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Warm-adapted microbial communities enhance their carbon-use efficiency in warmed soils

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Ecosystem models predict that climate warming will stimulate microbial decomposition of soil carbon (C), resulting in a positive feedback to increasing temperatures. The current generation of models assume that the temperature sensitivities of microbial processes do not respond to warming. However, recent studies have suggested that the ability of microbial communities to adapt to warming can lead both strengthened and weakened feedbacks. A further complication is that the balance between microbial C used for growth to that used for respiration – the microbial carbon-use efficiency (CUE) – also has been shown through both modelling and empirical study to respond to warming.

In our study, we set out to assess how chronic warming (+5°C over ambient during 9 years) of a temperate hardwood forest floor (Harvard Forest LTER, USA) affected temperature sensitivities of microbial processes in soil. To do this, we first determined the temperature relationships for bacterial growth, fungal growth, and respiration in plots exposed to warmed or ambient conditions. Secondly, we parametrised the established temperature functions microbial growth and respiration with plot-specific measured soil temperature data at a hourly time-resolution over the course of 3 years to estimate the real-time variation of in situ microbial C production and respiration. To estimate the microbial CUE, we also divided the microbial C production with the sum of microbial C production and respiration as a proxy for substrate use.

We found that warm-adapted bacterial and fungal communities both shifted their temperature relationships to grow at higher rates in warm conditions which coincided with reduced rates at cool conditions. As such, their optimal temperature (Topt), minimum temperature (Tmin) and temperature sensitivity (Q10) were all increased. The temperature relationship for temperature, in contrast, was only marginally shifted in the same direction, but at a much smaller effect size, with negligible changes in Topt, Tmin and Q10 for respiration. When these physiological changes were scaled with soil temperature data to estimate real-time variation in situ during three years, the warm-adaptation resulted in elevated microbial CUEs during summer temperatures in warm-adapted communities and reduced microbial CUEs during winter temperatures. By comparing simulated microbial CUEs in cold-adapted communities exposed to warmed conditions to microbial CUEs in the warm-adapted communities exposed to those temperatures, we could demonstrate that the shifts towards warm-adapted microbial communities had selected for elevated microbial CUEs for the full range of in situ soil temperatures during three years. Our results suggest that microbial adaptation to warming will enhance microbial CUEs, shifting their balance of C use from respiration to biomass production. If our estimates scale to ecosystem level, this would imply that warm-adapted microbial communities will ultimately have the potential to store more C in soil than their cold-adapted counter parts could when exposed to warmer temperatures.