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Peatland Responses to Warming and Elevated CO_2: CO_2 and CH4 Flux Responses, the status of Vegetation Net Primary Production and Implications for Ecosystem Carbon Exchange After 3-Years of Manipulation

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The Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) experiment is operated as a decadal, ecosystem-scale experiment to examine vegetation, microorganism, and biogeochemical responses to warming and elevated CO_2 (eCO_2). The in situ whole ecosystem warming facilities in a high-C, ombrotrophic Picea-Larix peatland in northern Minnesota combine air warming with soil heating to 3 m depth to achieve +0, +2.25, +4.5, +6.75 or +9 °C with half the plots receiving eCO_2 at + 500 ppm. Whole ecosystem warming was initiated in August 2015, followed by eCO_2 atmospheres in June 2016. We describe results for greenhouse gas flux and vegetation net primary production and will provide a preliminary calculation of C-cycle changes for the range of treatments.

Net surface C flux estimates as CO_2 and CH4 were measured from 1.2 m diameter in situ collars monthly from April through December over three years. Paired collars outside the plots with active photosynthesizing vegetation removed were used to estimate heterotrophic C losses. In 2016 and 2017, the net flux of CO_2 and CH4 increased exponentially with warming temperatures, and the CO_2 flux was larger than CH4. In 2018, CO_2 efflux from the warmest plots was reduced, likely associated with near surface drying, but CH4 flux continued to show exponential responses. Annual assessments of tree growth were assessed with circumference observations at dbh and allometric relations were used to convert to NPP in C units. Shrub-level vegetation NPP was obtained from annual destructive harvest of multiple 0.25 m2 plots in each enclosure, separation of current-year leaf and stem tissue, and assessment of dry mass and C content. Sphagnum growth was measured in subplot collars by tracking rate of elongation and scaled to the plot-level based on transect population surveys.

The shrub layer showed significant increases in NPP with warming, however, the response varied by species with some increasing (Rhododendron) and others declining (Chamaedaphne) with warming. Tree growth exhibited a consistent reduction in annual growth rates with warming treatments that were primarily driven by changes in Picea mariana rather than Larix laricina trees. Sphagnum spp. production and presence declined dramatically with warming treatments, possibly due to increased drying and shading from the shrubs and has been nearly eliminated in the warmest plots after 3-years of sustained warming.

C-cycle changes were estimated by combining NPP C gains with C losses from peatland heterotrophic organisms. A consistent negative relationship with temperature exists, suggesting that warming is leading to a loss of C uptake potential driven by reduced NPP and some enhancement of C losses from CO_2 and CH4 emissions. This peatland currently gains approximately 30 to 50 gC m-2 y-1 but will likely transition to an ecosystem dominated by net C losses and a change in vegetation diversity with warming.