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

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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.

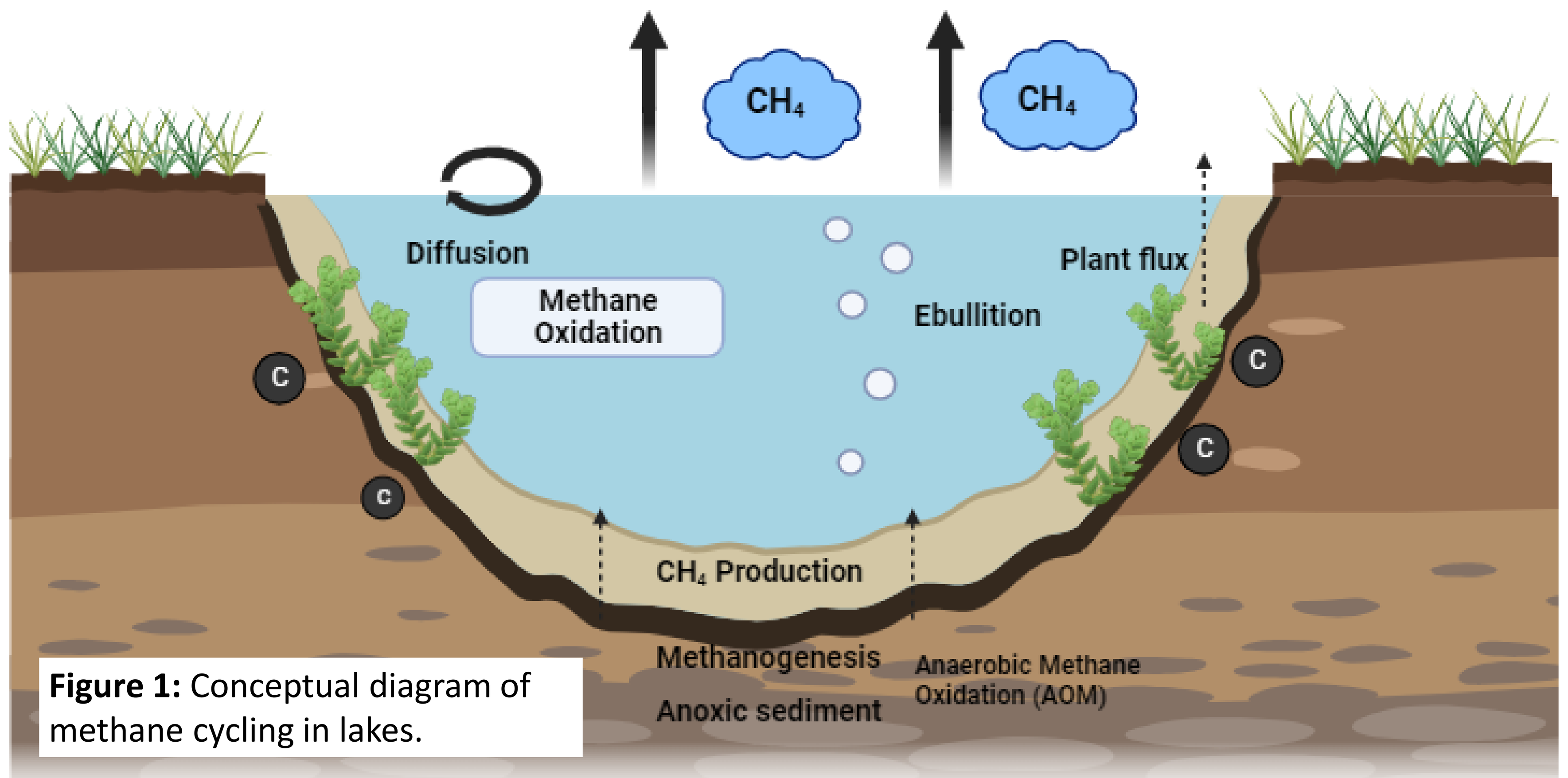


Figure 1: Conceptual diagram of methane cycling in lakes.

Hypotheses

H1: CH_4 production rates in the sediments will be higher under warmer temperatures because of increased methanogen activity.

H2: Ebullition will vary across the lake gradients, with greatest emissions located in shallow or more vegetated areas due to warmer temperatures and an increase in carbon input.

