Modelling and mapping potential pathogens in Canadian lakes: an eDNA-based tele-epidemiological approach

Anaïs Oliva, Rebecca E. Garner, David Walsh, Yannick Huot

May 2022

NSERC Canadian LakePulse Network

UNIVERSITÉ DE SHERBROOKE

Université Concordia University

Public Health Agency of Canada

GRIL Groupe de recherche interuniversitaire en limnologie et en environnement aquatique

Cartel Université de Sherbrooke

living planet symposium BONN 23–27 May 2022 TAKING THE PULSE OF OUR PLANET FROM SPACE

Impact of pathogens related to inadequate water, sanitation and hygiene (WASH)

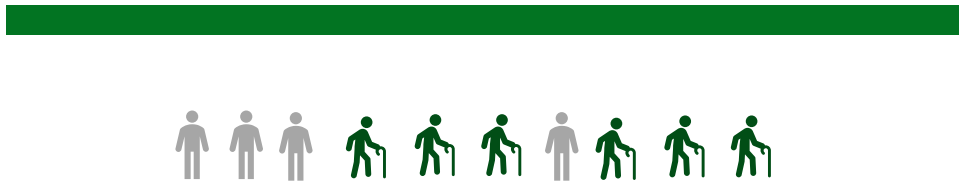
~348 pathogens (*i.e.,* bacteria, viruses, fungi) and 115 infectious water diseases (Yang et al., 2012)

WASH (WHO, 2019)

Mostly diarrheal, parasites, mosquitoes, respiratory diseases

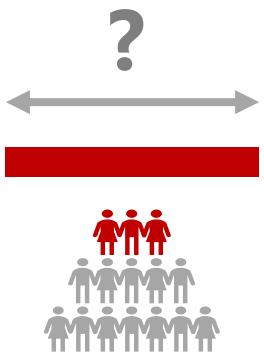
~2 million deaths/y (3.3% global deaths)

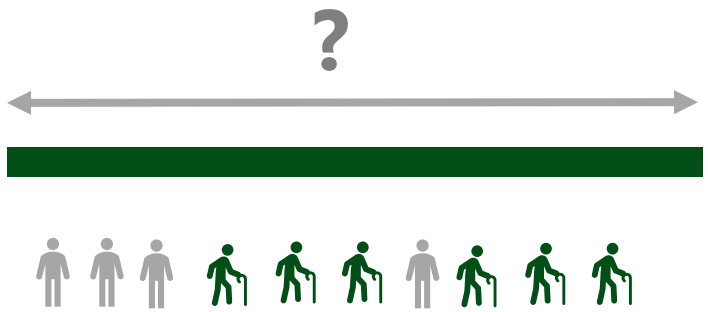
~123 million disability-adjusted life years/y (DALYs) (4.6% global DALYs)



WASH without global estimates

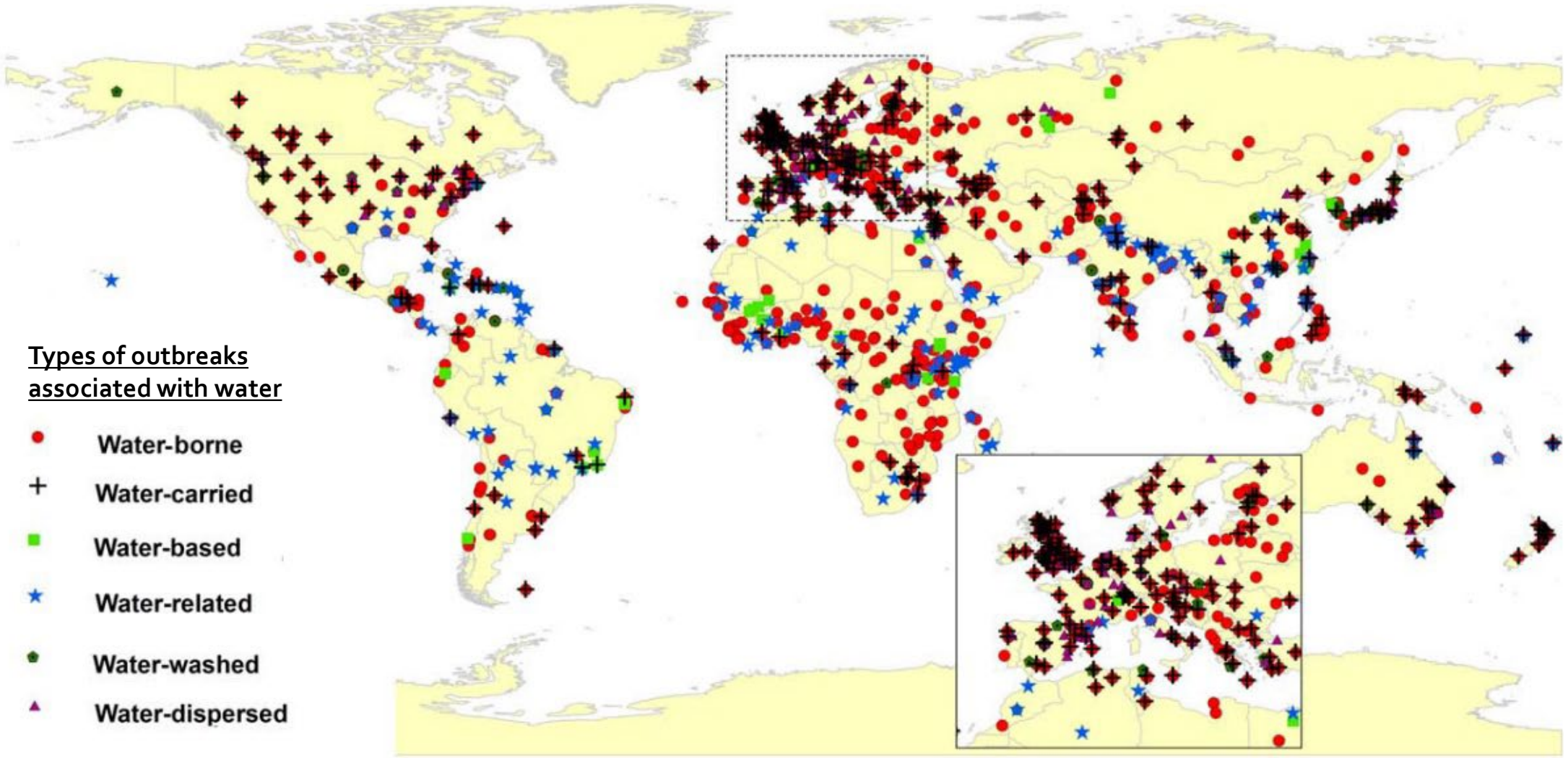
Ubiquitous freshwater and environmental pathogens? Microfungi?





DALYs: a time-based measure that combines years of life lost due to premature mortality (YLLs) and years of life lost due to time lived in states of less than full health, or years of healthy life lost due to disability (YLDs).

