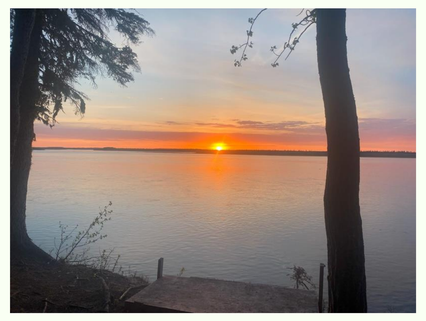
Land-to-Sea Carbon Delivery in Western James Bay

Keilan Ledger[1], Alex Litvinov[2], Zou Zou Kuzyk[1], Alessia Guzzi[1], Dave Capelle[3], Tim Papakyriakou[1]

[1]Centre for Earth Observation Science, University of Manitoba, [2]Land & Resources Department, Moose Cree First Nation, Timmins, ON, [3]Fisheries and Oceans Canada, Winnipeg, MB

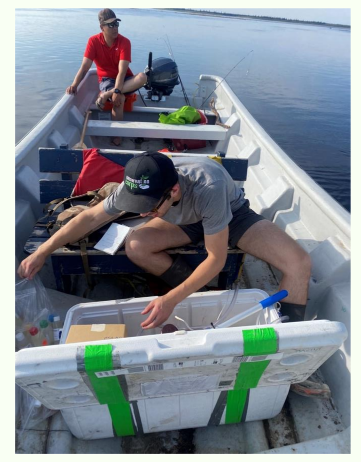
1. Introduction

Rivers are biogeochemical engines that transport and process large volumes of carbon (**C**), connecting the terrestrial and marine **C** cycles. Many large rivers drain the **C**-rich peatlands of the Hudson Bay Lowlands (HBL, **Fig. 1**) into Hudson Bay and James Bay. There exists and strong south to north permafrost gradient in the HBL. The region is subject to stressors associated with warming and development. **Little information exists on existing lateral terrestrial C losses from the HBL, and how these may change with continued shifts in regional hydro-meteorology and potential development impacts.**



2. Research Partnerships

This project is a research partnership between the Moose Cree First Nation (MCFN), Weenusk First Nation (WFN), the Mushkegowuk Council, and the UM's Center for Earth Observation Science. The analyses of water samples (dissolved inorganic **C – DIC** and dissolved organic **C – DOC**) augments an existing and well-developed MCFN water sampling program and supporting the development of a monitoring program with WFN. Water is jointly sampled, and data are shared. The sampling program is designed, to explore variability in **C** concentration in support of shared objectives.



3. Objectives and Methods:

(i) Quantify the seasonality in C concentrations and loads (DIC and DOC) within the lower Moose River (MR) watershed:

- *Water samples from across seasons and years within the lower Moose River were collected and analyzed.*
- *Measured concentrations were used to predict daily dissolved **C** concentrations and loads over a 2-year period using the **USGS Load Estimator (LOADEST)**[1].*

(ii) Develop regional load estimates for major rivers draining the HBL.

- Relationships between dissolved **C** (this project, [8], BaySys) and watershed properties (e.g., **Fig. 1**) were explored (Random Forest Decision Tree model) and used to estimate summertime DIC and DOC for major rivers draining the HBL.
- Seasonality in **C** concentrations observed from MR was used to extend modelling for other rivers beyond the summer season.
- Annual average river discharge[2,3] was used to predict **C** load.

