Recent findings and publications from collaborations in the far north of Ontario – Climate Change and Multiple Stressor Aquatic Research Programme, Laurentian University. January 2019

Bill Keller (bkeller@laurentian.ca) and Chantal Sarrazin-Delay (csarrazindelay@laurentian.ca).

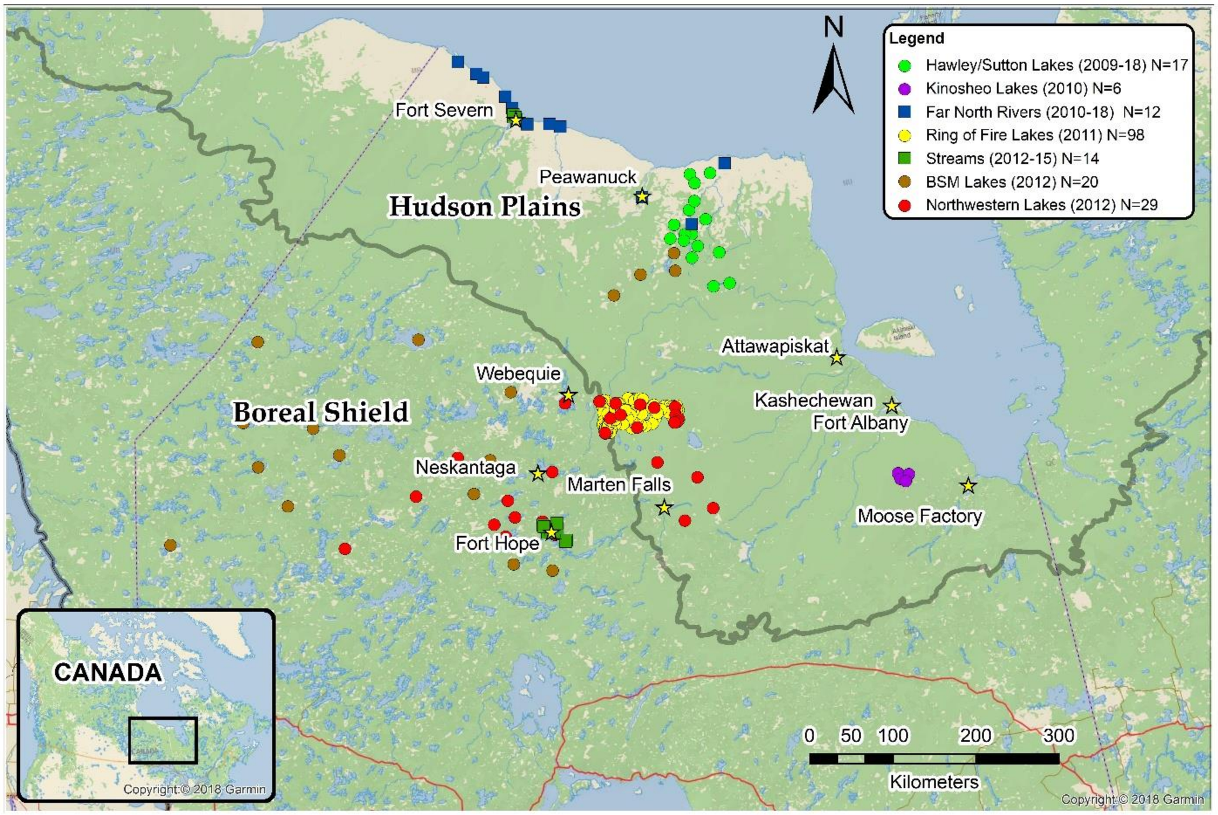
o Lakes across the far north of Ontario differ greatly because of differences in the land, especially in the geology and topography. More southern lakes are on the rugged Canadian Shield and they sit on hard granite bedrock. The more northern lakes are on the Hudson Bay Lowlands in a much flatter landscape of soft limestone bedrock. The water chemistry characteristics were found to be generally different in lakes on the Shield compared to the Lowlands. However, in the area where the Shield and Lowlands meet near the "Ring of Fire", there was no chemistry difference between the lakes. The thick cover of peat and materials (rocks, sand, gravel) deposited by glaciers in this area means that the water is less affected by the bedrock below. (MacLeod et al. 2017)

