Cooperative Freshwater Ecology Unit
Unité Conjointe D'écologie D'eau Douce

2021
Annual Report
Cooperative Freshwater Ecology Unit

"Clean Water Now and Forever"

A Message from the Director
"Coming Out of 2021"

Dear Co-op Unit and Friends,

On winter solstice (Dec. 21, 2021) I wrote about the year that was:

The sun is now rising on the shortest day of the year. Boy, it is good to see the light!

What a dark year we had, both at Laurentian with the CCAA, but also all across Canada with the pandemic, floods, fires and drought. However, what a magnificent team we brought to the challenges. Sure there were tears and panic attacks, but like the Raptors, with every injury, somebody new always seemed to step up.

For me some of the highlights of 2021 included: the big audience for the Troubled Waters symposium just days after insolvency was declared; the magnificent Earth Day AGM and Science North broadcast (just weeks after the brutal layoffs); the fabulous media blitz (Star, CBC, CTV, Quirks and Quarks); the honouring of our new Senior Fellows; being the first group to resume research activities (Killarney, Tom's lakes, Yukon, Hudson Bay pulsars, Brie and Joc's SES lakes, Coniston biosolids plots, kettle lakes, sphagnum bogs/fens, etc.); the Up North Climate adaptation group sustaining the community work; our PCAF analytical team keeping the ICP-MS going; our partners with MIRARCO/GSM moving the Mine Waste Biotechnology proposal ahead; Sci Comm winning NSERC grants and getting campus wide recognition; the opening of the

UN Restoration Trail (with Jane Goodall and Bob Rae videos) and the Recovery Garden (Oct. 21), followed by the Mirarco/VLWLC open house (first public gathering); Line Rochefort giving the Watershed Lecture and symposium (Oct. 22); the excellent final L-Care wrap up meeting (Dec 14); the Indiana Jones style team getting home safely from the Peru mountains; the student defenses, the courses delivered, and so many scholarships won this year; and then to cap it all off - a great Zoom Christmas party (Dec. 18) that was actually fun. Phew!

It all happened because so many good people, rowed hard together, all in the same direction.

Thank you to everyone, especially to our many partners and supporters who helped sustain us through a tough year. It is time now to rebuild (including adding CRCs), to continue to address the many environmental challenges we face, as well as the new research opportunities ahead in Year 2 of the UN Decade on Ecosystem Restoration.

John Gunn
Canada Research Chair in Stressed Aquatic Systems

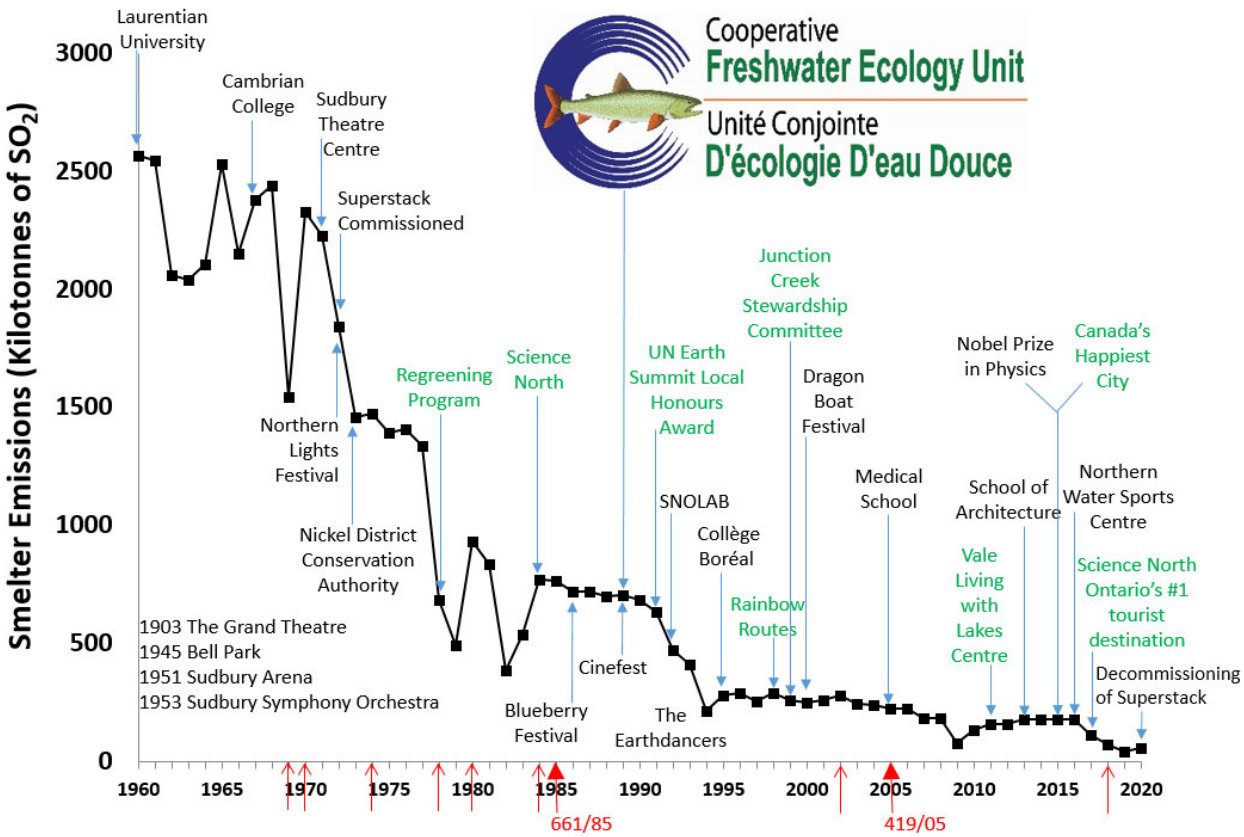


Fig. Creation of significant community assets with cleaner air in Sudbury. Timing of some of the government pollution control orders (↑) and regulations (▲) indicated.

Awards and Recognition

- Congratulations to our long time and much-loved Business Manager, Elizabeth Bamberger, who retired on May 31, 2021. The contributions Liz has made to the work of the Cooperative Freshwater Ecology Unit are evident daily to those of us who remain, the development and construction of the Vale Living with Lakes Centre would certainly not have happened without her hard work, unwavering commitment and relentless (and very successful) fundraising efforts. Her creative problem solving skills are unparalleled. It was a pleasure to work with Liz every day for so many years and we are happy to tell you that she is now a Grandmother... we know any grandchildren of hers are lucky kids. Thank you Liz, for everything.

- This year a number of our team stepped into new roles as CFEU Senior Research Fellows. We are grateful that this distinguished group will continue their work with the CFEU and Lake Centre. Although this wonderful group can technically be described as retired Emeritus

Professors, it is not yet time to use the past tense to discuss their amazing and ongoing contributions. More is yet to come from them. This group includes:
Dr. David Pearson, CFEU Senior Research Fellow in Climate Adaptation
Dr. Charles Ramcharan, CFEU Senior Research Fellow in Freshwater Biology
Dr. Peter Beckett, CFEU Senior Research Fellow in Ecosystem Restoration
Dr. Graeme Spiers, CFEU Senior Research Fellow in Pedology




- In 2021 Dr. Nadia Mykytczuk was named both the Interim Executive Director of the Goodman School of Mines and the Interim CEO and President of MIRARCO. In addition to these new duties Dr. Mykytczuk continues to supervise her students and run her research projects while serving as an Adjunct Professor at Laurentian and teaching her online course 'Environmental Remediation: Global Lessons from the Sudbury Story'.

- Congratulations to Dr. Heidi Swanson, who won the Jack Carlson Teaching excellence Award, Department of Biology, University of Waterloo.

<u>Student Scholarships, Fellowships, Bursaries</u>

- Kelly Chan Yam, PhD Candidate Laurentian (Basiliko), won an OGS Scholarship.

- Lisa Cicchetti, MSc Candidate Queen's (Arnott), won a Craigie Award.

- Jade Dawson, MSc Candidate Laurentian (Gunn/Edwards), received an NSERC Canadian Graduate Scholarship.

- Carrie Ewins, MSc Candidate Queen's (Arnott), won an OGS Scholarship.

- Kunali Gohil, MSc Candidate Laurentian (Gunn/Edwards), received an NSERC Canadian Graduate Scholarship and an Ontario Graduate Scholarship (declined).

- Adam Kirkwood, PhD Candidate Laurentian (Roy-Léveillée/Basiliko) won an NSERC Canada Graduate Scholarship, a W. Garfield Weston Award in Northern Research (Doctoral), a WCS Canada Boreal Conservation Fellowship, an Ontario Graduate Scholarship (declined) and support from Northern Scientific Training Program.

- Jade Lockie, Msc Candidate Laurentian (Ielpi) was awarded a graduate bursary of $46,000 from the Northwest Territories Geological Survey. Jade transferred to the PhD stream in May 2021.

- Jasmine Louste-Fillion, MSc Candidate Laurentian (Gunn/Edwards), received an Ontario Graduate Scholarship.

- Patrick Levasseur, PhD Candidate Trent (Watmough), was awarded the annual Tom Peters Memorial Mine Reclamation Bursary.

- Troy Martin, MSc Candidate Queen's (Arnott), won a Craigie Award and a Bracken Fellowship.

- Bronte McPhedran, MSc Student, Waterloo (Swanson) was awarded an NSERC Student Ambassador Grant.

- Haley Moskal, MSc Candidate Laurentian (Gunn/Edwards), received a Dean's Entrance Scholarship for Graduate Students, a Garfield Weston Fellowship through WCS Canada and a MITACS fellowship.

- Sarah Sandor, PhD Student Cambridge (Tanentzap), was awarded funding through the Harding Distinguished Postgraduate Scholars Programme.

- Hareena Sidhu, BSc Student Queen's (Arnott), was awarded the J. Allen Keast Lake Opinicon Undergraduate Research Fellowship.

- Rosie Smith, MSc Student Waterloo (Swanson), was awarded a Northern Scientific Training Program Grant and an Ontario Graduate Scholarship.

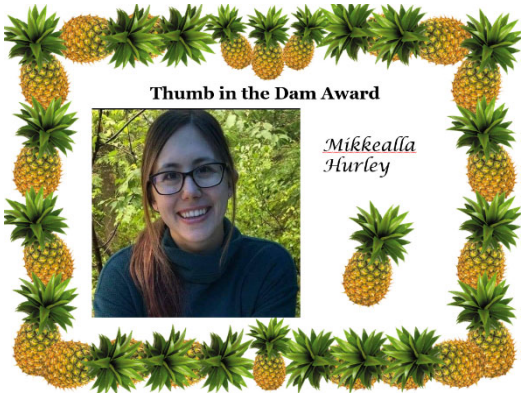
- Xinyu Sun, PhD Candidate Queen's (Arnott), received a Craigie Award.

- Christian Therrien, PhD Student Waterloo (Swanson), was awarded an Ontario Graduate Scholarship and an internship with an NSERC CREATE grant (FishCAST).

- Samuel Woodman, PhD Student Cambridge (Tanentzap), was recently awarded a NSERC Postgraduate Scholarship.

Annual Pineapple Awards

Pineapple awards are presented at the end of each year to recognize staff who have gone above and beyond.



"After the final no there comes a yes
And on that yes the future world depends."

Wallace Stevens

"Not knowing when the Dawn will come,
I open every Door"

Emily Dickinson

Community Outreach

The Lake Centre engaged the media to actively push "good news", student-focused research stories to local and national audiences to keep both the Lake Centre and Laurentian's image strong and positive.

Oct. 22, 2021 The Sudbury Star featuring the work of PhD Student Jonathan Lavigne (Basiliko)
https://www.thesudburystar.com/news/local-news/sudbury-accent-lu-researcher-tackles-the-next-frontier-of-sudburys-regreening-program

Oct. 6, 2021 MSc Student Haley Moskal (Gunn/Edwards) made the CTV National news (featured at approx. 1hr and 11minutes mark)
https://www.ctv.ca/shows/your-morning/wednesday-october-6-2021-s6e33

Sept. 11, 2021 CBC's Quirks and Quarks featuring MSc Student Haley Moskal (Gunn, Edwards)
https://www.cbc.ca/radio/quirks/sept-11-here-s-what-some-canadian-researchers-did-during-their-summer-of-science-1.6170965?fbclid=IwAR2bbxldexNoWw_o8VJaOz11L74juYnyqy3HqIqH3HcuWEkLN3Mbb1LWoig

Aug. 29, 2021 The Sudbury Star featuring the work of MSc Student Mackenzie Russell (Gunn)
https://www.thesudburystar.com/news/local-news/sudbury-accent-laurentian-researcher-studies-the-effects-of-drought-on-mining-impacted-wetlands?fbclid=IwAR1_rToyBRgrI6c_GBJKkoGgbNkhE6mvYcBKLQwbEVwbv6NoBiA9U95y1iY

Aug. 21, 2021 The Sudbury Star featuring PhD Student Adam Kirkwood (Basiliko, Roy-Léveillée)
https://www.thesudburystar.com/news/local-news/sudbury-accent-climate-change-is-impacting-the-worlds-tiniest-organisms?fbclid=IwAR1s8qxhbVzu1alXemZYtJi_rtBb71G8C9pIn_pC7ForDQWYQ9HyeZk1AHY

Aug. 8, 2021 The Sudbury Star featuring MSc Student Adam Lepage (Lescord, Gunn)
https://www.thesudburystar.com/news/local-news/sudbury-accent-lake-centre-looks-at-metals-found-in-local-fish-species?fbclid=IwAR0Q4Kz-PWLIh6BP3buGI9xA8aE661xxlJrTmtickEZs1bMBckrw1f-agqk

Aug. 2, 2021 The Sudbury Star featuring MSc Student Haley Moskal (Gunn, Edwards)
https://www.thesudburystar.com/news/local-news/how-long-does-it-take-for-a-lake-to-recover?fbclid=IwAR0TZYa90uajB6Qpo8HZlcX6cYvTeACHw71oNSlhoT7uyZJfq5vLXxi3lfQ

July 24, 2021 The Sudbury Star featuring PhD Student Arghavan Tafvizi (Ramcharan, James)
https://www.thesudburystar.com/news/local-news/living-with-lakes-predicting-the-effects-of-climate-change-on-the-regions-water-sources?fbclid=IwAR1xlTkKoFlAB0XPq_Krcfx_TOzeOQ0jlSrQKO52Qvt6RRuKzvkb84s5JWg

July 14, 2021 Northern Ontario Business
https://www.northernontariobusiness.com/industry-news/green/sudbury-researchers-look-for-innovative-ways-to-rehabilitate-old-aggregate-sites-3955156?utm_source=dlvr.it&utm_medium=facebook

Jun 10, 2021 CBC News featuring Dr. Peter Beckett
https://www.cbc.ca/news/canada/sudbury/regreening-sudbury-1.6057530?fbclid=IwAR3XXpOPNRqHqG20svXkOJMAcBjgYkVKM5dtUudOVBzbFslb53E7-4f2Iwg

- Dr. Shelley Arnott participated in the following public outreach initiatives in 2021:
  - ~ Gave presentation entitled 'Current water quality guidelines do not protect aquatic communities in all lakes.' to STEP Road Salt Working Group, Nov 2021
  - ~ Participated in 'Live from the Field: Freshwater Invasions' Sonoma State University, Oct 2021

- Dr. Chantal Barriault participated in the following outreach initiatives in 2021:
  - ~ Served as a panelist for "Let's Talk: Misinformation" with Dr. T Caufield and SCOM Graduate Student, S Fowler in the 'Let's Talk about COVID19' Series by Science North and Laurentian University, Jan 2021
  - ~ Served as a panelist for "Science journalism education" at the Science Journalism Educators Summit, Concordia University where she discussed 'What should be involved in science journalism curriculum and what new teaching methods should be used?' May 2021
  - ~ Coordinated communications objectives and strategies for the Vale Living with Lakes Centre, including successfully pitching H Moskal's research story for Quirks and Quarks, CBC Radio. Spring/Summer 2021
  - ~ Conducted Science Communication Skills Training: Professional Development 3 day workshop for 65+ academic scientists and researchers from across Northern Ontario and Canada. Aug 2021
  - ~ Conducted Science Communication Skills Training for Science North staff. Dec 2021
  - ~ Interviewed on Radio Canada on the topic of 'COVID19 and Misinformation' in Jan and Aug of 2021
  - ~ Interviewed on CBC Radio Morning North on the topic of 'COVID19 and Misinformation', Jan2021