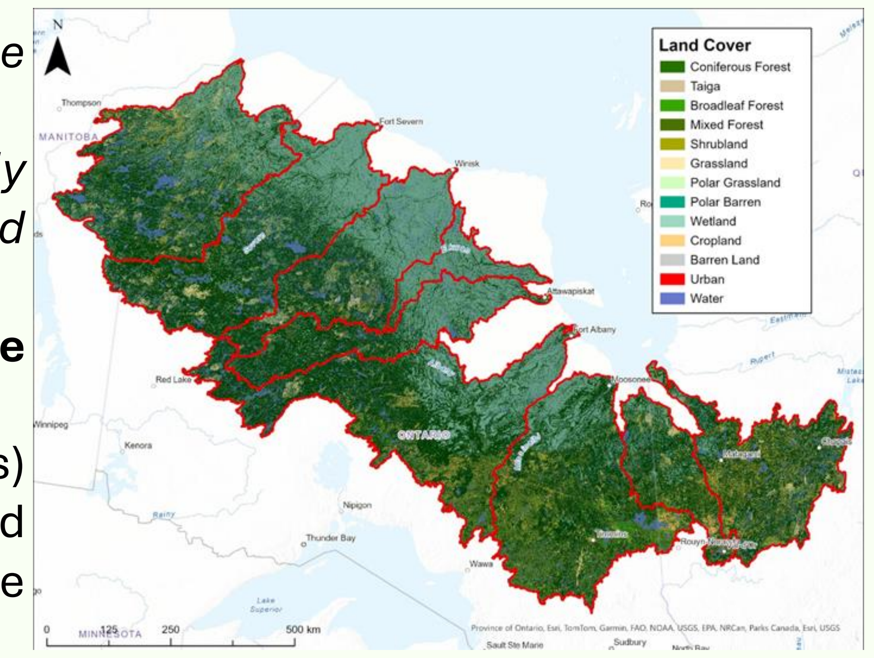


Figure 1: Rivers and land cover classifications of the Watersheds of the Hudson Bay Lowlands. (Watersheds: NRCan[4]; Landcover: Government of Canada[5,6,7])

4. Seasonality in Concentration and Load (Moose River)

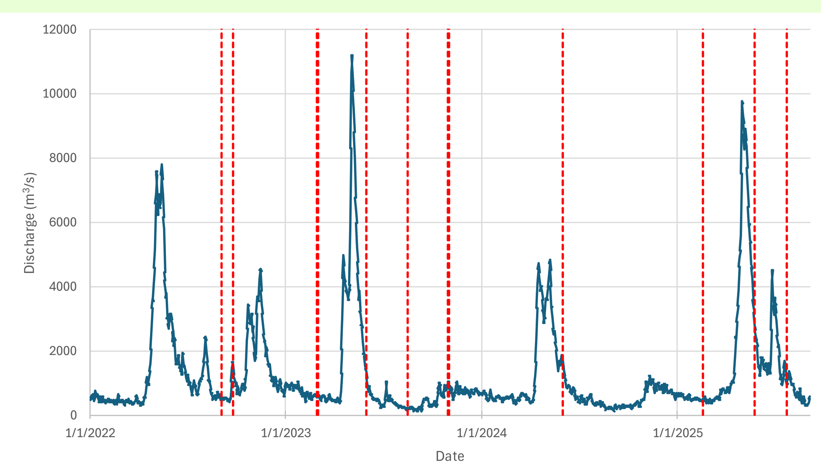


Figure 2: Timeline of samples collected for DOC measurements (red lines) overlain on MR Hydrograph.

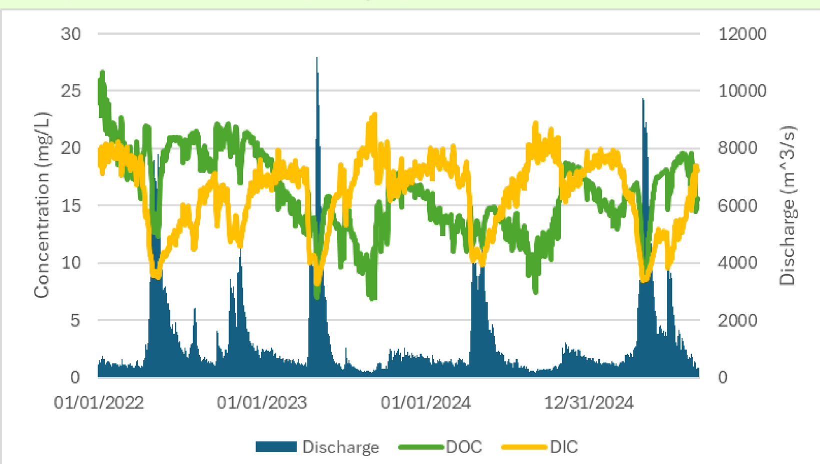
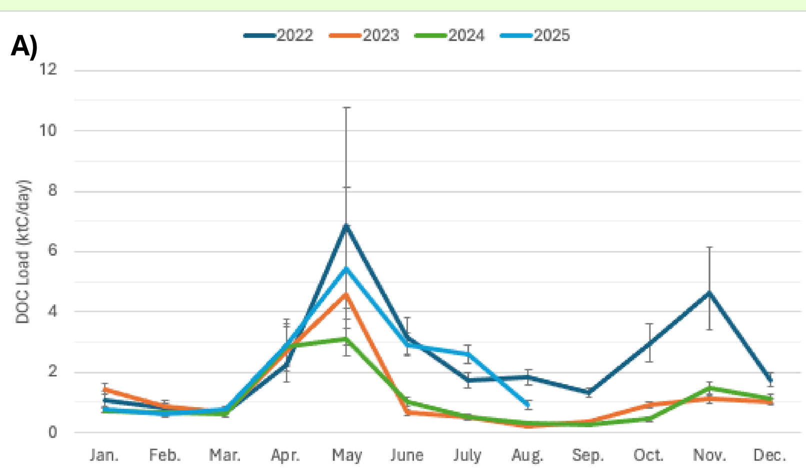


