Project Proposal – 2022 entry

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Global change processes in peatlands: A study of the microbiology and biogeochemistry of reactive nitrogen oxides</th>
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<tbody>
<tr>
<td>University (where student will register)</td>
<td>University of Warwick</td>
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<tr>
<td>Which institution will the student be based at?</td>
<td>As above</td>
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</tbody>
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| Theme (Max. 2 selections) | Climate & Environmental Sustainability ☒  
Organisms & Ecosystems ☒  
Dynamic Earth ☐ |
| Supervisory team (including institution & email address) | PI: Dr. Ryan M. Mushinski, University of Warwick  
Ryan.Mushinski@warwick.ac.uk |
|  | Co-I: Prof. Niall McNamara  
UK Centre for Ecology and Hydrology (CEH) – Lancaster  
nmcn@ceh.ac.uk |
|  | Co-I: Prof. Gary Bending  
University of Warwick  
gary.bending@warwick.ac.uk |
| Is the PhD suitable for part time study? | Yes ☐ |

Project Highlights:

- New research to unravel the significance of reactive nitrogen oxide (NO\textsubscript{y}) emissions from a network of UK peatland sites. Understanding peatland NO\textsubscript{y} is important for human and wider environmental well-being.
- A multi-institute supervisory partnership linking to state-of-the-art instrumentation and opportunities for wider collaboration in funded peatland research projects.
- A blend of laboratory and field experience, accessing skills ranging from molecular techniques to in-situ trace gas measurement.

Overview (including 1 high quality image or figure):  
Peatlands in the UK account for 9.5% of land cover\textsuperscript{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 demonstrated that N-deposition may transform these OM stocks into sources of greenhouse gases (CO\textsubscript{2}, CH\textsubscript{4}).\textsuperscript{2} However, to date much less attention has been paid to how enhanced N deposition may also change N-cycling processes that release reactive nitrogen oxides (NO\textsubscript{y} = NO, NO\textsubscript{2}, HONO).

Reactive nitrogen oxides are greatly understudied and may be emitted at high rates from peatlands, especially under increased N-deposition. NO\textsubscript{y} gases are categorized as air pollutants causing respiratory distress in humans and can also catalyse reactions that lead to ground level ozone formation and vegetation damage. At larger scales are globally significant as 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\textsubscript{y} are known products of nitrification and denitrification, a recently identified process involving iron (Feammox) has been suggested as being extremely important for the production and emission of NO\textsubscript{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. It is suggested that up to 7% loss of N from anaerobic soils\textsuperscript{3-6} may be mediated by Feammox but estimates are highly uncertain due to the paucity of research in this area.

Thus, there is a critical need to (i) determine the intrinsic ability of UK peatlands to produce NO\textsubscript{y}, (ii) explore the influence of N-deposition on N-cycle rates in these ecosystems, and (iii) differentiate the mechanisms by which N is transformed in peatlands, paying particular attention to microbe-iron mediated processes.

**Methodology:**

We will make seasonal field-based measurements of NO\textsubscript{y} emissions from various minerotrophic fens and ombrotrophic bogs throughout the UK over the course of one year. Sampling multiple locations will enable us to capture variable N deposition patterns and vegetation diversity. Both fens and bogs will be studied (N = 4 each) due to differences in water sources (inflow vs. atmospheric) and physicochemical properties (mineralogy, nutrients, pH).\textsuperscript{7} Combined, this will allow for a better determination of NO\textsubscript{y} flux mechanisms. In conjunction, we will establish laboratory mesocosms by taking intact cores from these same sites and analyse potential emissions of NO\textsubscript{y} from peatlands under differential N-addition amendments. Peatland soil will also be used to quantify the nitrogen-cycling microbial community and how it changes over the course of N addition. Soil–iron content will be analysed to determine any potential correlation with NO\textsubscript{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 with additional training opportunities through collaboration with UK-CEH scientists.

**Partners and collaboration (including CASE):**

Dr. Mushinski leads the Environmental Processes Laboratory (SLS-Warwick). His research group studies nitrogen cycle biogeochemistry and soil-microbe interactions in a range of natural and managed ecosystems. Professor McNamara leads the Plant-Soil Interactions Group at UK-CEH Lancaster, with expertise in the measurement and interpretation of GHG emissions. He works on a range of projects aimed at measuring and mitigating GHG emissions from UK peatlands. Professor Bending leads the Microbial Ecology Laboratory (SLS-Warwick), where his group studies the structure, diversity and function of microbial communities inhabiting plants, soil, and water - often integrating a variety of 'omics approaches, within an interdisciplinary context.
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 in line with current guidelines. The field component will proceed within the confines of a subsequent SOP - to be developed between the PI in accordance with 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:


