Functional Ecology

Disentangling the effects of methanogen community and environment on peatland greenhouse gas production by a reciprocal transplant experiment

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Data accessibility

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.sn02v6x16 (Juottonen 2020).

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Abstract

1. Northern peatlands consist of a mosaic of peatland types that vary spatially and temporally and differ in their methane (CH_4) production. Microbial community composition and environment both potentially control the processes that release carbon from anoxic peat either as CH_4 or carbon dioxide (CO_2), a less potent greenhouse gas than CH_4. However, the respective roles of these controls remain unclear, which prevents incorporating microbes in the predictions of peatland CH_4 emissions.
2. Here, a reciprocal transplant experiment was carried out to separate the influences of microbial community and environment in CH_4 and anaerobic CO_2 production. Peat from an acidic *Sphagnum* bog and a sedge fen with higher pH was enclosed in membrane bags with a pore size of 0.2 µm, preventing microbial colonization from the outside, and transplanted in the field for two months.
3. Potential CH_4 production was primarily controlled by the environment. The conditions in the bog suppressed the initially higher activity of fen methanogens and reduced CH_4 production by 79%. Against expectations, the inhibition was not specific to acetate-using Methanotrichaceae. Reciprocal transplantation favoured Methanosarcinaceae and potentially methylotrophic methanogenesis in general. Bog methanogens, mostly hydrogenotrophic Methanoregulaceae, retained their community structure and activity in the fen with a slight increase (+37%) in CH_4 production.
4. Anaerobic CO_2 production was controlled by both the microbial community and the environment. Transplantation led to increased CO_2 production in both bog (+50%) and fen peat (+57%) with distinct bacterial community, showing that the new environment directed more carbon to other anaerobic processes than methanogenesis.
5. Taken together, these results relate differences in CH_4 production of bogs and fens to ecophysiology of specific methanogen groups. The sensitiveness of fen methanogens to the acidic conditions in *Sphagnum* bogs can help explain the decrease of CH_4 emission in the typical boreal peatland succession from young fens to older bogs. Increase in anaerobic CO_2 vs. CH_4 production with transplantation shows that disturbances of boreal peatlands can activate poorly defined pathways of anaerobic decomposition.

Keywords: anaerobic decomposition, bog, boreal peatland, fen, methane, methanogenic archaea, microbial community, reciprocal transplantation

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Introduction

Microbe-driven ecosystem functions such as greenhouse gas production are regulated by environmental conditions and microbial communities. In most cases, the respective roles of these interacting controls and especially of microbial community composition remain elusive. Defining the role of microbial community can facilitate incorporating the appropriate controls of ecosystem processes into models (Graham et al. 2016). Factoring in microbes could especially benefit processes carried out by a specialized functional guild (Graham et al. 2016), of which methane (CH_4) production is a prime example. Peatlands are a major natural source of CH_4, but considerable gaps still exist in our ability to predict their greenhouse gas emissions (Bridgham et al. 2013). Consistent patterns are starting to emerge in the distribution of methanogenic archaea in peatlands, and better relating these community patterns to CH_4 emissions could improve predictions (McCalley et al. 2014).

A central factor in the variation of northern peatlands as CH_4 sources is peatland type defined by hydrology (Turetsky et al. 2014). In general, rainwater-fed bogs produce and emit and less CH_4 than groundwater-connected fens (Moore & Knowles 1990; Nykänen et al. 1998; Hines et al. 2008). This difference in water source is reflected in vegetation and nutrient levels: Bogs are dominated by *Sphagnum* mosses and have low pH and cations levels, whereas fens have higher cover of graminoids such as sedges and higher pH and nutrient levels (Rydin & Jeglum 2006). Higher CH_4 production in fens compared to bogs has been linked to labile carbon from sedge roots, favouring the acetoclastic pathway of methanogenesis in fens (Ström et al. 2003; Chanton et al. 2008). In bogs, the amount of dissolved organic matter (DOM) may be even higher than in fens (Moore 2003; Siegel et al. 2006), but in bogs a larger proportion of DOM is aromatic and less reactive (Chanton et al. 2008; Tfaily et al. 2013; Hodgkins et al. 2014). The main pathway of methanogenesis in bogs is typically hydrogenotrophy (Kelly, Dise & Martens 1992; Chasar et al. 2000), while fens tend to have at least some contribution of acetoclastic methanogenesis (Chanton et al. 1995; Hodgkins et al. 2014; McCalley et al. 2014). Correspondingly, methanogen community composition differs between bogs and fens (Juottonen et al. 2005; Dettling et al. 2007; Sun et al. 2012; Mondav et al. 2014). Peat DOM extracts rich in phenolic compounds have been shown to inhibit CH_4 production (Minderlein & Blodau 2010; Blodau & Deppe 2012), suggesting that peat chemistry directly controls activity of methanogens.