H3: 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 ranged from of 0 to 451.56 mg CH_4 m^{-2} d^{-1} throughout the sampling season, with Villasjön, edge* and shallow locations having highest average emissions overall.
- Methane production rates were greatest in Mellersta and center locations, with production rates greatest in intermediate areas incubated in 20 °C.
- Production rates increased when incubated in 20 °C, and the top 0-10cm sediment had greater production rates than the lower 10-20cm sediment in both temperatures.
- 0-10cm sediment methane production rates incubated in 15 °C displayed a significant linear relationship with ebullitive flux.
- Differences in physical and environmental factors could explain why sediment methane production rates and ebullition did not follow the same trends.

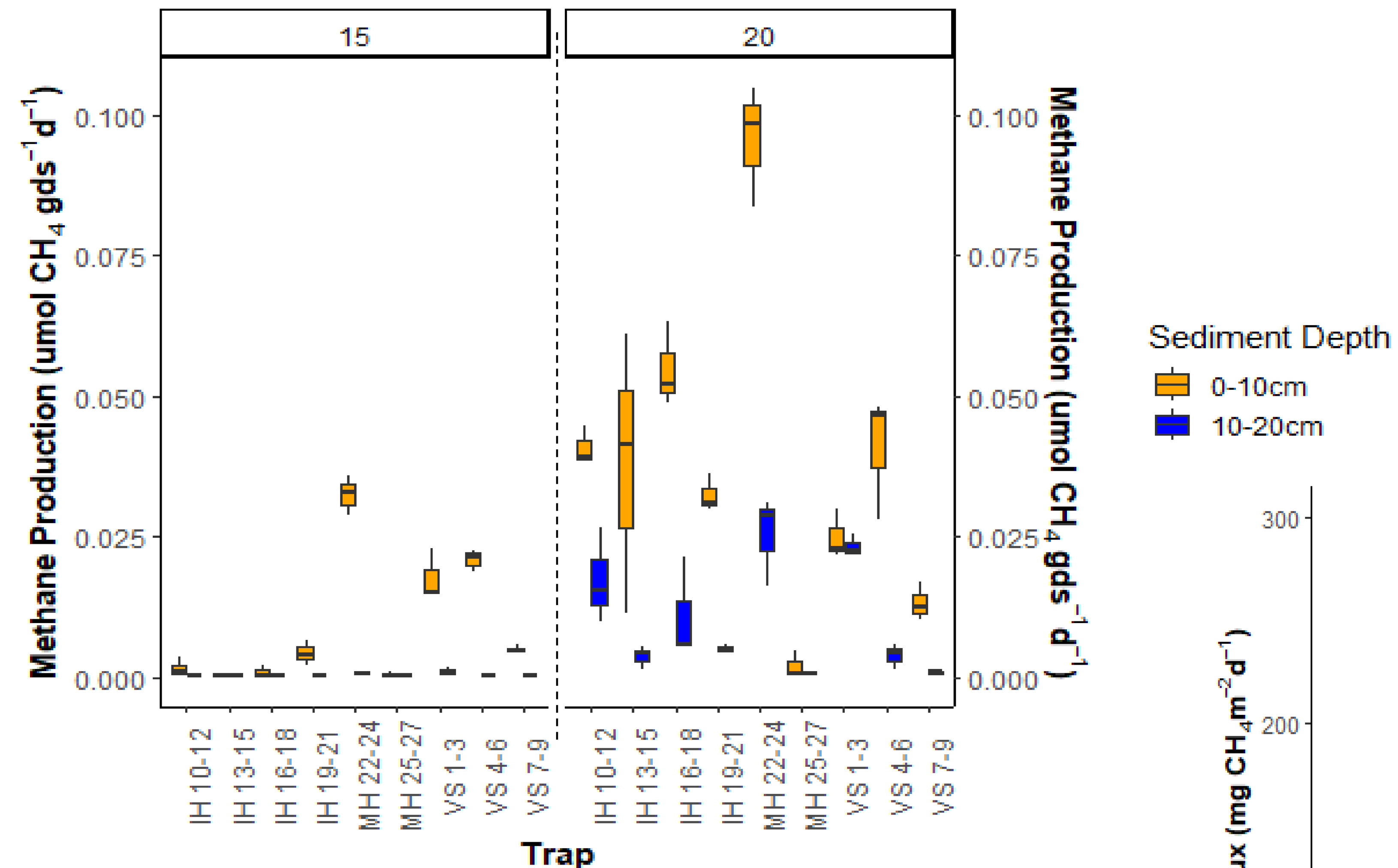
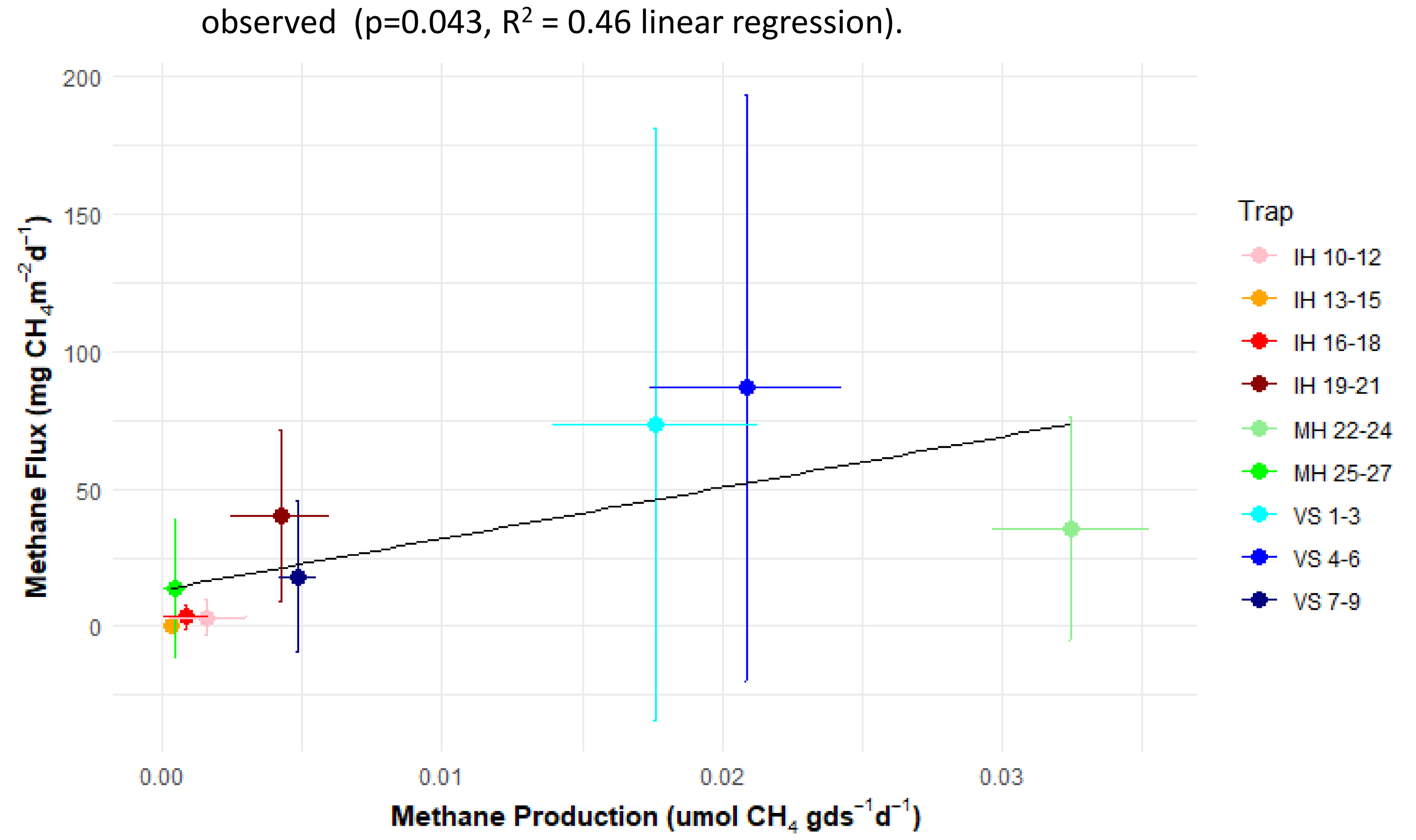


Figure 4 (above): Boxplot of CH_4 production rates for each sediment core at 15°C and 20°C. Significant difference in production rates between 15°C and 20°C for both sediment depths ($p < 0.001$, Wilcoxon pairwise). Top 0-10cm sediment displayed greater methane production rates in both temperatures ($p < 0.001$, Wilcoxon pairwise)

Figure 6 (below): Scatterplot of 15 °C 0-10cm sediment CH_4 production rates compared to CH_4 ebullition. Significant relationship between methane production rates and ebullition was observed ($p=0.043$, $R^2 = 0.46$ linear regression).



