Nitrogen fixation and its coupling to methane dynamics in the peat moss (Sphagnum) phytobiome of northern peatlands

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ABSTRACT

Peatlands are wetlands that lock away huge amounts of carbon as thick peat soil deposits. Referred to as a "carbon bank", scientists believe that the carbon stored in peat is at risk of being released to the atmosphere in response to environmental change. Mosses often dominate plant production in peatland ecosystems, which are concentrated in northern regions where the environment can become extremely cold and is nutrient poor. Similar to humans or to other plants, mosses contain a diverse microbiome, microbes that are intimately associated with the plant in a symbiotic relationship, that help the host to grow and thrive under extreme conditions. The plant host provides the microbiome with a stable environment in which to live and in turn the microbes are believed to help mosses acquire nutrients such as nitrogen and carbon. For example, some microbes convert nitrogen gas from the atmosphere into a form that moss plants can use. Similarly, there are microbes that can also help mosses acquire carbon from the conversion of methane (natural gas produced in wetland soils) to carbon dioxide.

This research will determine how much and how fast nitrogen and carbon are metabolized by peat moss microbiomes, as well as the implications for the growth of peat mosses and carbon storage in northern peatland ecosystems in Minnesota and Canada. Taking advantage of a large whole ecosystem experiment, the project will further examine the response of peat mosses and their constituent microbiomes to environmental change. This project will provide fundamental research on how microbiomes aid the growth of peat moss plants, which may store more carbon than any other plant on Earth. Results of the project will be used to improve predictions on whether peatlands will act as a net carbon source or sink in response to ongoing environmental change as well as the potential use of plant microbiomes as a natural biofilter for methane produced in landfills.

This research will also serve society by teaching the next generation of scientists about the important ecosystem services that wetlands provide and the role of microbes in maintaining these services. At least two graduate students, two undergraduate students, and a postdoctoral researcher will be involved in all aspects of the project. Two signature activities will be used as instruments to communicate project results to the public. A 5-day workshop in a Georgia wetland will train 16 middle and high school teachers on developing lesson plans for teaching ecosystem science in the context of conservation, restoration, and global environmental change. Project results will be disseminated to the public through an annual interactive activity at the Atlanta Science Festival (which reaches 20,000 people per year).

The overall goal of the research is to investigate the role of the peat moss microbiome in regulating peatland carbon (C) and nitrogen (N) cycles and the resilience of peatlands to environmental change. Objectives are to:

1) quantify in situ rates of nitrogen fixation and methanotrophy, and elucidate the contribution of keystone microbial associates mediating these processes in the peat moss microbiome,
2) determine the response of nitrogen fixation and its coupling to methane (CH_4) dynamics to perturbation of environmental change drivers in the laboratory and in a large-scale whole ecosystem experiment in the field, and
3) leverage datasets from two long-term field sites to estimate the microbiome contribution to ecosystem N and C budgets as well as model the response of microbiome function to perturbation of environmental change drivers.

Working hypotheses include:

H1: N fixation is a predominant N input to northern peatlands;
H2: The dominant nitrogen fixers are methanotrophic bacteria and cyanobacteria;
H3: Methanotrophs that also fix N represent a substantial CH_4 sink;
H4: Net primary production by peat mosses is directly supported by N acquired from nitrogen fixation and methane-derived C from methanotrophy;
H5: Peat moss productivity and its response to environmental perturbations will be largely determined by plant-microbe and microbe-microbe interactions;
H6: Increases in temperature and CO_2 will result in lower rates of N fixation due to decreased peat moss productivity.