Manaaki Whenua Landcare Research

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Short webinars for environmental policy-makers and practitioners

Geothermal hot spots as global warming experiments

The following questions were asked during our live webinar with Manpreet Dhami but due to time restrictions, we were unable to answer these in the session.

Can you comment on how will potential changes in the composition of soils impact the rates of biological or chemical changes within the soil even at very limited changes in average soil temperatures expected as a result of climate changes?

Soil composition is a strong determinant of soil chemistry and biology. And both soil chemistry and soil biology underpin biochemical reactions that are affected by temperature. At the core of every soil process, be it water holding capacity, nutrient turnover or soil carbon stabilisation, there sit a variety of these biochemical reactions. As temperature increases, the reaction rates increase. We think that there is an upper limit to the ability of organisms to continue to maintain physiologic processes at higher temperatures and this is where we are seeing the least certainty when we do experiments. Sometimes we see there is a threshold, sometimes we see that at least micro-organisms are able to adapt to warmer temperatures. Based on this, we hypothesise that certain processes such as carbon destabilisation will speed up, and lead to net losses of carbon. But the overall impacts are difficult to predict without a much deeper understanding.

What is the potential of microbial genome(s) to evolve special mechanisms and/or DNA changes to deal with the increased temperatures?

The genomic potential for micro-organisms to evolve is immense. However, the key to this is the rate of change. When we look at the geothermal hot spot microbes, like in our study, we are looking at slow changes over hundreds of years where microbes have an opportunity to adapt. Anthropogenic changes however tend to be faster. Microbes that experience extreme shifts, like flooding in dry lands, or desertification of soil, experience extreme changes and are likely to not have an opportunity to adapt. Environments where extreme changes are buffered, microbes are more likely to be able to adapt. One way some scientists think about it is with climate fronts, where slowly advancing warmer climate creates a boundary for organisms that can persist or not. At the boundary the organisms are most vulnerable, and some species will shift with the boundary (butterflies in the UK, alpine insects in NZ are a classic example), others will perish and some that may be buffered from immediate impacts of this boundary may be able to adapt.

Would you expect microbial composition and evolution of thermal resistance to be different if microbes don't have a choice of colder soils, which is only a few meters away in your study, but when translated to future temperature increases there wouldn't be possibility of an escape to colder soils.

This is a very good question. Whether there is a buffering of climate extremes for microbes via access to more habitable refugia? And whether the communities benefit from exchange of microbes from nearby more temperate soils. The refugia question is certainly of high import and very little studied for microbes - more examples for butterflies and vertebrates. Microbes in the air can travel with winds and also transcontinental air currents to quite long distances. However, the persistence of microbes in exceptionally warm areas will depend on any pre-existing adaptations they might have. To locally adapt, can take some time. So our hypothesis with the geothermal soil communities is that it's likely that local communities have evolved over the 100s of years to these warm temperatures. And there is certainly mixing with local 'cooler spots', often for new migrants but their persistence would be limited. When we project this to a future scenario, while difficult predict accurately, what we are seeing is that perhaps more homogenisation of the environment in some aspects (everywhere is warmer?), loss of microbial diversity unfit for this climate and possibly also loss of exchange with 'cool adapted' microbes. So yes, in a nutshell, it is likely that microbial community diversity would be much different in the absence of temperate soils, and their opportunities for exchange would be limited and overall their ability to adapt may be depressed.

Do you get a change in microbial biomass across the temperature gradient?

Yes, overall the biomass decreased with temperature. This effect was stronger for fungi actually along our transect, so overall we might also see a shift in the fungal/bacterial ratio, with a shift towards bacteria. Although this is based on 16S/ITS which isn't super quantitative as you know. But the trend was also visually obvious as the thickness of the organic layer declined closer to the stream heated depression. For some of our samples, we couldn't get any fungal amplification in the hottest spots. For the purposes of community composition, we can normalise for variability in amplification, but we still cannot reliably 'quantify' biomass without a much different approach.

How does a shift in microbial biomass factor into the potential loss via respiration?

We didn't incorporate microbial biomass into the calculation of rates of respiration as we cannot get reliable estimates of biomass from metabarcoding data. But, if I were to speculate, I would think that loss of microbial biomass would lead to lower respiration. For the soils that we incubated for MMRT calculation we only measured C:N ratio (which was correlated with respiration). We didn't measure actual biomass.

Even with evolution responses to temperature changes, there appears to be impacts to the biodiversity of microbes. Do we have an understanding of what this could mean for soil productivity?

You're exactly right. There is an overall shift in diversity. This trend is especially strong in fungi, where we are losing majority of the mesophilic species as they cannot tolerate high temperatures. The impact of this on soil productivity remains to be studied. Generally we are seeing this trend elsewhere as well that with warming, fungal diversity decreases and overall shift towards bacterial dominance. We know that fungi play a major role in nutrient cycling, especially in decomposing more recalcitrant compounds. These function would ultimately be depressed and therefore there will be impacts on soil productivity.

Thank you very much, that was an excellent and clear webinar. Really looking forward to the future work on functionality - that was the question I had. How would that change, and how do you investigate this? I.e. is it the temperature, the available moisture, or the microbial community composition?

Thank you. We are currently planning some follow-up work at the same site. We have two experiments in mind. The first one is further characterisation of the metagenomes of these microbes. Metagenomes tell us a bit more about the functions of the microbes as we sequence entire genomes that are present. However, whether or how readily these genomes are functioning can only be studied through perturbation experiments. Which is the plan for our second experiment - we would bring soil samples back to the lab and this time characterise the gene function of selected genes under experimentally recreating the warming. In our published work, we recreated the warming across a range of 4-48 C in the lab, but we only measured respiration. This time, we will also measure gene function using qPCR and perhaps even carbon use efficiency - the latter is a lot more work and quite expensive to do. So really we are limited by budgets rather than ideas. We would replicate the temperature, moisture and communities as closely possible to the real environment.