- Dr. Nathan Basiliko serves on the Regreening Advisory Committee (VETAC) for the City of Greater Sudbury and participated in the following activities:
  - ~ Featured in article 'LU researcher tackles 'the next frontier' of Sudbury's regreening program' by Colleen Romaniuk, Sudbury Star, 22 Oct 2021 https://www.thesudburystar.com/news/local-news/sudbury-accent-lu-researcher-tackles-the-next-frontier-of-sudburys-regreening-program
  - ~ Featured in article 'Sudbury researchers look for innovative ways to rehabilitate old aggregate sites' in Northern Ontario Business 14 Jul 2021 https://www.northernontariobusiness.com/industry-news/green/sudbury-researchers-look-for-innovative-ways-to-rehabilitate-old-aggregate-sites-3955156

- Dr. Peter Beckett is the Outreach Coordinator with the VLWLC. He served in the following Capacities in 2021:
  - ~ VETAC: Chair
  - ~ Canadian Land Reclamation Association (Ontario Chapter): Director
  - ~ American Society of Mining and Reclamation: Chief Student Presentations Judge

~ Junction Creek Stewardship Committee: Technical Advisor and Board Member
~ Rainbow Routes: Environmental Advisor and Board Member
~ Sudbury Naturalists: Co-chair
~ Friends of Mashkinonje Park: President
~ Reclamation Member of SER Working group within the UN Decade on Ecological Restoration Framework

Dr. Beckett also gave the following tours and presentations:

~ Gave a presentation about Sudbury's regreening history via Zoom at a meeting in Prague, Czechia as part of the 3rd International Conference on Forest and Landscape Restoration of Post-mining Sites 2 Jun 2021
~ Delivered a talk on the Regreening of Sudbury with G. Spiers to a Grade 12 Earth and Space Science class at the Canadian Ecology Centre, Mattawa. 4 Aug 2021
~ Presented via ZOOM on "Over 40 years of healing and creating novel functional ecosystems on a smelter-impacted landscape of Sudbury, Ontario, Canada" with G. Spiers at the Mine Closure Conference in Mongolia. 17 Aug 2021
~ Delivered a talk on the Regreening of Sudbury to participants of the Mine Life Cycle Tour with G. Spiers at the Canadian Ecology Centre, Mattawa. 26 Aug 2021
~ Discussed the Sudbury Regreening Program (via ZOOM) in a workshop at the 3rd International Symposium on Land Reclamation and Ecological Restoration, Xuzhou, Jiangsu, China. 16-19 Oct 2021
~ Gave Annual Watershed Lecturer, Dr. Line Rochefort (Laval University), a tour of Regreening sites, including the Jane Goodall Trail. 21 Oct 2021
~ Gave an invited presentation entitled 'Restoration of Urban Forests in Smelter-Emissions Impacted Landscapes Enhances Biodiversity and Carbon Sequestration to Mitigate Today's Climate Emergency' with G. Spiers at the Conference on Bioremediation of the Arctic Coastline, Moscow. Organized by the Arctic Council. 25-26 Oct 2021
~ Led a discussion on the link between the UN Decade on Ecological Restoration and Sudbury's Regreening Program to the Science Communication Program at Laurentian University. 28 Oct 2021
~ Led a discussion on the link between the UN Decade on Ecological Restoration and Sudbury's Regreening Program to the Sudbury Naturalists. 9 Nov 2021
~ Gave a talk on 'Potential use of restoring urban forests for carbon sequestration in today's climate emergency' to 100 delegates at the British Ecological Society Annual Meeting in Liverpool, England. 15 Dec 2021

- Dr. Brie Edwards participated in the following public outreach initiatives in 2021:
  ~ Served as Co-host of the Five Part Webinar Series "Troubled Waters Forum" which featured research presentations from internationally recognized water experts including Drs. J. Gunn, N. Yan, S. Sharma, A. Kirkwood and J. Smol. The event was co-organized by the Greater Sudbury Watershed Alliance, the Vale Living with Lakes Centre and The Federation of Ontario Cottagers' Associations. Feb-Mar 2021

- ~ Served as guest lecturer in BIOL4035 (Honours Course) in March 2020 speaking on the topics of Careers.

- Dr. Erik Emilson served on the City of Sault Ste. Marie Environmental Sustainability Committee and the Sault College School of the Natural Environment Advisory Committee in 2021.

- Dr. John Gunn participated in the following public outreach initiatives in 2021:
  - ~ Contributed to MP Marc Serré's Circular Economy Symposium on 19 Jan 2021
  - ~ Presented Webinar on "Imagine Sudbury in 2050: A Global Change Community" at the Troubled Waters Symposium on 4 Feb 2021
  - ~ Featured in article 'Sudbury is a city primed for change', J. Moodie, The Sudbury Star, 10 Feb 2021
  - ~ Was one of 3 featured panelists in a 'This Is Mining' Podcast Episode called 'Breaking the cycle of climate conflict with hope and renewal' AmberMac Media on 21 May 2021 https://podcasts.apple.com/ca/podcast/bonus-epsiode-breaking-the-cycle-of-climate/id1541198021?i=1000522608920
  - ~ Opened the School of Natural Sciences seminar series with presentation 'Adapting to Climate Change: Environmental Science and the Circular Economy' 15 Oct 2021.
  - ~ Presented "Rebuilding and Rebranding Environmental Research and Programming at LU" as a vision for the future at the public session of the Laurentian Board of Governors Meeting 29 Oct 2021
  - ~ Gave a presentation to students from Xi'an University entitled "The Sudbury, Canada Recovery Story", 3 Dec. 2021

- Dr. Gretchen Lescord, along with students C. Kluke, A. Lepage, and C. Tudor gave a presentation to the Mushkegowuk Terrestrial Working Group on arsenic and chromium in northern fish and discussed the implications of their work for environmental monitoring in the Ring of Fire region.

- Dr. Nadia Mykytczuk participated in the following outreach initiatives in 2021:
  - ~ Was interviews on CKNW (Vancouver) with Sterling Faux: Morning talk radio on 'What mining, oil and gas industries can learn from Sudbury, the city that went from major polluter to thriving environment 18 Sep 2021
  - ~ Wrote an article called 'What mining, oil and gas industries can learn from Sudbury, the city that went from major polluter to thriving environment' that was published in The Conversation on 25 Aug 2021 and reprinted in the National Post 26 Aug 2021.
  - ~ Was one of 3 featured panelists in a 'This Is Mining' Podcast Episode called 'Breaking the cycle of climate conflict with hope and renewal' AmberMac Media on 21 May 2021 https://podcasts.apple.com/ca/podcast/bonus-epsiode-breaking-the-cycle-of-climate/id1541198021?i=1000522608920

- Dr. David Pearson participated in the following public outreach initiatives in 2021:
  - ~ Lockerby Composite School presentation "Why and How Much is Climate Changing Up North in Ontario?" 28 Oct 2021 (in person)
  - ~ Radio piece for Matawa Radio Broadcast hosted by Cristina Ross regarding climate change effects on the north on Wawatay Radio Station 16 Feb 2021
  - ~ Sault Climate Hub. "The Effects of Climate Change in Ontario's Far North" – 21 Apr 2021 (online)
  - ~ Climate Change Training for OFNTSC / IESO re Wataynikaneyap Powerline workers – Dec 2, 2021 (online)

- Dr. Charles Ramcharan participated in the following outreach initiatives in 2021:
  - ~ Served as a member of the City of Greater Sudbury Watershed Advisory Panel
  - ~ Served as a member of the Ramsey Lake Stewardship Committee
  - ~ Served as a member of the Greater Sudbury Community Garden Network
  - ~ Member of the Laurentian University Environmental Sustainability Committee
  - ~ Coordinator of the Laurentian Community Garden.

- Dr. Bjorn Rosseland, CFEU Senior Research Fellow in Ecotoxicology, provided training in the International Cooperative Programme (ICP) Waters Fish Dissection Certification Course to a group of 3000 students in Columbia.

- Chantal Sarrazin-Delay and Kim Fram actively posted climate change awareness material on the UpNorthOnClimate Facebook page in 2021.

- Dr. Graeme Spiers served as a member of VETAC and gave a number of virtual talks to students and the general public (see Beckett) including a ZOOM presentation on the Regreening Program in the Remediation of Degraded Zones and Landscapes Session at Agromin2021, Peru. 24 Nov 2021.

- Dr. Heidi Swanson participated in the following outreach activities in 2021:
  - ~ Presentations on results at two communities in NT Feb 2021
  - ~ Rosie Smith (PhD student) – served as science mentor for the Ikaarvik Coppermine River Health Monitoring Project – summer 2021
  - ~ Swanson and co-instructor Dr. Jennifer Liu forged a collaboration between an interdisciplinary Arts class on water and students from Six Nations Polytechnic. Seventeen high school students and 3 teachers attended the final course event at UWaterloo.

- Dr. Andrew Tanentzap with John Gunn and PhD student Samuel Woodman wrote for a piece for *The Conversation* on Sam Woodman's insect paper: https://theconversation.com/very-hungry-caterpillars-can-have-large-effects-on-lake-quality-and-carbon-emissions-171657

- Dr. Shaun Watmough participated in the following outreach activities in 2021:
  - ~ Gave seminar to Leaside High School class on Climate Change
  - ~ Hosted Sustainable Development Goals Seminar and Workshop at Trent

- Dr. Norman Yan participated in the following public presentation activities in 2021:
  - ~ "Imagining a better future for our lakes despite climate change" Invited keynote at Federation of Ontario Cottagers Associations (FOCA) Fall Seminar, 5 Nov 2021
  - ~ "Becoming Gardeners of the forest with wood ash". Invited keynote to Leonard Lake Stakeholders Association AGM. 23 Oct 2021
  - ~ "ASHMuskoka as a nature-based solution to climate change mitigation in Muskoka" Metroland Media Virtual Town Hall on climate change, 21 Oct 2021
  - ~ "Becoming gardeners of the forest", update on AshMuskoka research at the 2021 FMW AGM, 11 Aug 2021
  - ~ Yan, N.D. Protecting our Lakes Forever: Moving from rehabilitation to prevention during a time of climate change" Invited keynote lecture at Lake Kashagawigamog AGM, 18 May 2021
  - ~ "Imagining a good future for our lakes despite climate change" Invited concluding webinar in Muskoka Steamships and Discovery Centre's series on sustainability, Love Muskoka/Sustain Muskoka. 27 May 2021
  - ~ "From Fireplace to Pancakes: addressing calcium decline in Muskoka forests - a project of the Friends of the Muskoka Watershed With the help of Camp Big Canoe" Invited keynote address at Camp Big Canoe AGM. 22 Mar 2021
  - ~ "Pass the calcium, please but hold the salt: The Friends of the Muskoka Watershed's work to restore the chemistry of Muskoka watersheds". Invited webinar to the Muskoka Lakes Association, 11 Feb 2021
  - ~ "From fireplace to pancakes: a Friends of the Muskoka Watershed Project to address the widespread issue of calcium decline" Invited talk to FOCA and Sudbury lakes collaborative webinar series
  - ~ "From your fireplace to your pancakes:" Good News stories from the environment. Invited zoom lecture to grade 9 geography class, Trillium Lakelands board, 26 Jan 2021

2021 Watershed Lecture with Dr. Line Rochefort

Dr. Line Rochefort from the Université Laval gave the annual Watershed Lecture on Friday, October 22, 2021 entitled: 'Peatland Restoration: a nature-based solution to mitigate climate change and other impacts'.

Dr. Line Rochefort is a professor in the Dept. of Plant Sciences at Université Laval. She is the leader in peatland ecological restoration in Canada and one of the world's pioneers in this field. Dr. Line Rochefort's research addresses a very important social problem, namely the need to protect natural resources and ensure integrated management of peatlands for the benefit of future generations. She founded the Peatland Ecology Research Group (PERG; GRET in French) in 1992-1993 bringing together researchers from several universities, industrial partners and federal and provincial government agencies, creating a fertile and stimulating field of exchange for students and researchers.
On the same day, Dr. Rochefort hosted the annual Watershed Symposium with our graduate students. Lake Centre students presented their research projects and Dr. Rochefort provided feedback and guidance.

Dr. Rochefort's lecture, along with previous Watershed Lectures, can be found on our website at: https://laurentian.ca/living-with-lakes/research/instructional-videos

L-CARE "Mining Atmospheric Carbon" 2017-2021

Landscape Carbon Accumulation through Reduction in Emissions (L-CARE) was a $2.0M project funded by NSERC and OCE through the Target GHG Program in partnership with Vale Canada Ltd., Glencore's Sudbury Integrated Nickel Operations and the City of Greater Sudbury. The objective is to qualify how massive sulphur and metal emissions reductions in Ontario's largest mining and smelting centre, coupled with novel ecosystem reclamation practices, can lead to long-term C sequestration and influence the underlying processed of primary production, mineralization of C and energy transfer through ecosystems and interrelated GHG fluxes.

The project was led by Nathan Basiliko and John Gunn with Co-PI's at:
Laurentian: P. Beckett, B. Edwards (OMECP), N. Mykytczuk and G. Spiers
Trent: S. Watmough. Emily Smenderovac served as project manager.
Sherbrooke: J-P Bellenger
UQAM: P. del Giorgio and Y. Prairie
Cambridge: A. Tanentzap
Queen's: J. Smol, A. Paterson (OMECP)
McMaster: M. Waddington

Collaborators are located at Canadian Forest Service, NRCan (E. Emilson, T. Jones), Cornell University (J. Yavitt) the Northern Ontario School of Medicine (G. Ross), Collège Boréal (M. Hubert) and the City of Greater Sudbury (S. Monet, T. McCaffrey).

LCARE AGM June 27, 2019

LCARE Final Recommendations:

1. Industrially degraded lands or lands held in public trust (e.g. conservation areas, parks) should be the main priority for restoration efforts to prevent later loss of treed sites to urban development, roads, easements or other land-use conflicts.

2. Soil amendments are needed to maximize carbon sequestration rates. Natural regeneration rates without soil amendments or without active tree planting are simply too low. However, additional research is needed to select optimal tree planting density to meet enhanced carbon accumulation goals.

3. Reapplication of fertilizer and lime should be conducted in restored areas if soil nutrients (e.g. P), alkalinity and base cations (Ca) start to decrease as the forest stands age. The additional treatments are needed to maintain optimal tree growth rates and to prevent mobilization of metals from the soil.

4. More research into soil C dynamics is needed to be able to assess the stabilities of both old and new carbon and to determine why soil C pools are not increasing and may actually be declining. Research should include studies of how various restoration techniques could stimulate microbial nutrient cycling to maximize carbon sequestration within the trees and in the soil organic pools.

5. Continued soil erosion on slopes appears to limit soil carbon storage and tree growth. Specialized treatment of exposed slopes are needed to reduce erosion (e.g. seeding with lichen particles, addition of coarse organic matters, etc.). Regreening of slopes will be key to limiting flooding in the future.

6. In preliminary trials on upland sites, agricultural addition rates of a locally sourced lime stabilized municipal biosolid or pulp and paper mill residuals significantly increased growth, soil moisture retention, ground cover, and biodiversity compared to the standard limestone + fertilizer treatment of the "Sudbury recipe". However, before being recommended as an upland soil amendment, various logistical and potential health and environmental concerns must be addressed. Similar materials are used as substrates for thick caps (~20x higher addition rates) on mine tailings locally, but for lower addition rates and where groundwater is not monitored, questions remain about material processing for aerial/broadcast application by aircraft, and nutrient leaching. A small, watershed scale trial is recommended.

7. Regreening with the standard limestone + fertilizer treatment has often resulted in sites with low plant species diversity. This may be improved by using low cost organic amendments (municipal biosolids, pulp and paper sludge and biosolids, etc.) as well as an increased variety of planted tree and shrub species. However, species-specific planting directives (sun/shade) (dry/moist) need to be followed with an overall plan of creating a forest mosaic of species. For example, to maximize upland species richness and reduce seedling mortality, only sun and drought tolerant deciduous species should be planted in sloped and/or exposed areas until a canopy is well established.

8. The shaded to semi-shaded upland areas with topographic depressions should be reserved for deciduous species or conifers with high moisture and shade requirements. Refrain from planting fast-growing stress tolerant conifers (i.e., birch/poplars, pine) within these limited shaded or depressed areas to avoid competition with the more sensitive species.

9. Consider using more browse resistant species (e.g. staghorn sumac, eastern hemlock, balsam fir) in locations where seedlings are being quickly lost to birds and mammals. Browsing rates can also be significantly decreased on particularly expensive seedlings or ecologically important species by planting in denser vegetation areas, rather than out in the open.

