

Towards a microbial process-based understanding of the resilience of UK peatland systems: *Workshop 4 Linking microbial research in peatlands to stakeholder needs: 10th January, Manchester*

This document provides a summary of the above workshop, held to develop joint research priorities between peatland restoration practitioners and the academic community.

Session 1: Desirability and viability of incorporating microbial knowledge into peatland management practice

This workshop aimed to draw on the experience of participants to identify where microbial knowledge has previously contributed to peatland management practice (if at all). We asked participants to identify key knowledge gaps in peatland science and management, and establish whether microbial knowledge may be able to assist in these matters. This session used small group discussions to provide evidence to answer the questions in the following section headings.

What do we know about microbial processes that underpin peatland ecosystem services?

We have some understanding of mechanistic contribution of microbial community to peatland functioning e.g. methanogen/methane oxidising microbial community and relationships with abiotic processes. There are also some observations that suggest that microbial ecology could be an important factor in restoration success, e.g. bringing in *Sphagnum* from local donor sites is more effective than micro-propagated material. Does the microbiome introduced in restoration therefore matter?

We have lots of restoration datasets including factors effecting e.g. methane production and nitrous oxide, however we have very little data on microbial community structure and function, although there are significant datasets on testate amoeba (for which there is potential for a meta-analysis to show health of a peatland). What data we do have shows high variability of microbial community in undamaged sites, suggesting there may be issues in scaling up any data collected. Also, current data often only tells us which microbes are where, whilst their role in actual soil processes remains unknown.

What don't we know about microbial processes that underpin peatland ecosystem services?

What we do not yet know is how multidimensional variables (space, time, depth) affects microbial community functioning or what a healthy end point or target microbial community is. Without this knowledge it is difficult to begin to consider how we might incorporate microbial factors into restoration work or take the next step in considering how we could engineer the microbial community to aid restoration processes.

Attendees noted it may take a long time to get the science to a point where it will be useful to inform restoration practice, however the idea of engineering the microbial community is of interest. Potential applications could be to introduce methanotrophs before restoration to limit the spike in methane post-restoration. Experiments will be needed to understand which bacteria could be added to improve different ecosystem services.

Whilst we have some knowledge about soil microbial processes and CH₄/N₂O, we have very little understanding of ecosystem functions such as water quality and broader carbon cycling. We also need to be able to link work on enzymes with microbial community data as well as link DNA and RNA data. Could microbioma explain why some areas are hard to restore and remain bare peat?

We don't yet know how the microbiome responds to extreme conditions and whether this may affect our current understanding of the water table / functioning relationship i.e. do we need the 'microbial plumber' to fix problems? Characterising just the 'normal' community might not be enough if we also need to understand the parts of the microbial community adapted to more extreme conditions. Both 'normal' and 'extreme' microbiota are likely to be needed to have a resilient system.

We also don't know if microbes drive processes or if they follow abiotic conditions and vegetation development. This has been characterised as the 'chicken or the egg' problem for understanding the dynamic relationship between vegetation, microbes and abiotic factors. There is some suggestion that the beneficial microbes are already present, but need the right conditions to promote them. Finally, there may be additional interactions between soil fauna and microbes which are currently not understood.

Session 2: Prioritised research questions

After the group discussions on what we do and do not know about microbial processes in peatlands, we developed and prioritised a set of research questions. The foal of these questions was to help the academic and practitioner community understand ecosystem functioning and potentially move to using the microbial community as a monitoring tool or end goal in itself. The research questions developed are given below in the order of the number of votes they received from workshop participants.

Question	Priority
Are there differences in microbial communities between sink and source sites and can we define keystone groups as well as an 'ideal' state?	Higher
Can microbial intervention enhance restoration practice? E.g. inoculation with a desirable community, and if so via what method?	Higher
How does the microbial community change with respect to time, space and depth at a site as well as peatland condition across sites?	Higher
Can we link carbon cycle functions to particular microbial groups?	Higher

What are the links between plants and microbes (chicken and egg in terms of order of influence during restoration)? This would likely include inoculation experiments, recovery from stress, resilience and persistence	Medium
Does microbial understanding explain the residual variance in the proxies we use to understand peatland carbon functioning (e.g. water table)?	Medium
What are the timescales and trajectories of microbial processes linked to carbon loss?	Medium
Does microbiome change impact peat structure and what are the feedbacks?	Medium
Are there situations where natural recovery of microbial biota won't happen?	Medium
What is the speed of response of the microbiome to stresses, restoration and management including lags, turnover dynamics and trajectory?	Lower
What is the contribution of the microbiome to ecosystem response to extreme shock?	Lower
What functional groups relate to ecosystem function? Redundancy, DNA, RNA	Lower
What is the heterogeneity of microbial communities and functions?	Lower

What do we need to move forward?

To answer these research questions we are likely to need more active research sites which include microbial community characterisation. Ideally, these would include a range of conditions and restoration practices so we can understand the changes in microbial community with space, time, depth, pH, state of degradation etc., rather than just using existing sites which have received a lot of focus (Moorehouse and Forsinard, for example).