Investigating the Relationship Between Ebullition and Sediment Methane Production in Arctic Lakes, Stordalen Mire, Sweden

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Abstract ID: B21K-2095

Background

Methane (CH_4) is a greenhouse gas that is responsible for 20% of the global greenhouse effect and has a warming potential 32 times that of carbon dioxide[1]. **In many lake ecosystems, methane emissions are primarily driven by ebullition[2].** As global temperatures continue to rise, **methane emissions are predicted to increase.** The lake ecosystems of Stordalen Mire have been a focus of study for methane emissions for decades, however the relationship between sediment CH_4 production, and ebullition is still unknown.

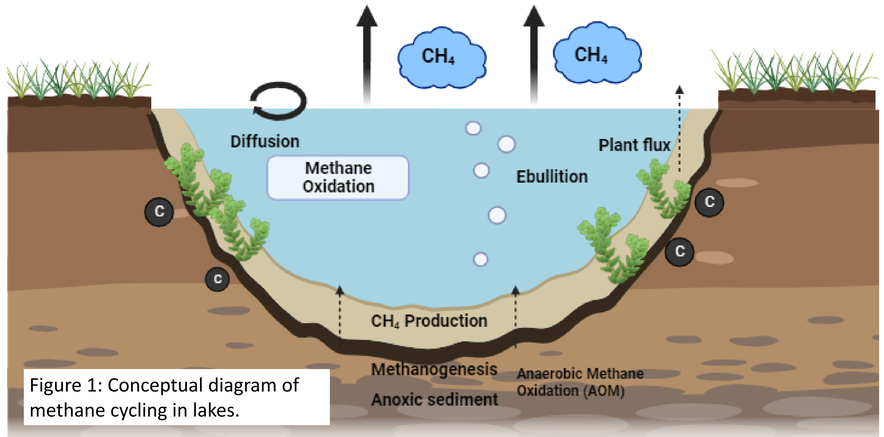

Figure 1: Conceptual diagram of methane cycling in lakes.

Research Questions/Hypotheses

1.Does CH_4 production in the lake sediments increase with increasing temperature?
H: CH_4 production rates in the sediments will be higher under warmer temperatures because of increased methanogen activity.
2.Is there correlation between methane production in the sediments and CH_4 released through ebullition along depth gradients throughout the lakes?
H: Ebullition is the transport of gasses built up in sediments, therefore CH_4 production in the sediment and ebullition measurements will correlate.

Methodology

- Ebullition: bubble traps (i.e inverted funnels) were used to collect gas bubbles[2] (Figure 2a-b). Traps were deployed and sampled from June - July 2023.
- Production: Sediment cores were collected via gravity corer near the ebullition locations. Subsets of the cores were incubated at temperatures 15°C and 20 °C.
- Additional measurements: lake temperature profiles, dissolved organic carbon (DOC), water quality parameters (pH, dissolved oxygen, conductivity, TDS).
- Lab Analysis: CH_4 was measured via a Gas Chromatograph with a Flame Ionization Detector (GC-FID).

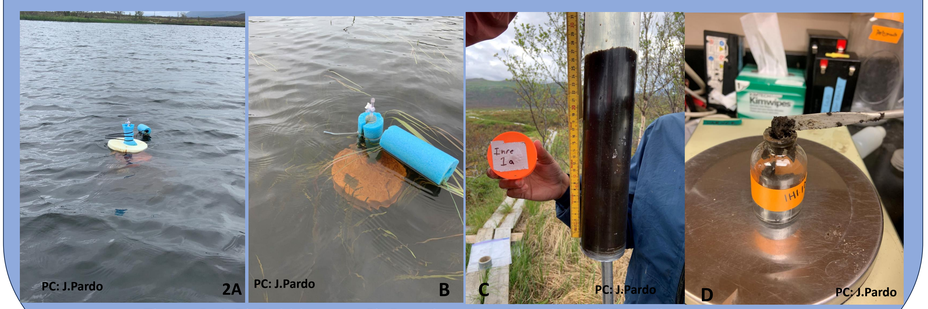

Figure 2. A-B) Bubble traps C) Core from Inre Harrsjön D) Sampling material for incubations