Hudson Bay Lowlands

Canadian Shield

Overhead and on the ground photos of Hudson Bay Lowlands and Canadian Shield in Ontario

o The water in far north lakes on the Canadian Shield had more calcium, magnesium and total phosphorus than near north Shield lakes (south of 50°N). In the far north, there is much limestone, formed at the bottom of large ancient lakes or dropped by melting glaciers. The minerals in the soft limestone dissolve giving the water more nutrients and ions than similar lakes further south. The water of the Hudson Bay Lowland lakes often had less dissolved minerals because the thick cover of peat separates the lake water from the rock. (MacLeod et al. 2017)

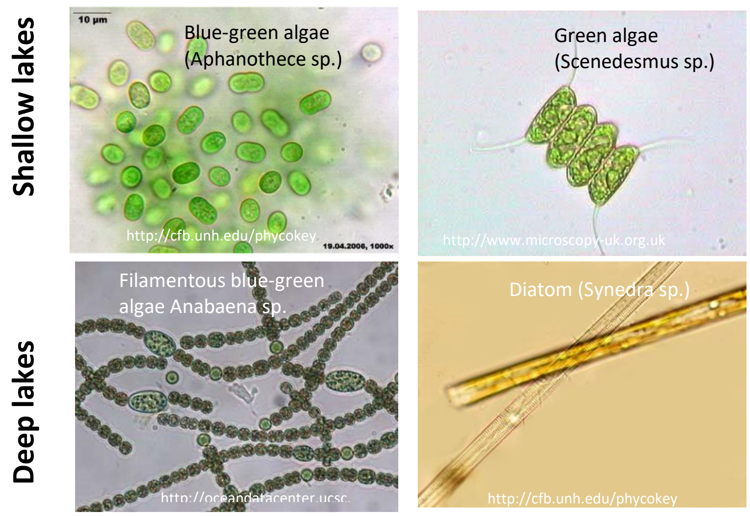


Climate Change and Multiple Stressor Aquatic Research Programme: Sampling sites from far north collaborations

o In general, climate warming should have little effect on large fish species in lakes in the far north of Ontario through effects on the food that they eat. By studying the food webs of these lakes, large fish were found to eat a wide variety of foods and should be able to adapt to changes in food availability. The fish in lakes on the Hudson Bay Lowlands will likely be damaged by climate warming in a more direct way. The warming air will warm the water of very shallow Lowlands lakes potentially killing fish in them that need cool waters (e.g. lake whitefish, white sucker). (Persaud et al. 2015)

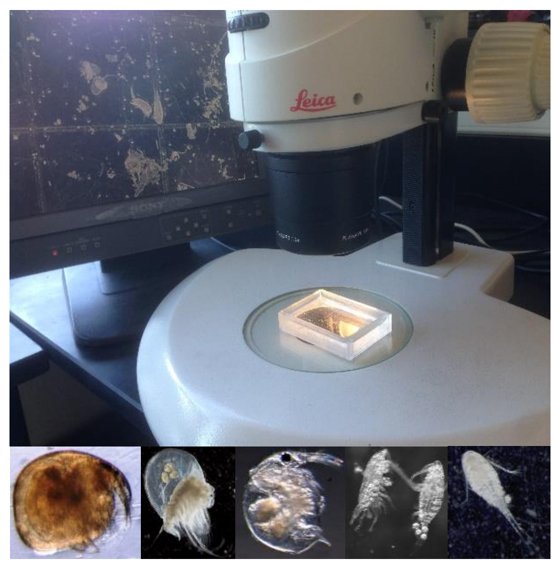
o Rivers and the fish in them are very important to communities in the far north of Ontario. Near the Hudson and James Bay coasts, whitefish and cisco are particularly important country foods. Most of these fish move between the large rivers and the bays (DeJong 2017). Because whitefish, cisco and brook trout spend part of their lives in salt water they have less mercury and more good fats making them a good food choice. (Heerschap 2018)

○ Phytoplankton include different species of tiny plants that float in the water, capture energy from the sunlight and are eaten by zooplankton. The species of phytoplankton found in the far north lakes depends on the depth of the lake and the amount of nutrients in the lake. Shallow lakes had many blue-green algae and green algae. Deeper lakes had mostly filamentous blue-green algae and diatoms. (Paterson et al. 2014)



