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Project title:
Pests and pollution: Mycorrhizal mediation of carbon cycling in heather moorlands

Project description:

Potential fieldwork location; the Orkney Islands.

The multiple drivers of environmental change, such as climate change and pollution, have led to widespread negative impacts on ecosystem functioning and services that are critical for human well-being. Heather moorlands are very sensitive to these drivers and, therefore, their future is very difficult to predict. It is critical that we understand the impacts, interactions and feedbacks of current drivers of change in order to sustainably manage and conserve these unique and globally important environments.

Moorlands are found in uplands of the temperate zone, with 75% of the world's heather (*Calluna vulgaris*) moorland located in the UK (Holden *et al.* 2007). Moorlands are critically important habitats supporting a unique diversity of flora and fauna upon which globally rare species are heavily dependent, such as golden plover, dunlin and hen harrier. Given the decline in this habitat over the last 100 years, heather moorlands are also a habitat of high conservation priority in the UK.

Moorland habitats are usually associated with acidic, base deficient soils, such as peat, and therefore represent a significant terrestrial carbon store. However, UK moorlands may act as both a significant sink and source of carbon (Billett *et al.* 2011) depending on management, climate and atmospheric pollution, including nitrogen deposition. A fundamental, yet poorly-understood, component in this ecosystem that influences carbon and nutrient dynamics involves the intimate symbioses between the roots of heather and ericoid mycorrhiza-forming fungi (EMF). These associations are assumed to be mutualistic, with the fungus supplying nitrogen (N) from the soil – a critical limiting factor– to the host plant in exchange for photosynthetically-fixed carbon.

Periodic pest outbreaks are a clear biological signal that ecosystem processes are being disrupted. Outbreaks of insect herbivores on heather can lead to severe defoliation, but the effect on belowground processes and the carbon cycle is unknown. Evidence suggests defoliation reduces symbiotic fungal diversity and slows nutrient cycling in birch forests in arctic ecosystems (Parker *et al.* 2017), but a similar effect on EMF and nutrient cycling remains untested in moorlands. Furthermore, the extent to which carbon and nutrients may themselves drive the pest outbreaks, mediated by EMF and nitrogen deposition, are unknown. EMF may increase plant nutritional quality and enhance plant defences against herbivores. Whether the enhanced nutrient status of EMF-associated plants (Kowal *et al.* 2018) makes them more attractive to herbivore pests, or whether the greater access to resources makes them more resilient to pests is unknown (Thirkell *et al.* 2017). How these factors are themselves influenced by changes in the environment remains unexplored, despite their potentially critical implications for the conservation of these threatened habitats.

The focus of this project is, therefore, on understanding of the impacts of pests and pollution on EMF, and thus carbon cycling, in heather moorlands across a nitrogen pollution gradient in the UK. The research will identify the feedback mechanisms that link below-ground soil nutrients and above ground productivity with herbivore abundance, integrating field and laboratory-based research techniques and combining the expertise of Steven Sait (community ecology of insects; https://biologicalsciences.leeds.ac.uk/school-of-biology/staff/132/dr-steven-sait), Katie Field (mycorrhizal physiology; https://biologicalsciences.leeds.ac.uk/school-of-biology/staff/65/dr-katie-j-field) and Pippa Chapman (soil biogeochemistry; https://www.geog.leeds.ac.uk/people/p.chapman). Measurements will be carried out on UK heather moorlands, including Yorkshire, Scotland and the Orkney Islands. Over 15 years of fieldwork in Orkney has revealed varying patterns in abundance of insect pests (Fig. 1), including outbreaks, and their natural enemies (e.g. Graham *et al.* 2004; Hick *et al.* 2015), but the below-ground soil-plant-fungal interactions in this system are entirely uncharacterised, representing a significant knowledge gap.

Figure 1. Typical fragmented heather moorland in the Orkney Islands. Periodic outbreaks by herbivores, such as the magpie moth, can cause severe defoliation.

