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NORTHERN PEATLANDS IN GLOBAL CLIMATIC CHANGE

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Possible responses of northern peatlands to climate change in the zone of discontinuous permafrost, Manitoba, Canada

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Introduction

Over half of the world's peatlands occur in the boreal zone (45 - 60° N. lat), a region that global climate models predict will experience large changes in temperature and precipitation with increasing atmospheric CO₂ concentrations (Hansen et al. 1988). The northern part of the boreal zone is characterized by discontinuous permafrost, an area that is particularly sensitive to climate change with the possible degradation and thawing of frozen peat. Peatlands are large sources of atmospheric methane (CH₄), an important greenhouse gas. Yet few measurements of methane have been conducted in discontinuous permafrost environments. As part of the Boreal Ecosystem-Atmosphere Study (BOREAS)(Sellers et al. 1995), we measured CH₄ flux in a diverse peatland complex (bogs, fens, peat plateaus, and collapse scars), representing the complete range of temperature, moisture, and plant community gradients found in northern peatlands. The measurement period May to September 1994 was one of the warmest and driest seasons on record, which provided an opportunity to observe the short-term responses of different parts of the peatland ecosystem to a warmer and drier climate as an analog to predicted climate change in the region.

Results and Discussion

Peak seasonal CH₄ fluxes ranged from 0 in the frozen peat plateaus and palsas to 1200 mg m⁻² d⁻¹ in the open sedge-rich fens and saturated lagg areas of collapse scars, where the permafrost was degrading. Continuous measurements of water table and peat temperature showed that hummocks were usually warmer than hollows at a peat depth of 10 cm even though CH₄ flux from the hummocks was significantly lower. However,

the peat temperature at the average position of the water table was higher in the hollow, suggesting that the temperature at the most active zone of CH₄ production and oxidation is a better predictor of CH₄ flux than a standard depth from the peat surface. The seasonal average peat temperature at the water table explained most of the variability in mean CH₄ flux ($r^2 = 0.63$)(Fig. 1).

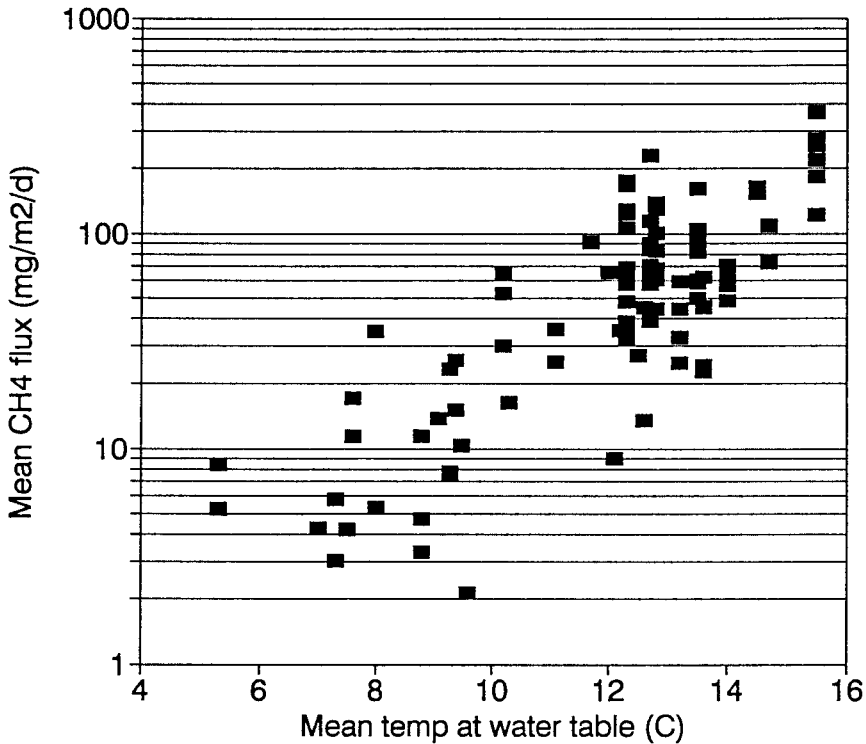


Fig. 1. Seasonal mean CH₄ flux versus mean temperature at mean position of water table (regression). Each point represents an individual collar. $\log \text{CH}_4 \text{ flux} = 0.16 \text{ temp} - 0.35$. $r^2 = 0.63$; $p < 0.001$; standard error of the estimate = 0.28; standard error of x coeff = 0.0003.

At the wet end of the moisture gradient, where fluxes were the highest, a variety of complex processes may explain the variability in CH₄ emission. Laboratory incubations of the different peat types in flooded areas showed that methane production potentials did not correlate well with CH₄ flux. But we suggest that a variety of mechanisms may be important: 1) ebullition, 2) floating peat, 3) ecosystem productivity and 4) degrading peat.

1) Ebullition: In areas of open water with thick ice cover, a large flux of methane was observed in May as the ice melted. In some sites, ebullition occurred sporadically throughout the season. These large emissions often dominated the total seasonal flux. 2) Floating peat: Even though 1994 was the third driest year on record, areas of floating peat maintained high CH₄ emissions throughout the season. Continuous measurements of the peat surface and water table showed that the peat surface adjusted to the falling water table, maintaining anaerobic conditions for CH₄ production and minimizing oxidation in the upper layers of peat. 3) Ecosystem productivity: When the sites were flooded, a strong relationship between net ecosystem productivity (NEP) and CH₄ flux was observed (Bellisario, unpub. data), perhaps due to the production of root exudates providing substrates for methanogenesis. However, as the season progressed and the water table dropped below the rooting zone of the dominant vascular plants, the relationship weakened. When the peat became drier, oxidation probably dominated the flux and the production of root exudates was no longer below the water table in the zone of CH₄ production. The most productive sites were dominated by sedges, esp. *Carex* and *Eriophorum* species. 4) Degrading pools: In many areas of northern peatland, pools develop in later successional stages and emit large amounts of CH₄ (Moore et al. 1994). Other types of open water areas with high CH₄ emissions include lagg areas of collapse scars in degrading permafrost and beaver ponds (Roulet et al. unpub. data). Little or no vegetation occurs in these areas and the temperature, composition and age of the peat may be important in determining CH₄ flux.

