Methane Emissions from Waterlogged Soils

H.M. Rask* and J.J. Schoenau,
Soil Science Dept., University of Saskatchewan, Saskatoon, Sk. S7N 0W0

Introduction

Increasing atmospheric levels of methane (CH_4) are of concern since methane is a powerful greenhouse gas. Higher atmospheric levels of CH_4 are found in the northern hemisphere, especially in the fall (Khalil & Rasmussen, 1983). Methane production in boreal forest wetlands may be an important contributor. By understanding the natural contributions to atmospheric CH_4, the significance of man-made CH_4 additions can be assessed. Methane flux measurements are needed to determine the importance of natural wetlands in global CH_4 cycles. As well, CH_4 flux is a major form of carbon loss from wetlands.

Materials and Methods

Methods

Clear plastic storage tubs with a rubber septum installed in the bottom were inverted over surface peat and plants in the field. The opening of the tub was made air tight by inserting the edge below the water surface of the wetland. Air samples were taken every week by syringe and injected into evacuated vacutainers. After sampling, the chambers were opened to the atmosphere and then resealed. The next sample was taken 24 hrs later. The short sampling period was used to avoid measurement errors due to temperature alterations and methane accumulation over the week-long period. Methane samples were measured on a Hewlett Packard gas chromatograph equipped with a flame ionization detector ran at 150°C, using a 2m long Porapaq Q column.

Sites

Canwood Forest Reserve

The Canwood fen is filled with a solid layer of peat which runs throughout the fen area. The sampling transect runs from thin peat under trees at the edge of the fen to peat approximately 130 cm thick in the center of the fen. The peat is poorly decomposed and contains low amounts of available nutrients. In the spring, water flows through the center of the fen.

Prince Albert National Park

Two sites were sampled in the park: 1) a fen at the edge of the part (Boundary fen), and 2) an upland basin (kettle).

In Boundary fen, the sampling transect runs from the edge of the fen to the middle; from thin peat under spruce trees to a thick solid peat, then to a floating peat mat over a column of water and a sunken peat mat, and finally to open water over a sunken peat mat in the center of the fen. The peat is poorly decomposed as the site remains permanently flooded.

The second site in the park consists of a basin located at a higher altitude which collects runoff from surrounding slopes. Therefore, the site is flooded in the spring but dries out by fall. The basin contains an organic soil which is moderately decomposed and has a higher nutrient status. The aerobic period in the fall allows greater decomposition rates which release nutrients like sulfate.

Results

Methane flux occurred for a relatively short period in mid-summer in the Canwood fen. The majority of the CH_4 emissions occurred from the first part of June till the first of September (Fig. 1). A large decline in fluxes accompanied a strong frost during the first part of August. As the water level and the temperature below the peat surface remained unchanged, the death of sedges and other plants in the fen as a result of the frost may have altered the environment and decreased CH_4 flux. For example, plant transport of CH_4 through the roots to the surface could be reduced. The frozen plant matter may also increase the supply of soluble organic compounds and thereby alter microbial activity. The peat profiles at the edge of the Canwood fen began releasing CH_4 later in the season, likely because the edge areas are shaded by trees and remain colder (Fig.1). The highest flux occurred at a distance about 1/3 from the edge. At this location a slight pulse of methane was noted during the spring thaw, indicating methane accumulation under the ice during the previous fall and/or winter.

