The influence of hydrologic connectivity on the diversity and productivity in Arctic thermokarst lakes

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Introduction

- **Permafrost** in the Canadian Arctic is under constant stress from increased global warming in high latitudes.
- The active layer which freezes and thaws seasonally, is under constant morphological change from permafrost melt and meteorological change.
- The **active layer** surrounding thermokarst lakes above the tree line in the Canadian Arctic are witnessing erosion and changes in hydrologic connectivity due to global warming.
- **Hydrologic connectivity** is the paths rainwater, permafrost melt, snow melt, and groundwater wake to reach the sampled thermokarst lake.
- **Phytoplankton/algae and microbes** (including heterotrophic bacteria) are at the base of the thermokarst lake ecosystems, and their diversity and productivity is influenced by changes in hydrologic connectivity.

Project

Hypothesis: Climate change is affecting the diversity of primary production in Arctic thermokarst lakes by altering hydrologic connectivity along the aquatic-terrestrial interface.
Prediction: An increase in connectivity in the lakes will have increased microbial and algal production

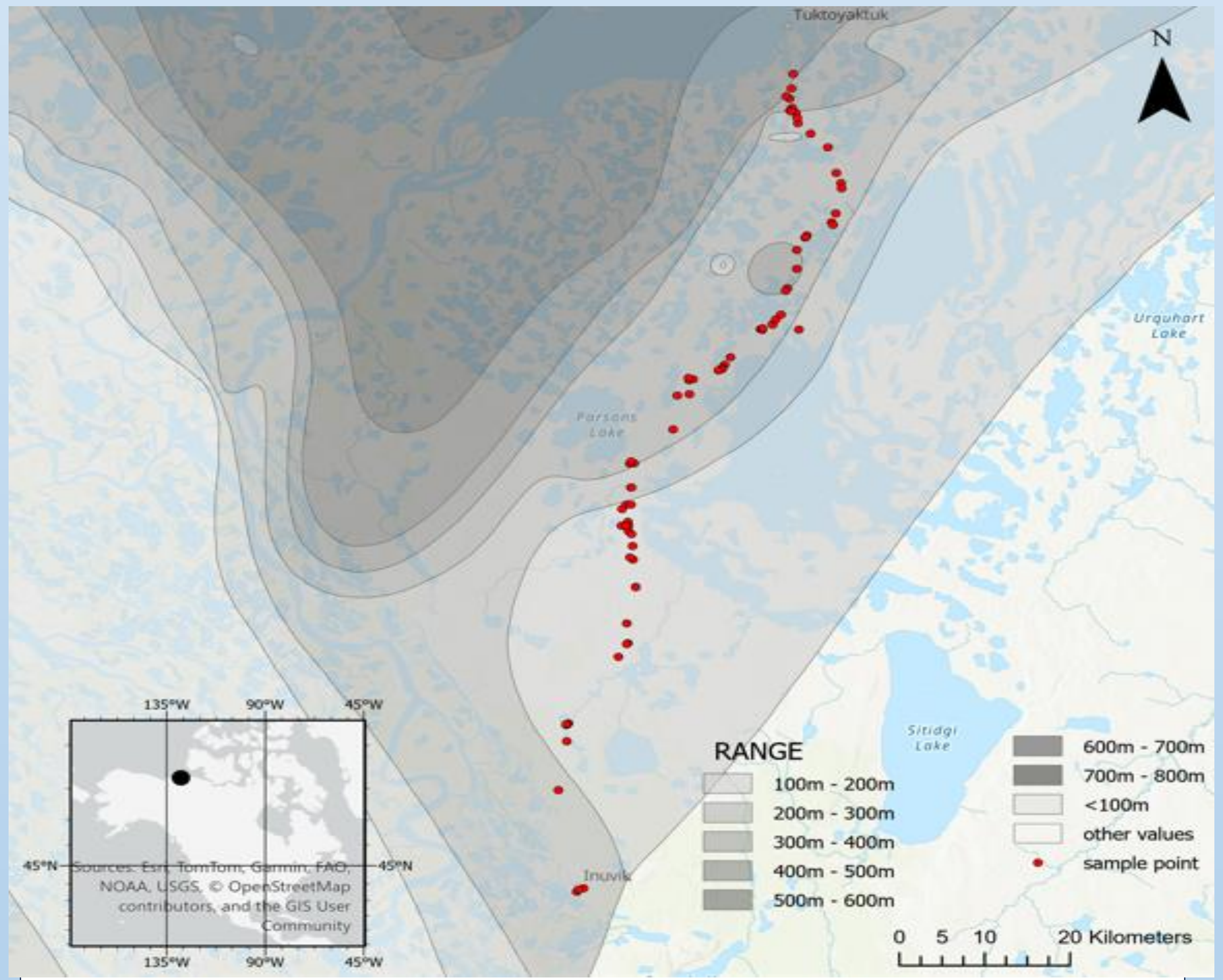

Figure 1 A map of sampled points distributed over a permafrost gradient between Inuvik and Tuktoyaktuk (NWT). Samples were taken within ~400m of the Inuvik-Tuktoyaktuk Highway when it was not raining nor within 1 day of a rain event. The map is under the North Pole Lambert Azimuthal Equal Area Projection and created using ArcGIS Pro.

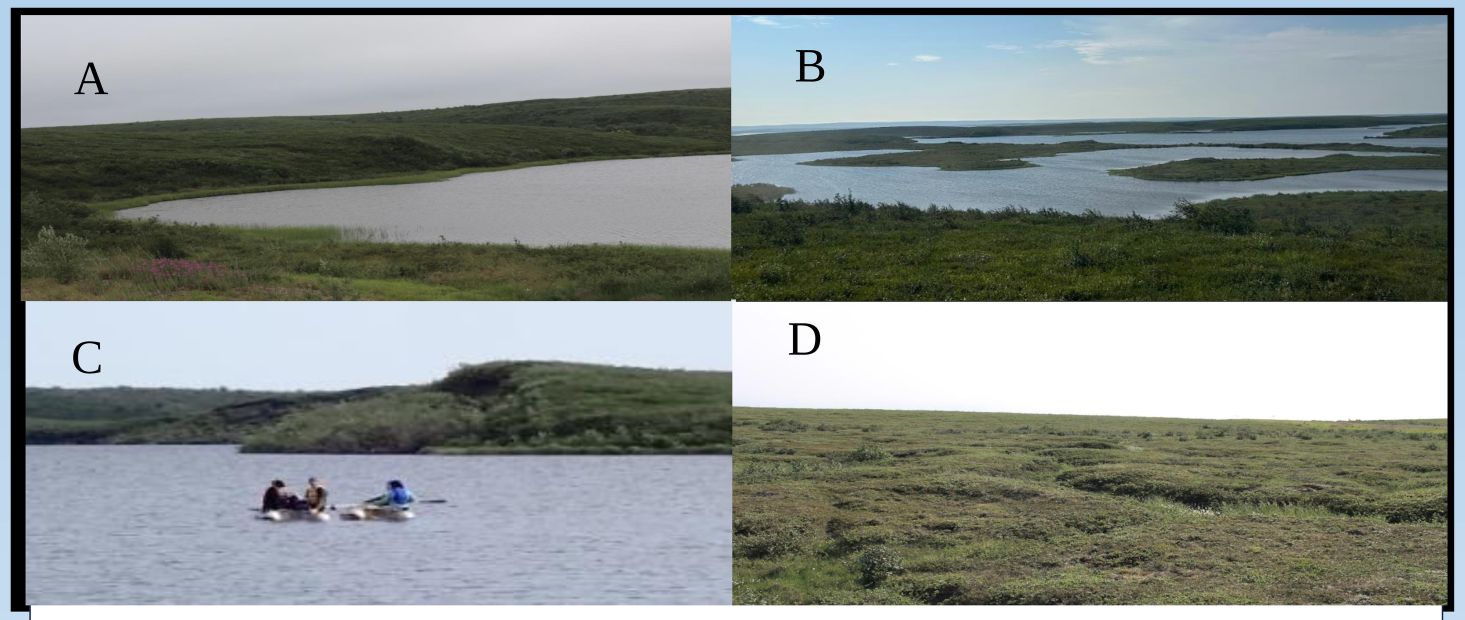

Figure 2 A) An average sized lake that was sampled within the transect. **B)** Example of a larger lake located within the transect. **C)** Taking water samples in lake 7 from within the transect, visible erosion is visible in the background. **D)** an example of polygons that were sampled for oxygen isotopes from within the transect.