Infectious diseases outbreaks associated with water from 1991 to 2008



Modifications of Yang *et al.* 2012

Ongoing pathogen threat challenging our health systems

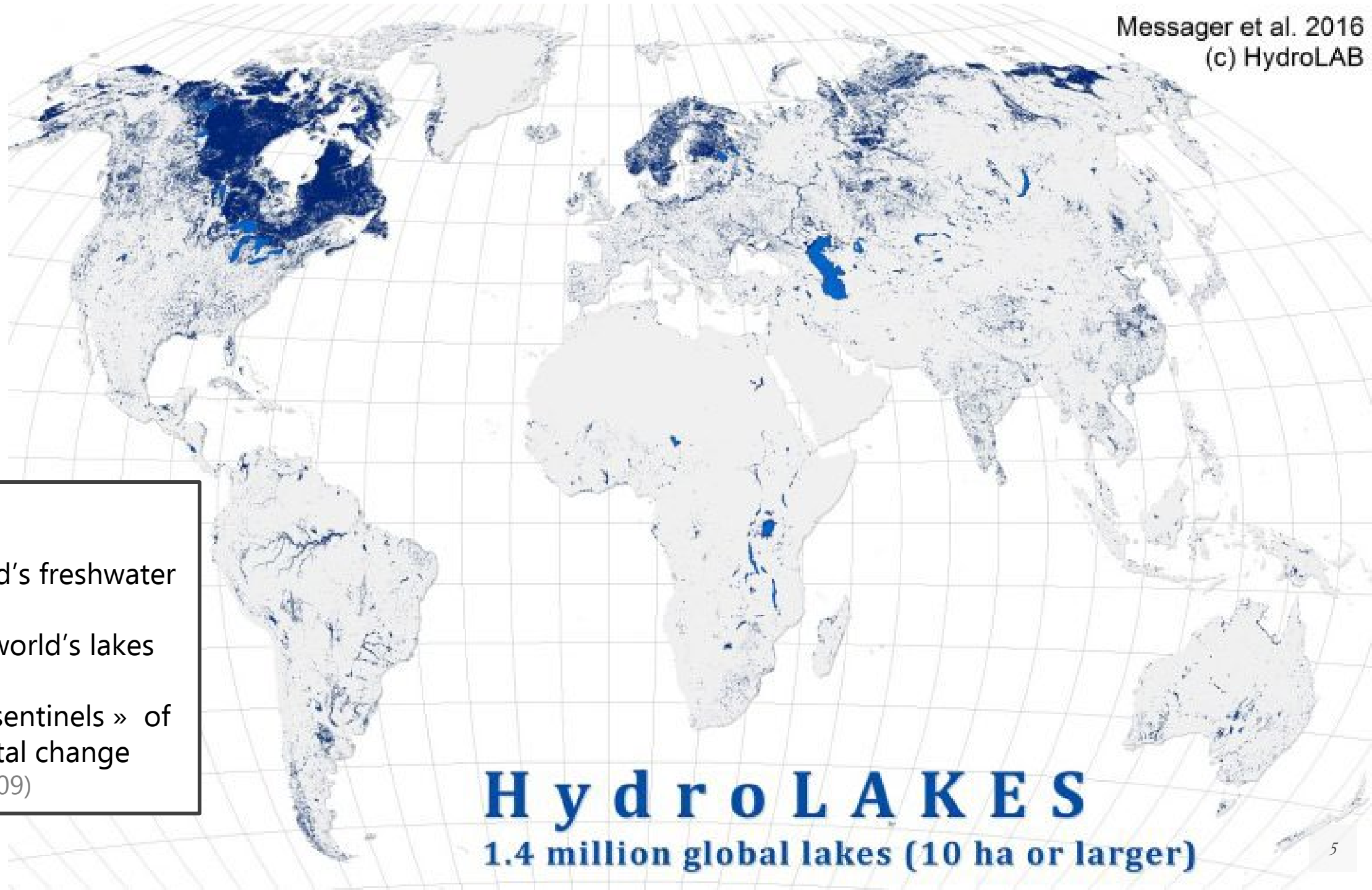
Pathogen survival and their geographical ranges (Ogden & Gachon, 2019)

New potential pathogens released from the melting permafrost. (Wu et al, 2022)

Increase in extreme weather events and water contamination. (Charron et al, 2008)

Antibiotic resistance. (Adegoke, Faleye and Stenström, 2018)

Cross-species transmission of potential infectious zoonitic pathogens. (Reperant and Osterhaus, 2014)



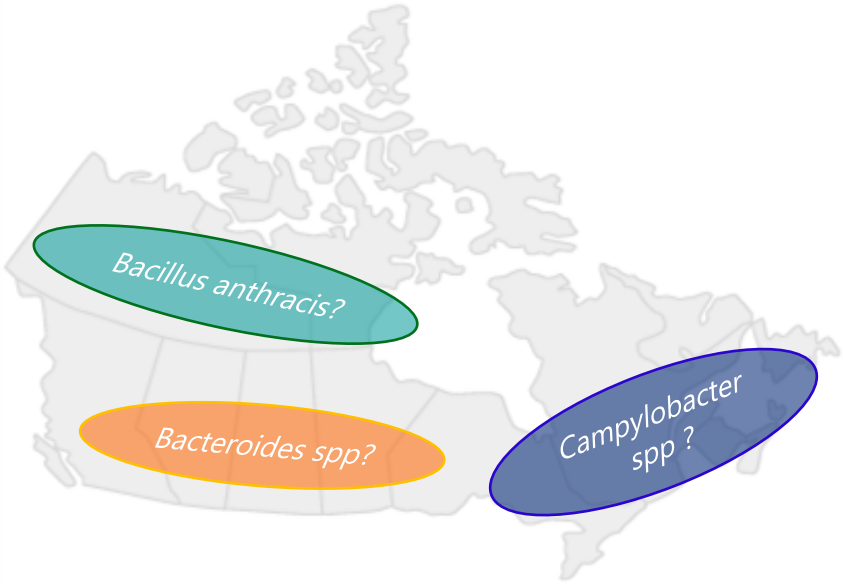
Canada

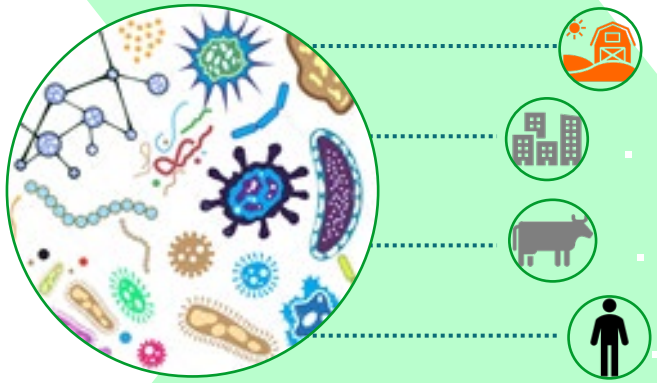
(Cott *et al.* 2016)

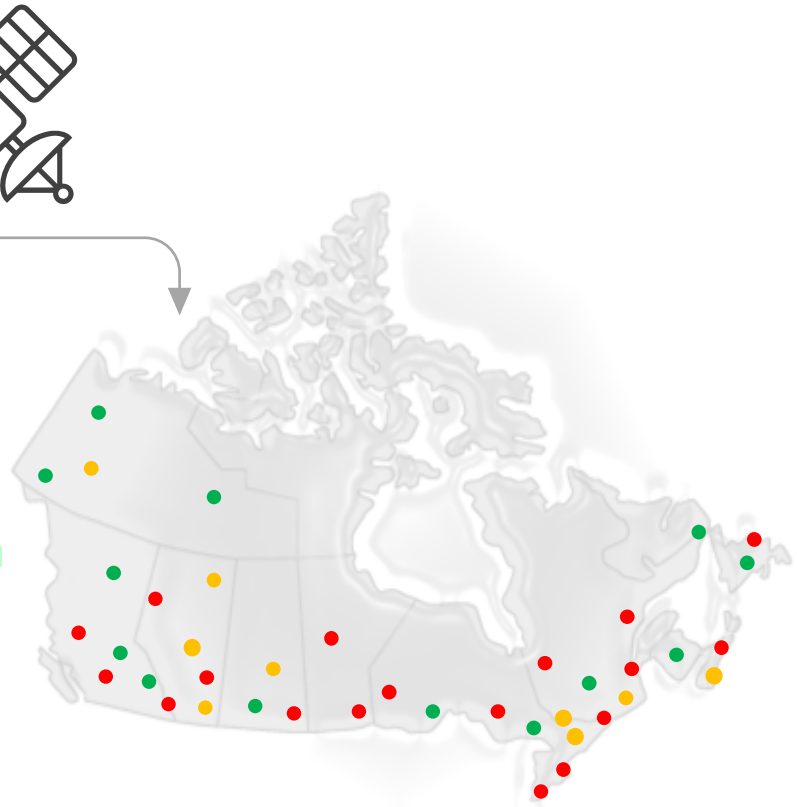
- 20% of world's freshwater resources
- 50% of the world's lakes

- Lakes are « sentinels » of environmental change (Schindler, 2009)