Phytoplankton as seen under the microscope, magnified 60 times

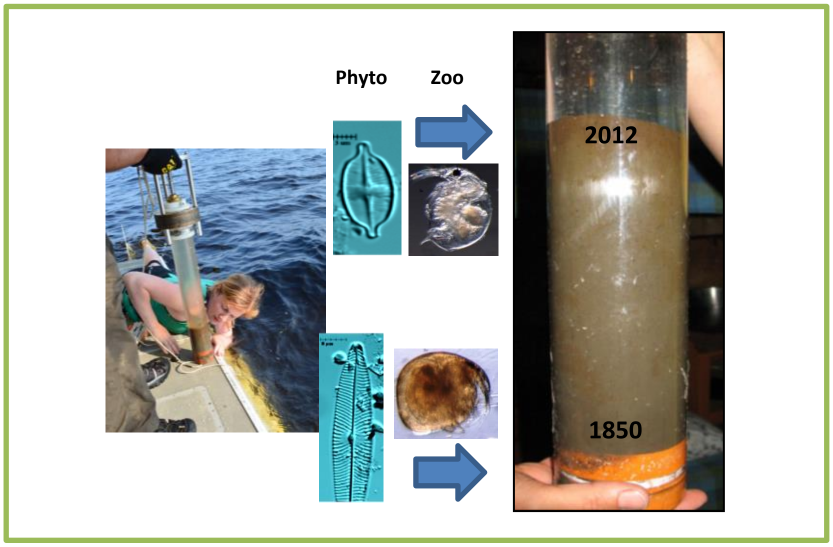
○ Zooplankton include different species of tiny animals about the size of the period of a sentence that live in the water of lakes, rivers and ponds. They are very important in food webs because they eat the tiny plants (phytoplankton) in the water and pass this energy on to the fish that eat them. The same species of zooplankton were generally found in the lakes of the far north as the ones found in more southern lakes of Ontario. A few species were rare or not found in the most northern lakes. Lakes in the Lowlands had fewer zooplankton species than the Shield lakes, because they are shallow and offer fewer types of habitats that the different species need. (Paterson et al. 2014; MacLeod et al. 2018)



Zooplankton on screen of microscope, magnified 40 times

○ In five rivers that drain into Hudson Bay, the community of small animals that live in the rocks at the bottom (benthic invertebrates) was influenced by the water quality, the river width and flow, and by the size of the rocks. Benthic invertebrates can be used to track changes in northern rivers. (Jones et al. 2014)


Benthic invertebrates as seen under the microscope magnified 20 times



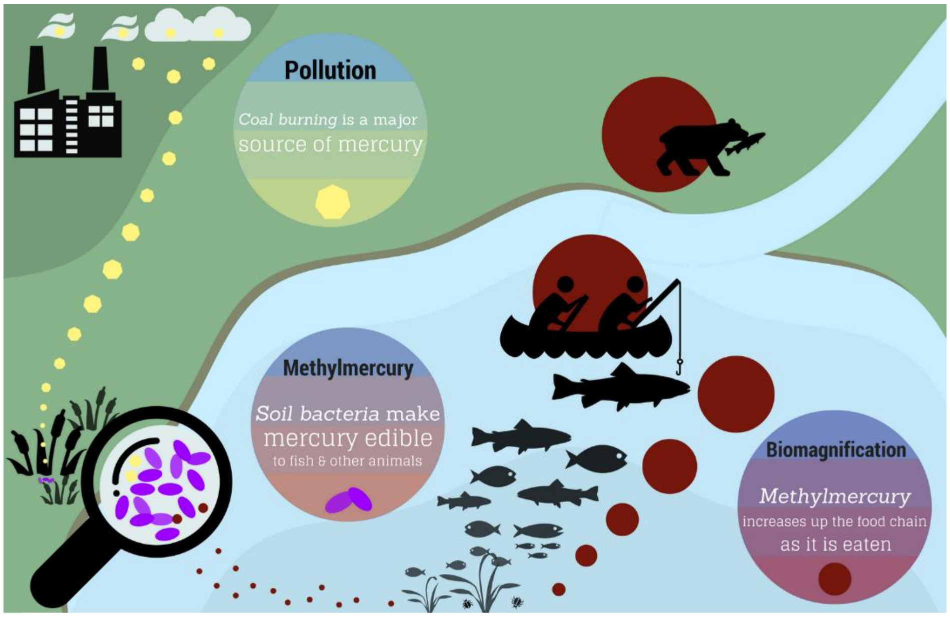
Paleolimnology: Studying the mud at the bottom of lakes to reconstruct their history

