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Microbial growth in a warming Arctic: Exploring controls and temperature responses in permafrost soils

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Permafrost soils are particularly vulnerable to climate warming. With ~1,500 Gt Carbon (C), they store a significant proportion of global soil C. Organic matter that was frozen and thus unavailable for microbial decomposition for millennia, is now thawing. How much of this permafrost C is decomposed will be determined by microbial activities and the partitioning of assimilated C to microbial growth (potential C stabilization) or microbial respiration (C loss). Our current knowledge on the controls of microbial growth and respiration in permafrost soils is, however, limited.

The objective of this study was to analyze microbial growth and respiration in permafrost soils and to explore soil organic matter composition, microbial community composition and various soil parameters as potential drivers. We collected 81 soil samples from four soil layers (organic, mineral, cryoturbated, permafrost) and three lowland tundra polygon types (low-center, flat-center, high-center) in Arctic Canada. We used pyrolysis-GC-MS fingerprinting to characterize soil organic matter composition and amplicon sequencing (16S, ITS1) to identify archaeal, bacterial, and fungal community composition. Temperature responses (Q_{10}) were analyzed in an 8-week laboratory incubation experiment, subjecting soil aliquots to 4 °C and 14 °C. Microbial growth was determined by ^{18}O-H_2O-incorporation into DNA and microbial respiration by gas analysis.

Soil organic matter composition differed between soil layers along a gradient of degradation and C content. Organic matter complexity and diversity decreased with the level of decomposition. We found distinct soil organic matter composition for each polygon type, including all soil layers, suggesting different decomposition pathways, induced by differences in vegetation and soil water regime. Anoxic conditions in low-center polygons resulted in more archaea and distinct fungal communities. Microbial community composition differed among all soil layers, with particularly more fungi in organic soils. Microbial mass-specific growth and respiration differed among

polygons and soil layers, and both increased with warming. Overall, temperature responses (Q_{10}) were higher for respiration than for growth, implying that microbes are less efficient in using C for growth. Linear mixed effect models revealed that soil organic matter composition and microbial community composition were good predictors for mass-specific growth at field and warmed conditions. Mass-specific respiration was best explained by microbial community composition. Our predictors, however, did not explain the temperature responses.

Our results indicate that under warming, microbes allocated more C to respiration, leading to increased greenhouse gas emissions per unit of carbon taken up. We found these results while including all soil layers and polygon types, suggesting these responses to be representative for lowland Arctic ecosystems. Moreover, we could show that organic matter composition and microbial community composition are good predictors for microbial growth and respiration, thus deserving more attention in future studies.

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