Main objective of the study





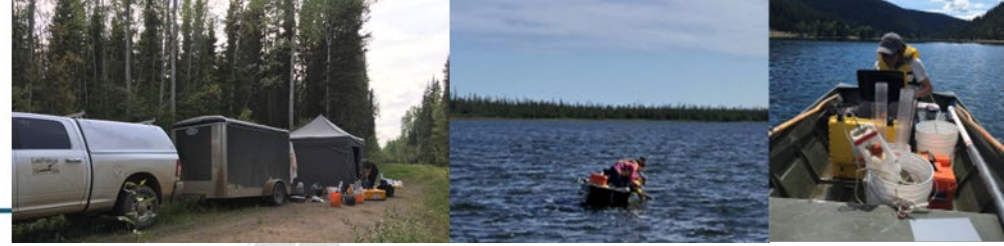


1) Distribution, occurrence and abundance of pathogens in sampled lakes

2) Determine main geospatial drivers of microbial contamination

3) Predictive models for individual pathogens and multi-pathogen clusters

NSERC LakePulse Network - 664 lakes



https://lakepulse.ca/

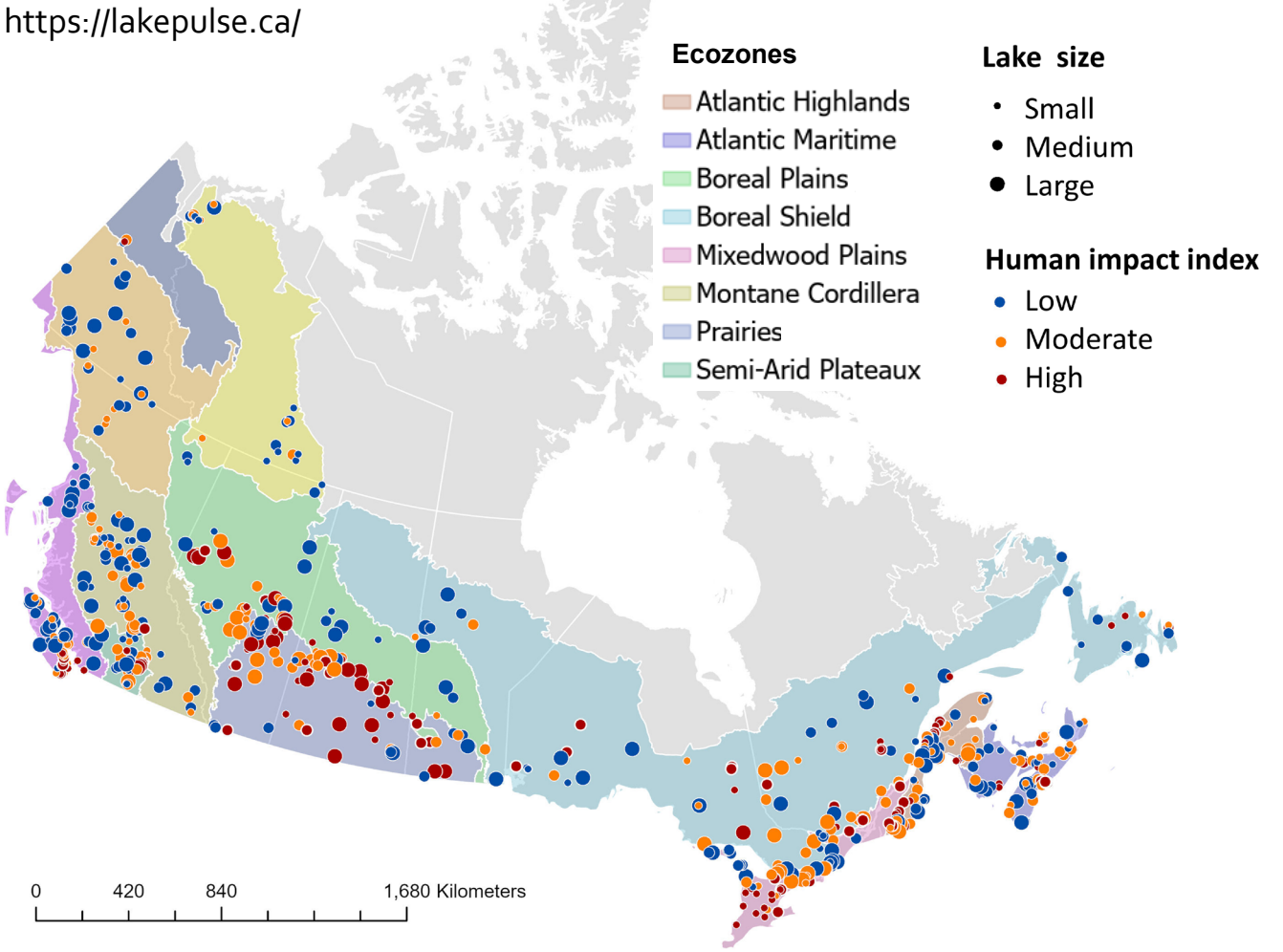
- Sampled once and over 3 summers, 2017-2019
- 11 ecozones

- ~100 collected variables:

Environmental DNA (pathogens)

Water quality data (bio-optical variables)

Secchi disk depth
CDOM absorption
Chlorophyll *a* quantity
Total Suspended Solids



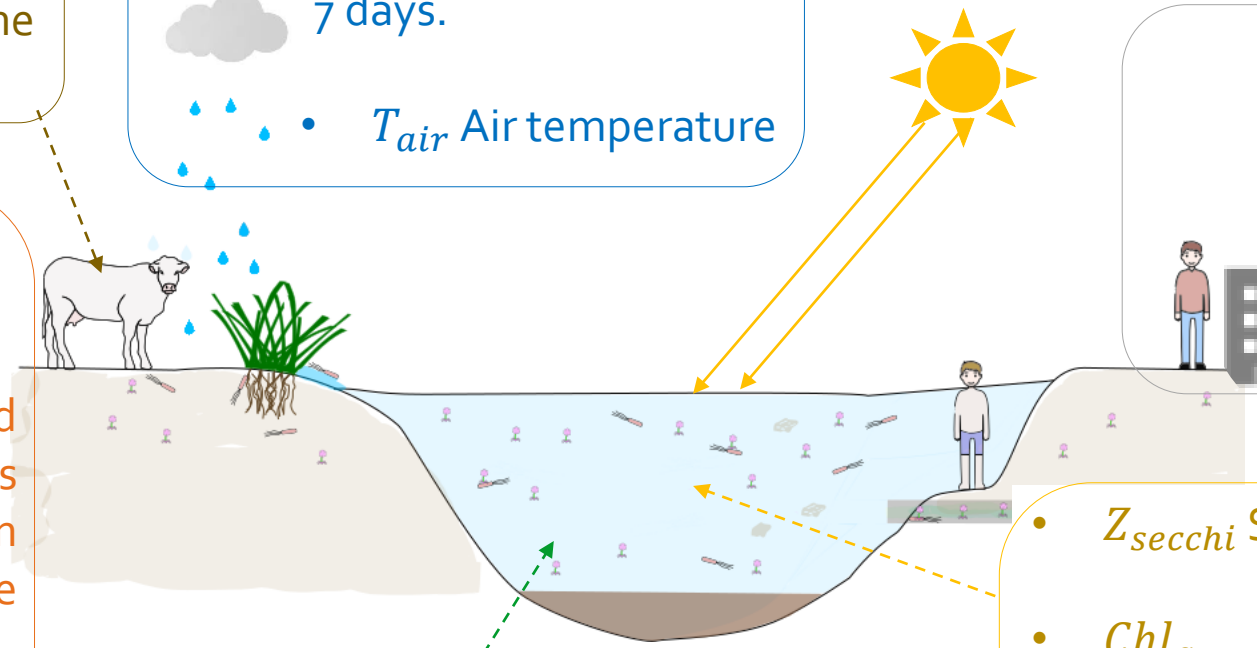
Sampling method in Huot et *al.*, 2019

Independent variables selected

- ρ_{anim} Density of livestock animal units within the census area.

- $\Sigma_{precip7d}$ Cumulative precipitation in the last 7 days.
- T_{air} Air temperature

- ρ_{pop} Population density in the watershed.
- F_{urban} Fraction of urban area in the watershed.



- F_{manure} Fraction of the watershed area where manure was applied on the operation the year prior to the census.

- $A_{agripas}$ Area of agriculture and pasture in the watershed.