Main Conclusions

- Methane ebullitive fluxes were an average of 0.33 to 108 mg CH_4 m^{-2} d^{-1} throughout the lake locations, with Villasjön and edge locations having highest emissions overall.
- In the 20 °C incubations, the surface sediments showed higher CH_4 production rates when compared to the deeper sediments, but there were no significant differences at 15 °C.
- Sediment structure, carbon quantity and quality, temperature, and/or microbial activity could be the reasons for the lack of correlation between ebullition and sediment CH_4 methane production we observed.
- Rising global temperatures increase CH_4 methane production in surface layer sediments, which could result in higher ebullitive and net emissions.

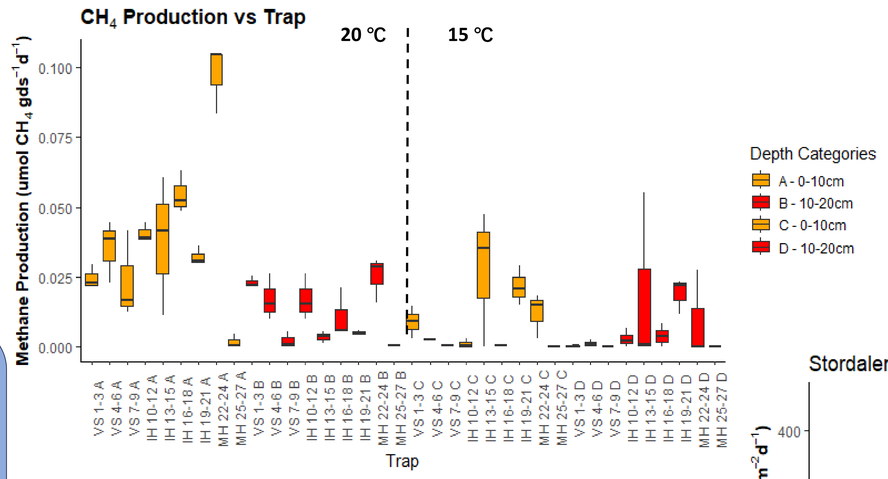

Figure 4 (above): Boxplot of CH_4 production rates for each sediment core at 15°C and 20°C. No significant difference in 15°C production rates for 0–10cm and 10–20cm ($p=0.50$, ANOVA). However, there were significant differences in 20°C production rates in 0-10cm and 10-20cm ($p < 0.001$,ANOVA) and a significant difference in production rates at 15°C and 20°C ($p < 0.001$, paired $t-test$).

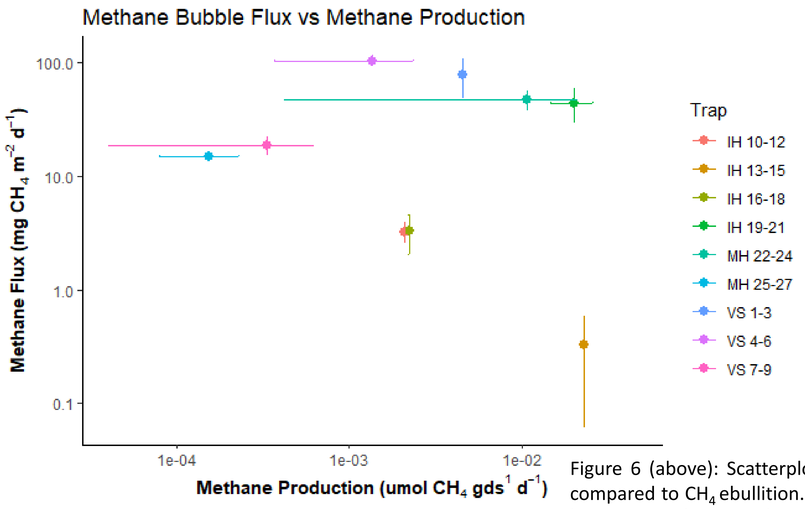

Figure 6 (above): Scatterplot of CH_4 production rates compared to CH_4 ebullition. No significant relationship between methane production rates and ebullition was observed (p=0.057, linear regression).