Because of the different processes controlling CH₄ emission from these ecosystems, we would expect a variety of responses to climate change (Table 1). A warmer and drier climate would potentially affect these various types of peats differently, resulting in higher CH₄ flux in some cases (floating and degrading peats, collapse scars), lower flux in others (non-floating peat). The effect on sedge-dominated sites is ambiguous because of the competing processes of increased plant productivity and increased microbial oxidation of CH₄.

Table 1. Climate change scenario: If the climate became warmer and drier in the future, we would expect different short-term responses from the various types of peatland environments as observed in the abnormally dry and warm 1994 summer season. Some areas would probably experience higher CH₄ emissions, some lower. In the long run, plant community structure and hydrological function would change in each of these systems resulting in a different set of ecosystem responses.

<u>Peatland environment</u>	<u>Predicted change in CH₄ flux</u>	<u>Rationale</u>
Non-floating peat	decrease	Decrease in water table would have a greater effect on CH ₄ oxidation than increase in temperature would have on production (Roulet et al. 1992).
Floating peat	increase?	Peat surface would adjust to falling water table, but higher temperatures would increase CH ₄ production. However, there may be a limit to peat surface adjustment.
Sedge-dominated sites	decrease?	Higher temperatures may increase productivity, but lower water table would decouple rooting zone from anaerobic zone of CH ₄ production.
Degrading pools	increase	Higher temperatures would increase decomposition and a drop in water table would create an aerobic zone only in very shallow pools.

Plant communities indicate many of these ecological processes that control CH₄ flux (Bubier et al. 1995, in press): They are indirect indicators of mean water table position, which is a good predictor of seasonal CH₄ emissions, and may be used to extrapolate flux from the chamber to the landscape scale using remote sensing. Canonical correspondence analysis (CCA)(Fig. 2) shows that treed sites have low CH₄ flux because they correlate with dry (height above mean water table - HMWT), aerated conditions. Open graminoid sites are associated with high CH₄ flux because sedges indicate flooded

anaerobic conditions, highly productive ecosystems, and areas of vascular plant transport enhancing CH_4 emissions. Floating peats, typically near the lagggs of collapse scars, are characterized by certain vascular and bryophyte species, especially *Carex rostrata* and *Sphagnum riparium*. In the long-term, plant communities and CH_4 emissions will change in response to a warmer and drier climate as the hydrology and thermal regime of the peatlands evolve.

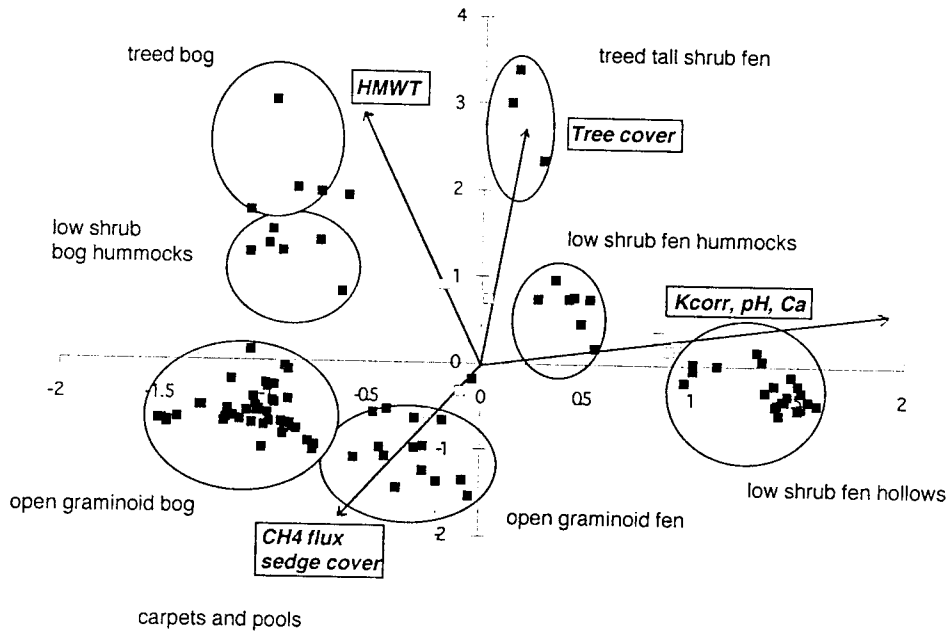


Fig. 2. Canonical correspondence analysis (CCA) of vascular and bryophyte assemblages and environmental variables. Solid boxes on the sample biplot represent individual collars; vegetation classes and microtopographic groupings are circled. The vectors (drawn from open boxes) represent environmental variables increasing in the positive direction from the center (0,0 point) of the biplot, which represents the mean value of all environmental variables. Negative values are by extending the vectors in the opposite direction. The position of each collar along an environmental gradient can be inferred by drawing a perpendicular line from the collar to the vector of interest. Eigenvalues of axes 1,2 and 3 are 0.72, 0.54, and 0.43. Interset correlations for pH, calcium, and corrected conductivity (Kcorr) with axis 1 are 894, 861, and 814 respectively. Interset correlations for height above mean water table (HMWT), tree cover, sedge cover, and CH_4 flux with axis 2 are 837, 687, -633 and -546 respectively.

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