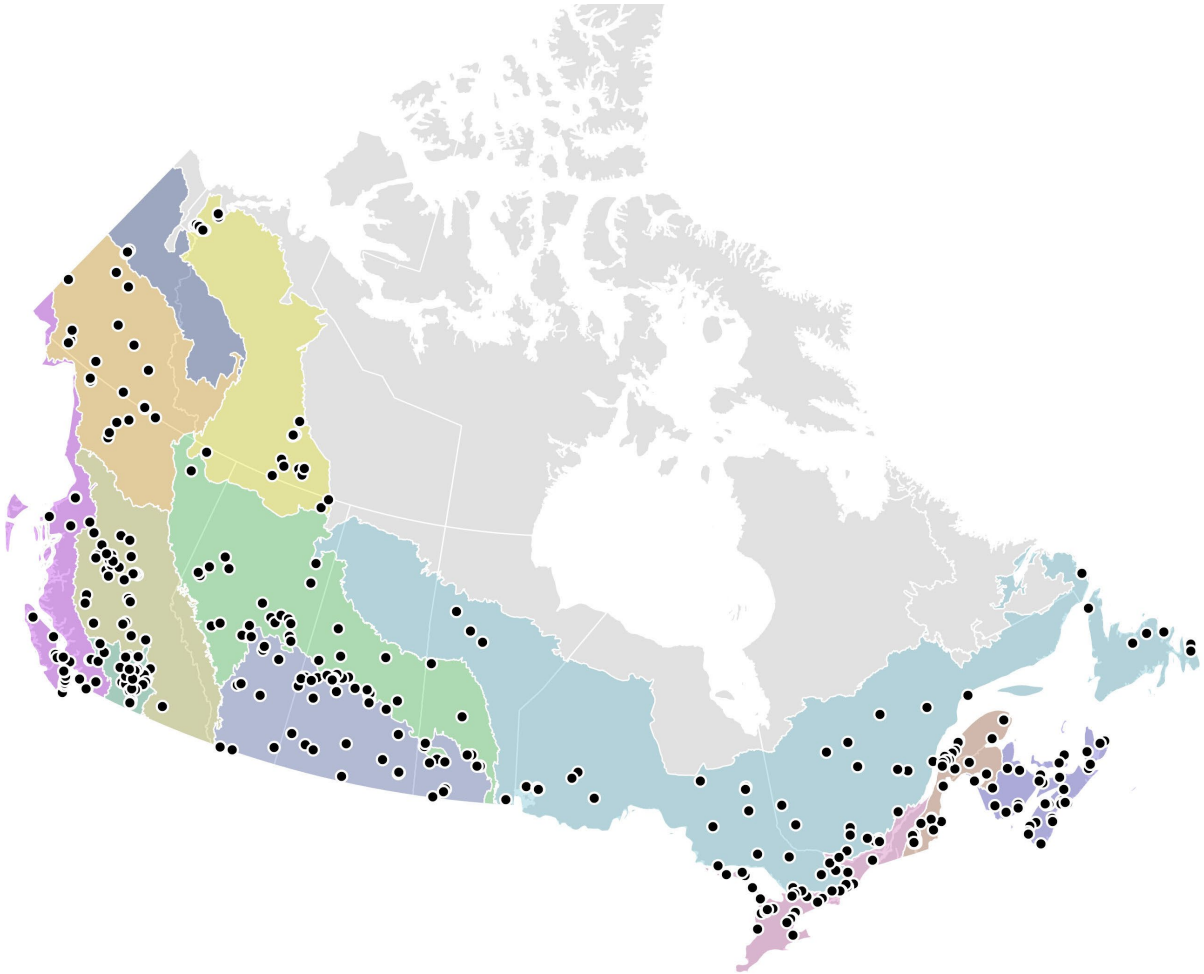
- A_{lake} Lake area.
- S_{100} Average slope within a 100 meters buffer around the lake.

- Z_{secchi} Secchi disk depth.
- Chl_a Chlorophyll a average above thermocline.
- $a_{CDOM}(400)$ Colored dissolved organic matter absorption at 400nm (or 280nm).
- TSS Total Suspended Solids

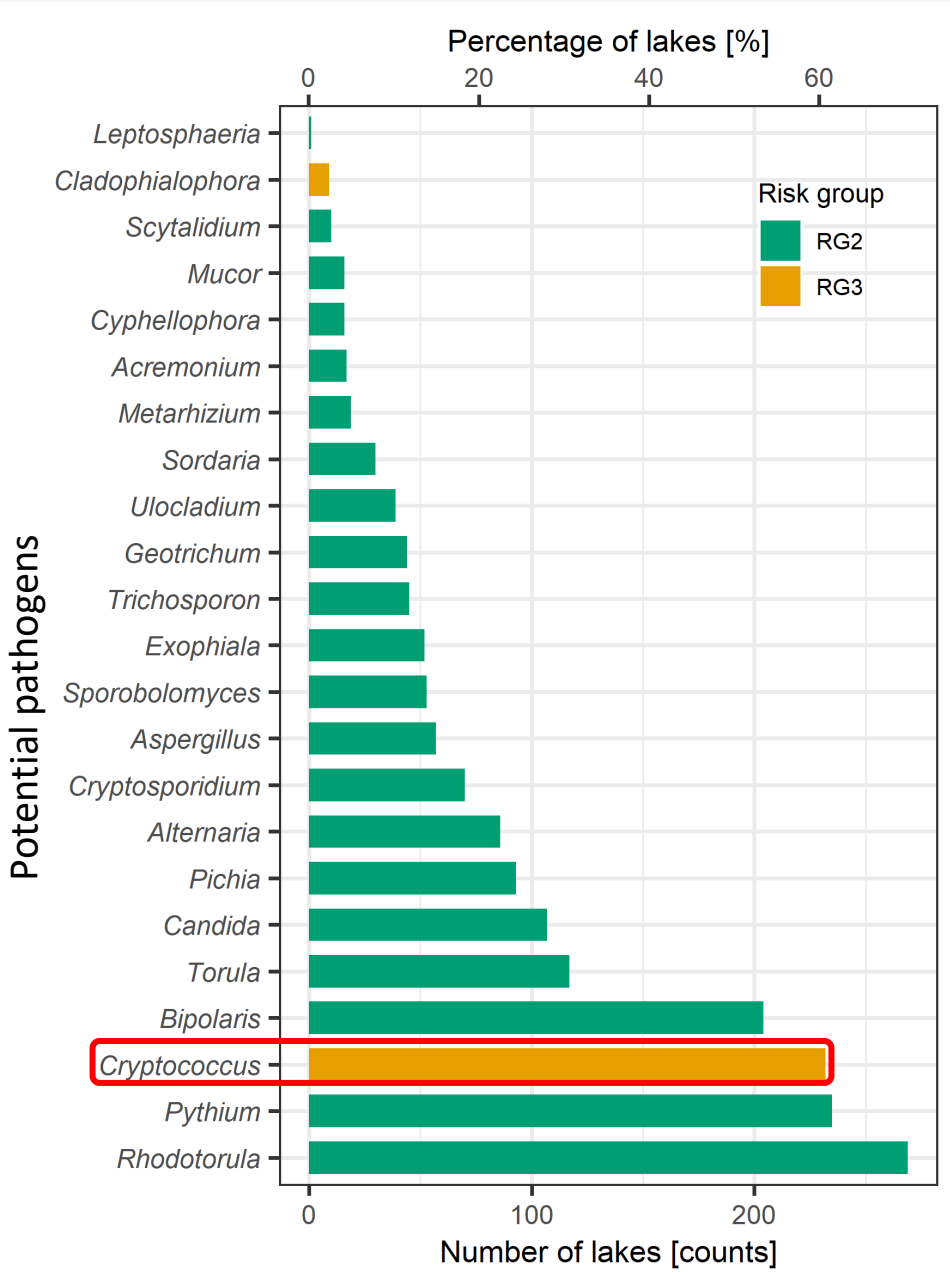
Study 1: Microfungi and parasites

- 382 sampled lakes
- Modelling the occurrence of pathogens in lakes using a bootstrapped Boosting Regression Trees (BRTs)