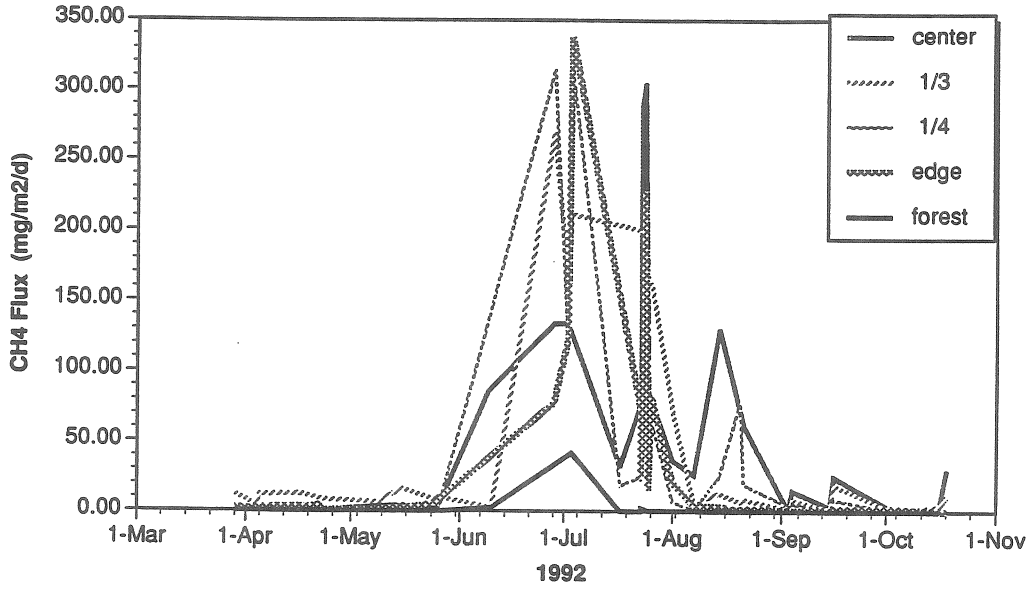

Fig.1. Methane fluxes in Canwood fen at profiles from the forest to center

The Boundary fen showed similar seasonality in methane flux patterns, except that the large fluxes were delayed by two weeks, starting in about mid-June. This location takes longer to warm up in spring because it is located about 100 km farther north (Fig.2). The early frost in August also reduced the fluxes in this site. At the edge of the boundary fen, tree cover was more dense, creating a cooler location with a shorter CH_4 flux period than at the center of the fen. The Boundary fen released considerable amounts of CH_4, even during very cool periods in early summer, indicating active methane production at cold temperatures. Methane production may occur in unfrozen peat at depth even during the winter. Methane originating in the winter may be partly responsible for a small surge in CH_4 during spring thaw in the solid peat profile. A CH_4 surge was also noted during freeze-up in open water.