Methods

1. Field data was collected in July of 2023, samples were taken upstream from the vessel. Water column data like temperature, total dissolved solids, pH was collected *in-situ* using a YSI.
2. Oxygen isotope samples, trace metal samples, and nutrient data was sent elsewhere for analysis
3. Fluorescent dissolved organic matter (FDOM) samples were processed using a Cary Eclipse Spectrofluorometer.
4. Data was analyzed using R Studios and Sigma Plot to produce PCAs and water isotope plots. Imagery was also used with GPS tags.

FDOM Protocol

1. Samples were thawed in the dark and kept in the dark until use to avoid photodegradation
2. Samples were inserted into a 10mm-by-10mm quartz cuvette using a sterile syringe attached to a new 0.20µm filter per sample, bubbles were removed.
3. A fixed wavelength protocol was run on peaks T, B, R, A, C, and M [using a 5nm Ex/Em bandwidth, 5000nm/min scan speed, Xe light source, medium (600) PMT voltage].
4. Samples were run in duplicates then averaged.
5. The data was transformed into Raman units that neglects background noise and machine error.

Peak Name	Ex/Em	Component	Source
T	280/350	Tryptophan-like, protein-like, slightly degraded peptide material, intact proteins	Autochthonous, sometimes soil freeze/thaw processes on microbes, associated with high microbial activity, positively correlated to leucine-aminopeptidase activity
B	270/315	Tyrosine-like, protein-like, more degraded peptide material	Autochthonous, sometimes soil freeze/thaw processes on microbes
R	275/305	Tyrosine-like, protein-like, very degraded peptide material, like peak B but much smaller in molecule size	Autochthonous, sometimes soil freeze/thaw processes on microbes
A	250/400-460	UVC humic like, high molecular weight, many aromatics,	Terrestrial, microbially transformable (but not transformed)
C	320-360/420-460	UVA humic like	Terrestrial, anthropogenic, agriculture, plants, inland, microbially transformable (but not transformed)
M	290-320/370-410	UVA humic like, Low molecular weight,	Associated with biological activity, from wastewater, wetlands, and agriculture

Table 1 A reference to Figure 3 explaining FDOM protein-like peaks: T, B, and R; as well as the humic-like peaks: A, C, and M. Peaks were achieved using Spectrofluorometry. A sample with a high intensity of M or C is typically seen as containing water with lots of humic-like substances and it typically shows less bacterial activity. A sample with a high peak T intensity is typically seen as to have many protein-like substances and have more bacterial activity and is said to be more labile.
Ex/Em = Excitation / Emission