- Published in Oliva et *al.* (2022), *Water Research*

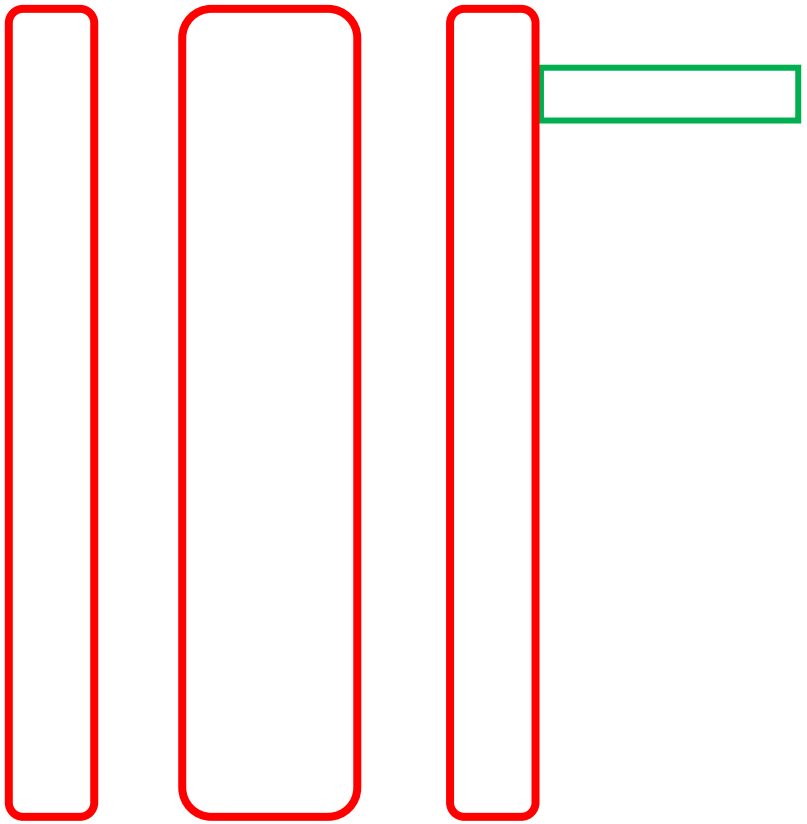


Occurrences of microfungi and parasites



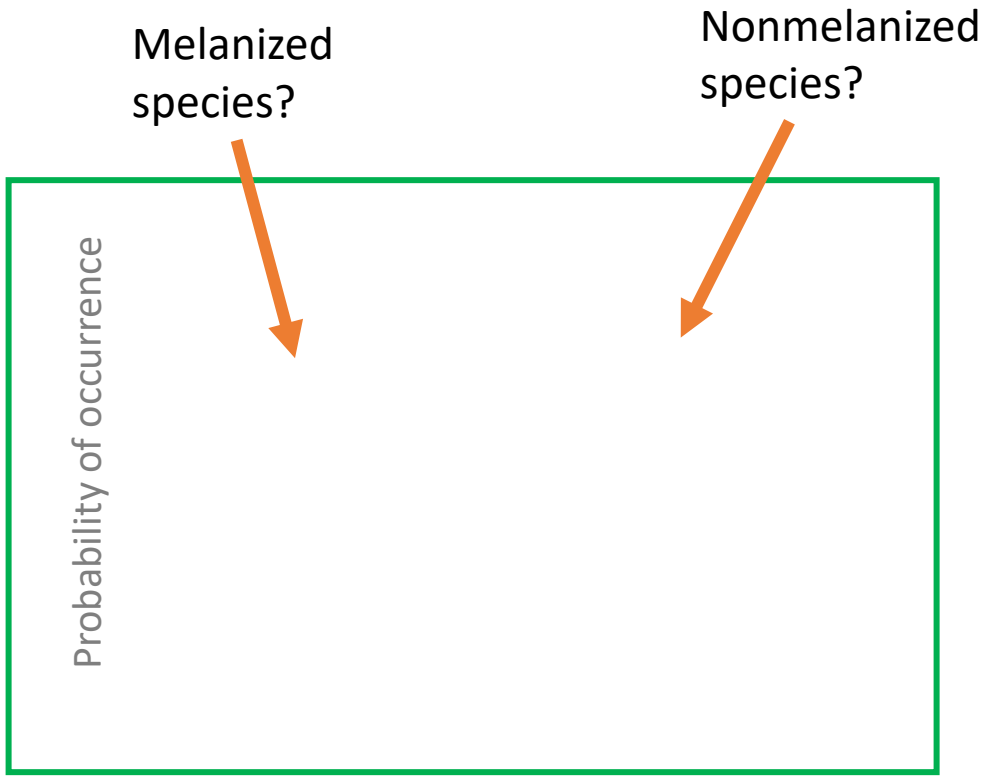
Number of lakes with pathogen data collected= 382