Research Site

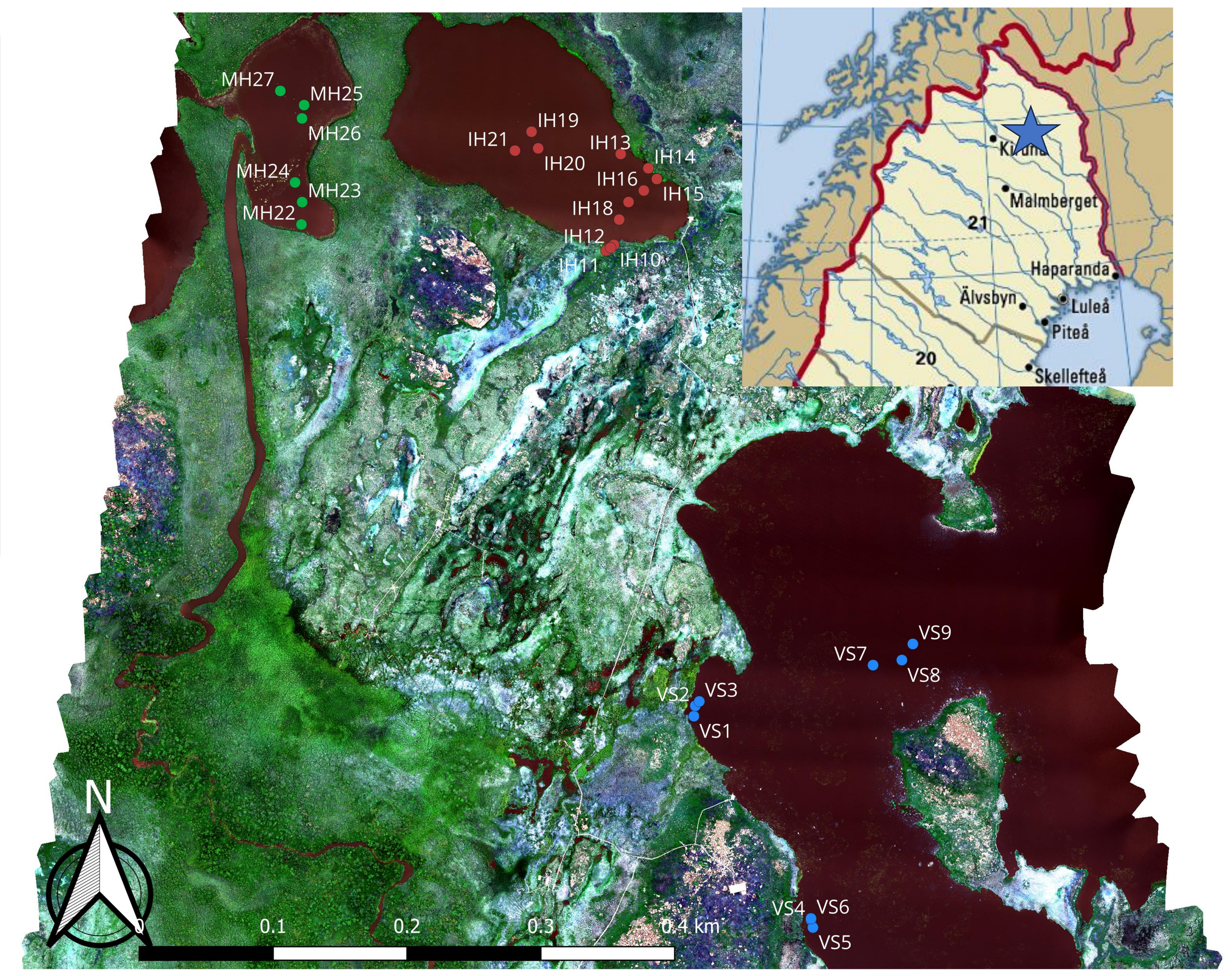


Figure 3: Map of sampling locations, colored dots represent bubble traps. The sampling area includes lakes Mellersta Harrsjön, Inre Harrsjön, and Villasjön in Stordalen Mire, Abisko Sweden.