Results

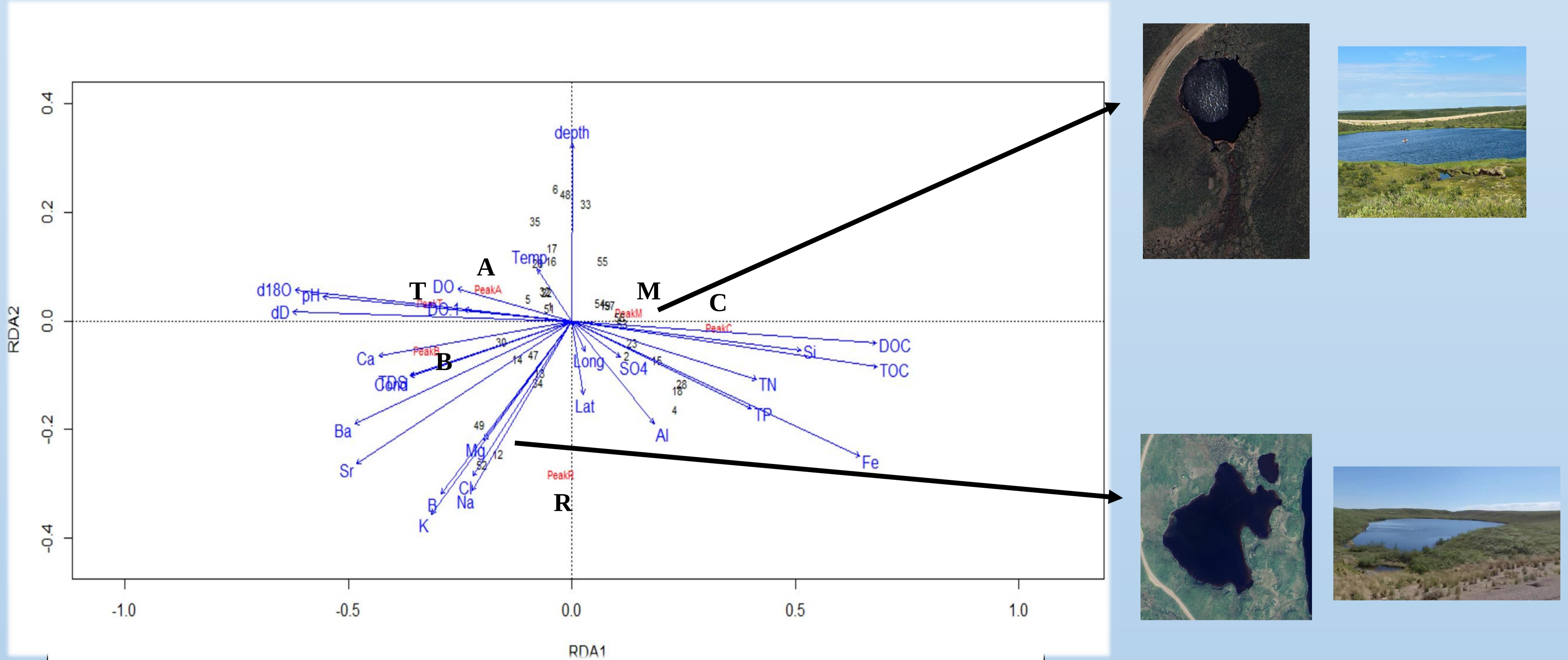

Figure 3 A PCA is used to show exploratory data gathered from prior field work in this study. It has been reduced to a 2D graph. Vector length correlated to the strength of a given parameter in comparison to the primary or secondary axis, while angles shows similarity to parameters. Samples are distributed throughout the graph and show relatedness to the vector parameters. FDOM peaks are also shown here and can be further understood in Table 1. The X axis is primarily dissolved organic carbon (DOC) and the Y axis is depth and latitude. On the right side of the X-axis, sample nutrients primarily come from water input, while the left side of the Y-axis shows more erosion and anthropogenic sourced material. Images of the lakes can be seen on the right of the PCA from lake 56 on top and 12 on the bottom. Photos are aerial from google earth or as a landscape view and taken during the 2023 field season.