Drivers associated with the occurrence of microfungi and parasites

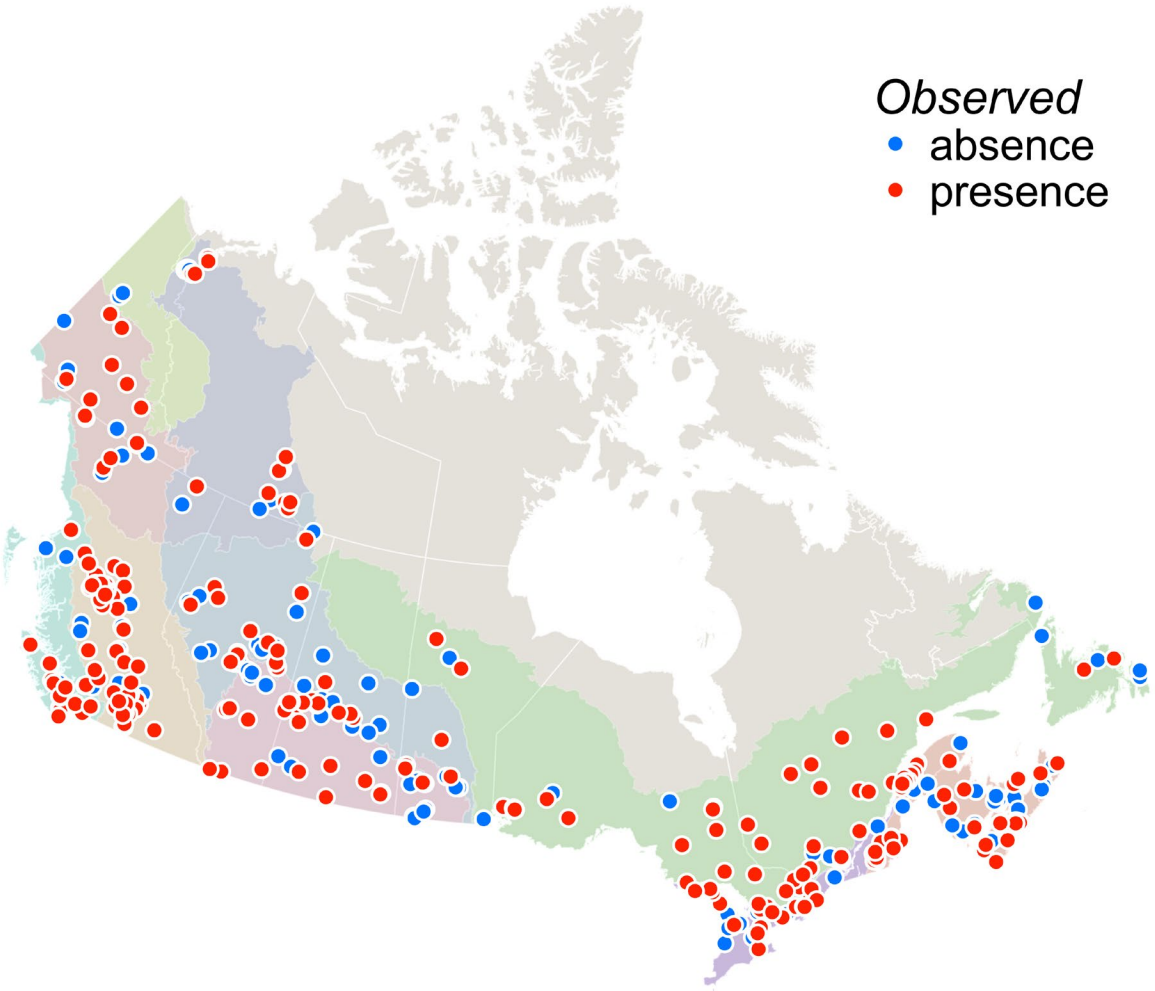


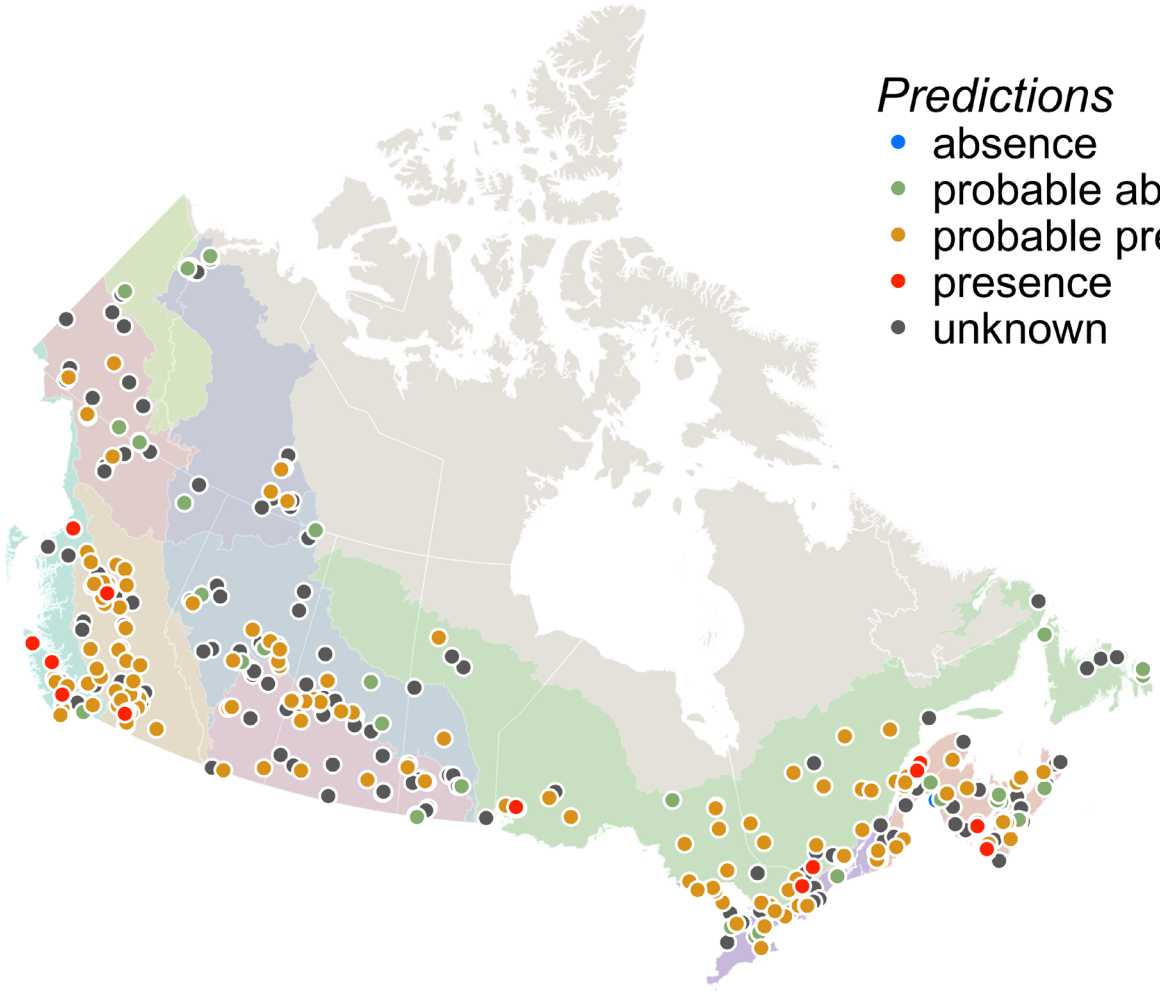
Geospatial drivers

Pathogens found



Occurrence predictions on potentially pathogenic *Cryptococcus*



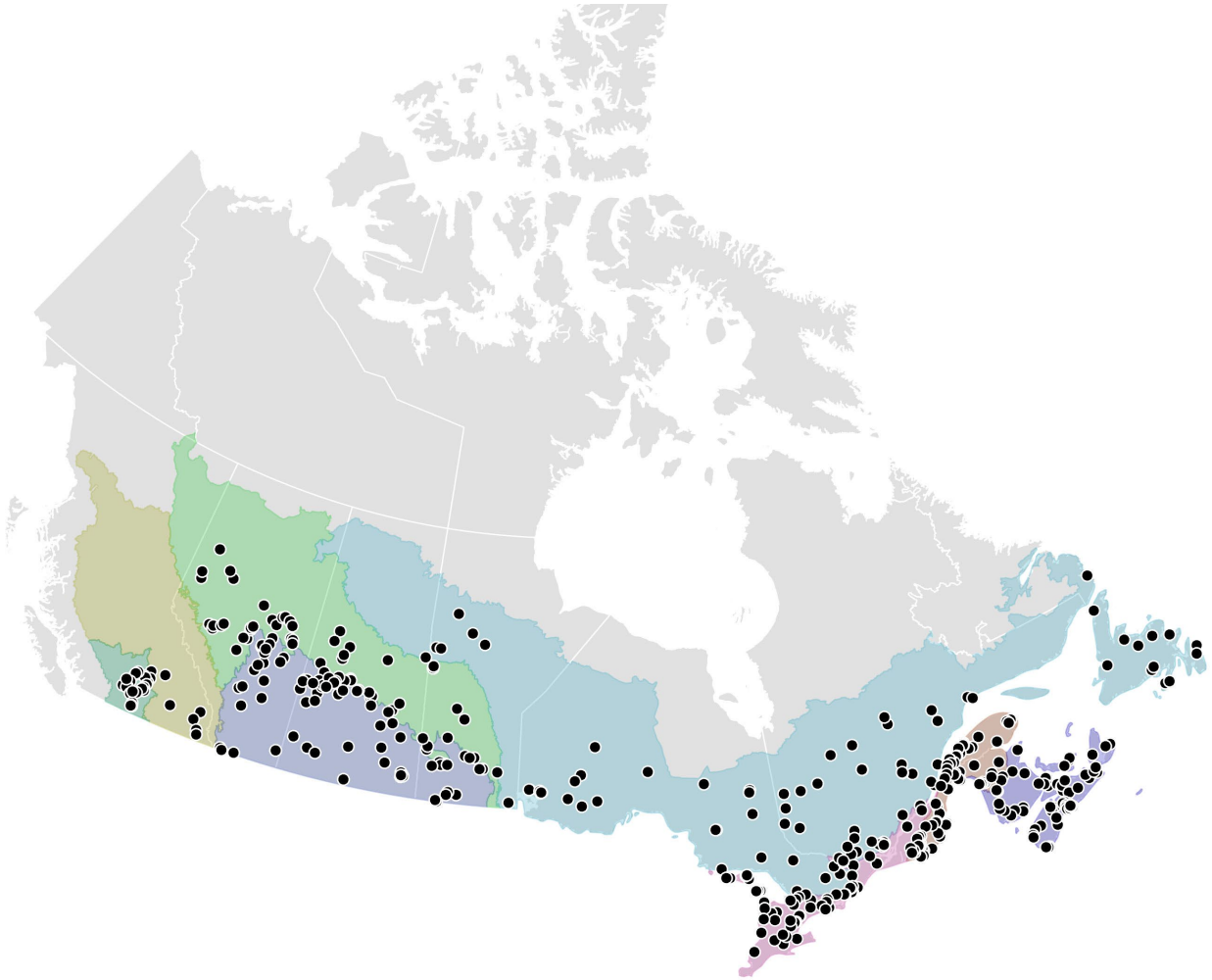


Deviance explained 42.9%

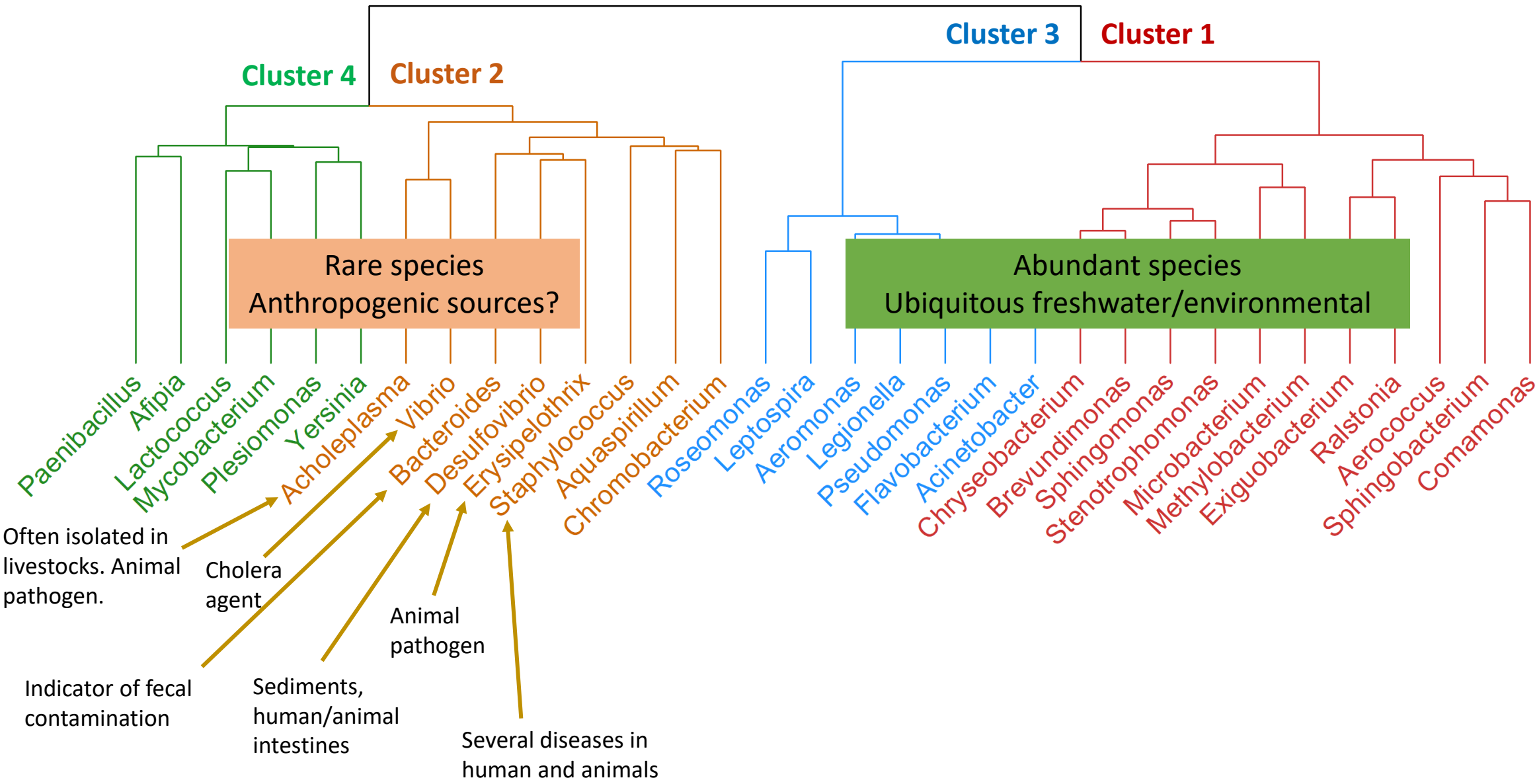
Study 2: Bacteria

- 445 sampled lakes in southern ecozones