Research Site

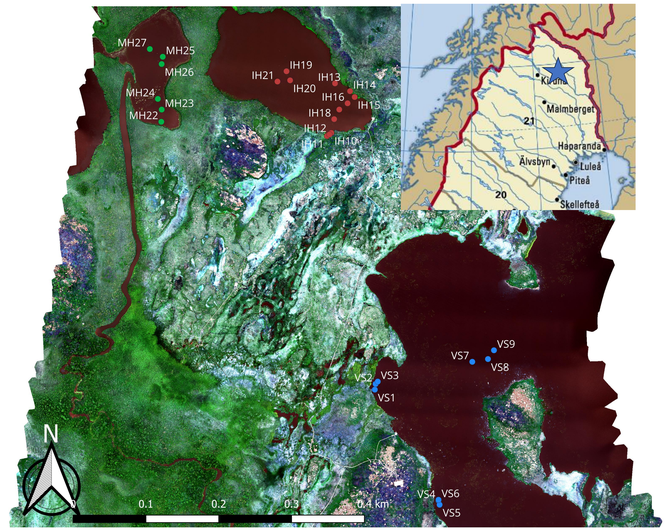

Figure 3: Map of sampling locations, colored dots represent bubble traps. The sampling area includes lakes Mellersta Harrsjön, Inre Harrsjön, and Villasjön in Stordalen Mire, Abisko Sweden.

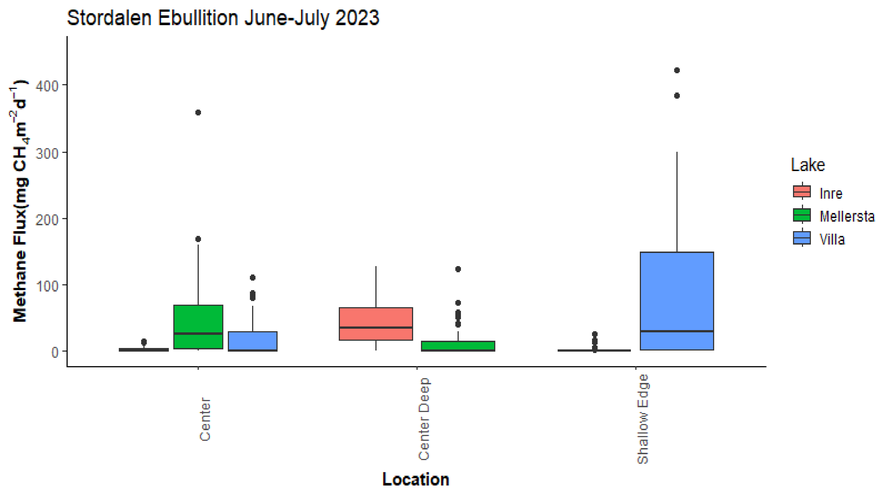

Figure 5 (above): Ebullitive CH_4 emissions grouped by location of bubble trap for each lake. No significant differences in bubble flux between depths ($p=0.32$,ANOVA)) but there was significance in bubble flux by location ($p < 0.05$,ANOVA).

Acknowledgements & References

1. Myhre, G et al. 2013; 2. Wik, M. et al. 2013

Thank you to my committee for their aid and guidance during the creation and implementation of this project. I am also grateful to Apryl Perry, Micheal Palace, Christina Herrick, and Franklin Sullivan for providing materials and data. I would like to thank Swedish Polar Research Secretariat and SITES for the support of the work done at the Abisko Scientific Research Station. SITES is supported by the Swedish Research Council. Thanks to the UNH Earth Sciences Department, Department of Energy (DE-SC0023456), Heising-Simons Foundation (#2022-4087), the EMERGE Biological Integration Institute (DBI-2022070), and the CARPE Program (NSF Grant #2125868) for my funding.