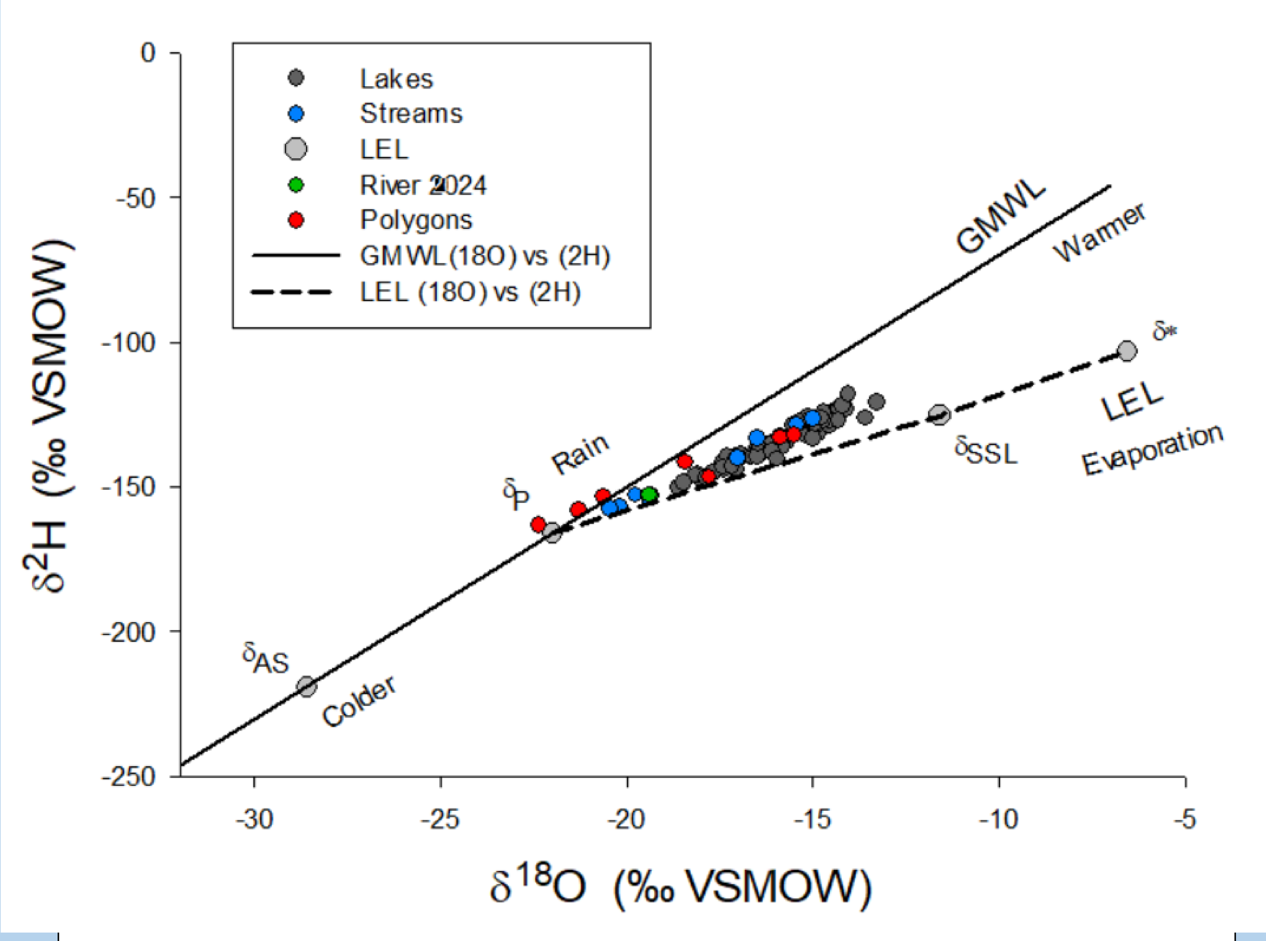

Figure 4 O^{18} isotopes compared to the VSMOW (Vienna Standard Mean Ocean Water) is on the X-axis, while H^2 isotopes compared to the VSMOW is the Y-axis. The GMWL (Global Meteoric Water Line) is sued as a standard to show samples that are influenced primarily by precipitation, the LEL (Local Evaporation Line shows samples that are primarily affected by evaporation stress. This line was create using an artificial evaporation setup during July of 2023 in a similar location to that of the taken samples and compared to data from 2014. Samples closer to the left of the graph are in cooler sources compared to those at the right which come from warmer sources. Lake samples in the south end of the permafrost gradient were typically warmer than those in the north end. Polygon samples above the GMWL are likely snow melt or ice lens sourced.

Conclusion

- Water temperature seems to decrease in a north to south altitude gradient and lake source water is not precipitation dominated.
- Lakes, polygons, and streams differ from each other in terms of sources.
- Polygons near lakes typically also feed the lakes
- Warmer lakes tend to have more bacterial activity, more analysis is needed to understand the conditions required for optimal peak T production and therefore more labile DOM.

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