- Modelling the occurrence and abundance of clustered bacteria pathogens in lakes using a bootstrapped “hurdle” Boosting Regression Trees

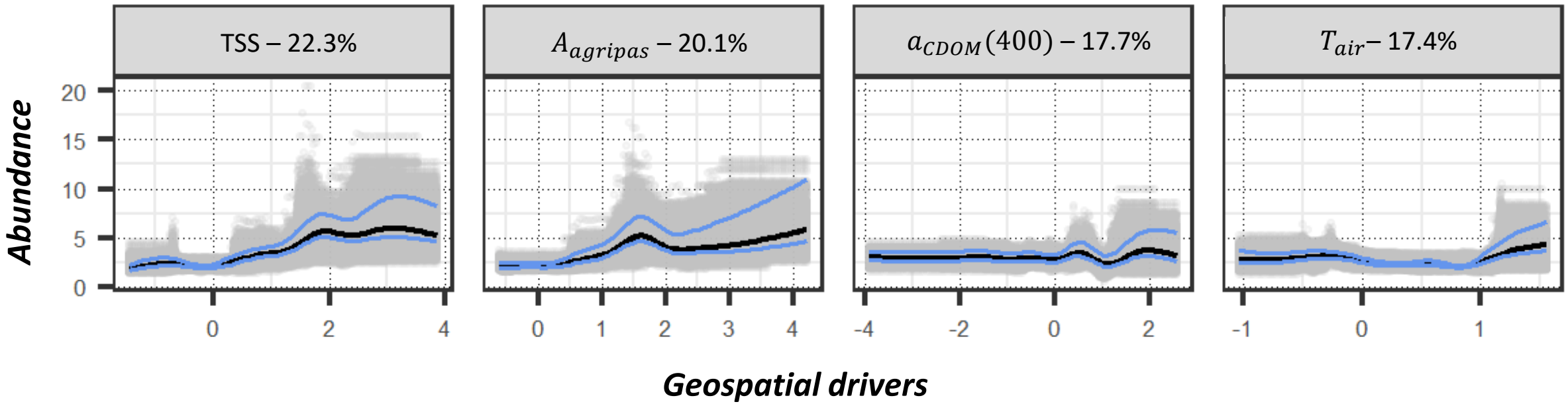
- Oliva et *al.*, in prep.



Clusters of potentially pathogenic bacteria

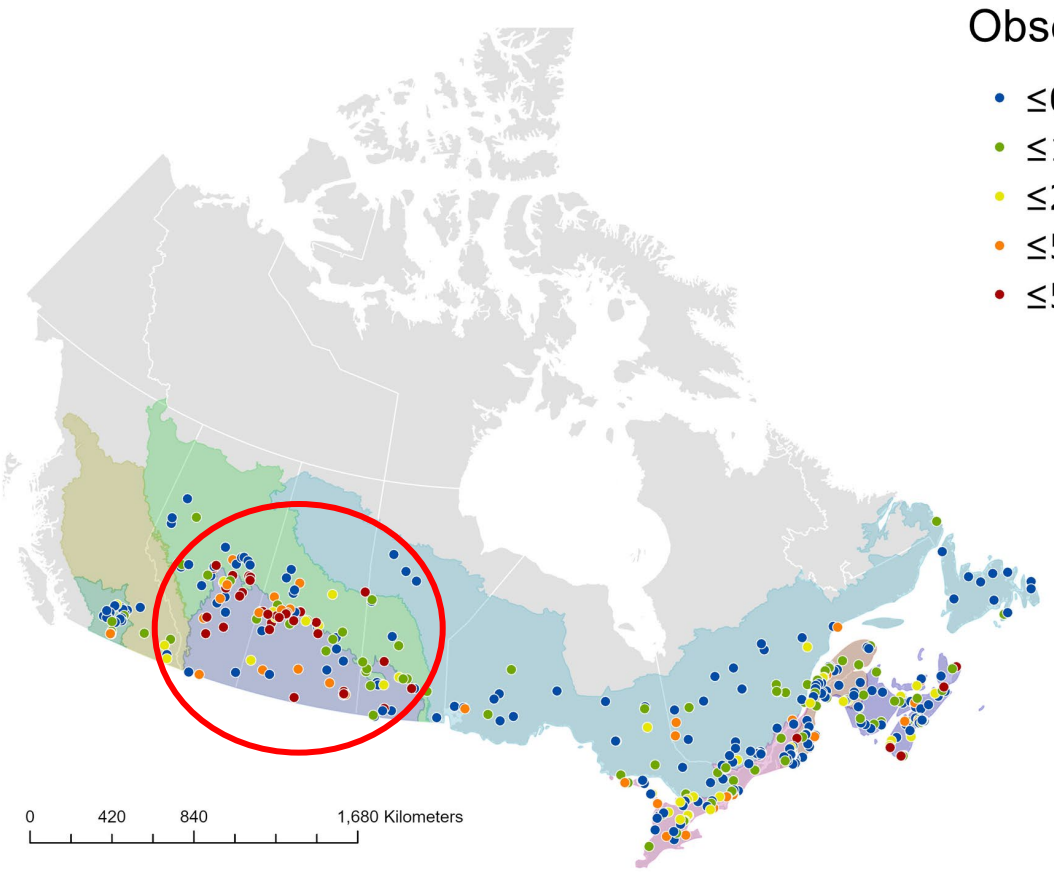


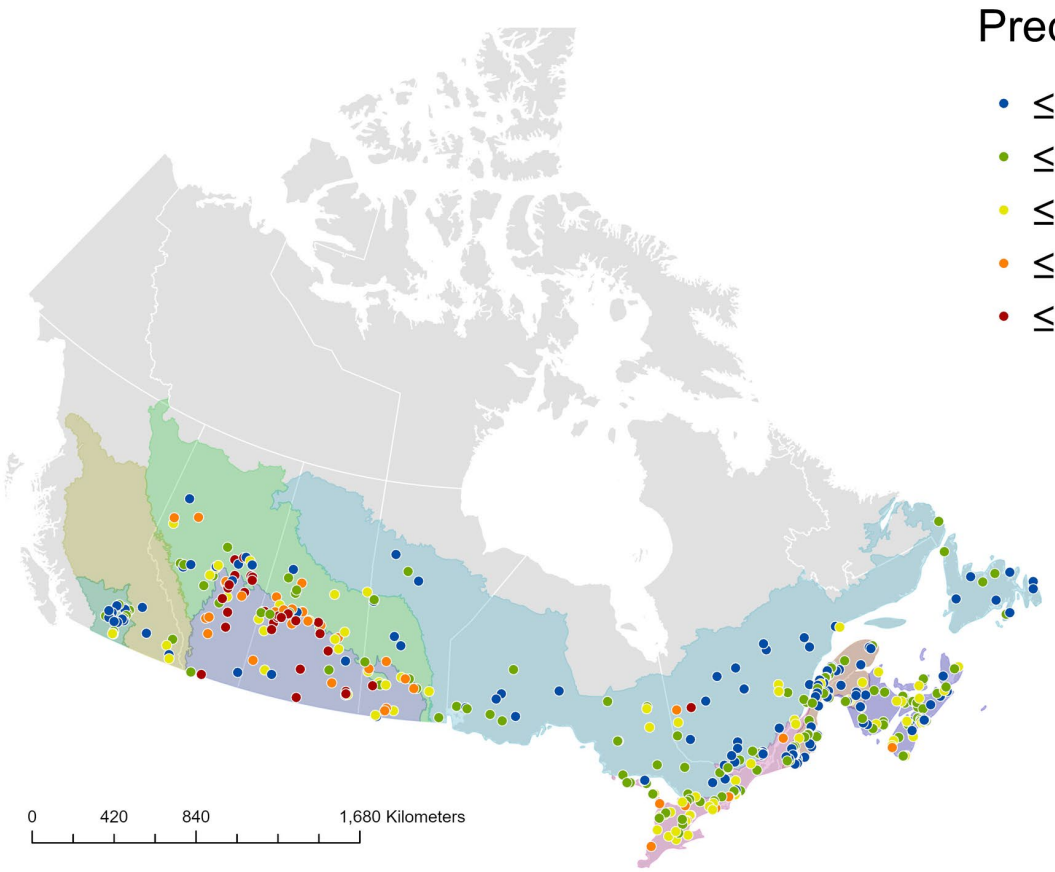
Drivers associated with Cluster 2



Legend Bootstrapped values — Confidence intervals 95% (smoothed) — Median (smoothed)