10. Peatland reclamation, including active Sphagnum moss regeneration, may represent an important new opportunity for landscape-level carbon capture in the Sudbury area. Experiments and "space-for-time" surveys across Sudbury indicate improved potential for Sphagnum survival post-emissions-reductions, while 35y ago this was not possible. However, large scale reclamation efforts should not proceed before long-term (peat core analyses) and current (eddy-covariance and flux chamber approaches) C balances and past ecological states are determined.

11. Concurrent with #10, Establish greenhouse mesocosm trials to test sphagnum growth and survival under different nutrient and metal exposures, drought duration etc.

12. Test the peat-block transplant technique (e.g. using material from highway 69 construction sites) in a highly contaminated peatland, and determine the geochemical processes controlling the fate of metals in Sphagnum moss/peat and implications for restoration success. Begin modelling study on the longer-term carbon storage resilience of transplant sites to climate change (drought, wildfire)

13. Expand on the gradient and resampling work by Gingac and Beckett in the mid-1980s and in the LCARE project to complete a peatland inventory across the damaged zone as well as the larger Sudbury deposition zone. Building on information in 10-12, assess the role of peatlands in regional carbon accumulation and the C sequestration potential under future active reclamation. We will identify and map naturally recovering peatlands as reference sites for regional restoration strategies; particularly water table dynamics and metal concentration

measurements at these sites will help identify current limits to Sphagnum regeneration at severely contaminated sites.

14. Reductions (>95%) in emissions of both acids and metals have greatly improved water quality throughout the historic Sudbury deposition zone, and DOC in lake water is now returning to near normal levels. However, acidity remains a problem at several distant lakes located on sensitive bedrock (Killarney, Lady Evelyn/Smoothwater) and residual metals in free ionic form potentially remain a toxicity problem in nearby lakes. Lake monitoring therefore needs to be maintained to detect whole lake effects under multiple stressors, while we also now need to develop new nearshore (littoral zone) protocols to assess recovery of the high productivity zone (e.g. sensitive indicator species, organic matter shredders, biodiversity).

15. Future restoration treatments should focus on creating and maintaining healthy ecosystem corridors and connectivity (watersheds, connected wetland complexes, dispersal routes) to assist with biodiversity recovery and adaptation to climate change.

16. More work is need to quantify the relative effects of DOC input from restored peatlands and forests vs the in-lake processes (pH-related) that lead to DOC rise in lakes and the detoxification of residual metals (i.e. Can restoration effort generate more DOC from the catchment areas?)

17. Additional research is needed to assess and model the effects of acidification recovery, restoration and climate change on C storage and GHG emissions at the scales of lakes to watersheds and across the larger deposition zone. Information gaps remain around the impacts that reclamation procedures, new soil amendments or planned wetland restoration work may have on GHG (CO_2, CH_4, N_2O) emissions from freshwater systems, and the fate of different watershed and aquatic carbon pools under different future conditions.

18. The regional extent of impacts to forest health and C sequestration related to historically large pollution sources such as Sudbury potentially extends well beyond the visible damage zones, requiring remote sensing technologies (LANDSAT, LiDAR, Hyperspectral, etc.) to assess both impacts and recovery. Additional work is needed to ground truth estimates of carbon pools and processes (e.g. soil respiration/decomposition) requiring more use of remotely sensed information (e.g. annual measures of soil temperature).

19. We need to develop new completion criteria (beyond the regional reference approach) to assess recovery state for novel aquatic ecosystems that now have permanent alterations such as the arrival of invasive species (e.g. milfoil, bass) or expanded urban development.

20. Complete necessary fisheries assessment to allow additional lake trout fish stocking in lakes with suitable pH (e.g. OSA, Norway, Killarney, Ruth-Roy, Frederick, Dougherty, Marjorie etc.) in support of government agency restoration goals.

21. Develop disease-free culture facilities (perhaps in partnership with community colleges) to repatriate species not available in hatchery program (e.g. perch, slimy sculpins) to rebuild food webs for both fish and wildlife (e.g. loons) communities in still damaged lakes.

22. Encourage continued collaboration and use of Provincial park sites (e.g. Killarney's Lumsden Lake hilltop chain; Daisy Park's experimental sub-catchments; waterway parks) to reduce various confounding effects at study sites.

* The Briefing notes developed for the Final Project Meeting in December 2021 are included at the back of this report.

Sudbury Environmental Study (SES) Lakes

The Ministry of the Environment, Conservation and Parks (MECP) at the Cooperative Freshwater Ecology Unit (CFEU) leads 2 main lake monitoring programmes as complementary components of the long-term Sudbury Environmental Study (SES): SES Intensive Sentinel and SES Extensive Spatial.

The SES Intensive Sentinel programme is a set of lakes sampled monthly through the ice-free season for a wide range of physical, biological and chemical parameters (water chemistry, Secchi disc water clarity, temperature/oxygen profiles, zooplankton, and phytoplankton), which provide a greater variety and intensity of data on a smaller group of lakes.

The SES Extensive Spatial programme includes a set of 44 lakes, located within a 100 km zone around Sudbury. These lakes were all acidified to below pH 5.5 in the early 80s but are now in various stages of recovery. These lakes are sampled once annually during the period from late June through July. The data are intended to provide information on regional patterns in water quality and lake recovery in the lakes near Sudbury.

Associated with the Spatial lakes are a set of 24 Reference lakes, all of which were non-acidic during the original lake surveys in the 1980s. These lakes have historically been visited cyclically in the same mid-summer window, for three consecutive years per cycle with approximately 10-20 years between cycles (1981-1983; 2003-2005 and 2016-2018). For both SES Extensive and reference lakes, sampling for water chemistry occurs on every visit, and sampling for other parameters (physical and biological) occurs periodically.

In 2021, both programmes initiated a new rotating sampling regime. The majority of Intensive and Extensive lakes will now be sampled in alternate years, whereas Reference lakes will be sampled on a 3-year cycle. In accordance with this rotational schedule, 2021 field season achieved monthly sampling of 7 Intensive lakes, and mid-summer sampling of 22 Extensive and 8 Reference lakes.

MECP also provided information and analytical support for several pilot whole-lake community surveys, in collaboration with CFEU colleagues Tom Johnston (MNRF) and John Gunn, in support of the Conservation and Restoration of Aquatic Diversity in the face of Legacy and Emerging Stressors lakes (CRADLES) project, as well as for a new recovery assessment of Killarney Provincial Park, in collaboration with John Gunn and MSc candidate Haley Moskal.

Lynne Witty (as Identazoop) continued to process zooplankton samples for MECP, including those collected for the regular SES Lake Monitoring programmes, and the L-CARE and CRADLES projects.

SES Database management activities during 2021 included: 1. Updating and cleaning the Intensive and Extensive data sets, and preparation of the chemistry records for posting to the Province's open data portal, data.ontario.ca, 2. Updates to the Zooplankton database for both

the Sudbury and DESC groups under ILNSU and preparation of the Intensive zooplankton records for posting to the open data portal, data.ontario.ca. 3. In addition, several data requests were addressed from partners and collaborators. Support for other projects, including graduate student projects was also provided (data, expertise and logistics).

These monitoring programmes continue to be a critical component of Canadian and international efforts to assess the effects of acid deposition and the responses of lakes to sulphur emission controls, as well as numerous emerging concerns for Boreal Shield waters. Results from these sampling programmes have been presented and interpreted by CFEU partners and numerous collaborators. Publication highlights included several new products of the L-CARE aquatic theme, including Bridgitte Semattis's look at recent Cladocera assemblages from the paleo record in association to contemporary lake conditions, and Laura Hall's investigation of sources of DOC and relationships with other recovery signals.

Northern Fisheries Research Program

This program improves our understanding and aids the management of the fish populations that support the recreational, commercial and subsistence fisheries of northern Ontario. The program is led by Tom Johnston (MNRF) and has included a variety of projects examining the biology, ecology, and ecotoxicology of northern fish populations. Work on this program in 2021 was primarily directed at two fields of research:

i) Food web structure and contaminant bioaccumulation in northern fish populations. This work was supported in 2021 by MNRF Aquatic Research and Monitoring Section and MECP Environmental Monitoring and Reporting Branch. The geographic focus of this work is on Near North waters, particularly in the historical acid-deposition zone of NE Ontario.

ii) Reproductive ecology of northern fishes. This research was funded in 2021 by the MNRF Aquatic Research and Monitoring Section, and the Canada-Ontario Agreement (COA). We initiated a controlled-breeding experiment to determine the influence of maternal traits on egg survival in a Lake Huron lake whitefish spawning stock.

Dr. Tom Johnston provided a seminar to Laurentian's School of Natural Sciences outlining the research contributions of the MNRF:
https://laurentian.ca.panopto.com/Panopto/Pages/Viewer.aspx?id=10d85539-e2e3-4e22-b509-ae55013027d7

Contaminant burdens and speciation profiles in freshwater fishes

A project related to the Northern Fisheries Research is the analysis of various metals in freshwater fish from across Ontario and beyond. This work is being led by post-doctoral fellow and CFEU PhD graduate Gretchen Lescord and John Gunn in collaboration with Alan Lock and others at the new Purdue Central Analytical Facility (PCAF) and several researchers with the

Wildlife Conservation Society (WCS) Canada. A key component of the research, which began in February 2019, is to better understand which affects arsenic (As) and chromium (Cr) bioaccumulation and speciation in Ontario fish; recent reports from the provincial monitoring program suggest that subsistence consumers should lower their consumption of locally-harvested fish due to elevated As and Cr concentrations. This research is funded by an NSERC CRD partnership with DeBeers Canada (533736-18, Gunn and Branfireun, "Development of New Analytical Methods for Speciation of Chromium in Subsistence Fish from northern Ontario"), as well as a MITACS partnership with WCS Canada (IT13105, Lescord, "Metal concentrations and speciation in fish from the Far North of Ontario; implications for subsistence consumption and the Ring of Fire development"), 2019-2022. It also included a chromium/Ring of Fire session at the Mining and the Environment Conference held in June 2019 with participants from the US and Canada across research sectors.

The Ion Chromatography (IC) paired with Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is set-up at the Purdue Central Analytical Facility (PCAF). The equipment was installed in Spring 2019 and is being used to develop analytical methods for chromium speciation (i.e. differentiating between harmful Cr^6 and benign Cr^3) in fish tissue. These results will be used to refine fish consumption advisories.

Freshwater Invertebrate Research Network of Northern Ontario (FIRNNO)

Biological indicators such as benthic macroinvertebrates (BMI) are useful in gauging the degree of impact due to human activities. The Reference Condition Approach (RCA) to bioassessment is implemented when traditional before-after/ upstream-downstream designs are not feasible, and is based on the premise that when a site is to be assessed, its BMI community is compared to that of many minimally impacted reference sites with similar habitat characteristics. Effective implementation of the RCA design requires a large network of reference sites encompassing many habitat types from which to best match a site of interest. Such a network is currently maintained by the CFEU.

The Freshwater Invertebrate Research Network of Northern Ontario (FIRNNO) was designed to assist the metal mining industry in locating suitable reference sites to meet the Environmental Effects Monitoring (EEM) requirements of the Fisheries Act. Ongoing objectives of FIRNNO include the maintenance of an accessible database of BMI abundance and chemical/physical habitat characteristics for Northern Ontario lakes and streams and use of these resources to assess and monitor anthropogenic effects on surface waters by detecting any change in BMI community structure.

Since FIRNNO's establishment in 2003, BMI data for over 400 sites have been collected in the vicinity of 4 mining centers including Red Lake, Hemlo, Sudbury and Timmins along with accompanying water chemistry as well as site, channel and watershed level habitat data. Between 2013 and 2018, FIRNNO sampling was extended to include more than 200 additional sites as part of MECP's Ring of Fire (ROF) Baseline Environmental Data Collection Programme.

Crews from the Co-op Unit and Marten Falls First Nation added both new and temporal repeat samples across the Attawapiskat River Basin and Upper Albany River Basin, distributed across both the Hudson Bay Lowlands and Boreal Ecozones. These data provide information on the unique freshwater environments that extraction activities, infrastructure and potential transportation corridors are expected to pass through.

In 2021, sampling included 16 long-term monitoring sites in the Sudbury area, representing both local reference and impacted condition. These sites are currently on a 4-year sampling cycle, dating back to 2005.

A major initiative was also completed, to enhance collaboration and integration with the broader Ontario Benthic Biomonitoring Network (OBBN) of MECP. Brie Edwards has joined the OBBN Science Advisory Panel and is working with Chris Jones to advance OBBN research initiatives and provide province wide guidance on field and analytical best practices. In addition, all of the FIRNNO holdings have been integrated into the OBBN database and are being made available with regular updates on the Province's open data portal, data.ontario.ca.

Federal Partnerships with Canadian Forest Services/ NRCan

Dr. Erik Emilson with the Great Lakes Forestry Centre (NRCan's Canadian Forest Service) in Sault Ste. Marie, provides a digital contribution to the report as a seminar in Laurentian's School of Natural Sciences, documenting the extensive partnership projects focus on land/water linkages entitled "Managing Canada's Forest: Partnership with Cooperative Freshwater Ecology Unit"

https://laurentian.ca.panopto.com/Panopto/Pages/Viewer.aspx?id=3aef8359-0b86-419f-895e-ae4e013a3317

Ontario University Program in Field Biology (OUPFB)

The OUPFB Program did not run in 2021 due to the Covid-19 pandemic. We look forward to being able to safely offer this experience to students again soon. Dr. Gunn continues to serve as the OUPFB Coordinator for Laurentian University and Karen Oman provides administrative assistance.

Laurentian's OUPFB Class of 2019 in Killarney Park, ON.

Collaborative Project with Peru

A research team comprised of MIRARCO's President and CEO, Dr. Nadia Mykytczuk, Laurentian University Emeritus Professor and CFEU Senior Research Fellow in Freshwater Biology, Dr. Charles Ramcharan, and MSc. student Lianne Girard, travelled to Peru to initiate the first phase of a new collaboration with Universidad Nacional de Moquegua (UNAM) and CORE Foundation. The project, which is led by MIRARCO and UNAM, aims to better understand the mining and other anthropogenic impacts in the Coralaque River watershed and work to develop treatment solutions and a remediation plan to improve the water quality throughout the watershed. In spite of pandemic-related challenges, it was imperative that the project got underway in order to help the local Peruvian communities that have been living in a state of emergency due to concerns about water quality in the area.

The team successfully completed the initial investigation phase that included challenging fieldwork, working throughout the entire watershed of the Coralaque river, from the high altitude mine areas (4800 meters above sea level) to the lowlands where the Tambo River reaches the Pacific ocean. A total of 17 sites were sampled overcoming treacherous roads and rapidly shifting weather conditions, from rain and snow to very dry conditions. Other project researchers include CFEU Senior Research Fellow in Pedology, Dr. Graeme Spiers and CFEU Senior Research Fellow in Ecosystem Restoration, Dr. Peter Beckett both of whom will be leading different phases of this operation.

New collaboration opportunities with several Peruvian universities were first initiated by Laurentian University's Goodman School of Mines in 2019. This project is the first of several collaborative efforts both Laurentian University and MIRARCO will be participating in. The successful commencement of this venture would not have been possible if not for the support of UNAM faculty and staff, Core Foundation, and several regional environmental research groups. Endeavors such as this one require support not only from partner universities but also regional and national entities in Peru. During their time in Peru, Dr. Mykytczuk and the team met with the governor of Moquegua to share information, request additional support, and build partnerships across sectors.

Science Communication at the Vale Living with Lakes Centre

www.sciencecommunication.ca

Master's and Graduate Diploma in Science Communication (MSCom, G.Dip)

Having delivered our program remotely for the entirety of the 2020-2021 academic year, it was truly a pleasure to finally be in person at the Lake Centre with our new cohort of 11 Science Communication students in September 2021. The Science Communication Graduate Program continues to contribute to the projects, research and education of graduate students at the Vale Living with Lakes Centre. We do this through research projects and communication products that focus on the work being done by CFEU researchers and VLWLC scientists. Despite the pandemic, and perhaps partially due to it, a total of 16 students (13 full time and 3 part time), graduated with a Master's of Science Communication in the fall of 2021. The remote and online course delivery was a welcomed option for students whose personal life commitments would have prevented them to make the move to Sudbury for a year.

