Determining the Fate of Redox-Active Organic Matter in Northern Peatlands under Global Climate Change

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Redox-Active Organic Matter and Northern Peatlands

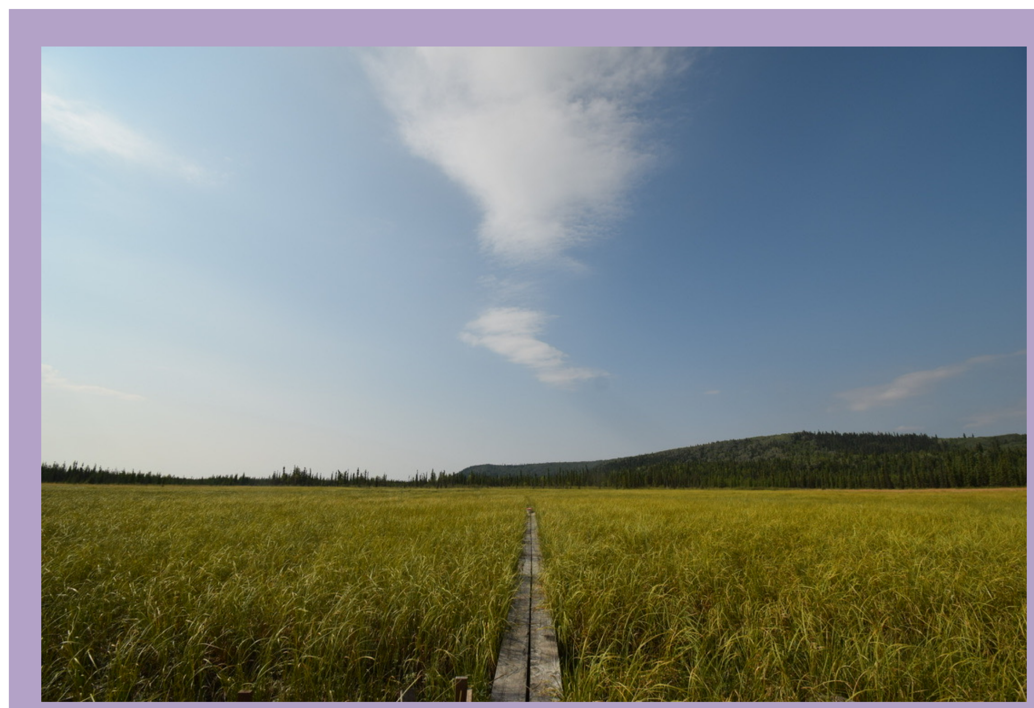

Fig. 1. A rich fen located in interior Alaska at the Bonanza Creek LTER.

- Northern peatlands (Fig. 1) are important carbon reservoirs, storing ~500 Gt of carbon[1].
- **What is the fate of these large carbon stores under consequences of global climate change; i.e., rising air temperatures, permafrost thaw and changes in water-table levels?**
- We must study **controls on carbon greenhouse gas production** in these ecosystems to see if they will switch from carbon sinks to sources under global change.

Redox-Active Organic Matter (RAOM); a key control on carbon greenhouse gas production

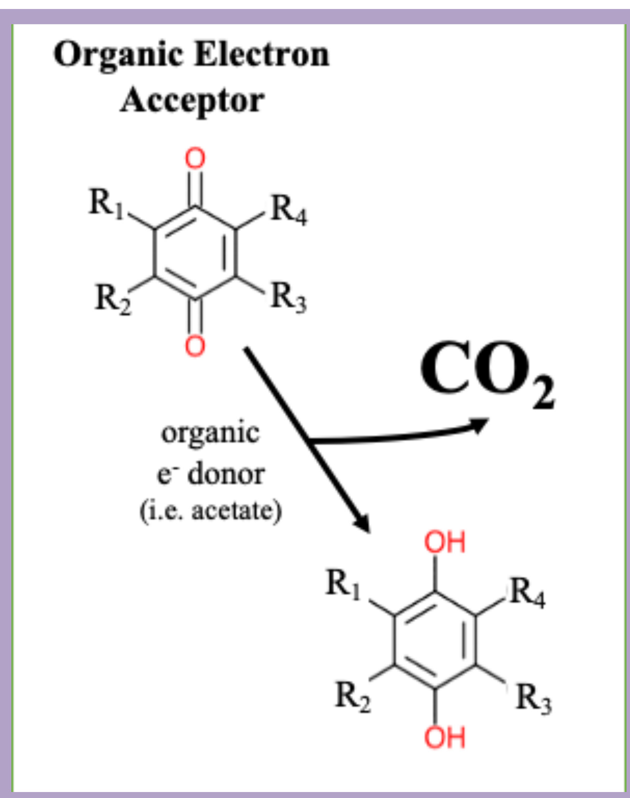

Fig. 2. A schematic of a redox-active organic molecule participating in microbial anaerobic respiration.