The fieldwork will be supported by lab experiments that make use of the world class facilities within the Schools of Biology and Geography, including quantification of CO_2 fluxes from soil mesocoms using a portable gas analyser (Fig. 2) and a ground-breaking meso- and microcosm-based isotope tracing approach pioneered in earlier studies by co-supervisor Katie Field (see Field *et al.* 2015). This exciting and novel multi-disciplinary project will lead to new insights into the link and feedback loops between above- and below-ground biotic and abiotic processes and how this may influence the carbon cycle in these important ecosystems. The research will have broad implications for our understanding of ecosystem function in the face of environmental change with important applications in conservation and land management.

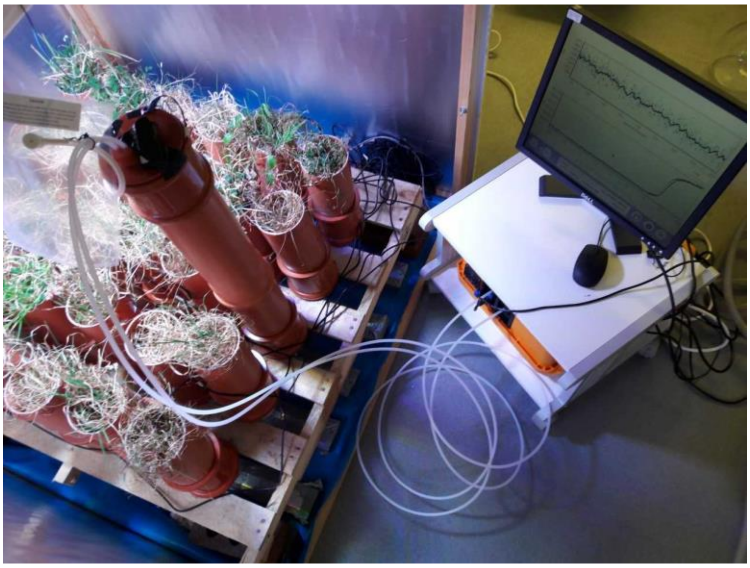

Figure 2. Measuring CO_2 flux from a soil mesocosm experiment in a controlled environment cabinet.

The successful candidate will develop a range of research skills, including experimental design, field sampling, chemical analysis, statistical analysis and data interpretation, academic writing skills and giving presentations. Training will be provided in field/laboratory health and safety procedures and the use of field and analytical equipment. In addition the candidate will develop their understanding of (i) insect community ecology and the mechanisms that drive their patterns in distribution and abundance (ii) soil processes and fluxes related to the cycling and storage of carbon in heather moorlands, (iii) ecophysiology of ericoid mycorrhizas.

The student will be supported throughout the studentship by a comprehensive PGR skills training programme that follows the VITAE Research Development Framework and focuses on knowledge and intellectual abilities; personal effectiveness; research governance and organisation; and engagement, influence and impact. Training needs will be assessed at the beginning of the project and at key stages throughout the project and the student will be encouraged to participate in the numerous training and development course that are run within the NERC DTP and the University of Leeds to support PGR students, including statistics training (e.g. R, SPSS), academic writing skills, grant writing. Supervision will involve regular meetings between all supervisors and further support of a research support group.

Student profile:

The student should have a keen interest in ecology, environmental change and biotic interactions, with a strong background in biology, ecology, physical geography, earth sciences, soil science, environmental sciences or related discipline. Strong analytical/statistical/fieldwork skills are desirable, but not essential, as full training will be provided during the PhD.

Fit to NERC Science

This project is aligned to the NERC 'Terrestrial and freshwater environments' research area. Specifically the project aligns to the following NERC research areas: (1) **Biogeochemical cycles** – by considering the fluxes and cycling of carbon in heather moorlands and the impact of pests and pollution on these fluxes (2) **Land - atmosphere interactions** – through quantification of the fluxes and transformations of material between the land (including the biosphere) and the atmosphere (3) **Soil science** – by quantifying the impact of pests and pollution on mycorrhizal functioning in peat , and (4) **Ecosystem scale processes** – by assessment of functioning of, and influence of pests and pollution on, heather-ericoid mycorrhizal associations and resultant impacts on pests (and natural enemies?).

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