Methane emissions from beaver-impacted aquatic ecosystems in Alaska

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Background

Beavers (Fig. 1) are known for their role in enhancing ecosystem methane (CH_4) emissions in temperate and subboreal ecosystems by engineering flooded aquatic habitats and concentrating carbon stocks in anaerobic settings (Bubier 1993). In permafrost regions, ponding accelerates permafrost thaw, which should lead to elevated CH_4 emissions from anaerobic decomposition of thawing soil organic matter (Figs. 2,3). While Clark (2024) proposed a relationship between hyperspectral AVIRIS-NG CH_4 hotspots and beaver expansion into Northwest Alaska tundra, to our knowledge, observational field data of beaver-associated CH_4 emissions are lacking for permafrost ecosystems.

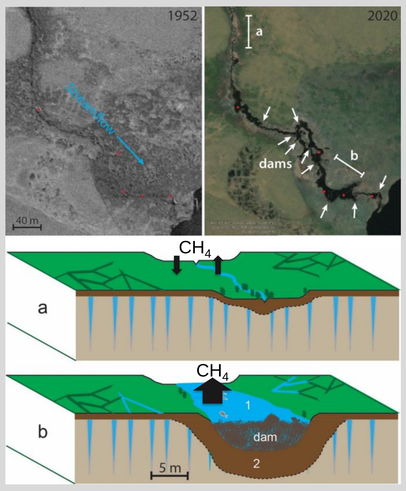

Fig. 2. Example of thermokarst ponds created by beaver dams in Northwest Alaska between 1952 and 2020 (modified from Tape 2022).

Hypothesis

Permafrost thaw should mobilize previously frozen soil organic carbon, increasing CH_4 emissions compared to pre-beaver conditions.

Methods

We conducted field measurements (n = 813) of diffusive CH_4 fluxes using a portable chamber connected to a Los Gatos Greenhouse Gas Analyzer at 14 beaver-impacted lakes, ponds and streams in Alaska (Figs. 4,5). Field sites spanned tundra and boreal forest ecotypes characterized by permafrost.

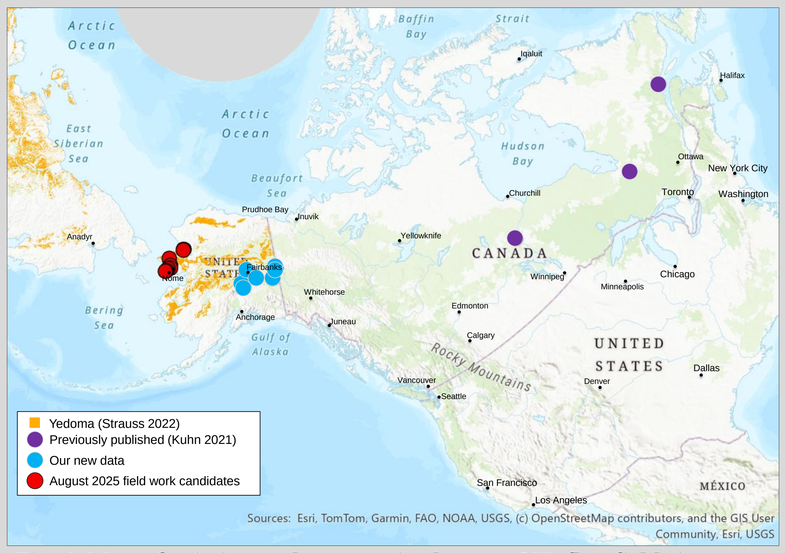

Fig. 4. Map of existing and prospective beaver-CH_4 flux field sites.

Fig. 5. Photos of CH_4 flux measurements using a portable chamber in winter (a) and summer (b).

Fig. 1. Photograph of an Alaskan beaver (*Castor canadensis*). Source: Alaska Department of Fish and Game.

Fig. 3. Methane bubbles concentrated around a beaver lodge in an Alaska Range pond. Photo: Katey Walter Anthony

Results

Beaver Impact on Methane Emissions

Methane emissions within 3-m of beaver lodges were 5 to 38 times higher than emissions away from lodges, and 2 to 400 times higher than the adjacent terrestrial ecosystems that represent pre-beaver fluxes (Fig. 6).