Cluster 2 : Abundance predictions in southern ecozones





Deviance explained

BRT Occurrence: 42.2%

Main variables: S_{100}, $a_{CDOM}(400)$, *TSS*

BRT Abundance: 45.2%

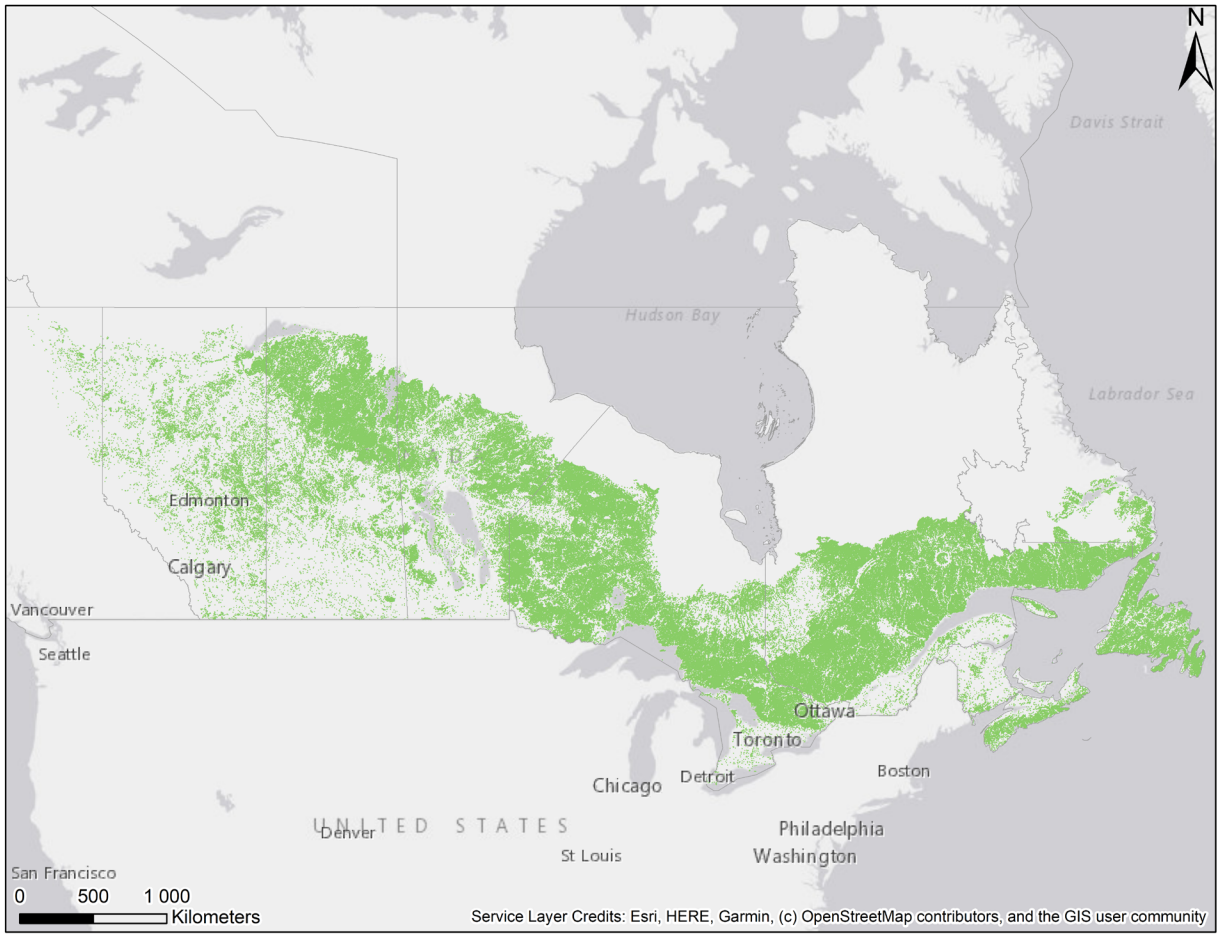
Main variables: TSS, $A_{agripas}$, $a_{CDOM}(400)$, T_{air}

Conclusion & perspectives

- Tele-epidemiology enables mapping and prediction of pathogens in lakes
- Bio-optical, hydrological and meteorological data are important predictors
- Diffuse anthropogenic sources detected with enteric pathogens
- More discussion on the cluster analysis in the upcoming paper

UPCOMING:

Cluster 2 prediction on southern ecozones - **325 850** lakes



Tele-epidemiology has more potential to be explored !

Thank you!

This project was made possible through the amazing efforts of the LakePulse Network ☺

Yannick Huot
Marie-Pierre Varin
Maxime Fradette
Jelena Juric
Gabriel Diab
Catherine Brown
LakePulse field crew
PI's and partners
Walsh lab
Huot lab

https://lakepulse.ca/

Anaïs Oliva
anais.oliva@usherbrooke.ca

NSERC Canadian LakePulse Network

UNIVERSITÉ DE SHERBROOKE

Université Concordia University

Public Health Agency of Canada

GRIL Groupe de recherche interuniversitaire en limnologie et en environnement aquatique

Cartel Université de Sherbrooke

References:

Cott, P.A., Szkokan-Emilson, E.J., Savage, P.-L., Hanna, B.W., Bronte, C.R., Evans, M.S., 2016. **Large lakes of northern Canada: Emerging research in a globally-important fresh water resource**. J. Great Lakes Res. 42, 163–165. https://doi.org/10.1016/j.jglr.2016.02.003

Huot, Y., Brown, C.A., Potvin, G., Antoniades, D., Baulch, H.M., Beisner, B.E., Bélanger, S., Brazeau, S., Cabana, H., Cardille, J.A., del Giorgio, P.A., Gregory-Eaves, I., Fortin, M.-J.J., Lang, A.S., Laurion, I., Maranger, R., Prairie, Y.T., Rusak, J.A., Segura, P.A., Siron, R., Smol, J.P., Vinebrooke, R.D., Walsh, D.A., 2019. **The NSERC Canadian Lake Pulse Network: A national assessment of lake health providing science for water management in a changing climate.** Sci. Total Environ. 695, 18. https://doi.org/10.1016/j.scitotenv.2019.133668

Messager, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O. (2016). **Estimating the volume and age of water stored in global lakes using a geo-statistical approach.** Nature Communications, 7: 13603. https://doi.org/10.1038/ncomms13603

Oliva, A., Garner, R.E., Walsh, D., Huot, Y., 2022. **The occurrence of potentially pathogenic fungi and protists in Canadian lakes predicted using geomatics, in situ and satellite-derived variables: towards a tele-epidemiological approach**. Water Res. 209, 117935. https://doi.org/10.1016/j.watres.2021.117935

Schindler, D.W., 2009. **Lakes as sentinels and integrators for the effects of climate change on watersheds, airsheds, and landscapes.** Limnol. Oceanogr. 54, 2349–2358. https://doi.org/10.4319/lo.2009.54.6_part_2.2349

Yang, K., LeJeune, J., Alsdorf, D., Lu, B., Shum, C.K., Liang, S., 2012. **Global distribution of outbreaks of water-associated infectious diseases.** PLoS Negl. Trop. Dis. 6. https://doi.org/10.1371/journal.pntd.0001483

World Health Organization (WHO), 2019. **Water, Sanitation, Hygiene and Health: A Primer for Health Professionals**, World Health organisation.