The pandemic has put a spotlight on the importance of effective and impactful science communication, making our program and our expertise in this field highly sought after by scientists, health professionals and potential students alike. The demand for professionally and academically trained science communicators ensures our program's sustainability. We are still uniquely positioned as the only Science Communication graduate program in Canada. The following paragraphs will highlight some of the many successes our students and our faculty had in 2021.

Audience Engagement Highlights

As Laurentian faced an uncertain future, it was of utmost importance to demonstrate to the local community the valuable and unparalleled work done by the CFEU and VLWLC researchers and students. One of the ways we were able to do this was to host a virtual Earth Day Celebration, in collaboration with Science North called *"Science for a Changing North"*. Science Communication faculty collated the zoom recordings of the researchers' AGM presentations, and produced a series of science stories that were shared and moderated to a live online audience through Science North's Facebook and YouTube channels. Everyone who tuned in heard directly from the researchers who continue the vital environmental work in our region - students, scientists, and innovative research teams tackling the environmental challenges of yesterday, today, and tomorrow. Science North was proud to help us "Celebrate Earth Week by learning how the Vale Living with Lakes Centre team helps ensure clean water, now and forever".

Student achievements:

The Science Communication graduate students continue to benefit from belonging to the Vale Living with Lakes Centre. Collaborations between the Science Communication program and Lakes Centre's graduate students and researchers allows CFEU and VLWLC research to be the focus of SCOM student projects and assignments. For example, in 2021, the Science Communication students developed and produced short research videos in collaboration with the Master's in Biology students, and wrote media releases based on the published work of lake centre researchers. The Science Communication students were judges for over 30 graduate research

presentations, including graduate students from VLWLC, at the Graduate Research Symposium during LU Research Week 2021. And finally, all of the students from the SCOM class of 2021 were employed in their field by the end of the year!

Alumni Nina Nesseth (class of 2018) and Sole Machado (Class of 2020) published their master research papers with the guidance of Science Communication faculty in 2021:

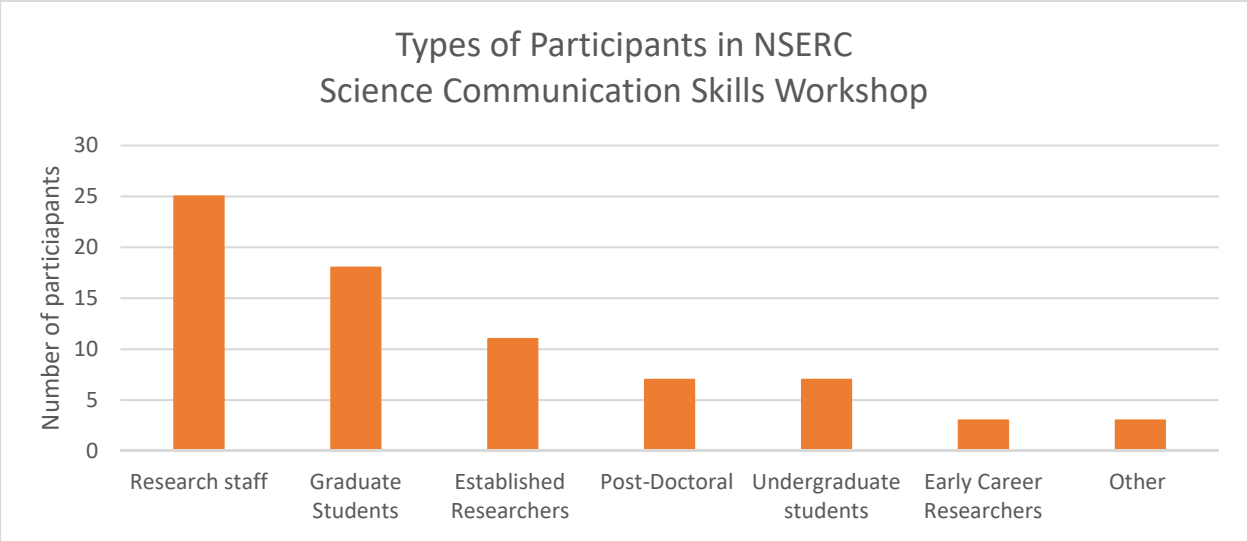
Nesseth, N.M., Henson, A.M., and Barriault, C.L. 2021. A Framework for Understanding the Nature of Questions Asked by Audience Participants at Science Cafés. *Frontiers in Education.* 6: 674878. doi:10.3389/feduc.2021.674878

Machado Corral, S., Monteiro, P.H.N., Pisani, K., and Barriault, C.L. 2021. Facilitators Improve the Learning Experience of Visitors to a Science Centre. *Frontiers in Education.* 6:675124. doi:10.3389/feduc.2021.675124

Program and Faculty Highlights:

Science Communication Professional Development and Training of HQP

In 2020, we were awarded one of 20 NSERC Science Communication Skills Training Pilot Grants in Canada. In 2021, we developed, produced and delivered science communication professional development during a 3-day virtual workshop for scientists, researchers and faculty from across Canada. In August, a total of 74 participants (Figure 1) joined SCOM faculty Dr. Chantal Barriault and Michelle Reid virtually to learn about evidence-informed science communication strategies and to develop a toolbox of practical skills to engage in their own science communication efforts.



Covid-19 Communication

The global pandemic certainly put a spotlight on the need to communicate science for maximum understanding and impact. The Science Communication Faculty was invited to contribute to many COVID-19 communication projects. Dr. Chantal Barriault was a panelist for Science North

and Laurentian's webinar series *Let's Talk About COVID-19: Misinformation in a Global Pandemic Era*, with Dr. Tim Caulfield and SCOM graduate, Samatha Fowler.
Michelle Reid provided training for Science North staff on how to deal with COVID-19 misinformation, and was an invited panelist on this subject for Science North's virtual Nerd Nite. We were also part of CROSH's NSERC grant to develop and deliver the Northern Ontario Community Immunity Tour. Finally, our students effectively delivered a month-long social media campaign to train people how to deal with COVID-19 information and misinformation online.

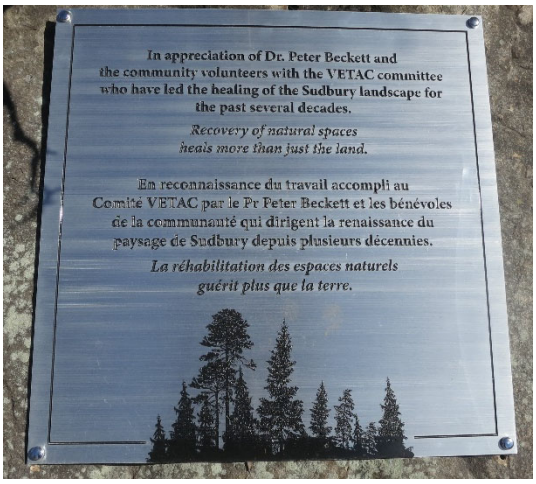
Carbon Offset Forest

The City's recent celebration of 40 years of regreening, under the leadership of many, including CFEU scientist Dr. Peter Beckett, has focused primarily on the beautification and increased biodiversity of the region, but increasingly we recognize the importance of reforestation of barren industrial landscapes in carbon sequestration as well. Our researchers have, for example recently estimated that more than 1 million tons of C have been captured through the regreening efforts to date and through the return of a natural regenerating forest with cleaner air. That is the amount of carbon in wood needed to build over 550 Living with Lakes Centres. However, much more is needed in the battle to slow the rise in atmospheric CO_2. The CFEU has greatly contributed to the science needed to enhance carbon sequestration through its L-CARE research, but it also worked to encourage the University and partners to continue to cooperate on pollution reduction and remediation projects, and to promote a restored landscape through tree planting and creating organic covers for industrial properties.

Dino Otranto, COO Vale Ltd., McGill Professor and Indigenous Scholar Dr. Cindy Blackstock and Peter Xavier, VP Sudbury Integrated Nickel Operations Glencore were among guests who helped to initiate the new carbon offset forest at LU.

Recovery Garden

The Student General Association (SGA) with assistance from John Gunn at the VLWLC were delighted to open a beautiful recovery garden in Founders Square in 2021. The limestone-encircled garden is dedicated to Dr. Peter Beckett and the VETAC Committee for their decades of regreening work in Sudbury. The garden also incorporates an existing memorial to Dr. Thomas Peters, from Inco (later Vale), who was one of the pioneers of the regreening program. The recovery garden features many of the plants used by the City in restoration and the name "recovery" speaks to the benefits a healthy environment provides to us all in these challenging times.



United Nations Restoration Trail

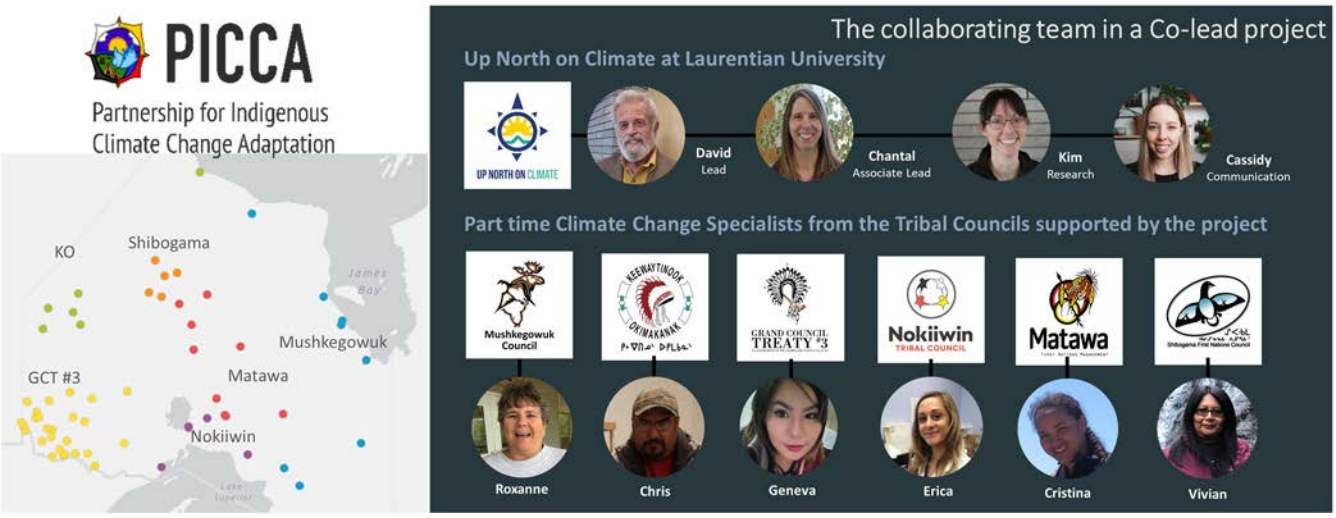
On Oct. 21, 2021, the UN Restoration Trail was officially opened on campus, beginning in Founders Square and moving down through the pine forest established by delegates of the Mining and the Environment Conference, held at Laurentian on May 28-Jun 1, 1995 to recognize the regreening award won by Sudbury at the UN Earth Summit Conference at Rio de Janeiro in 1992. The trail loops back to the Indigenous Sharing and Learning Centre and then ends at the Laurentian beach on Nepahwin Lake. UN Ambassador Bob Rae and global environmental leader Dr. Jane Goodall provided video messages of hope and appreciation to Laurentian and the students.

Message to Laurentian Students from Dr. Jane Goodall
https://drive.google.com/file/d/1J_-TMJNeSEls9SFSz4KYsuVsuwbcgqsT/view?usp=sharing

Message to Laurentian Students from Bob Rae
https://drive.google.com/file/d/1QVKBLm8xHFzXA9mLNMXKTE7Ew0zDm9bS/view?usp=sharing

Up North on Climate - Northern Climate Change and Adaptation

During 2021, our "Up North on Climate" team collaborated with Grand Council Treaty 3 and five Tribal Councils across the north of the province in an NRCan supported project through the Building Regional Adaptation Capacity and Expertise (BRACE) program: "Building Climate Change Adaptation Capacity of First Nations in Far Northern Ontario Through Knowledge-Exchange and Collaboration". We have collaboratively come to a name for our group: "Partnership for Indigenous Climate Change Adaptation", PICCA.



The objective of the project is to build climate change adaptation capacity in northern First Nations; to establish an interactive, regional, online adaptation knowledge network; to co-produce culturally appropriate adaptation resources, and to co-design an ArcGIS online GeoHub on key climate change topics including traditional Indigenous and science knowledge.

The process we have developed involves training and paying a Climate Change Specialist (CCS) recruited by each of the six co-lead councils. The role of the Climate Change Specialist is to promote climate change adaptation in their tribal council and member communities. The whole team of CCSs and the Laurentian group meet weekly. A Coordinating Panel of the Co-leads meets approximately every 6 weeks or as needed.

The project is capitalizing on previously written community climate vulnerability reports produced as part of our earlier collaborative 2016 – 2018 "Climate Change Impact and Adaptation Study for the North", that splice community-gathered Traditional Ecological Knowledge with climate science. CCSs are using gathered information that will help communities develop a climate change adaptation plan.

A previously developed 100-page adaptation document included in each community report as well as 36 detailed InfoSheets covering drought, ecosystem shifts, fire, flooding, food security,

health, infrastructure, and transportation were the basis for an adaptation Quick Guide. With a series of 8 graphic 2-pagers, the Adaptation Quick Guide provides a visually appealing starting point to begin discussions about preparing for the climate of the future, as well as adapting to the climate of today. A Climate Change Quick Guide is also being developed covering; What is climate change, the greenhouse effect, climate change then vs now and climate projections.

A quadrilingual climate change glossary, “Climate Change Word Guide: 101 climate change words and their meaning” is in the translation stage. We have also created an Adaptation Framework to help First Nation communities or Tribal Councils move towards climate change adaptation. Steps include learning about climate change and adaptations, gathering knowledge from the community, discussing adaptation options, implementing projects, and evaluating success.

All resources are posted on UpNorthOnClimate.ca. The website also showcases locally developed data visualizations, graphics, and GIFs on seasonal temperature. We continue to moderate ACClimateNow, a closed Facebook Group for the Climate Change Specialists and staff in Tribal Councils and communities with responsibilities touched by climate change in northern Ontario First Nations. It serves as a social learning and discussion platform. Bi-weekly 100-word posts keep CCS engaged and stimulate conversations. Resources, as they become available are also being posted on ACClimateNow to allow for ease of access to printable resources for CCS to distribute to their communities. Similar 100-word posts are also being provided to the general public on our open FB page, Up North On Climate.

This year, we began to build the GeoHub and course for First Nations by First Nations. We are collaboratively creating an online GeoHub, the Partnership for Indigenous Climate Change Adaptation, as a one-stop culturally appropriate, plain language and graphically accessible source for climate change information and data (maps from open data, knowledge, both scientific and Traditional Knowledge, monitoring data, adaptation case studies, adaptation planning tools, discussions of best practices and experiences on the land) all relevant for First Nations considering the impacts of climate change in Northern Ontario. All GeoHub resources are being

presented in a Storymap to guide the reader through how resources can be useful in developing adaptation plans in their community. These Storymaps will form the basis for the course.

The project's future goals are to complete the PICCA GeoHub and course. We also hope to visit communities and interview Elders and youth to include more indigenous voices in the GeoHub. We are exploring how to host the course, perhaps on Laurentian University's D2L, as a microcredential for First Nations and others. We are also working to include near north First Nations into the project.

Conference Organizing, Program Coordination and Editorial Activities

Arnott, S

- Associate Director, Queen's University Biological Station
- Associate Editor for Ecology & Ecological Manuscripts
- Guest Editor for Ecological Applications
- Served on Planning/Program committee and Plenary subcommittee for the Joint Aquatic Sciences Meeting (JASM2) 2022 to be held in Grand Rapids, MI in May 2022

Barriault, C

- Topic Editor, Frontiers in STEM Education. Special Issue: Learning Science in Out-of-School Settings.

Basiliko, N

- Associate Editor, Soil Research
- Associate Editor, FEMS Microbiology Letters
- World Congress of Soil Science 2030 Bid Committee member (for the Canadian Society of Soil Science bidding to hold the meeting in Toronto in 2030)
- Past President of the Canadian Society of Soil Science 2021

Beckett, P

- Served on the Technical Committee for the Planning for Closure International Conference, Chile
- Co-Chair of the Ontario Nature Annual Gathering and AGM being held in Sudbury, June 2022

Belzile, N

- Associate Editor for the Journal of Geochemical Exploration
- Served on the Editorial Board of the Research Journal of Environmental Sciences
- Served on the Editorial Board of Green and Sustainable Chemistry
- Served on the Editorial Board of Environments

Emilson, E

- Associate Editor for the Canadian Journal of Forest Research

Gunn, J

- Director of the Vale Living with Lakes Centre, Laurentian University (2011-present)
- Special Editor PNAS
- NSERC DG and CRD program reviewer

Ielpi, A

- Associate Editor for Precambrian Research
- Guest Editor for a Special Volume of the Geological Society of London

Lescord, G

- Provided reviews for the journals of Environmental Science and Technology, Science of the Total Environment, Environmental Toxicology and Chemistry, and Food Webs.