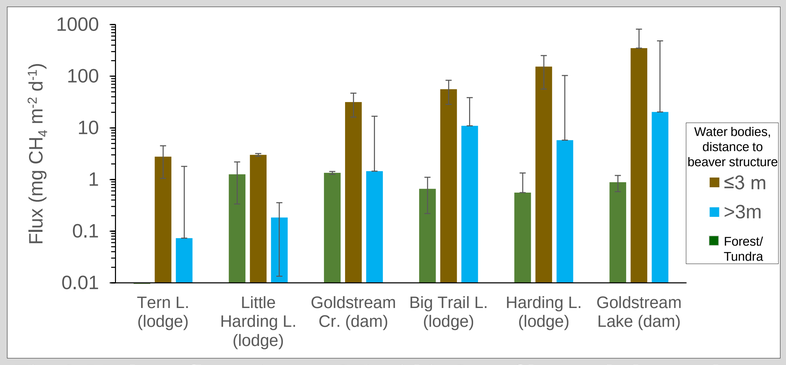

Fig. 6. Methane fluxes (mean, SE) within 3 m of beaver lodges and dams, in water bodies more than 3 m away, and in adjacent terrestrial ecosystems.

Seasonality

Methane emissions were higher in summer compared to winter (Fig. 7), likely due to the ice sheet impeding fluxes in winter and warmer temperatures enhancing methanogenesis in summer.

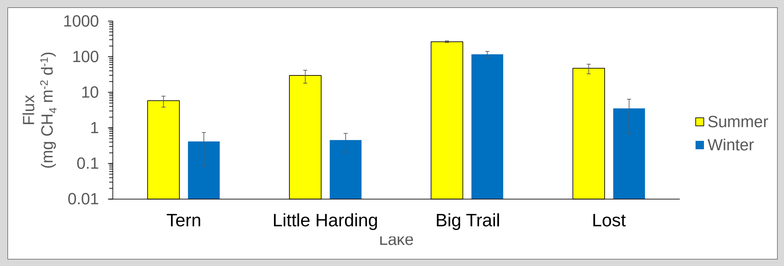

Fig. 7. Summer and winter CH_4 fluxes (mean, SE) from beaver-impacted lakes.

Regional differences

The distribution of emissions among our 14 tundra and boreal sites was similar to that of the 8 beaver-impacted sites at lower latitudes with sporadic or no permafrost reported in previous global CH_4 inventories (Wik 2016, Kuhn 2021) (Fig. 8). Among our Alaska study sites, emissions were highest from thermokarst lakes and ponds formed within recent decades in Yedoma permafrost. Emissions were lower from sites where the surrounding permafrost soil carbon stocks were also lower (i.e. non-yedoma regions).

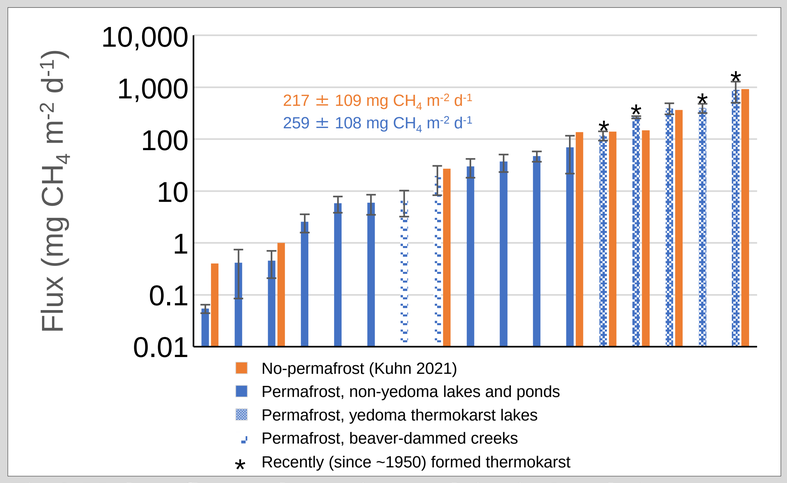

Fig. 8. Methane fluxes at beaver-impacted sites in Canada (orange, literature data) and Alaska (blue, this study).

Conclusions

- Our dataset doubles the number of beaver-impacted study sites in North America.
- Despite a more northern, colder climate regime, CH_4 fluxes were similar in Alaska to the more southern beaver-impacted sites previously studied.
- In Alaska, the between-site variability in beaver site CH_4 flux appears to be driven by the same factors that control aquatic CH_4 emissions in general, such as soil and vegetation carbon stocks (Walter Anthony 2016).
- Nonetheless, our data support the suggestion that beavers have the potential to increase ecosystem CH_4 emissions at the local scale (i.e. dams, lodges) by concentrating organic carbon substrates, and at the regional scale by increasing inundation and thermokarst (Clark 2022).

Future directions

Next steps of this research include: a) expanding the geographic scope of fieldwork, b) incorporating field- and SAR remote-sensing based estimates of ebullition, and c) comparing field flux observations to hyperspectral AVIRIS-NG CH_4 hotspots mapping in the same regions.

Acknowledgements

Tape (TE 2021): *Characterizing a widespread disturbance regime in the ABoVE domain: Beaver engineering*

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