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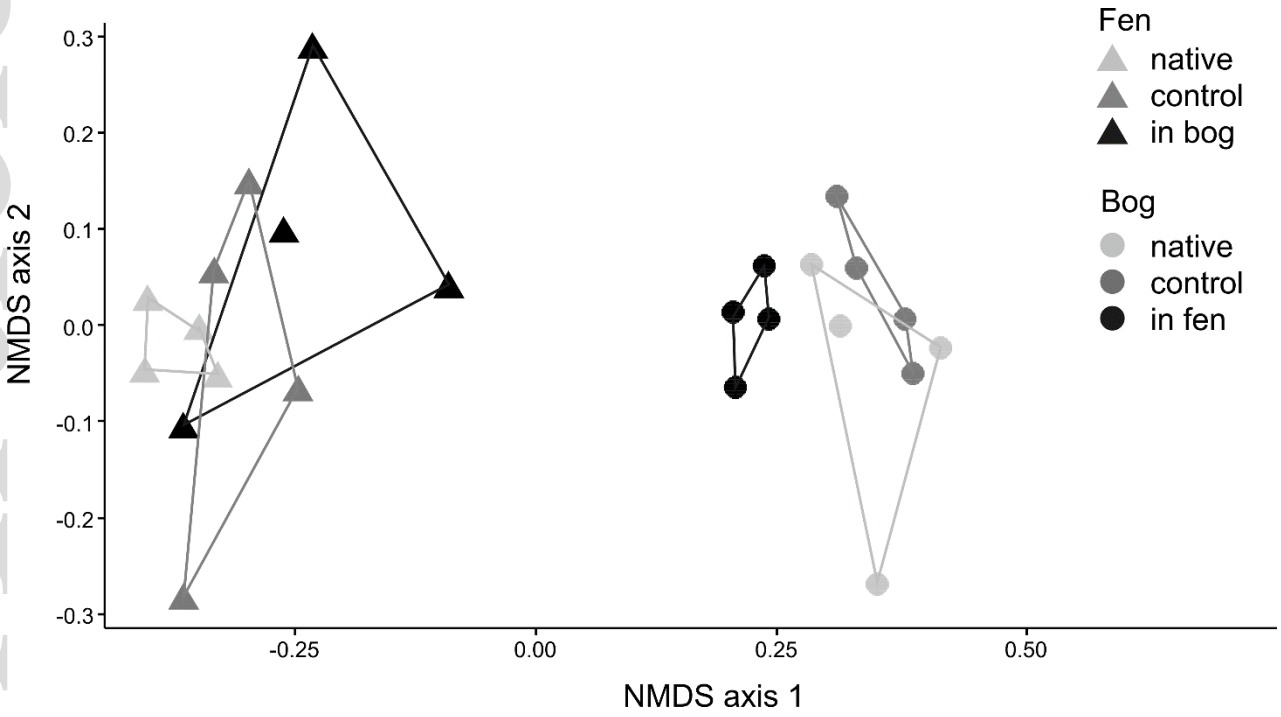

Fig. 3. Non-metric multidimensional scaling (NMDS) plot of bacterial communities (RNA-based 16S rRNA gene T-RFLP) in reciprocal transplantation between bog and fen, in control transplantations (peat transplanted back to its sampling location), and in native peat (sampled at the transplant location at the end of the experiment) (n=4). Stress=0.07.

