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Oxic and anoxic mineralization of simple carbon substrates in peat at low temperatures

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Northern peatlands store approximately one-quarter of the world's soil carbon and typically act as net carbon sinks. However a large fraction of the carbon fixed during the growing season can be emitted back to the atmosphere during winter as CO_2 and CH_4, despite low temperatures and frozen conditions, making low temperature biogeochemical processes crucial for the long-term net ecosystem carbon balance. However, the metabolic processes driving carbon mineralization under winter conditions are poorly understood and whether or not peat microbial communities can maintain metabolic activity at temperatures below freezing is uncertain.

Here we present results from an incubation study aimed at elucidating the potential of peat microbial communities to mineralize simple carbon substrates to CO_2 and CH_4 at low temperatures. Peat samples from the acrotelm were amended with [13C]- glucose and incubated at -5 °C, -3 °C, +4 °C, and +9 ºC under both oxic and anoxic conditions, and rates of CO_2 and CH_4 production were determined. In addition, incorporation of the labelled substrate into phospholipid fatty acids (PLFAs) were determined to account for microbial growth during mineralization and the metabolic partitioning between catabolic and anabolic activity. Biogenic [13C]-CO_2 was produced from the added substrate in peat samples incubated both under oxic and anoxic conditions. Under oxic conditions the production rates were 3.5, 2.3, 0.3 and 0.07 mg CO_2 g $SOM^{-1}day^{-1}$ at +9 °C, +4 °C, -3 °C and -5 °C, respectively, and corresponding rates for anoxic conditions were 1.1, 1.0, 0.03 and 0.01 mg CO_2 g $SOM^{-1}day^{-1}$. Consequently the observed Q10 values of the temperature sensitivity under both oxic and anoxic conditions increased dramatically upon soil freezing. However, anoxic mineralization appears less sensitive to temperature as compared to when oxygen is present. Methane was also produced and detected across the range of the incubation temperatures in the anoxic incubations, and the impact of freezing was more severe than for CO_2.

The strong reduction in metabolic rates induced by freezing is likely coupled to constraints on substrate diffusion rates that we can attribute to the reduced liquid water content of the frozen soil, which exacerbates the observed temperature response. We conclude that the peat microbial population can remain viable as temperatures drops below the freezing point of the bulk soil water. Although activity is markedly reduced the capacity of the microbial population to adapt to harsh winter conditions can have important implications for the long-term net ecosystem carbon balance of northern peatlands.