Figure 3: Daily modelled dissolved **C** concentration estimates using **LOADEST** and discharge for the MR from 2022 to end of August 2025.



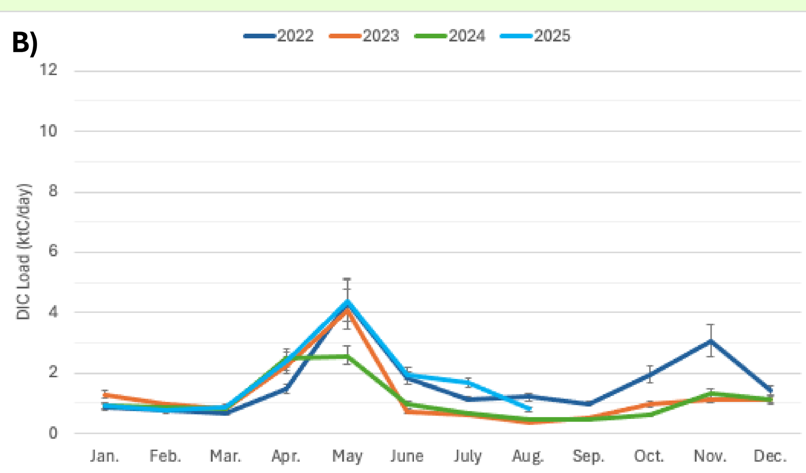


Figure 4: Monthly adjusted maximum likelihood mean dissolved **C** loads with 95% confidence bounds for the MR from 2022 to end of August 2025 for **A)** DOC and **B)** DIC.

5. Random Forest Modelling

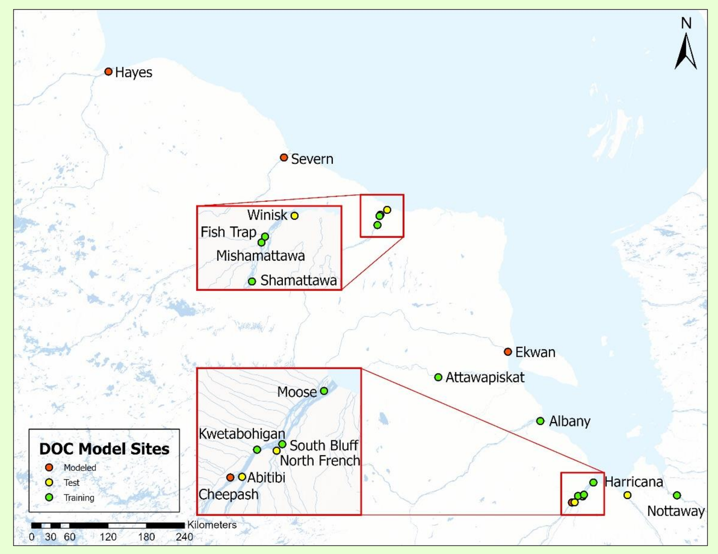


Figure 5: DOC sample locations for test, training, and predicted concentrations (Nottaway and Hayes DOC data from De Melo et al[8]).

River data (DOC) sites from summer sampling used to develop the Random Forest model (**Fig. 5).** A similar approach was adopted for DIC.