- RAOM are complex carbon molecules that contain redox-active components like quinones.
- Microbes can use RAOM as alternative terminal electron acceptors (TEAs) in anaerobic respiration (Fig. 2). This produces carbon dioxide (CO_2) and suppresses methanogenesis since it is a more thermodynamically favorable process.
- **It is unclear how much RAOM contributes to greenhouse gas production in different peatland types and how these contributions will shift under global climate change.**

1. How do long-term water-table fluctuations change the RAOM pool?

- The Alaskan Peatland Experiment (APEX; Figs. 3 and 4) has been manipulating the water-table of a rich fen for ~20 years, with a lowered and raised manipulation relative to a control. The site has also experienced prolonged periods of flooding in the summers due to increased precipitation (Fig. 4). During this time, no water-table manipulation can take place.

Fig. 3. Collecting porewater at the rich fen experiencing water-table manipulation during a dry summer.

Late July 2021 vs 2022

Fig. 4. Collecting porewater at the rich fen during a flooded season.

- We looked at RAOM reduction in July 2020 vs 2021. We hypothesized that, during water-table manipulation, the raised treatment would have the most reduced RAOM. During the flooded year, we did not expect to see differences in RAOM as peat chemistry is resilient.

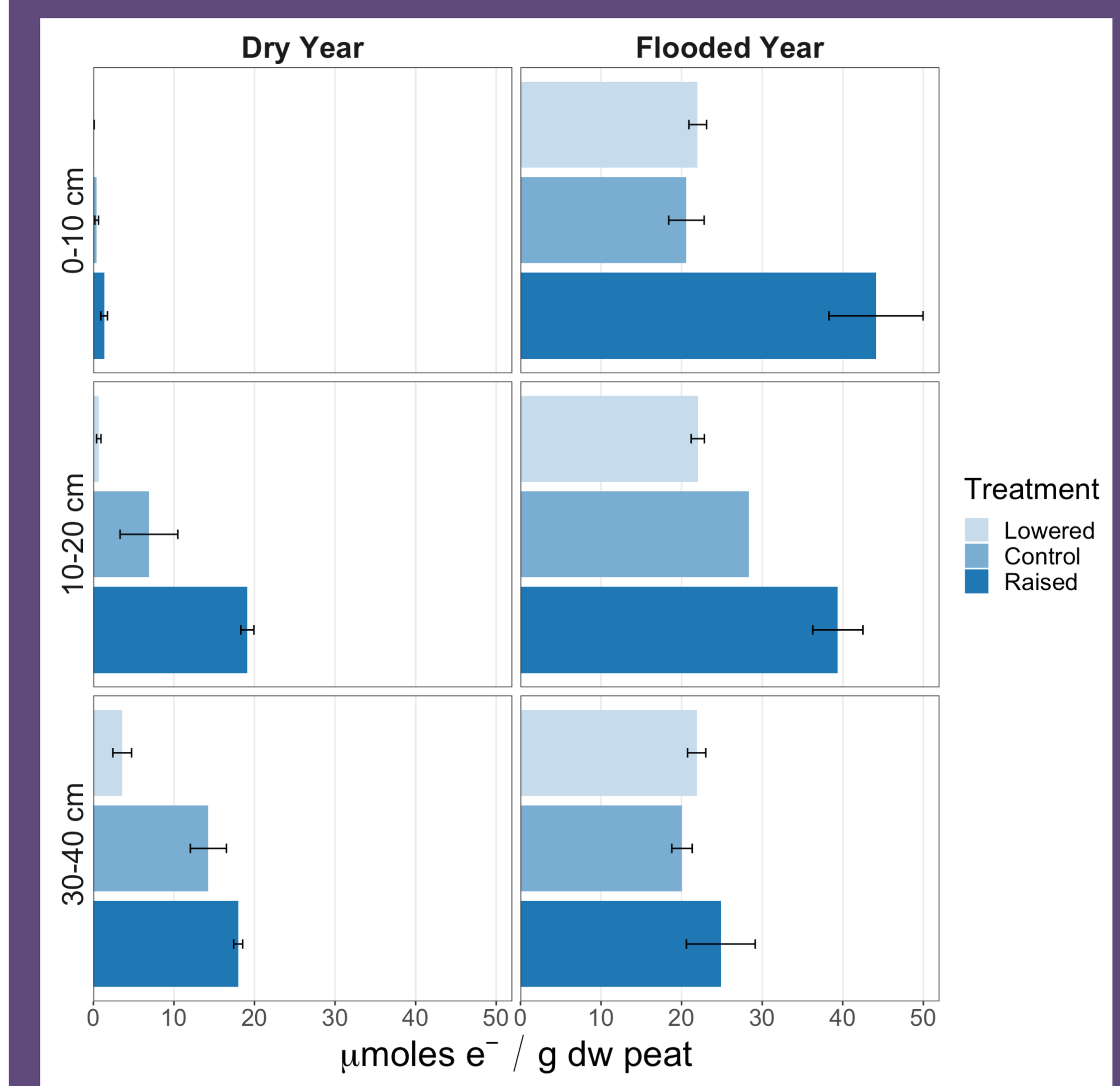

Fig. 5. The average amount of electrons (+/- 1 SE) represents how reduced the RAOM is in each treatment. Here, we see legacy effects of water-table manipulation even when all sites are flooded.

