Title: Whole Ecosystem Warming Stimulates Methane Production Fueled by Plant Metabolites in Peatlands.

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Project Abstract: Climatically sensitive, northern peatlands store approximately one-third of Earth's terrestrial soil organic carbon. The objective of this project is to quantify the response of belowground carbon stores, greenhouse gas emissions, and heterotrophic microbial communities in peatlands to environmental disturbance (warming, CO_2 enrichment). Our investigations leverage the Spruce and Peatland Responses Under Changing Environments(SPRUCE) experiment where air and peat warming are combined in a whole ecosystem warming approach. We hypothesized that, in addition to stimulating microbial activity directly, warming would enhance the production of plant-derived metabolites, resulting in increased labile organic matter inputs to the surface peat, thereby further enhancing microbial activity and greenhouse gas production. In support of this hypothesis, significant correlations were observed between metabolites and temperature consistent with increased availability of labile substrates which may stimulate more rapid turnover of microbial proteins[1]. Production of the potent greenhouse gas methane(CH_4) was shown to increase at a faster rate in comparison to carbon dioxide(CO_2) in response to warming. Predominant methanogens were identified and the dominant species were highly similar to a Ca. Methanoflorens stordalenmirensis genome recovered from a peatland in northern Sweden. While Methanoflorens is thought to produce CH_4 from hydrogen and CO_2, the organism remains uncultivated and our metagenome data suggest methane production from alternate metabolic pathways. Further, other methanogens were also detected that produce methane from methylated compounds such as methanol, and multiple lines of evidence (isotopes, metabolomes, metagenomes, tracer studies) point to a shift toward methylotrophic methanogenesis with warming. While our results clearly show that methanogens in SPRUCE peat are responding to warming, no significant change in the absolute abundance of methanogens, as determined by qPCR, has yet been detected. We thus interpret the observed responses as a more rapid, pronounced change in the physiology or activity of methanogens in response to temperature, whereas a change in abundance or biomass is likely more muted and difficult to detect beyond natural heterogeneity. Methanogens thus appear to increase their efficiency, resulting in an increase in the CH_4 to CO_2 ratio. While soil carbon has accumulated over millennia in peatlands, our results demonstrate that the vast deep carbon stores are

vulnerable to microbial decomposition in response to warming. Elevated rates of methanogenesis are fueled by plant metabolites, Thus, as peatland vegetation trends towards increasing vascular plant cover with warming, we can expect a concomitant shift towards increasingly methanogenic conditions,which are likely to persist resulting in amplified climate-peatland feedbacks.

References:

[1]Wilson, RM, et al…. JE Kostka. 2021. Soil metabolome response to whole ecosystem warming at the SPRUCE and Peatland Responses Under Changing Environments experiment. Proceedings of the National Academy of Sciences, 118, In press. 10.1073/pnas.2004192118