Measurements were split randomly into 75% training data and 25% test data to create and test for best linear fit.

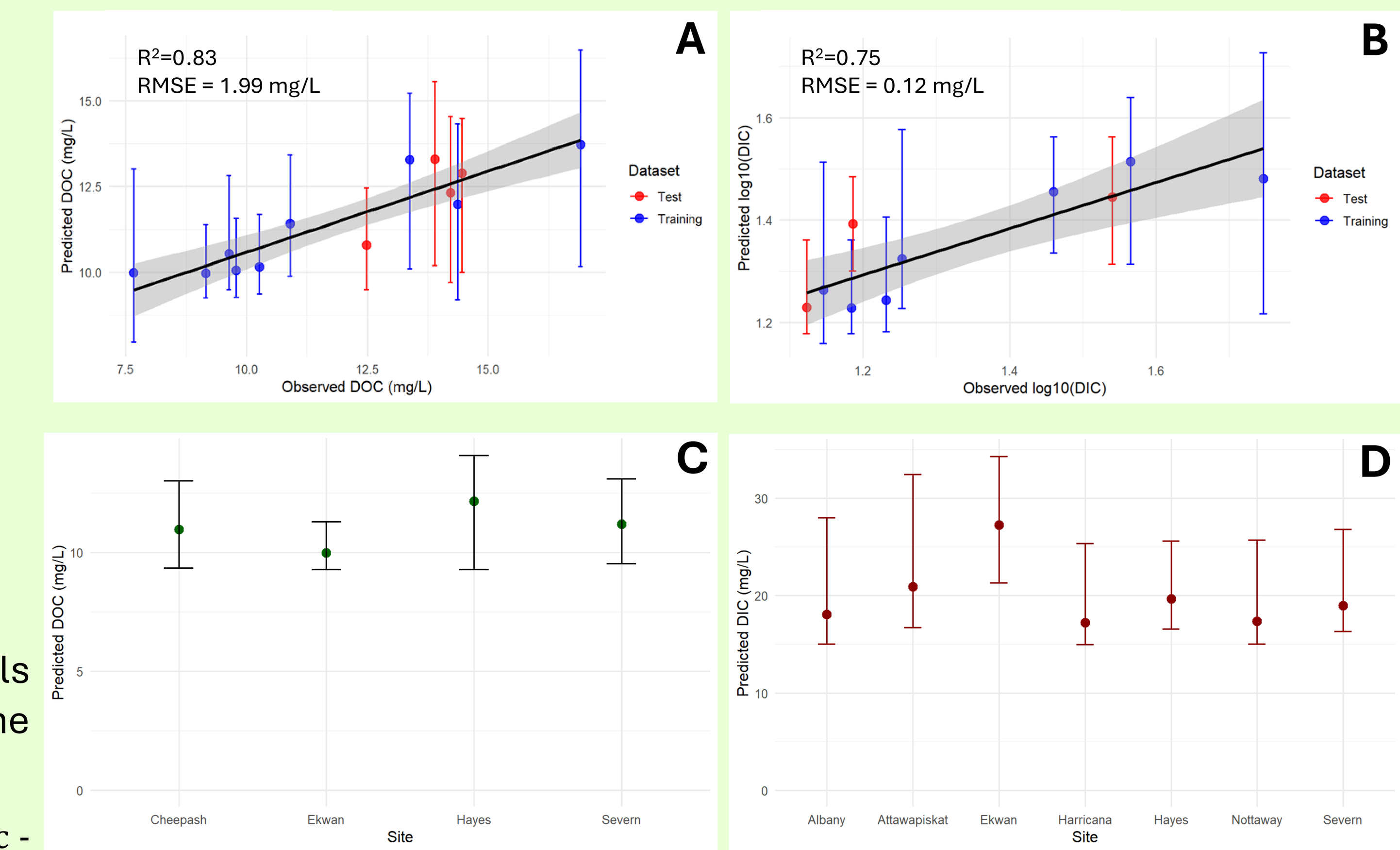


Figure 6: Linear equations developed from the Random Forest model for DOC (A) and DIC (B); Predicted summertime DOC and DIC for external rivers with 95% confidence intervals for DOC (C) and DIC (D).

