Project Title	Global change processes in peatlands: A study of the microbiology and biogeochemistry of reactive nitrogen oxides
University (where student will register)	University of Warwick
Which institution will the student be based at?	As above
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☒ Organisms & Ecosystems ☒ Dynamic Earth ☐
Key words	Peatlands, Reactive Nitrogen, Global Change
Supervisory team (including institution & email address	**PI:** Dr. Ryan M. Mushinski, University of Warwick Ryan.Mushinski@warwick.ac.uk **Co-I:** Professor Gary Bending, University of Warwick gary.bending@warwick.ac.uk

Project Highlights:

- Peatlands act as large reservoirs of organic matter; however, environmental change processes, such as increased atmospheric nitrogen deposition, may lead to large emissions of greenhouse and trace gases from these ecosystems.
- In this project, you will quantify emissions of a rarely studied group of trace gases (reactive nitrogen oxide; NO_y) from peatlands
- You will use laboratory mesocosms to assess the impact of atmospheric nitrogen deposition on peatland nitrogen cycling
- You will use molecular and biogeochemical techniques to determine if iron-mediated microbial processes are a key source of NO_y from peatlands

Overview:

Peatlands in the UK account for 9.5% of land cover[1] and are currently experiencing rapid modifications in response to environmental stimuli such as increased atmospheric nitrogen (N) deposition sourced from human activity. These ecosystems perform a plethora of functions, none more critical than acting as large reservoirs of organic matter (OM). Research has focused on how processes such as N-deposition may transform these OM stocks into sources of greenhouse gases. These studies demonstrate a stimulatory effect of N-deposition on CO_2 and CH_4 emissions[2]; however, much less attention has been paid to changes in N-cycling associated with enhanced N-deposition.

Net rates of N-cycle processes such as nitrification and denitrification are quite slow in peatlands. In fact, these process account for less than 5% of N removal from these ecosystems.[3] However, a different group of N-gases, the reactive nitrogen oxides (NO_y = NO, NO_2, HONO), are greatly understudied and may actually be emitted at high rates from peatlands, especially under increased N-deposition. NO_y gases are categorized as air pollutants causing respiratory distress in humans and are also atmospherically relevant in that they control the oxidative capacity of the atmosphere, the lifetime of greenhouse gases, and the rate of secondary aerosol formation that directly and indirectly affects climate.

While NO_y have been shown to be products of nitrification and denitrification, an under-investigated process involving iron (Feammox) may be extremely important in the cycling of N and subsequent production of NO_y in these ecosystems. Feammox is a microbial process that generally occurs under anoxic conditions of saturated soils such as peatlands, where iron oxides can act as an electron acceptor and play a critical role influencing N reactions in the absence of oxygen. However, there has been little research exploring whether this reaction results in NO_y production.

Thus, there is a critical need to (1) determine the intrinsic ability of UK peatlands to produce NO_y, (2) explore the influence of N-deposition on N-cycle rates in these ecosystems, and (3) differentiate the mechanisms by which N is transformed in peatlands, paying particular attention to microbe-iron mediate processes.

Methodology:

We will make seasonal field-based measurements of NO_y emissions from minerotrophic fens and ombrotrophic bogs throughout the UK over the course of one year. Both fens and bogs will be studied due to differences in water sources (inflow vs. atmospheric) and physicochemical properties (mineralogy, nutrients, pH). This will allow for a better determination of NO_y flux mechanisms. In conjunction, we will establish laboratory mesocosms by taking intact cores from these same sites and analyse potential emissions of NO_y from peatlands under differential N-addition amendments. Peatland soil will also be used to quantify the nitrogen-cycling microbial community as well as how it changes over the course of N addition. Soil–iron content will be analysed to determine any potential correlation with NO_y production.

Training and skills:

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and ‘free choice’ external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

Training during this fellowship includes a wide range of molecular techniques and analyses (microbial culturing, DNA extraction from soil, PCR, sequencing, and bioinformatics) as well as analytical chemistry (nitrogen oxide quantification, reactive oxygen extraction from soil and subsequent quantification, and building sampling mesocosms). Field-based sampling and measurements from peatland ecosystems will also be emphasized.

Partners and collaboration (including CASE):

Both Dr. Mushinski and Professor Bending have substantial expertise in nitrogen cycle biogeochemistry as well as soil-microbe interactions, evidenced by publications in the *Proceedings of the National Academy of Sciences*, *New Phytologist*, and *Soil Biology and Biochemistry*. The UK Centre for Ecology and Hydrology (CEH) may be an avenue for partnership on this project.

COVID-19 Resilience of the Project:

The School of Life Science at the University of Warwick has SOP’s in place to allow research to continue in light of COVID-19. This includes reducing the capacity of people in laboratory spaces, placing protective barriers between workstations, and working from home when possible. The laboratory portion of this work will proceed as normal, within the scope of the SOP’s. All meetings associated with this project will be virtual. The field component will also proceed; however, a subsequent SOP will be developed between the PI and student to adhere to all University- and government-mandated requirements.

Possible timeline:

Year 1: Explore potential research sites to establish physicochemical gradients from fens and bogs. Remove intact peat cores from the sampling locations and establish mesocosm experiment in laboratory setting. Nitrogen addition experiments will commence.

Year 2: Seasonal field measurements of NO_y from sites where mesocosm cores were taken. Soil will also be sampled during each field measurement time point to explore variation in physicochemical parameters over the course of the year. DNA and RNA will be extracted from mesocosm N-addition experiments (from year 1) and analysed for N-cycle genes using quantitative PCR as well as sequenced to identify key N-cycle taxa.

Year 3: Molecular data coupled with NO_y flux levels and physicochemical parameters will be used to determine if Feammox is a possible source of NO_y in peatlands. If evidence suggests that this is a possibility, experiments will be devised to explore how NO_y is produced via Feammox. This is in conjunction with writing up results from years 1 and 2.

Further reading:

[1] Bain, C.G. et al. (2011) ‘IUCN UK Commission of Inquiry on Peatlands’, *IUCN UK Peatland Programme*, Edinburgh.

[2] Bragazza, L. et al. (2006) ‘Atmospheric nitrogen deposition promotes carbon loss from peat bogs’, *Proceedings of the National Academy of Sciences* 103: 19386–19389.

[3] Hill, B.H. et al. (2016) ‘Comparisons of soil nitrogen mass balances for an ombrotrophic bog and a minerotrophic fen in northern Minnesota’, *Science of the Total Environment* 550: 880–892.