- The plankton (tiny plants and animals) in lake water have changed because of climate warming. Looking at the animal (cladoceran) and plant (diatom algae) parts left in the layers of mud (paleolimnology), allows us to reconstruct the history of a lake. Comparison to the deep, oldest layer shows that the number and types of plankton have changed in the past 100 years. The changes in these plants and animals reveal that in the past, lakes had ice for a longer part of the year, the water was not as warm and algae were less productive. (Rühland et al. 2013, 2014; Jeziorski et al. 2015; Hargan et al. 2016)

- Plankton communities (tiny plants and animals) have changed most in shallow lakes. This warming-caused change started in the 1970s in lakes far from Hudson and James bays. Near the coast, the change in plankton happened later, in the middle of the 1990s. In the past, the ice on the bays kept the land and the nearby lakes cooler in the summer. Now the sea ice melts earlier and doesn't keep the land and the lakes as cool into the summer. (Rühland et al. 2013)

- There was little difference in the tiny plants (diatoms) found in the peatlands (bogs and fens) of northern Ontario compared to other peatlands around the world. These plants are well adapted to this harsh environment of land and water. Diatoms from peatlands can serve as monitors of environmental change in the Lowlands. (Hargan et al. 2015)

- Northern lakes are more productive now with climate warming. There are more remains of dead plants (organic matter and chlorophyll a) in the top layers of lake mud. In the deeper, older layers there is less organic material which means that there would have been less plankton or algae in the past. (Brazeau et al. 2013b; Rühland et al. 2013)



Mercury in the environment

○ The amount of mercury in the mud (sediment) at the bottom of lakes has been increasing. This is surprising because there is now less pollution from burning coal, the source of mercury in northern lakes. The increase in mercury in the sediment is probably because as the lakes become warmer, there is more algae. The algae take up the mercury from the water and when they die and fall to the bottom, the mercury within the algae becomes part of the sediment. (Brazeau et al. 2013b)

○ With the help of microbes, mercury can move from the mud at the bottom of lakes into the water where it can more easily accumulate in animals and cause them harm. As the temperature increases and the water changes, more mercury might be dissolved back into the water. (Brazeau et al. 2013a.)

○ Mercury is toxic but it becomes even more toxic when attached to carbon (methylmercury), in a process caused by microbes. In northern lakes, total mercury in the muddy sediment doesn't determine how much methylmercury is there. Instead, the organic content of the top and deep sediment was related to the amount of methylmercury. This helps explain why lakes across the landscape have different amounts of methylmercury; the more organic material there is in the mud, the more methylmercury is usually there too. (Brazeau et al. 2013b)

○ The gene that microbes have to help detoxify mercury increased about 200 years ago, at the time of the industrial revolution. The deep layers of mud contain remains of microbes. These microbes lived before there was pollution and were found to rarely have the detoxifying gene. In the upper layers deposited after pollution started, more of the detoxifying gene was found. Looking at the genes of microbes can be a useful tool to monitor pollution deposits in northern lakes. (Poulain et al. 2015)

Far North Publications

Journal papers:

Brazeau, M.L., J.M. Blais, A.M. Paterson, W. Keller, and A.J. Poulain. 2013a. Evidence for microbe-mediated production of elemental mercury (Hg^0) in subarctic lake sediments. Appl. Geochem. 37: 142-148.

Brazeau, M. L., A.J. Poulain, A. Paterson, W. Keller**,** H. Sanei, and J.M. Blais. 2013b. Recent Changes in Mercury deposition and primary productivity inferred from sediments of lakes from the Hudson Bay Lowlands, Ontario, Canada. Environ. Pollut. 173: 52-60**.**

Hadley, K.R., A.M. Paterson, K. Rühland, H.White, B. Wolfe, W. (Bill) Keller, and J.P. Smol. 2019. Biological and geochemical changes in shallow lakes of the Hudson Bay Lowlands: a response to recent warming (in press, J. Paleolimnology).

Hargan, K.E., K.M. Rühland, A.M. Paterson, S.A. Finkelstein, J.R. Holmquist, G. MacDonald, W. Keller**,** and J.P. Smol. 2015. The influence of water table depth and pH on the spatial distribution of diatom species in peatlands of the Boreal Shield and Hudson Plains, Canada. Botany 93: 57-74.

Hargan, K.E., C. Nelligan, A. Jeziorski, K.M. Rühland, A.M. Paterson, W. Keller**,** and J.P. Smol. 2016. Tracking the long-term responses of diatoms and cladocerans to climate warming and human influences across lakes of the Ring of Fire in the Far North of Ontario, Canada. J. Paleolimnology 56: 153-172.