The linear equations created to explain the DOC and DIC Random Forest models (**Fig 6A & 6B**) were developed using Bootstrapped Monte Carlo Simulations with the top 5 or 6 predictor variables[5,6,7]:

$$\text{DOC (mg/L)} \approx 18.398 - 2.876 * \text{slp} + 0.729 * \text{mf} + 0.016 * \text{np} + 0.432 * \log_{10}(\text{wa}) - 0.032 * \text{tocc} - 2.031 * \text{bf}$$

$$\text{DIC (mg/L)} \approx 10^{2.096+0.008*\text{mf}-0.077*\log_{10}(\text{wa})-0.003*\text{np}-0.022*\text{socc}-0.001*\text{cp}}$$

slp=slope; mf=%mixed forest; np=%without permafrost; wa= watershed area; tocc=total organic carbon content; socc=surface organic carbon content; bf=%broadleaf forest; cp=%carbonate rock

6. Annual Totals

Tables 1a and b: Annual average **C** load based on Mean, Upper and Lower 95% Monte Carlo confidence intervals, for HBL rivers during average discharge conditions for (A) DOC and (B) DIC.

A) DOC	Mean Load (TgC)	Lower Error (TgC)	Upper Error (TgC)
Albany	0.65	0.48	0.79
Attawapiskat	0.18	0.16	0.22
Ekwan	0.04	0.04	0.04
Harricana	0.21	0.16	0.25
Hayes	0.34	0.26	0.39
Moose	0.78	0.59	0.89
Nottaway	0.55	0.48	0.65
Severn	0.14	0.12	0.16
Winisk	0.23	0.20	0.26
TOTAL	**3.12**	**2.49**	**3.65**

B) DIC	Mean Load (TgC)	Lower Error (TgC)	Upper Error (TgC)
Albany	0.40	0.33	0.62
Attawapiskat	0.17	0.14	0.27
Ekwan	0.05	0.04	0.06
Harricana	0.13	0.11	0.19
Hayes	0.29	0.25	0.38
Moose	0.46	0.41	0.62
Nottaway	0.40	0.34	0.59
Severn	0.13	0.11	0.18
Winisk	0.27	0.22	0.34
TOTAL	**2.31**	**1.96**	**3.26**

