemistry and computer science, making it an exciting and dynamic field.

I believe climate change is one of the most urgent challenges we face, and biogeochemistry plays a crucial role in understanding how the Earth will respond. It offers valuable insights into how ecosystems and biogeochemical cycles will be affected by climate change and provides guidance on how we can modify land management practices for both climate adaptation and mitigation strategies.

The fieldwork opportunities I had as an undergraduate were pivotal in shaping my career. I worked on a project quantifying the greenhouse gas balance of hydroelectric reservoirs, which was my first experience with eddy covariance and, ultimately, set the course for my future research. Additionally, I worked as a summer field assistant in Peru, examining the impact of glacier recession on water resources. These experiences deepened my interest in field-based research and solidified my passion for research in environmental sciences.

One of my greatest achievements has been co-leading two major international synthesis efforts on wetland methane emissions, which contribute approximately 25 to 40% of global methane emissions. My colleagues and I compiled a database of eddy covariance methane flux measurements and published numerous peer-reviewed papers focused on methane fluxes in wetlands. Our research enhanced the understanding of how wetland methane emissions respond to a changing climate and highlighted the potential for a wetland methane feedback loop in a warming climate.

My goal is to continue training the next generation of environmental scientists who will not only advance our understanding of climate change but also enhance our ability to address its complex challenges. I find great joy in teaching and fostering critical thinking in my students, encouraging them to think independently and question the information presented to them. This ability to critically evaluate data and ideas is essential for pushing the boundaries of scientific knowledge.

I am deeply committed to fostering inclusivity and diversity in science, as I firmly believe that a diverse and inclusive workforce leads to more innovative and comprehensive solutions. By creating an environment where all voices are heard and valued, we can tackle global challenges like climate change from a variety of perspectives, ultimately strengthening the scientific community and improving the impact of our work.

Sara's *top tips*

1. Do not fear failure. Science is an iterative process, and setbacks are often the most valuable learning opportunities in science (and in life). Embrace challenges, learn from mistakes, and use them to grow.

2. Take chances and be bold as many breakthroughs come from thinking outside the box.

3. Build a network of mentors and peers who inspire and challenge you. These relationships will help you grow and open doors to exciting opportunities throughout your career.

Biogeochemistry

with Dr Sara Knox

Talking *points*

Knowledge & Comprehension

1. What are the different types of wetlands, and where in the world can they be found?
2. What is the carbon cycle, and how do wetlands store carbon?
3. What types of human activities disturb wetlands, and how? What impact does this have on the carbon cycle?
4. Why is it important to include other greenhouse gases such as methane and nitrous oxide in measurements and models?

Application

5. How does Sara investigate the transfer of carbon between wetlands and the atmosphere, and what questions could you ask Sara to learn more about her research methods?
6. What interests you most about biogeochemistry? What steps could you take now if you wanted to pursue a career in biogeochemistry, or environmental sciences more generally?

Analysis

7. Sara says that biogeochemistry involves multidisciplinary work, collaborating with colleagues from different fields. Why do you think this is important and beneficial?

Evaluation

9. Why do you think wetlands are not as prominent in public awareness as other ecosystems, such as woodlands, grasslands or rivers? What impact do you think this could have on efforts to manage them? What could be done to increase public awareness and understanding of wetlands?
10. Which of Sara's top tips do you find most useful, and why?

Activity

In a small group, design a short presentation for your fellow students about the importance of wetlands and the research being done to understand and manage them. Using Sara's article and your own research, include information about the following:

1. Descriptions of the different types of wetlands (marshes, swamps, bogs, fens and mangroves), including where in the world they can be found, and the animals and plants that make them their homes
2. An explanation of the carbon cycle, and how wetlands play a part in it
3. How human activities are disturbing wetlands
4. How an eddy covariance flux tower can be used to measure greenhouse gases in wetlands
5. How these data can help to protect and restore wetlands, and in turn, the delicate carbon balance.

Think about what diagrams, facts and images you could include to make your presentation more engaging and understandable.

Present your work to your fellow students, watch their presentations, and give each other feedback. Reflect on the following:

1. How easy was your presentation to understand? What additional information would you include in a future presentation, or is there anything you would remove?
2. What did you learn from the other presentations?
3. What impact did your visual aids such as diagrams and images have on your presentation?
4. How comfortable did you feel speaking to an audience? What skills could you develop to help you to feel more confident in future?
5. What would you change about your presentation if you were talking to a different audience? For example, think about the following groups:
   - A class of eight-year-olds
   - A group of journalists wanting to report on the state of wetlands
   - Possible funders of future research.

More *resources*

This TED talk covers many reasons to love wetlands: **youtube.com/watch?v=ULZZZMmLUs0**

The Waterlands podcast by the Wildfowl and Wetlands Trust in the UK explores all things wetlands: **wwt.org.uk/discover-wetlands/wetlands**

This TED talk explores the importance of wetlands in Zambia, and why it is crucial to conserve them: **youtube.com/watch?v=dgQxXJpAGQk**

Read this Futurum article about how peatlands store carbon and how they can be restored: **futurumcareers.com/studying-and-restoring-canadas-peatlands-and-their-carbon-storage-superpower**

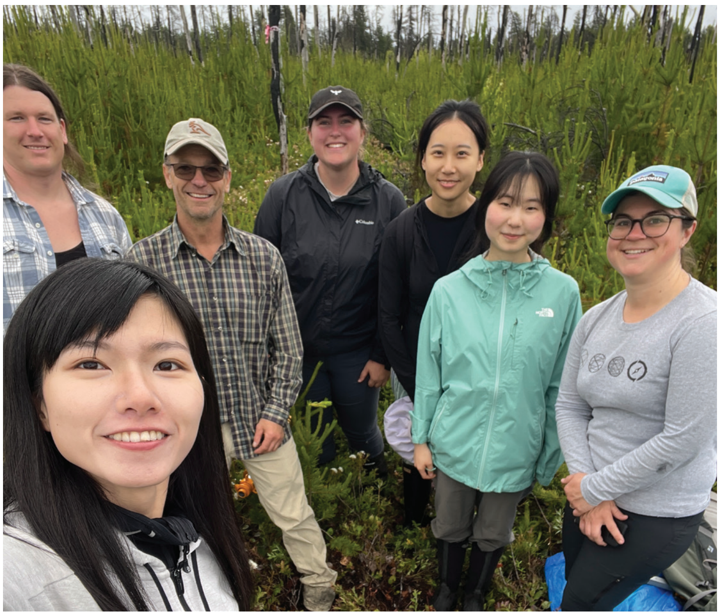

Photo *montage*

Top and Middle row, left: *A flux tower in a salt marsh near Vancouver, British Columbia, Canada. This tower is part of a project studying carbon cycling in Canada's coastal ecosystems.*

Middle row, right: *An eddy covariance tower measuring greenhouse gas fluxes at Burns Bog.*

Bottom: *Dr Sara Knox and her research team (from right: Himari Honda, Hehan Zhang, Kelcey McGuire, Rick Ketler, June Skeeter and Tzu-Yi Lu) doing fieldwork at Burns Bog.*

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