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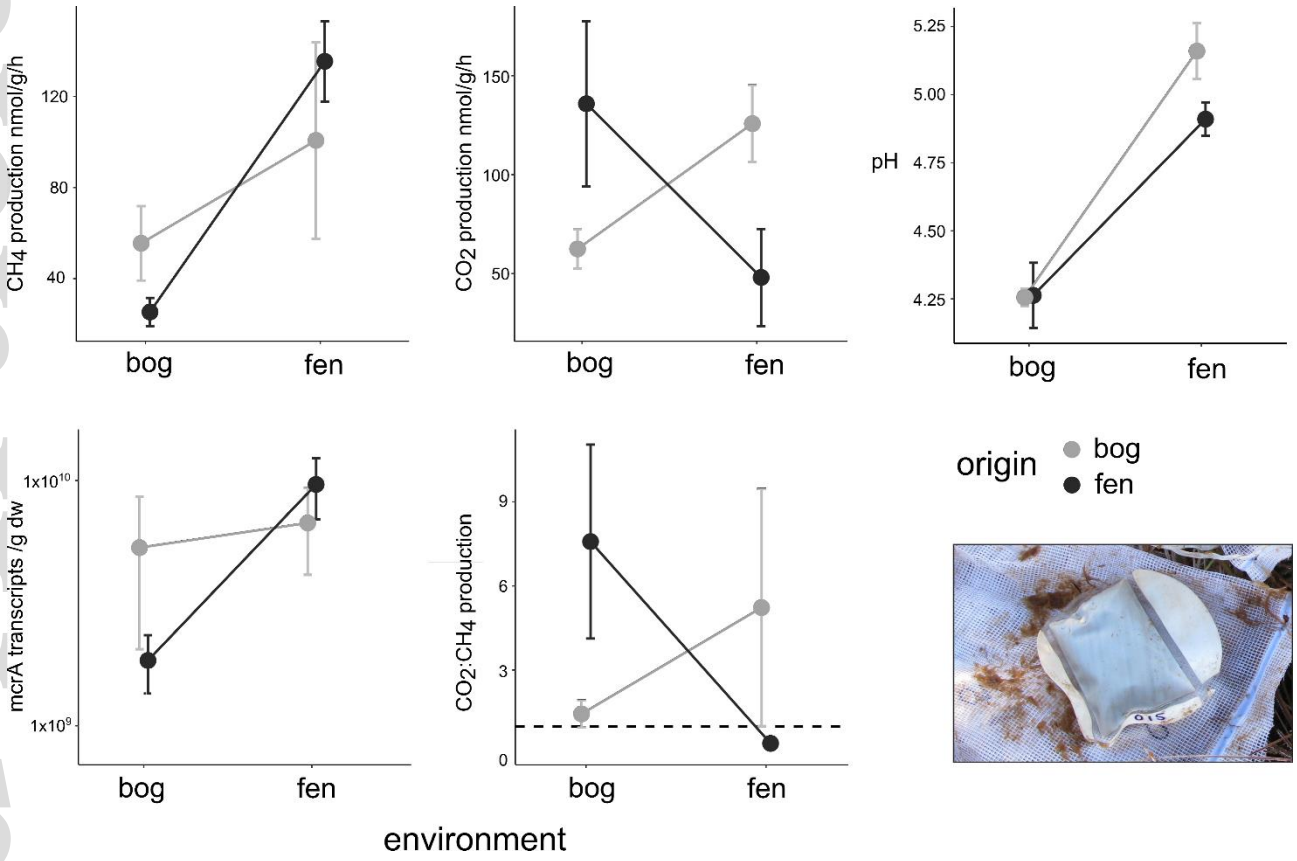

Fig. 4. Potential anaerobic greenhouse gas production, abundance of active methanogens (*mcrA* transcripts) and pH in a reciprocal transplant experiment between a bog and a fen (n=4, mean±SE). The dashed line for CO_2:CH_4 production indicates ratio of 1. Lower right corner: a membrane bag used as a microbial cage in the transplantation.

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