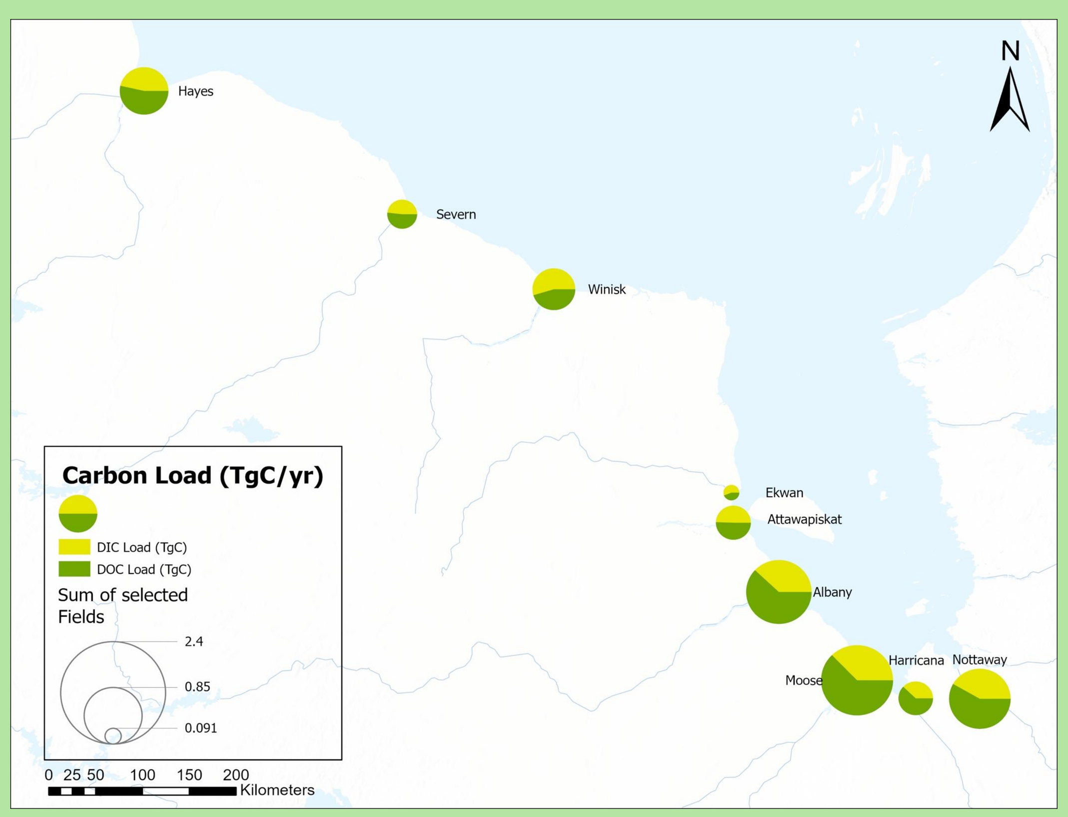


Figure 7: Mean annual load of DOC and DIC (TgC/year) for rivers draining the HBL.

7. Summary & Next Steps:

- Water sampling did not capture peak flow (**Fig. 2**), and this upcoming year we will attempt to capture the freshet's peak flow.
- Transported **C** (DOC and DIC) can be estimated in the HBL using watershed landscape properties (**Fig. 6**).
- Modelled concentrations and loads for DIC and DOC show pronounced seasonal and interannual variability (**Fig. 3, 4A & B**).
  - Peak May (freshet) mean modelled loads for the MR range from 6.8 ktC/Day DOC (4.1 to 10.8 ktC/Day) to 3.1 ktC/Day DOC (2.5 to 3.7 ktC/Day).
  - Seasonal uncertainty for load DOC estimates is largest during the freshet (**Fig. 4A**).
- Uncertainty in DOC concentration prediction is largest for northern rivers (e.g., **Fig. 6C**) and in southern rivers for DIC (**Fig. 6D**).
- Mean average annual dissolved **C** load from the major rivers draining the HBL (Hayes to the Nottaway) is 5.4 TgC (4.4 to 6.9 TgC).
  - DOC:DIC ratio is 1.3 (**Fig. 7**)
- Results would benefit from increased sampling of both DOC and DIC for HBL across seasons and in particular during the freshet.

Acknowledgments:

The project is supported by Parks Canada and the NSERC Alliance and Discover Grant Programs.

Special thanks to the Moose Cree First Nation for granting us permission to work within their territorial lands, and for their collaboration on this project. Additional thanks to the MCFN technicians and community members who have helped with sample collection. Lastly to the staff and students at CEOS who have helped with this project, in particular Ashley Soloway, Ayub Regehr, Sam St. Germain-Silva, Daniel Gedig, Heidi Ahrenholtz.

References:

[1] Runkel R.L. et al. (2004) U.S. Geol. Surv. Tech. and Meth., book 4, chap. A5, 69 pp., U.S. Geol. Surv., Denver, Colo.

[2]Environment and Climate Change Canada Real-time Hydrometric Data. 2024. https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html

[3]Déry, S. J., et al. (2011) Journal of Marine Systems, 88(3), 341–351. https://doi.org/10.1016/j.jmarsys.2010.12.002

[4]National Resources Canada. 2025. https://open.canada.ca/data/en/dataset/a4b190fe-e090-4e6d-881e-b87956c07977

[5]Government of Canada, Natural Resources Canada, Canada Centre for Remote Sensing. (2025, August 20). 2020 Land Cover of Canada. Natural Resources Canada, Federal Geospatial Platform. https://osdp-psdo.canada.ca/dp/en/search/metadata/NRCAN-FGP-1-ee1580ab-a23d-4f86-a09b-79763677eb47

[6]Tarnocai, C., I.M. Kettles and B. Lacelle. 2011. Peatlands of Canada; Geological Survey of Canada, Open File 6561 (digital database); CD-ROM.

[7]Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release–Data 126 - Revision 1.

[8]De Melo, M. L., Gérardin, M.-L., Fink-Mercier, C., & Del Giorgio, P. A. (2022). Patterns in riverine carbon, nutrient and suspended solids export to the Eastern James Bay: Links to climate, hydrology and landscape. *Biogeochemistry*, *161*(3), 291–314. https://doi.org/10.1007/s10533-022-00983-z