2. How does elevated temperature affect the structure of RAOM in permafrost peatlands?

- Due to their remote locations, less is known about the RAOM pools of arctic and permafrost peatlands and how a changing climate will affect these important carbon sinks.
- Permafrost contains rich carbon compounds that will be released by climate-induced thawing. This may introduce more RAOM into the ecosystem and change carbon cycling.
- This summer, I will collect peat cores from wet sedge and permafrost peatlands near the Toolik field station (Fig. 6) to understand the structures of the RAOM and how those structures will be impacted by warming.

Fig. 6. Satellite imagery of Toolik Lake and field station (provided by Google Maps). Stars represent planned sampling locations for the summer of 2023.

- While the RAOM structure in Fig. 2 represents a reversible pool, RAOM can also serve as irreversible electron sinks during hydrogenation reactions[2]. This study will therefore track structural components of RAOM related to reversibility throughout an incubation experiment using analyses like mass spectroscopy and ^{1}H-NMR (Fig. 7).

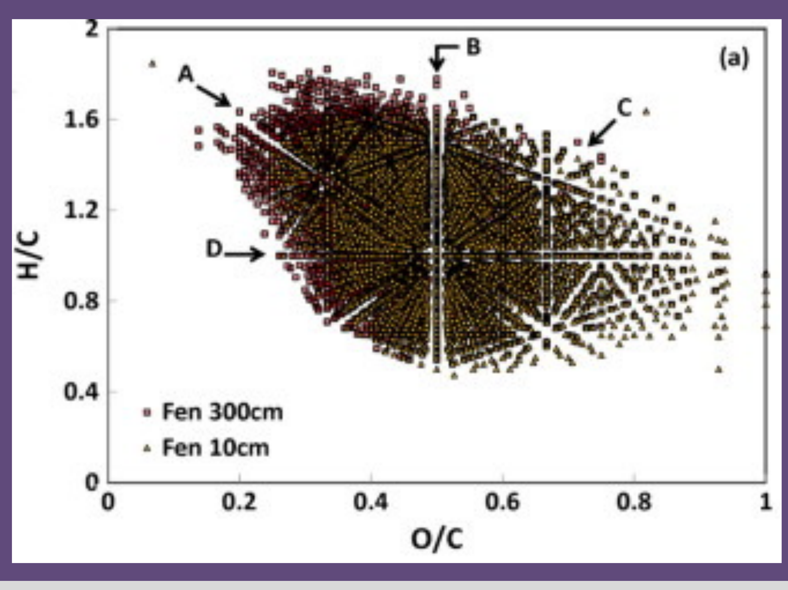

Fig. 7. Work from Tfaily et al., 2013 looking at the chemical structure of RAOM in fen porewater. The letters present different chemical reactions indicative or reversibility and are: (A) methylation, demethylation; (B) hydrogenation or dehydrogenation; (C) hydration; and (D) oxidation or reduction.

3. How does sustained belowground warming and elevated atmospheric CO_2 affect RAOM reduction?

- The Spruce and Peatland Responses Under Changing Environments (SPRUCE) site in the Marcell Experimental Forest in northern Minnesota has exposed an ombrotrophic bog to varying atmospheric and belowground temperatures (from + 0 °C to + 9 °C) and elevated atmospheric CO_2 for almost 10 years (Fig. 8).

Fig. 8. Aerial view of the SPRUCE site and the experimental chambers. Photo provided by Oak Ridge National Lab.

- Previous work by Rush et al. 2021 showed that there were no legacy effects of 2 years of warming on RAOM reduction[3]. Later studies, however, did show changes to the chemistry of the carbon at the site[4,5].
- After 10 years, would the results of Rush et al. 2021 be different to reflect these changes in carbon chemistry?
- We hypothesize that there will be legacy effects of the *in-situ* treatments on solid-phase RAOM. Additionally, the *in-situ* treatments will change the rate of RAOM reduction, measured using peat peepers (Fig. 9) with warmer temperatures and elevated CO_2 leading to slower rates.

Fig. 9. Peat peepers are PVC pipe with holes drilled along its length to allow for exchange between the peeper and the environment. We place mesh packets of a common peat substrate at 10 cm depth increments to measure the effects of environmental, experimental manipulation on RAOM.

Acknowledgements and References

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