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The microbial temperature sensitivity to warming is controlled by thermal adaptation and is independent of C-quality across a pan-continental survey

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Climate models predict that warming will result in an increased loss of soil organic matter (SOM). However, field experiments suggest that although warming results in an immediate increase in SOM turnover, the effect diminishes over time. Although the use and subsequent turnover of SOM is dominated by the soil microbial community, the underlying physiology underpinning warming responses are not considered in current climate models. It has been suggested that a reduction in the perceived quality of SOM to the microbial community, and changes in the microbial thermal adaptation, could be important feed-backs to soil warming. Thus, studies distinguishing between temperature relationships and how substrate quality influences microbial decomposition are a priority.

We examined microbial communities and temperature sensitivities along a natural climate gradient including 56 independent samples from across Europe. The gradient included mean annual temperatures (MAT) from ca -4 to 18 ˚C, along with wide spans of environmental factors known to influence microbial communities, such as pH (4.0 to 8.8), nutrients (C/N from 7 to 50), SOM (from 4 to 94%), and plant communities, etc. The extensive ranges of environmental conditions resulted in wide ranges of substrate quality, indexed as microbial respiration per unit SOM, from 5-150 μg $CO_2 g^{-1}$ SOM g^{-1} h^{-1}.

We hypothesised microbial communities to (1) be adapted to the temperature of their climate, leading to warm adapted bacterial communities that were more temperature sensitive (higher Q_{10}s) at higher MAT; (2) have temperature sensitivities affected by the quality of SOM, with higher Q_{10}s for lower quality SOM.

To determine the microbial use of SOM and its dependence on temperature, we characterized microbial temperature dependences of bacterial growth (leu inc), fungal growth (ac-in-erg) and soil respiration in all 56 sites. Temperature dependences were determined using brief (ca. 1-2 h at 25˚C) laboratory incubation experiments including temperatures from 0 to 35˚C. Temperature relationships were modelled using the Ratkowsky model, and cardinal points including minimum temperature (T_{min}) for growth and respiration along with temperature sensitivity (Q_{10}) values were used as indices to compare sites.

Microbial communities were cold-adapted in cold sites and warm-adapted in warm sites, as shown by T_{min} values ranging from ca. -20 ˚C to 0 ˚C. For every 1˚C rise in MAT, T_{min} increased by 0.22˚C and 0.28˚C for bacteria and fungi, respectively. Soil respiration was less dependent on MAT, increasing 0.16 ˚C per 1˚C. Temperature dependence analyses grew stronger when regressed against summer temperatures, and weaker when regressed against winter temperatures. Hence, microbial communities adjusted their temperature dependence for growth more than for respiration, and higher temperatures had more impact than low temperatures did. The correlation between T_{min} and MAT resulted in Q_{10}s increasing with MAT, showing that microorganisms from cold regions were less temperature sensitive than those from warmer regions. For every 1˚C increase in MAT, Q_{10} increased with 0.04 and 0.03 units for bacterial and fungal growth respectively, and 0.08 units for soil respiration. In contrast to previous studies, we found no relationship between temperature sensitivity and substrate quality.

We demonstrate that the strongest driver of variation in microbial temperatures sensitivities (Q_{10}s) is the microbial adaptation to its thermal environment. Surprisingly, the quality of SOM had no influence on the temperature sensitivity. This calls for a revision of the understanding for how microbial decomposers feed-back to climate warming. Specifically, the thermal adaptation of microbial communities need to be incorporated into climate models to capture responses to warming, while the quality of SOM can be ignored.