Mykytczuk, N

- Editor, Canadian Journal of Microbiology (2017-present)
- Associate Editor, Water, Air, and Soil Pollution (2016-present)
- Served on the Editorial Board for the Journal of Microbiological Methods (2014-present)
- Review Editor: Frontiers, Terrestrial Microbiology, Biogeochemical Dynamics (2018-Present)
- NSERC DG program external reviewer (2013-present)
- NSERC CRD program external reviewer (2017-present)
- MITACS external reviewer (~2/year 2017-present)
- Canada Research Chairs (CRC) Program External reviewer (2021)

Ramcharan, C

- Associate Editor, Canadian Journal of Fisheries and Aquatic Sciences

Swanson, H

- Associate Editor, Arctic Science
- Associate Editor, Canadian Journal of Fisheries and Aquatic Sciences

Tanentzap, AJ

- Associate Editor at the Journal Nature Scientific Reports
- Associate Editor at Journal of Vegetation Science
- Associate Editor for PLoS Biology
- Dr. Tanentzap has also been coordinating a global network of >100 individuals from 70 sites worldwide that are sampling water as part of the GLEON DOMseasons project (https://gleon.org/research/projects/domseasons-tracking-seasonality-dissolved-organic-matter)

Watmough, SA

- Director of the Trent School of the Environment (appointed June 2016)
- Board Member, Canadian Colleges and University Environmental Network
- Editorial Board Member for The Science of the Total Environment
- Performed 3 grant reviews for Northeaster States Research Cooperative
- Reviewed 22 journal articles
- Conducted a Program Review for Mount Royal Environmental Science Program (Oct 2021)
- Led working group to develop a new Degree "Climate Change Science and Policy" that starts in Sept 2022.

Partners and Collaborators

- Aboriginal Aquatic Resources and Oceans Management Program
- Agnico Eagle Mines Ltd.
- Appalachian State University
- Boniferro Millworks
- Canadian Kraft Papers
- City of Greater Sudbury
- Clergue Forest Management
- Cornell University
- Dehcho First Nations
- Dept. of Fisheries and Oceans Canada
- DMI- Peace River
- Domtar Inc.
- Dorset Environmental Science Centre
- Dryden Forest Management Company
- Environment and Climate Change Canada
- Forest Protection Limited
- Friends of Killarney
- Government of Northwest Territories
- Glencore Sudbury INO
- Global Salt Initiative
- Grand Council Treaty 3
- Great Lakes Forestry Centre, NRCAN-CFS
- Great Lakes Fishery Commission
- Hunters and Trappers Organization, Kuglutik NU
- Irving Pulp and Paper
- Keewaytinook Okimakanak (Northern Chiefs) Tribal Council and member First Nations
- Laurentian University
- Matawa First Nations Management, Four Rivers Environmental Services Group and member First Nations
- McGill University
- McMaster University
- Memorial University
- Michigan Tech U
- Ministère des Forêts, de la Faune et des Parcs (MFFP)
- Mushkegowuk Tribal Council and member First Nations
- Natural Resources Canada
- Nipissing University
- Nokiiwin Tribal Council and member First Nations
- Northwest Territories Geological Survey
- OMECP
- OMNRF
- Ontario Forest Research Institute (MNRF)
- Queen's University
- Rayonier Advanced Materials
- Ryerson University
- Science Up First

- Shibogama Tribal Council and member First Nations
- Skidmore College
- South West U. of Science &Technology
- Tianjin Univ. of Science &Technology
- Trent University
- University Health Network
- University of Birmingham
- University of Cambridge
- University of Geneva, Switzerland
- University of Guelph
- University of New Brunswick
- University of Northern British Columbia
- Université Laval
- Université du Québec à Montréal
- University of Sherbrooke
- University of Toronto
- University of Victoria
- University of Waterloo
- University of Winnipeg
- US Fish and Wildlife Service
- US Forest Service
- US Geological Survey
- Vale Ltd.
- Western University
- Weyerhauser Canadian Timberlands
- Wildlife Conservation Society Canada
- York University
- Yukon Geological Survey

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Verbeke B, LJ Lamit, E Lilleskov, J Chanton, S Hodgkins, N Basiliko, E Kane and 55 co-authors subsequently listed alphabetically including S Johnson and M Carson. 2022. Latitude, elevation, and mean annual temperature predict peat organic matter chemistry at a global scale. Global Biogeochemical Cycles 36: e2021GB007057

Watkinson A, M Juckers, LD Andrea, P Beckett and G Spiers. 2022. Ecosystem recovery of the Sudbury technogenic barrens 30 years post-restoration. Eurasian Soil Science. DOI: 10.1134/S106422932205012X

Watmough, SA, J Aherne and D Marmorek. 2021. Letter to the Editor: Impacts of industrial atmospheric emissions on watershed export of dissolved ions in coastal streams: a Bayesian modeling approach. Environmental Monitoring and Assessment 4:1-3.

Watmough SA, S Gilbert-Parkes, N Basiliko, LJ Lamit, E Lilleskov (core author group) and 47 others including C Robinson, M Carson, G Guo and S Johnson. 202X. Evaluating carbon and nitrogen concentrations in peatland soils at the global scale. PLoS-One. In review.

Wang B, Y Huang, W Liu, S Chen, J Zhu, N Belzile, Y-W Chen, M Liu and C Liu. 2021. Returning excrements from livestock, poultry and human to farmlands as nutrient resources for crop growth: Assessment of in rural China. Process Safety and Environmental Protection 146:412-423. doi.org/10.1016/j.psep.2020.09.001

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Webster KL, JA Leach, PA Hazlett, RL Fleming, EJS Emilson, D Houle, KHY Chan, F Norouzian, AS Cole, JM O'Brien, KE Smokorowski, SA Nelson and SD Yanni. 2021. Turkey Lakes Watershed, Ontario, Canada: 40 years of interdisciplinary whole-ecosystem research. Hydrological Processes 35(4):e14109.

Webster KA, JA Leach, D Houle, PA Hazlett and EJS Emilson. 2021. Acidification recovery in a changing climate: Observations from thirty-five years of stream chemistry monitoring in forested headwater catchments at the Turkey Lakes watershed, Ontario. Hydrological Processes 35(9):e14346.

Woodman SG, S Khoury, RE Fournier, EJS Emilson, JM Gunn, JA Rusak and AJ Tanentzap. 2021. Forest defoliator outbreaks alter nutrient cycling in northern waters. Nature Communications 12:6355. *Reported on by The Telegraph, The Times, The Independent, etc; TV interviews with CTV; Selected as Editor's Highlight.

Yin MX, C Martineau, I Demers, N Basiliko and NJ Fenton. 2021. The potential environmental risks associated with the development of rare earth element production in Canada. Environmental Reviews 29:354–377.

Zabel N, RI Hall, BA Branfireun and HK Swanson. 2021. Mercury accumulation in sediments of Lhù'ààn Mân' (Kluane Lake, YT): Response to past hydrological Change. Arctic, Antarctic, and Alpine Research. https://doi.org/10.1080/15230430.2021.1940790

Zheng R, B Wang, S Chen, Y-W Chen, N Belzile, Y Yang, Y Chen, B Lin, Z Liu, J Sun and W Wang. 2021. Historic records on mineralogical and chemical compositions of a long sediment core from the Three Gorges Reservoir and implications for future studies. Environmental Earth Sciences. 80-612, 16 pages + 9 pages of on-line supporting information. doi.org/10.1007/s12665-021-09830-0

Zuykov M, G Kolyuchkin, GA Spiers, M Gosselin, P Archambault and M Schindler. 2021. Pre-exposure to Cu2+ and CuO NPs leads to infection of caged blue mussels, Mytilus edulis L., by pathogenic microalga: Pilot study in the Lower St. Lawrence Estuary (Québec, Canada). Mar Pollut Bull. 166:112180.

Zuykov M, L Hayhurstb, N Murakami-Sugiharac, K Shiraic, G Spiers and M Schindler. 202X. Periostracum of bivalve mollusks shell a novel passive sampler of engineered metal nanoparticles: a case study of sulfidized silver nanoparticles in Canada's experimental lake. In review.

Reports

Johnston, TA, JJ Montgomery, GL Lescord, KA Patterson, LC Haslam, K Tremblay, GE Morgan, HK Swanson, N Commanda, SD Kaufman and JM Gunn. 2021. An isotopic analysis of food web structure and trophic interactions in Lake Nipissing, Ontario. Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry, Science and Research Branch, Peterborough, ON. Science and Research Technic

Nerentorp M, F Wang, GL Lescord, et al. 2021. Chapter 4: Changes in Arctic mercury levels – Processes affecting mercury fate and biological uptake. AMAP Assessment 2021: Mercury in the Arctic. Arctic Monitoring and Assessment Programme. https://www.amap.no/ . Summary for policy makers: https://www.amap.no/documents/download/6758/inline.
al Report TR-45. 62 p. + appendices

Conference Presentations
(Presentations in 2021 were delivered virtually due to Covid-19 travel restrictions)

Arnott SE. Studies across scales to understand impacts of environmental change. 2nd International Aquatic Mesocosm Research Symposium - from local processes to cross-domain interactions. Heraklion-Crete, Greece. 12-16 Apr 2021. Invited Plenary.

Basiliko N. The tiny majority: how microbes mediate ecosystem functioning under anthropogenic stressors. Laurentian University School of Natural Sciences Seminar Series. Mar 2022.

Basiliko N. Mill residual utilization. 33rd Annual Pulp and Paper Research Consortium at the University of Toronto, ON. Nov 2021.

Basiliko N and K Chan-Yam. Challenges and prospects of methane management in ecosystems: a case study of enhancing methane and energy recovery from organic waste streams in the forestry sector. First annual International Methane Workshop, U Waterloo, ON. Mar 2021.

Beckett PJ and GA Spiers. 2021. Restoration of urban forests in a smelter-emissions impacted landscapes enhances biodiversity and carbon sequestration to mitigate today's climate emergency. Bioremediation of the Arctic Coastline, Conference sponsored under the framework of the Arctic Council Russia's chairmanship (2021-2023), Moscow. 25-26 Oct 2021. Invited.

Beckett PJ and GA Spiers. 2021. Sudbury, Canada - 40+ Years of Healing and Creating Novel Functional Ecosystems on a Smelter-Impacted Landscape. Third International Conference Forest and Landscape Restoration of Post-mining Sites, Prague. 3-6 Jun 2021.

Bodmer P, JP Casas-Ruiz, KA Bona and 15 others including EJS Emilson. Integration of aquatic and terrestrial fluxes to improve landscape-atmosphere carbon exchange assessments. International Boreal Forest Research Association. 2021.

Buren S and SE Arnott. Salty Experiments: The effects of calcium on acute chloride toxicity in *Daphnia* species. International Conference on Conservation Biology. Dec 2021.

Byun E, F Rezanezhad, L Fairbairn, N Basiliko, J Price, W Quinton, P Roy-Léveillée, K Webster and P Van Cappellen. 2021. Temperature and moisture controls on non-growing season CO_2 emissions in laboratory incubations with soils from northern peatlands. European Geophysical Union General Assembly. 19-30 Apr 2021.

Dawson JC, BA Edwards, EJ Emilson, KS McCann, MM Guzzo and JM Gunn. Sampling scale matters most when detecting change in everything from microbes to fish in recovering ecosystems. CCFFR-SCL. 15-19 Feb 2021.

Deslauriers C, M Allard and P Roy-Léveillée. 2021. Ground temperature responses to climatic trends in a range of surficial deposits near Kangiqsualujjuaq, Nunavik. Cold Regions Engineering 2021, American Society of Civil Engineers. 2021 Regional Conference on Permafrost and 19th International Conference on Cold Regions Engineering, Boulder, CO, USA. 24-29 Oct 2021.

Edwards BA. Monitoring Ontario's inland waters: Overview and recent insights from the Sudbury region. Laurentian University School of Natural Sciences Seminar Series. Mar 2022.

Freeman E, EJS Emilson, T Dittmar and AJ Tanentzap. Dissolved organic matter molecular diversity and flow within the harvested forest terrestrial-aquatic network. Changing Boreal Biome, International Boreal Forest Research Association.

Freeman EC, EJS Emilson, T Dittmar, G Singer and AJ Tanentzap. Dissolved organic matter molecular diversity and flow within the harvested forest terrestrial-aquatic network. ASLO Aquatic Sciences Meeting. 22–27 Jun 2021

Gohil K, BA Edwards and JM Gunn. Zooplankton community compositions in DOC enriched Sudbury lakes. CCFFR-SCL. 15-19 Feb 2021.

Hutchinson NJ and ND Yan. 2021. Climate Change as a Stress Multiplier Governing Algal Blooms in Oligotrophic Lakes. Canadian Ecotoxicity Workshop. Halifax, N.S. 5 Oct 2021.

Ielpi A. 2021. Bridging Geomorphology and Precambrian Geology: A broad view of the Precambrian fluvial record, and why modern hinterland basins matter. Virtual Seminars in Precambrian Geology, University of California-Riverside, Riverside, CA USA, 26 May 2021. Invited.

Ielpi A. 2021. Rivers of change: Fluvial geomorphology as key to UN's decade on ecosystem restoration. School of Earth, Environment & Society, McMaster University, Hamilton, ON. 4 May 2021. Invited.

Johnston TA, JJ Montgomery, GL Lescord, KA Patterson, LC Haslam, K Tremblay, GE Morgan and HK Swanson. 2021. Food web structure of Lake Nipissing following recent community shifts. Canadian Conference for Fisheries Research (Virtual), 17 Feb 2021.

Kidd KA, L Negrazais, M Erdozain, M Gray and EJS Emilson. 2021 Are there downstream impacts of forest harvesting on food webs and their bioaccumulation of mercury? Canadian Ecotoxicity Workshop. Halifax, N.S. Oct 2021.

Kirkwood A, P Roy-Léveillée, B Branfireun, M Pakalen, J McLaughlin and N Basiliko. 2021. Mercury, methylmercury, and microbial communities in a degrading palsa of the Hudson Bay Lowlands, Far North Ontario. Cold Regions Engineering 2021, American Society of Civil Engineers. 2021 Regional Conference on Permafrost and 19th International Conference on Cold Regions Engineering, Boulder, CO, USA. 11-16 Jul 2021.

Lepage A, G Lescord and JM Gunn. Bioaccumulation and speciation of As and Hg in Fish Tissue within Se-rich aquatic environments near Sudbury, Ontario. Society of Environmental Toxicology and Chemistry (SETAC) North America Meeting. 14-18 Nov 2021.

Lescord G. Food for thought: mercury, arsenic, and chromium in Ontario fish. Ontario regional Chapter of the Society of Environmental Toxicology and Chemistry. April 2021.

Louste-Fillion JS, JM Gunn and BA Edwards. Recolonization and repatriation of chemically recovered lake trout lakes. CCFFR-SCL. 15-19 Feb 2021

Mitchell C, K Kidd, S Melles, EJS Emilson, R Mackereth, WY Lam, P Huang, V Mangal and C Lajoie. Mercury and Forest Harvest. CIF-SEEK Meeting. 2021.

Mykytczuk, N. Remediación del paisaje de Sudbury. CONGRESO ECOMIN. 19-20 Oct 2021. Peru. Delivered in Spanish. Invited seminar.

Negrazis L, KA Kidd, M Erdozain, EJS Emilson, CP Mitchell and M Gray. Longitudinal impacts of forest management on mercury bioaccumulation and trophic transfer. SETAC North America 42nd Annual Meeting. 14-18 Nov 2021.

Robinson C, P Roy-Léveillée, K Turner and N Basiliko. 2021. Impacts of shrubification on ground temperatures and carbon cycling in a sub-arctic fen near Churchill, MB. Cold Regions Engineering 2021, American Society of Civil Engineers. 2021 Regional Conference on Permafrost and 19th International Conference on Cold Regions Engineering, Boulder, CO, USA. 24-29 Oct 2021.