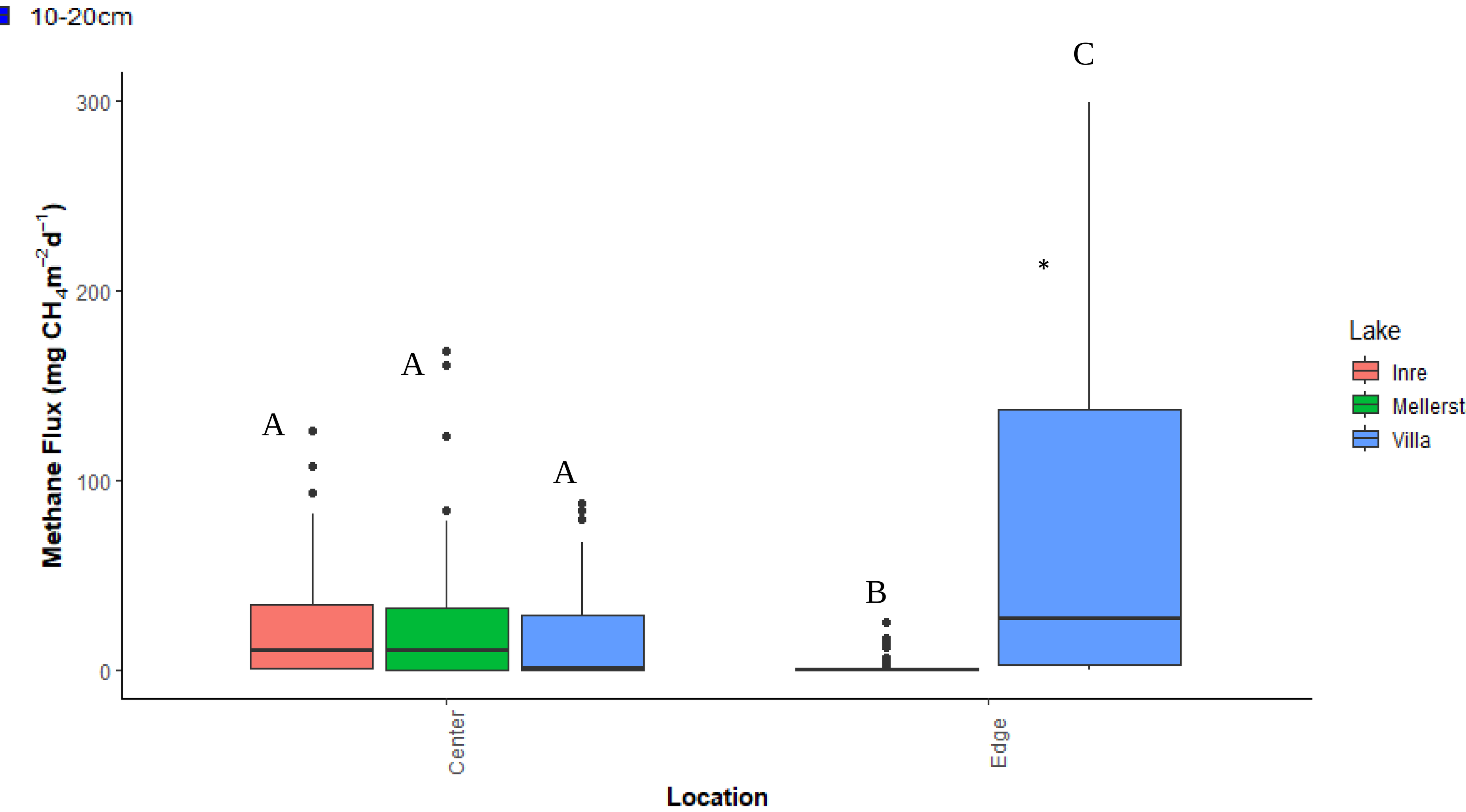


Figure 5 (above): Ebullitive CH_4 emissions grouped by location of bubble trap for each lake. Significant differences in bubble flux by location ($p = 0.046$, Kruskal Wallis; Wilcoxon pairwise). Villasjön edge traps had significantly larger ebullitive flux than edge locations in Inre Harrsjön ($p < 0.001$; Wilcoxon pairwise).

Acknowledgements & References

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

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