Jeziorski, A., B. Keller, R.D. Dyer, A.M. Paterson, and J.P. Smol. 2015. Differences among modern-day and historical cladoceran communities from the "Ring of Fire" lake region of northern Ontario: Identifying responses to climate warming. Fundamental and Applied Limnology 186: 203-216.

Jones, F.C., S. Sinclair, and W. Keller. 2014. Benthic macroinvertebrate communities in five rivers of the Coastal Hudson Bay Lowland. Polar Biology 37: 141-147.

Keller, W., A. Paterson, K. Rühland, and J. Blais. 2014. Introduction – environmental change in the Hudson and James Bay region. Arctic, Antarctic and Alpine Research 46: 2-5.

MacLeod, J., W. Keller, A.M. Paterson, R.D. Dyer, and J.M. Gunn. 2017. Scale and watershed features determine lake chemistry patterns across physiographic regions in the far north of Ontario, Canada. J. Limnol. 76: 211-220.

MacLeod, J., W. Keller, and A.M. Paterson. 2018. Crustacean zooplankton in lakes of the far north of Ontario, Canada. Polar Biology. doi. 10.1007/s003000018-2282-9.

Paterson, A., B.Keller**,** C. Jones, K. Rühland, and J. Winter. 2014. An exploratory survey of water chemistry and plankton communities in lakes near the Sutton River, Hudson Bay Lowlands, Ontario, Canada. Arctic, Antarctic and Alpine Research 46: 121-138.

Persaud, A., A. Luek, B. Keller, C. Jones, P. Dillon, J. Gunn, and T. Johnston. 2015. Trophic dynamics of several fish species in lakes of a climatically sensitive region, the Hudson Bay Lowlands. Polar Biology 38: 651-664. doi10.1007/s00300-014-1628-1.

Poulain, A.J., S. Aris-Brosou, J. Blais, M. Brazeau, W. Keller, and A.M. Paterson. 2015. Microbial DNA records historical delivery of anthropogenic mercury. ISME Journal 9: 2541-2550.

Rühland, K.M., A.M. Paterson, W. Keller, N. Michelutti, and J.P. Smol. 2013. Global warming triggers the loss of a key Arctic refugium. Proc. Roy. Soc. B. 280: 20131887.

Rühland, K., K. Hargan, A. Jeziorski, A. Paterson, W. Keller**,** and J. Smol. 2014. A multi-trophic exploratory survey of recent environmental change using lake sediments in the Hudson Bay Lowlands, Ontario. Arctic, Antarctic and Alpine Research 46: 139-158.

Journal Special Issues:

Environmental Change in the Hudson and James Bay Region, Canada. 2014. Arctic, Antarctic, and Alpine Research 46: 1-292 (18 papers).

Progress reports:

Progress Report – Aquatic Ecosystem Studies in the Hawley Lake/Sutton River Area of the Hudson Bay Lowlands, 2009 – 2010. Cooperative Freshwater Ecology Unit, Laurentian University.

Second Progress Report – Aquatic Ecosystem Studies in the Hawley Lake / Sutton River Area of the Hudson Bay Lowlands, 2009 – 2012. Cooperative Freshwater Ecology Unit, Laurentian University.

Progress Report - River Studies in the Fort Severn Area, 2011-2013. Cooperative Freshwater Ecology Unit, Laurentian University.

Progress Report - Lake and Stream Surveys in Northwestern Ontario, 2012 and 2013. Cooperative Freshwater Ecology Unit, Laurentian University.

Theses:

Brazeau, M. 2012. Historical deposition and microbial redox cycling of mercury in lake sediments from the Hudson Bay Lowlands, Ontario, Canada. M. Sc. University of Ottawa.

Dejong, R. 2017. Life history characteristics of lake whitefish (Coregonus clupeaformis), cisco (Coregonus artedi), and northern pike (Esox lucius) in rivers of the Hudson Bay Lowlands. M. Sc. University of Waterloo.

Hargan, K. 2014. Diatoms as indicators of environmental and climatic change in peatlands and lakes located across the Boreal Shield and Hudson Bay Lowlands of Canada. Ph. D. Queen's University.

Heerschap, M.J. 2018. Ecology and food quality of fishes in the coastal rivers of the far north of Ontario. M. Sc. Laurentian University.

MacLeod, J. 2014. Lakes in the far north of Ontario: Regional comparisons and contrasts. M. Sc. Laurentian University.