Spiers GA, P Beckett and N Mykytczuk. 2021. The Sudbury Protocol - Forty Five Years of Landscape Healing. II Convencion Agrominera, Lima, Peru. 24-26 Nov 2021. Invited.

Spiers GA and PJ Beckett. 2021. Manufacturing Carbon-Rich Anthroposols on Mine Waste Materials in Boreal Regions of Ontario, Canada. Bioremediation of the Arctic Coastline, Conference sponsored under the framework of the Arctic Council Russia's chairmanship (2021-2023), Moscow. 25-26 Oct 2021. Invited.

Research Grants

Arnott, S

- NSERC Discovery Grant, A multi-scale approach to identifying the ecological impact of co-occurring environmental stressors (2019-2024)
- OMECP, Effect of water hardness on chloride toxicity (2021-2023)
- Science Communication Skills Grant (Pilot). Development of an anti-racist science communication training program. PI Orihel and Yakimowski (2021-2022).
- South Frontenace Ecosystem grant. Effects of road salt runoff on South Frontenace Lake Ecosystems. PIs MSc Students Cicchetti and Martin (2021-2022)
- ArcticNet, Ensuring water security in the High Arctic: understanding the impacts of changing permafrost, hydrology, and water quality on aquatic ecosystems. Lafreniere (PI) (2019-2024)
- Matariki Queen's-Dartmouth Fund, Assessing zooplankton response and resilience to chloride contamination (2019-2021)

Barriault, C

- SSHRC Insight Development Grant, Collaboration project with the Huron Wendat Nation (HWN) to examine Wendat history through pottery in the Lower Great Lakes and St. Lawrence Valley. Funding for SCOM students to develop and deliver an archeological pottery exhibit for Science North and the Huron Wendat Museum. PI: Dr. Alicia Hawkins. (2020-2022)
- NSERC PromoScience, Science Communication Training Pilot Fund (2020-2021)
- NSERC Encouraging Vaccine Confidence in Canada fund, Collaborator (Jul 2021 to Jan 2022)

Basiliko, N

- NSERC Canada Research Chair Tier II in Environmental Microbiology (2018-2023)
- NSERC Discovery (DG) The tiny majority: how microbes mediate ecosystem functioning under anthropogenic stressors in boreal environments (2019-2024)
- NSERC Innovation Links Grant. Constraints on northern aggregate mine reclamation and novel reclamation strategies for enhancing biodiversity and ecosystem functioning with

M Hebert, M Nellis, R Rochon, S Bouchard, R Craig (Collège Boréal), G Spiers, and P Beckett (Laurentian U) (2021-2024)

- NSERC Advancing Climate Change Science in Canada (ACCS) program: Winter carbon losses in wetland ecosystems under current and future climates. With F Rezanezhad PI et al. at (U Waterloo), Bill Quinton (Wilfrid Laurier), P Roy-Léveillée (Laval) (2019-2022)
- MITACS Accelerate. Capture and repurposing of waste industrial emissions for improved economic and environmental sustainability. With Scott (PI) and Laamanen (2019-2021)
- SSHRC Partnership Development Grant. Reassembling Ontario's "Near North": Reparation through university-museum-Indigenous research partnerships. With Greer (PI) Peltier and Helmsworth (Nipissing U) (2019-2022)
- NSERC Collaborative Research and Development Grant (CRD): Enhancing dewatering, drying, combustion and utilization of pulp and paper mill biosludge with G Allen (PI) and 7 others (2017-2021)
- NSERC Research Tools and Infrastructure (RTI) Grant. A macronutrient (C and N) analysis system for studies of natural and stressed soils and waters. Nathan Basiliko (PI), and J Gunn. Awarded April 2020
- CFI- John Evans Leaders Fund (JELF) Environmental geophysical infrastructure for understanding permafrost change and biogeochemical feedbacks. Nathan Basiliko (PI) with P Roy-Léveillée and N Mykytczuk. Awarded Fall 2020; matching ORF funding pending.
- Polar Knowledge Canada How shrubification influences hydrology, permafrost, and mercury mobilization: a cross-disciplinary approach to landscape change to support community resilience in Old Crow Flats, YT. P Roy-Léveillée PI, with Turner, Branfireun and Calmels (2020-2023)
- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use. N Basiliko (PI) with J Gunn (co-PI), N Mykytczuk, G Spiers, P Beckett (Laurentian), J Smol, A Paterson (Queens University), JM Waddington (McMaster University), S Watmough (Trent University), P del Giorgio, Y Prairie (UQAM), JP Bellenger (University of Sherbrooke). $2,000,000 from NSERC, OCE, and industrial partners Vale Ltd. and Glencore's Sudbury Integrated Nickel Operations (2018-2021).

Beckett, P

- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)
- NSERC Innovation Links Grant. Constraints on northern aggregate mine reclamation and novel reclamation strategies for enhancing biodiversity and ecosystem functioning with M Hebert, M Nellis, R Rochon, S Bouchard, R Craig (Collège Boréal), and G Spiers and Basiliko (Laurentian U) (2021-2024)

Belzile, N

- NSERC Discovery Grant: Study of factors to improve the removal of trace metals/elements from mine effluents using low cost adsorbents. (2019-2025)
- NSERC Equipment Grant: Powder XRD diffractometer. A. McDonald P.I. and others (2021-2022)

Edwards, B

- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)
- Vale Ltd. Community Restoration of Acid Damaged Lakes (CRADL), Co-PI with Gunn and Johnston

Emilson, E

- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)
- Atlantic Canada Opportunities Agency. Spruce budworm pest management as a conservation tool for critical habitats and ecological integrity of forest watersheds. Co-Lead with Statsny (2018-2021)
- NSERC Strategic Partnership Grant. Identifying and evaluating the effectiveness of best management practices to mitigate mercury contamination in managed forests. Collaborator with Mitchell, Kidd and Melles (2019-2022)
- Genomics Research Development Initiative. Ecobiomics: Metagenomics Based Ecosystem Biomonitoring (2018-2022)

Gunn, J

- NSERC Canada Research Chair Tier 1 in Stressed Aquatic Systems
- NSERC Discovery, Terrestrial ecosystem services and recovery of damaged aquatic systems (2016-2021)
- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)
- NSERC CRD – Chromium in Fish study in partnership with DeBeers, with Gretchen Lescord, Brian Branfireun (Western), Al lock (PCAF)
- MITACS/WCS – for PDF support of Dr. Gretchen Lescord
- Vale Ltd. Community Restoration of Acid Damaged Lakes (CRADL), Co-PI with Edwards and Johnston

- Glencore's Sudbury Integrated Nickel Operations. Restoration ecology studies in Greater Sudbury area including the airport kettle lakes (2021-2022)

Ielpi, A

- NSERC Discovery Program. Precambrian rivers and potential analogs with modern terrestrial and extra-terrestrial fluvial landscapes (2016-2021)
- Northern Scientific Training Program from Polar Knowledge Canada, 2020-2021 and 2021-2022.
- Nordenskiold River Permafrost Project from Yukon Geological Survey, 2021-2022.
- Nonacho Lake Mapping Project from Northwest Territories Geological Survey, 2020-2021 and 2021-2022.

Johnston, T

- NSERC Discovery Program. Individual specialization and the trophic niche of aquatic consumers (2015-2021)
- NSERC Discovery Development Grant Program. The trophic niche in boreal lake food webs. (2020-2022)
- Ontario Ministry of Natural Resources and Forestry, Aquatic Research and Monitoring Section. Northern fisheries research (2004 – present, renewed annually)
- Ontario Ministry of Natural Resources and Forestry, Canada-Ontario Agreement (COA) on Great Lakes Water Quality and Ecosystem Health The influence of female spawner characteristics on the early life survival and recruitment of lake whitefish (2020 - 2022)
- Vale Ltd. Community Restoration of Acid Damaged Lakes (CRADL) Co-PI with Gunn and Edwards

Lescord, G

- Dept. of Fisheries and Oceans (DFO) Ecosystems Oceans Science Contribution Framework. Impacts of land-use change on lake sturgeon habitat use, feeding ecology, contaminant exposure, and health in the James Bay Lowlands. Partners: Moose Cree First Nation, WCS Canada, Laurentian, MNRF, Ontario Tech University. (2021-2023)

Mykytczuk, N

- Sudbury GSDC: Community Economic Development Grant in support of a Feasibility study for the Centre for Mine Waste Biotechnology. PI (2020-2021)
- NSERC Discovery- Understanding variability in microbial biomining and bioremediation consortia; adaptation mechanisms for multiple extremes. (2019-2024)
- CFI/ORF John R Evan Leader's Fund: A field and laboratory analysis facility for advancing biomining and bioremediation of mine wastes. PI (2017-2021)
- MRI Early Researcher Award. Application of acid mine drainage microbial communities to remediation of mining wastes in northern environments. PI (2017-2021)
- Ontario Research Fund, Research Excellence Round 8: Elements of Bio-Mining (EBM): Genomics-Driven Improvements in Bioleaching, Sulfur and Selenium Stabilization in Mine Operations. Co-Lead (2016-2022)

- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)

Pearson, D

- Building Regional Adaptation Capacity and Expertise (BRACE), NRCan, January 23, 2019-March 31, 2022

Roy-Léveillée, P

- Research Chair in permafrost geomorphology in Nunavik, Ministère de l'Environnement et de la Lutte aux Changements Climatiques (2020-2023)
- Chaire de recherche Sentinelle Nord sur le pergélisol, Sentinelle Nord (2020-2025)
- NTCF Northern Arctic Call, PermaRail. Co-lead (2022-2029)
- Crown Indigenous Relations and Northern Affairs Canada, Climate Change Preparedness for the North, Une approche pour la construction durable au Nunavik.
- NSERC, Strategic Partnership Grants for Networks, Permafrost Partnership Network for Canada. Co-PI (2019-2024)
- ArcticNet, Supporting Humans in a Thawing Landscape. Co-PI (2019-2021)
- Polar Knowledge Canada, Shrubification, hydrology, permafrost, and mercury mobilization: a cross-disciplinary approach to landscape change to support community resilience in Old Crow Flats, YT (2020-2023)

Scott, JA

- NSERC Discovery, Bioprospected microalgae and CO_2 in industrial emission utilization (2020-2025)
- CFI John Evans Leadership Fund, Bioprospecting in Canada for health beneficial compounds (2020-2021)
- Mitacs, Capture and repurposing of waste industrial emissions for improved economic and environmental sustainability (2019-2022)

Spiers, G

- NSERC Innovation Links Grant. Constraints on northern aggregate mine reclamation and novel reclamation strategies for enhancing biodiversity and ecosystem functioning with M Hebert, M Nellis, R Rochon, S Bouchard, R Craig (Collège Boréal), and P Beckett and Basiliko (Laurentian U) (2021-2024)
- MITACS-MIRARCO, MITACSS Accelerate Grant. Development of passive sampling devices for natural and artificial radionuclides in the context of pre- and postdeployment of small nuclear reactors in remote areas. Spiers and Caron (2019-2021)
- MITACS-Testmark, MITACSS Accelerate Grant. Development of passive sampling devices for natural and artificial radionuclides in the context of pre- and post-deployment of small nuclear reactors in remote areas. Spiers (PI, LU) with Caron (CoI, RMC), Chabonneau (Testmark Project Lead). (2022 – 2024)

- OMAFRA Research Contract. Detailed Radiometric Analyses of Soil and Soil Mineral Fractions from Selected Ontario Surface Soils. (2019 – 2021)
- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)

Swanson, H

- Saugeen Shores and Nuclear Innovation Institute: Pre-feasibility assessment for restoration of an urban lake, Fairy Lake, in Southampton, ON. Rooney and Swanson (2021-2023)
- Government of the Northwest Territories: Preliminary assessment of ecosystem conditions in Frame Lake, Yellowknife, prior to aeration. Gray and Swanson. (2021)
- Government of the Northwest Territories: Developing tools for investigations of cumulative effects on water quality. PI (2021)
- Fisheries and Oceans Canada: Investigating genomics and life history in chars captured in Coronation Gulf. PI (2021)
- Great Lakes Fishery Commission Pilot Program: Seeing through a fish's eye: Using stable isotopes of fish eye lenses to understand life history. Fetzer, Swanson, Muir and Vinson (2021-2022)

Tanentzap, AJ

- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)
- European Research Council, Ecological and evolutionary importance of molecular diversity in dissolved organic matter. 5-year programme to study the biological relevance of chemical diversity in dissolved organic matter (2019-2025)

Watmough, SA

- NSERC Discovery, Calcium in the environment: the highs and the lows (2016-2021)
- NSERC Collaborative Research and Development Grant- Ontario Centres of Excellence TargetGHG program. Landscape Carbon Accumulation through Reductions in Emissions (L-CARE): developing brownfield management protocols for carbon sequestration and habitat use (see Basiliko)

Yan, N

- Ontario Trillium Foundation, Hauling Ash to Save Our Forest's Future. (2019-2021) with Trent University, University of Victoria, Laurentian University, District Municipality of Muskoka, Dorset Environmental Science Centre, Learning for a Sustainable Future, the Ontario Maple Syrup Producers Association, and Westwind Forest Stewardship Inc.

Theses Completed

PhD

Lavender, Mike. PhD. Patterns of species association: Quantifying and detecting patterns of association in ecological communities. Queen's University (Arnott/Rusak/Schamp)

MSc

Beckett, Anna. MSc. Response of cladocerans to native and invasive invertebrate predators in Lake Simcoe, Canada. Queen's University (Arnott/Young)

Gilbert-Parkes, Spencer. MSc. Trace Metal geochemistry of peatlands. Trent University (Watmough)

Humphrey, William. MSc. Biodiversity patterns along a forest time series in a remediated industrial landscape. Trent University (Watmough)

Kellaway, Ed. MSc. Legacy Effects associated with the world's largest ongoing liming and forest regeneration program in Sudbury, Ontario, Canada. Trent University (Watmough)

Methé, Alexandra. MSc. A metagenomic and metabolomics analysis of an Ecuadorian mine tailings microbial community. Laurentian University (Mykytczuk/Merritt)

Mohit, Shrisha. MSc. Efficacy of recreational watercraft decontamination practices to prevent the spread of aquatic invasive species. Queen's University (Arnott/Johnson)

Ott, Neil. MSc. The influence of tree species litterfall on soil chemistry and implications for modelling soil recovery from acidification. Trent University (Watmough)

Robinson, Chantae. MSc. Assessing patterns and biogeochemical impacts of shrubification in sedge fens of the HudsonBay subarctic tundra. Laurentian University (Roy-Léveillée/Basiliko)

Russell, MacKenzie. MSc. Potential drought-driven metal release in Junction Creek: Effects of legacy contamination and the impacts of lime treatment. Laurentian University (Gunn/Rickwood).

Tremblay, Nathalie. MSc. Cultivation of microorganisms from sulfidic mine waste and genomic insights into *Acidibacillus ferrooxidans* and Penicillium sp. Laurentian University (Mykytczuk)

MSCom Major Research Papers/projects, Laurentian University

Cousineau, Laura. MSCom. All for one, and one for all: a historical comparison of messaging tones of the 1955 polio vaccination campaign and the 2021 COVID-19 vaccination campaign in Canada.

Farooqi, Birha. MSCom. Science communication through SciArt: A closer look at Canadian SciArt initiatives and their role in bridging the gap between the science and the public.

Hewson, Milas. MSCom. Voicing for advocacy: how environmental theatre uses storytelling to empower climate action.

Hung, Charlotte. MSCom. Science centre visitors' engagement online – A case study on COVID-19 webinars: Let's Talk COVID-19 and The Virus of Misinformation.

Jogoo, Akshay. MSCom. Level up: gamifying science centre exhibits to promote visitor engagement.

Klassen, Veronica. MSCom. The use of humour in videos about COVID-19 on TikTok.

McAuliffe, Maeve. MSCom. Developing an evaluation framework for CROSH knowledge translation materials.

McNeil, Laerie. MSCom. The power of dinosaurs: lessons learned from the sharing of #SciArt on Twitter.

Millar, Alex. MSCom. Phronesis in the face of uncertainty and changing knowledge: a case study of how Dr. Henry constructs credibility and engenders trust during the COVID-19 pandemic.

Montgomery, Alina. MSCom. Canadian news media and COVID-19 misinformation: an exploratory descriptive study.

Morris, Abigail. MSCom. You're hired: a content analysis of science communication job postings.

Simone, Kyra. MSCom. How do prominent news outlets frame climate change and discuss climate contrarianism?

Tam, Kristen. MSCom. Science communication training evaluation best practices: a systematic review through critical interpretive synthesis.

Thomas, Laura. MSCom. Exploring the use of digital tools to create meaningful Indigenous consultation in the mining industry in Canada.

Villanueva, Fiorella. MSCom. A vaccine for all? A rhetorical and stasis theory analysis of the COVID-19 vaccine intellectual property debate.

Undergraduate

Graham, Alec. BSc Thesis. Evaluation of meander cutoff and migration in the Vermilion River, Ontario. Laurentian University (Ielpi)

Lepage, Adam. BSc Thesis. Developing and validating an analytical method for speciation of arsenic in water and fish muscle using IC-ICP-MS. Laurentian University (Gunn/Lescord)

Lockie, Jade. BSc Thesis. Orogenic collapse in the Rae Craton recorded through U-Pb geochronology of the Paleoproterozoic upper Nonacho Group, Northwest Territories. Laurentian University (Ielpi)

Buren, Shakira. BSc Thesis. The effect of calcium on acute chloride toxicity in *Daphnia pulex*. Queen's University (Arnott)

HQP Supervised

Donovan, Rebecca. BSc Thesis in progress, Trent University (Watmough Co-Sup)
Gillen, Samantha. BSc Thesis in progress, Queen's University (Arnott)
Miller, Tori. BSc Thesis in progress, Laurentian University (Beckett)
Neuman, Jodi. BSc Thesis in progress, Trent University (Watmough)
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Appendix

L-CARE: ALTERNATIVE SOIL CONDITIONERS FOR LARGE-SCALE REHABILITATION OF ACID- AND METAL-STRESSED LANDSCAPES

Background

The City of Greater Sudbury Regreening Program currently treats soil acidity and metal toxicity with a single application of dolomitic limestone and fertilizer. This improves the chemical properties of soil and long-term landscape health but does not address one of the major challenges facing Greater Sudbury's most damaged soils: low organic content. Alternative soil conditioners, such as locally produced lime-stabilised municipal biosolids, pulp and paper mill sludge, and biomass boiler ash are waste products (low acquisition cost) and environmentally friendly (recycling as opposed to landfilling or incineration). These materials are high in organic matter, but may also provide high buffering capacity, and contain moderate essential nutrient levels - emulating lime and fertilizer. Alternative treatments have the potential to improve physical soil properties such as moisture retention and density, thereby improving plant growth.

Summary of Research Findings

In collaboration with Collège Boréal researchers, PhD students Jonathan Lavigne and Kelly Chan-Yam studied and compared the environmental effects and logistical requirements of eight treatments, including a zero-addition control and the current standard limestone + fertiliser application. The study was performed on two study sites: (i) a semi-barren sandy outwash area near the Glencore Falconbridge smelter and (ii) a rocky, sloped, semi-barren site in the Coniston area. As expected, soil and seedling response varied between the two sites. In the Coniston site, with poorer soils organic amendments had more pronounced improvements to soil moisture and soil density, and higher organic matter decreased drought stress. Ash treatments without organic matter, however, had lower soil moisture during the summer and greater drought stress. This response did not necessarily lead to improvements in seedling survival or growth compared to limestone + fertiliser, particularly for jack pine and red oak - staples of the regreening program. However, improvements in biodiversity are potentially more impactful than seedling responses. Ground cover response was heavily dependent on organic residual type. Organic residuals, particularly lime-stabilised municipal biosolids, increased biodiversity and species richness of sites, decreased bare ground cover, and shifted community structure to resemble post-disturbance pioneer tree and herb invasion (Table 1). Alternatively, treatments with ash often reduced biodiversity and increased bare ground cover. All novel amendments required a greater volume to attain the same nitrogen application rate as the standard limestone + fertiliser treatment, increasing labour requirements and logistical difficulty. Overall, pulp treatments required 24 times as much material and labour, while municipal biosolids required twice as much material but half the labour, as compared to current methods.

Table 1. Average change in species richness (SR), effective species number (ESN), vegetated cover (VC), and bare ground (BG) from pre-treatment conditions to 3 years post-treatment. Order of recommendation from left to right.

	Biosolid (high)	Biosolid (low)	Pulp Sludge 1	Lime+Fert	Ash+Fert	Pulp 2 +Ash	Pulp Sludge 2
SR	**3.10**	**3.60**	**3.25**	**-0.40**	**0.63**	**-1.30**	**-1.75**
ESN	**95.0%**	**55.2%**	**79.1%**	**55.2%**	**-3.9%**	**23.2%**	**21.0%**
VC	**323.3%**	**311.3%**	**198.5%**	**96.4%**	**33.8%**	**124.6%**	**52.1%**
BG	**-7.0%**	**-15.9%**	**28.2%**	**7.0%**	**51.6%**	**45.5%**	**56.7%**

Recommendations

- The effectiveness of new treatments should be evaluated based on improvements to biodiversity, bare ground cover, and vegetated cover together with seedling response. Sites regreened with the standard limestone + fertiliser treatment often retains the depressed diversity and vegetated cover of undamaged land, which can be improved with organic amendments.
- Limed municipal biosolids (N-Rich) most consistently improved growth, soil moisture retention, ground cover, and biodiversity, over both controls and the standard limestone + fertiliser treatment.
- Pulp sludge treatments improved soil properties but had mixed results for improving seedling survival and growth, and for improving species richness and vegetated cover. Treatment also introduced (n=6) invasive species. Further research into application rates and nutrient additions may improve results.
- Ash treatments should not be considered without blended organic amendments.
- The effect of pulp amendments is drastically decreased on sloped sites. On steep slopes, pulp amendments may not be as efficient as the standard Sudbury treatment.
- The feasibility of using granular limed biosolids in aerial application should be tested. Potential negative or positive effects of aerial treatment on wetlands of various types should also be addressed experimentally.

L-CARE: CARBON SEQUESTRATION BY TREES ON A METAL-IMPACTED LANDSCAPE: AN EFFECTIVE CARBON CAPTURE STRATEGY BUT RESTORATION TREATMENT MATTERS.

Background

Forests are carbon-dense ecosystems storing twice as much carbon than is found in the atmosphere. As such, tree restoration has been identified as an effective and affordable capture carbon strategy. Many governments around the world are promoting tree restoration, and specifically the Canadian Government has pledged to plant 2 billion trees as a key strategy for meeting Canada's climate targets. However, much of the available land for tree planting is required for agricultural use and urban development, which may result in future land-use conflicts reducing the long-term viability of the carbon store. In contrast, tree restoration on industrially degraded landscapes may have long-term viability due to its unsuitability for other human uses, but it is unclear if carbon sequestration rates will be comparable to that observed on non-industrially impacted land. An important consideration as additional tree planting is included in the City of Greater Sudbury's Community Energy and Emissions Plan.

Summary

Several restoration treatments have been applied across the Sudbury landscape with increasing intensity and effort. These include, LFS: the application of lime, fertilizer, and seed (the Standard Sudbury Soil Amendment); Tree-planting Only; and LFS+Tree: LFS and tree planting. Carbon pools following ca. 40 years of regreening on the Sudbury landscape were quantified by resampling a jack pine (*Pinus banksiana*) and red pine (*P. resinosa*) chronosequence that was subjected to the LFS-Tree treatment[1]. Tree and soil organic carbon (SOC) pools were the largest carbon pools, representing 47% and 42% of the total ecosystem carbon (TEC), respectively. Compared with unplanted sites, LFS+Tree resulted in a significant increase in the mean TEC, which corresponded to a carbon sequestration rate of 1.7 ± 0.3 Mg ha^{-1} yr^{-1}. This rate is comparable to that observed in silvicultural plantations within similar climate regions.

The impact of specific restoration treatments on carbon sequestration was also investigated within a single watershed (Daisy Lake) after ca. 24 years[2]. LFS+Tree had the largest tree carbon pool (Fig.1) that was 1.5 times greater than Tree-planting Only. Highlighting that soil amendments increase tree carbon sequestration rate. Natural tree regeneration in untreated plots and LFS plots stored very little carbon even 50 years after local pollution was massively reduced. This highlights that tree planting is essential for reforestation on this landscape.

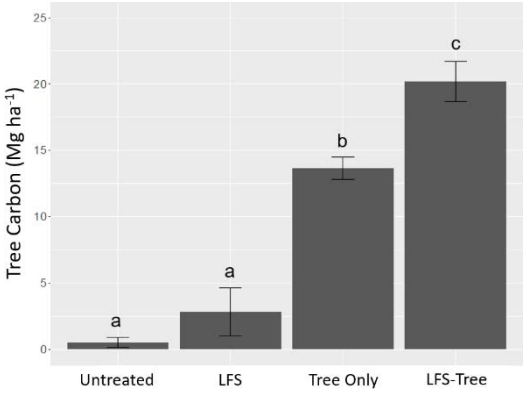

Figure 1: Mean tree carbon (± 1 S.E.) pool among treatments at Daisy Lake catchment. Letters indicate significant difference ($p < 0.001$).

Across both the chronosequence and Daisy Lake catchment, the SOC pool was generally large but also highly variable, probably due to past environmental disturbance. It is unclear whether the SOC pool is increasing or decreasing in size. Soil metal (Cu, Ni, etc.) concentrations remain above the provincial standard[2] and appear to be influenced by SOC quality between jack pine and red pine plots[3]. But metal concentrations did not affect microbial activity[3] indicating metal impacts on future restoration efforts may be low. Taken together, these studies show that tree restoration on impacted landscapes is a viable carbon sequestration strategy. But land managers must balance the financial cost of restoration with carbon sequestration potential.

Recommendations

- Tree restoration should be prioritized on industrially degraded land that has few land-use conflicts.
- Soil amendments need to be applied to maximize carbon sequestration rates including consideration of optimum tree planting density.
- At a minimum, tree planting is required across the impacted landscape as carbon sequestration by natural regeneration is very low.
- Research is required into the stability of the large soil organic carbon pool across impacted landscapes and how different soil fractions accumulate metals.
- Conduct research on restoration treatments that will stimulate microbial nutrient cycling to maximize carbon sequestration within the tree and soil organic carbon pools.
- Maintain the long-term viability of the forest ecosystem on the landscape by increasing the tree species diversity.

References: 1) Preston, M.D., Brummell, M.E., Smenderovac, E., Rantala-Sykes, B., Rumney, R.H.M., Sherman, G., Basiliko, N., Beckett, P. and Hebert, M. 2020. *For. Ecol. Management*. 463 (118012). **2)** Rumney, R.H.M., Preston, M.D., Jones, T., Basiliko, N., and Gunn, J. 2021. *For. Ecol. Management*. 483 (118896).
3) Ibrahim, A and Bellenger, J-P. Unpublished Research.

L-CARE: ON THE POTENTIAL FOR PEAT-BLOCK TRANSPLANTS TO RESTORE INDUSTRIALLY CONTAMINATED *SPHAGNUM* PEATLANDS

Colin McCarter, Paul Moore, and Mike Waddington (McMaster Ecohydrology Lab)

Peatland Restoration Challenge

Industrial smelting has led to the degradation of Sudbury area peatlands (*e.g.*, loss of *Sphagnum* moss, increased peat humification) due to emission and subsequent deposition of sulphate, nickel (Ni), and copper (Cu). Common peatland restoration approaches are likely not suitable to restore ecohydrological function due to metal toxicity. A successful restoration technique needs to limit periods of hydrological stress (high soil water tension, 100 mbar) and chemical stress (elevated Ni and Cu concentrations, ~10^{-6} mmol mL^{-1}) in the *Sphagnum* capitula (the cluster of branches at top of plant responsible for photosynthesis).

Figure 1: An example of a successful peat-block transplant on a horticultural peat extracted peatland in Québec.

Peat-Block Restoration

We propose that the peat-block restoration (PBR) technique, which involves transplanting the upper few decimeters of a donor peatland and directly placing it on the surface of degraded peat, can likely meet this challenge as the additional peat layers may create a buffer for metal toxicity. While the PBR technique has been shown to limit hydrological stress, it is unknown if the technique can also minimize near-surface pollutant concentrations and associated chemical stress. As a first step towards plot- and field-scale experimental assessment of the viability of the PBR approach, we utilized numerical hydrogeochemical modelling as a proven, cost-effective, and non-invasive research tool. We investigated the interactive effects of *Sphagnum* moss species, peat-block transplant thickness, and degraded peat Ni and Cu concentrations on the capitula soil water tension and Ni and Cu concentrations over a 10-year simulation period.

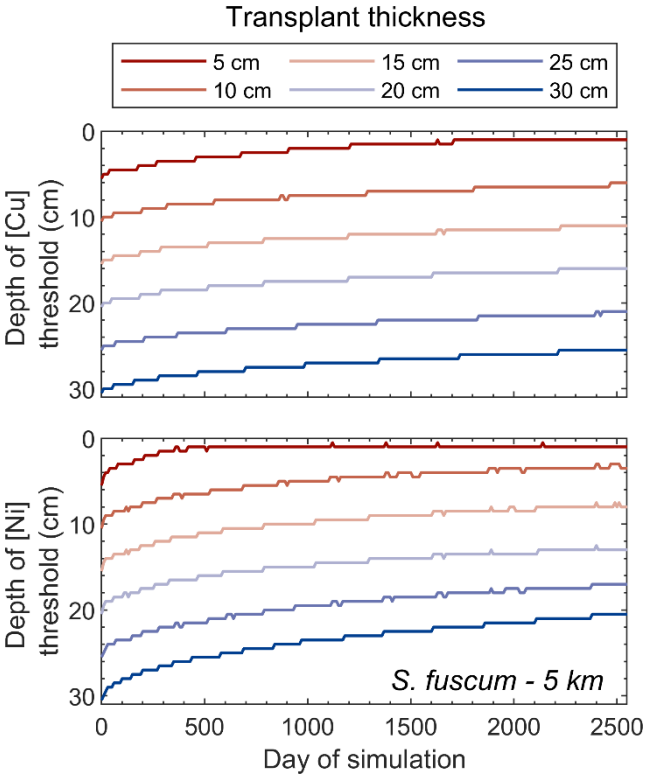

Figure 2: The depth of the critical concentration thresholds for Cu (top) and Ni (bottom) over the 10-year simulation

Summary of Research Findings

- Densely growing *Sphagnum* moss, such as *S. fuscum* and *S. rubellum*, of at least 20 cm thickness minimizes hydrological and chemical stress for 10+ years post-restoration.
- Peatlands with high remnant peat Ni and Cu concentration (*i.e.*, close to smelters) require thicker peat-block transplants than those farther away.
- Thinner peat-block transplants (5-10 cm) have the highest relative upward mobility of Ni and Cu, nearing the toxicity threshold at the surface and increasing the likelihood of restoration failure within 10 years.
- The capitula are critical to regulating the upward mobility of water, Ni, and Cu, and need to be included in the PBR transplant. Stockpiled peat alone is not suitable.

Research and Restoration Recommendations

- Targeted field-testing of the PBR technique in a highly contaminated peatland, focusing on densely growing *Sphagnum* species.
- Determine the geochemical processes controlling the fate of metals in *Sphagnum* moss/peat and implications for restoration success.
- Identify and map naturally recovering peatlands in order to integrate sites which do not require restoration into a regional restoration strategy. Expand water level and metal concentration measurements at these sites to help identify current limits to *Sphagnum* recolonization.
- Initiate eddy covariance GHG flux and carbon storage measurements in natural and disturbed peatlands to provide baseline data for an assessment of reclamation success beyond *Sphagnum* recolonization.
- Begin modelling study on the longer-term carbon storage resilience of PBR to climate change (drought, wildfire).
- Explore peatland restoration via re-wetting/flooding vs PBR carbon storage using natural beaver pond analogs.

We would like to thank Line Rochefort, Tasha-Leigh Gauthier, John Gunn, Nate Basiliko, Lorna Harris, Peter Beckett, Sophie Wilkinson, Greg Verkaik, Hope Freeman, Taylor North, and James Seward for research discussions on this topic.

L-CARE: Peatland restoration using *Sphagnum* transplant trials in Sudbury, Ontario

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Background

Healthy peatlands support freshwater systems, host unique biodiversity, and regulate global climate. Smelting activities in the Sudbury Basin, formerly one of the world's largest sources of sulphur dioxide (SO_2) and particulate nickel (Ni) and copper (Cu) emissions, caused severe damage to ecosystems across the region, including peatlands. Natural recovery is exceptionally slow, and "regreening" activities have so far been limited to upland ecosystems. During the initial stage of restoration efforts, it was reported that peatlands close to the smelters contained black and barren peat, with no peat moss or other natural vegetation typical of the ecosystem. Over 35 years later, we are re-assessing the vegetation cover, hydrology, peat properties, microbial community structure, and chemistry of these damaged peatlands. We have also installed *Sphagnum* moss and peat transplants from healthy peatlands near Parry Sound to determine the potential for *Sphagnum* moss recovery and a return to a functioning peatland ecosystem.

Results Summary

Our preliminary data show Ni and Cu concentrations in peatlands decrease with increased distance from the Falconbridge smelter, but that concentrations in our transplant site (Sud-B or SUD103) are much larger than the other sites (Fig. 1). The potential effect of these larger metal concentrations on the beta-diversity of microbial communities is shown in Fig. 2, where the communities of the transplant moss and peat appear to diverge from the donor sites (Parry Sound) towards the communities of the host peatland (Sud-B). Decomposition rates at the surface of the Sudbury peatlands do not differ significantly to the healthy peatlands near Parry Sound (Fig. 3), which may be partly due to consistently higher water levels at the Sudbury sites limiting decomposition. These higher water levels (above the surface for most of the year) may also limit the recovery of certain 'drier' *Sphagnum* species in the transplants at the Sudbury sites. At least three species of *Sphagnum* were found during a survey of Sud-C, but not Sud-A and Sud-B . Other peatlands that were barren in the past now have a vascular plant cover, and colonisation by *Sphagnum* species (Fig. 4).

Recommendations

- Continued monitoring of vegetation, hydrology, and 'health' and extent of *Sphagnum* transplants at the Sudbury peatlands
- Complete greenhouse gas flux measurements (CO_2 and CH_4) to assess status of peatlands in the Sudbury area as carbon sinks or sources.
- Establish greenhouse microcosm tests of *Sphagna* to simulate abiotic conditions and determine a protocol for *Sphagnum* establishment and growth on Sudbury peatlands.
- Use the microcosm results and protocol to further the trial restoration at Sud-B and extending to the small Daisy Lake peatlands.

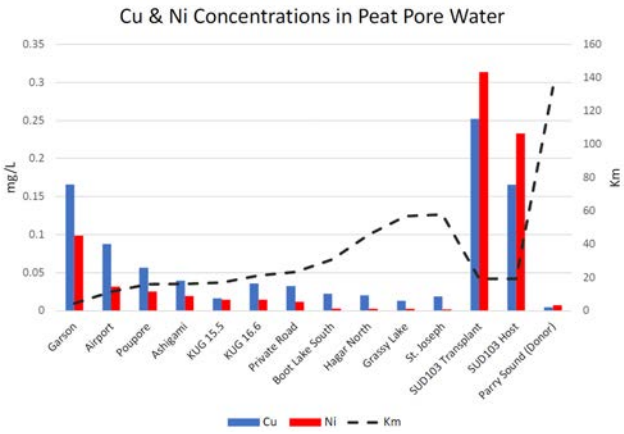

Fig. 1 Cu and Ni concentrations in peat porewater

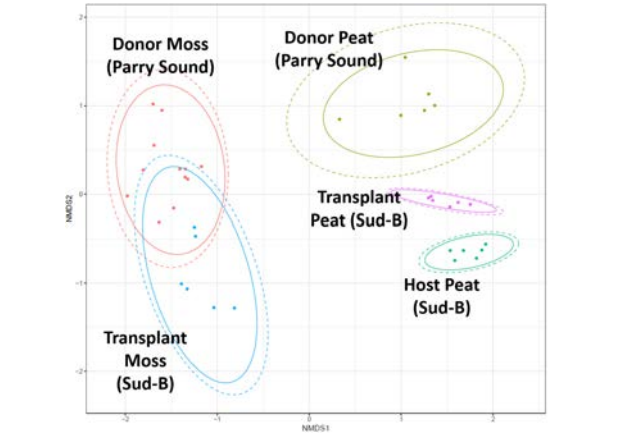

Fig. 2 Bray-Curtis dissimilarity NMDS of microbial communities

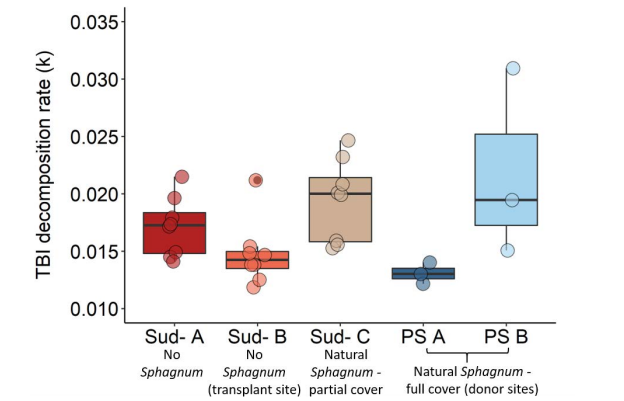

Fig. 3 Decomposition rates using the Tea Bag Index (TBI)

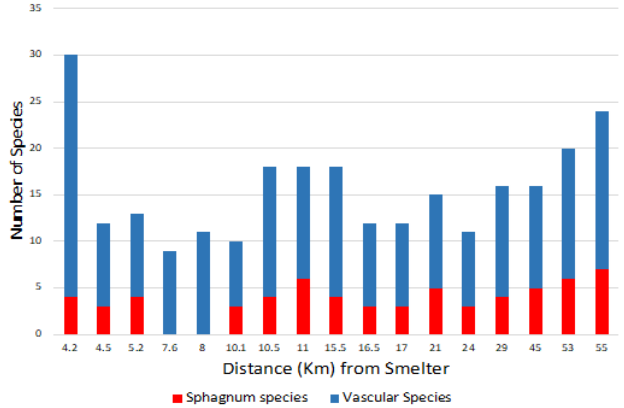

Fig. 4 Species counts of vascular plants and *Sphagnum* moss

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L-CARE: ARE SUDBURY LAKES GETTING THEIR NATURAL COLOUR BACK? RECOVERY OF TERRESTRIAL-AQUATIC CARBON DYNAMICS RECORDED IN LAKE SEDIMENTS.

Background

Dissolved organic carbon (DOC)) plays a fundamental role in lakes and streams by affecting physical, chemical, and biological conditions. While DOC produced within lakes (mainly from algae and plants) is only lightly coloured, the DOC in lakes comes from decomposing forest and wetland vegetation and is usually highly coloured, leading to a yellowish-brown "tea-stained" water colour. Changes in DOC and water colour can affect lakes in both positive and negative ways. For example, they control light and heat penetration in the water column, which, in turn, can influence available habitat for cold water organisms (e.g., lake trout). DOC can also combine with toxic trace metals, (residual metals from past emissions) lowering metal toxicity for biota, affect potentially harmful UV light penetration, and influence oxygen availability (i.e. oxygen is consumed as organic matter decomposes).

DOC concentrations have been increasing in most Sudbury lakes, with a twofold increase, on average, in acid-sensitive lakes since 1981 (Fig.1). This trend has been observed in other regions across North America and Europe, and has been attributed to the recovery from acid deposition, changes in land use and cover, and climate change, all of which affect the export of carbon from the surrounding landscape to lakes. While monitoring data provide crucial information on current DOC dynamics linked to the recovery of the Sudbury landscape, chemical and biological information recorded in dated lake sediments (i.e., the field of paleolimnology) allow us to put these recent environmental changes into a long-term perspective and identify natural variations in DOC and DOC baseline conditions prior to human activities.

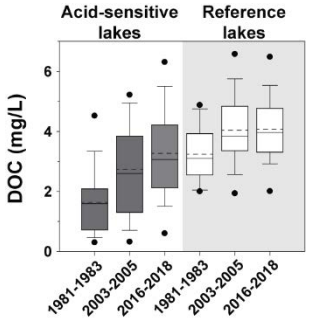


Figure 1: Boxplot of measured dissolved organic carbon (DOC) concentrations in 51 acid-sensitive (1980s pH < 6) and 24 reference (1980s pH > 6) Sudbury lakes during the time periods 1981–1983, 2003–2005, and 2016–2018. Dashed lines indicate mean DOC concentrations.

Summary of Research Findings

Changes in sulphate emissions and deposition were the main drivers for DOC dynamics in Sudbury lakes over the past ~200 years, initially suppressing DOC levels following the onset of mining and smelting in the area. Emission reductions facilitated DOC recovery towards more natural, pre-industrial conditions. However, recovery is not yet complete, as DOC is still below the pre-mining and smelting baseline in most lakes (Fig. 2).

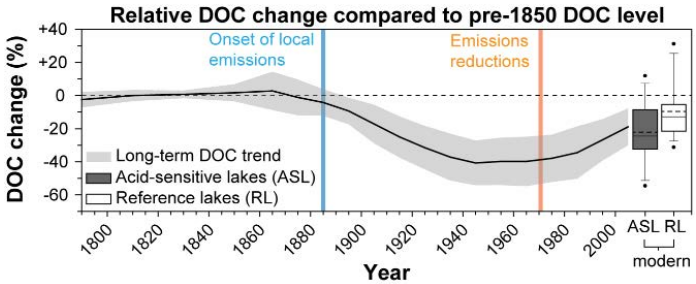


Figure 2: Long-term dissolved organic carbon (DOC) trend over the last ~200 years inferred from sediment records compared to the current (sampled in 2018) recovery state of 51 acid-sensitive (1980s pH < 6) and 24 reference (1980s pH > 6) lakes in the Sudbury region. DOC is expressed as relative change compared to pre-industrial (~pre-1850) DOC levels.

In our less acid-sensitive reference lakes, the rate of DOC increase has slowed over time (Fig.1), and DOC in these lakes is currently only ~10% below pre-industrial levels (Fig. 2). This means that Sudbury lakes are becoming less influenced by the effects of past acid deposition. Similarly, acid-sensitive lakes are slowly becoming more similar to reference lakes.

Climate change has contributed to the DOC rise and may eventually shift DOC in lakes to levels above pre-industrial concentrations. Thus, when considering appropriate DOC reference levels, it is important to consider other human environmental changes that have occurred since pre-industrial times, which may affect the terrestrial or aquatic DOC supply (e.g., changes in vegetation cover and composition, infrastructure development, lake eutrophication).

Terrestrial re-greening efforts have planted over 10 million trees to restore barren and semi-barren zones in Sudbury. Acid sensitive lakes in these high impact zones show some of the strongest increases in measured DOC since the early-1980s. However, when comparing present-day and pre-industrial DOC levels in these lakes, the results are inconclusive. Some of the lakes suggest full recovery, with other lakes showing DOC concentrations still 30-50% below pre-industrial levels.

Furthermore, while vegetation loss and soil erosion in lake catchments close to the smelters likely contributed to decreasing DOC in lakes, lakes without these terrestrial disturbances (e.g., lakes in Killarney Provincial Park) showed a similar magnitude of change in DOC. This shows that chemical acid deposition effects on DOC solubility and mobility in soils is an important process affecting DOC concentrations in Sudbury's lakes, perhaps more so than erosion and degradation of the terrestrial carbon pool.

Recommendations

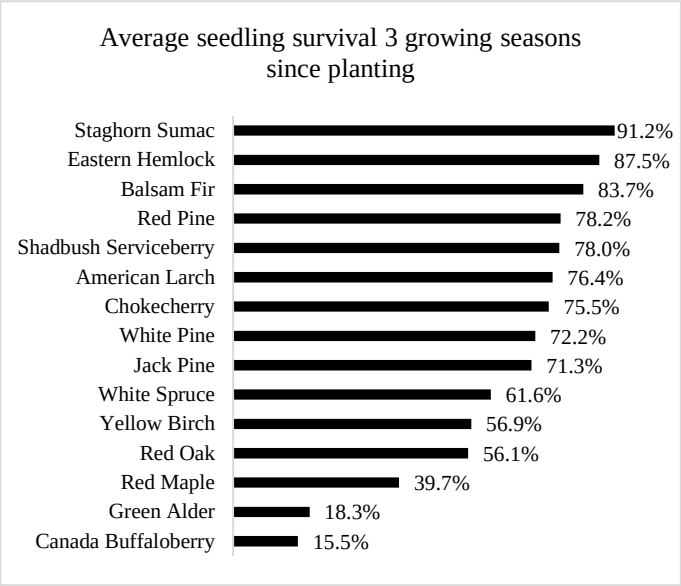
Future research is needed to specifically study the impacts of regreening activities on lake-water DOC concentrations at a catchment-scale. These should be controlled studies as it is difficult to separate the effects of re-greening efforts (i.e., liming, planting), from other processes (i.e., natural re-greening of the landscape, climate change).

Meyer-Jacob, C., Labaj, A. L., Paterson, A. M., Edwards, B. A., Keller, W. B., Cumming, B. F., & Smol, J. P. (2020). Re-browning of Sudbury (Ontario, Canada) lakes now approaches pre-acid deposition lake-water dissolved organic carbon levels. *Science of the Total Environment*, *725*, 138347.

L-CARE: OUTCOME OF 15 PLANTED TREE SEEDLING SPECIES IN A SMELTER-IMPACTED, SEMI-BARREN UPLAND

Background

In the Ecological Risk Assessment portion of the 2009 'Sudbury Soils Study', low plant diversity was cited as one of many challenges to the long-term health of the City of Greater Sudbury's urban forests. In response, the Regreening Program, on advice of VETAC, transitioned from a planting strategy composed of mainly coniferous species to one enhancing native forest tree and shrub diversity. As of 2021, the Regreening Program has increased the native species richness of their planting portfolio year after year (now over 70 species). However, data regarding mortality rates of these tree and shrub species in the boreal forest is limited to commercial tree species. During the seedling stage, trees and shrubs are at their most vulnerable, and are at a high risk of mortality during stress events. Seedlings are especially vulnerable when planted in the sloped, heavily eroded, and exposed uplands of this smelter-impacted region. Additionally, current methods now plant a suite of habitat appropriate species concurrently rather than revisiting sites as done in the past. However, the long-term viability, outcome, and benefits of a one-time "species-rich" planting versus a conifer-based planting is unknown. With planted seedling mortality rate being a strong indicator of reforestation success, tracking the performance of newly reintroduced species is vital to inform and amend current practices.



Summary of Research Findings

In 2018, PhD student Jonathan Lavigne (then MSc student) and a team of municipal tree planters planted 1842 seedlings belonging to 15 native tree and shrub species (n=>60) across 6 1-ha plots on a smelter-damaged semi-barren upland in Greater Sudbury, ON. Species-rich planting (n = 15 mixed-wood tree and shrub species) was done in 3 plots, while the remaining 3 were planted in a conifer-based method (n = 5 conifer species). Planting methods followed species specific planting directives (sun/shade) (dry/moist) and were done in accordance with the then current municipal practices of 300 individuals/ha. Species planted were selected from: sun and drought-tolerant shrubs (*Rhus typhina*), to shade-tolerant and slow growing conifers (*Tsuga canadensis*), to shade-tolerant trees with high moisture requirements (*Betula alleghaniensis*). Over the course of 3 growing seasons, seedling survival, growth, seedling browsing events were tracked during Spring (May) and Fall (October) months for a total of 6 surveying periods. Microsite and physicochemical soil conditions were surveyed at each seedling over the 2019 growing season. We found that animal browsing, and the absence of required semi-shaded to shaded conditions for some species best explained seedling mortality, with little response to immediate soil conditions. However, as planting sites were chosen in accordance with species requirements, drought-intolerant species survived at similar rates as drought-tolerant species when planted in the cool, moist, topographically depressed areas within the upland. Reintroducing species with diverse preferred habitats to a disturbed environment can be successful when landscape heterogeneity is considered prior to planting operations.

Recommendations

- Current species-specific planting directives (sun/shade) (dry/moist) are working when properly followed.
- To maximize upland species richness and reduce seedling mortality, plant only sun and drought tolerant deciduous species in sloped and/or exposed areas until a canopy is well established.
- Reserve shaded to semi-shaded, topographically depressed areas within uplands for deciduous species or conifers with high moisture and shade requirements.
- Refrain from planting fast-growing stress tolerant conifers (i.e., Red Pine) within existing shaded, depressed areas to avoid competition over time.
- Plan planting carefully to promote natural landscape-scale forest mosaics and heterogeneity
- Seedling browsing rates significantly decreased when planted in dense vegetation, consider this when planting especially expensive or ecologically important individuals.
- Consider more use of browsing resistant species (for example, Staghorn Sumac, Eastern Hemlock, Balsam Fir).