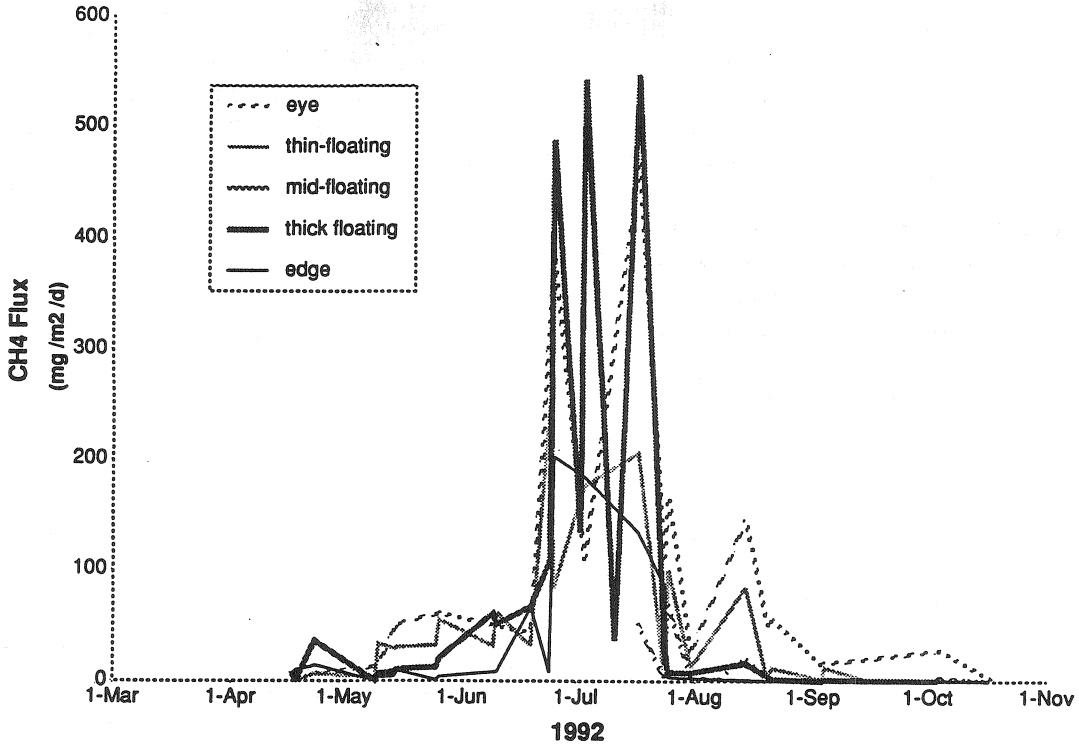

Fig. 2 Methane fluxes in boundary fen at profiles from forest edge to the open water

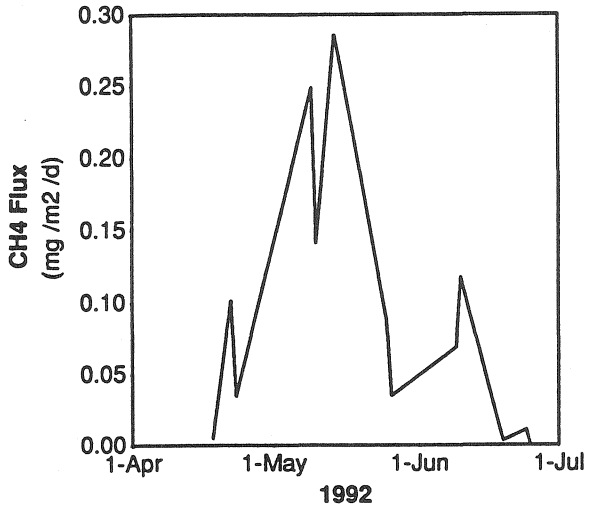

Fig. 3. Methane fluxes from the Basin in the watershed

Methane fluxes from the upland basin were very low and only significant when the peat was thawing (Fig.3). The low levels of CH_4 may reflect an inhibition of methanogenesis by sulfate reducers. Higher levels of sulfate and reduced sulfur compounds were found in the basin, indicating considerable sulfate reduction activity. Sulfate reducers may out-compete methanogens for substrates. Therefore, if sulfate reduction is occurring, then methanogenesis may be virtually eliminated (Lovley et al,1982).

Methane fluxes were found to vary according to the conformation of the peat in the area. In the Canwood fen, the CH_4 flux increases as the peat becomes thicker (Fig.4). Low fluxes in the forest profile may reflect cooler temperatures created by the shading of trees as well as lower water levels creating less strongly reducing conditions. Lower than expected CH_4 fluxes in the center of the Canwood fen could be attributed to slow water flow through the area, especially in the spring. Water movement increases the O_2 levels in the peat which may lower CH_4 production and increase CH_4 oxidation.

Canwood fen has CH_4 production levels which are comparable with fluxes recorded in peak seasons for Michigan (0.28 g CH_4 m^{-2} d-1 by Baker-Blocker et al, 1977); Minnesota (0.42 g CH_4 m^{-2} d-1 by Harriss et al, 1985; 0.2 g CH_4 m^{-2} d^{-1} by Crill et al, 1988) or Sweden (0.3 g CH_4 m^{-2} d^{-1} by Svensson & Rosswall, 1984) and are higher than production values reported in the Southeastern United States (Harriss & Sebacher, 1981) or France (Giani et al, 1989).

The Boundary fen has higher CH_4 fluxes than the Canwood fen, possibly due to deeper peat accumulations (Fig.5). Emission values of 0.10 to 0.25 g CH_4 m^{-2} d^{-1} are similar to other flux values for the peak flux season reported in the rest of the world. The open water profile at Boundary fen showed higher emissions (0.25 g CH_4 m^{-2} d^{-1}) than the other profiles.

The Boundary fen fluxes increased as the thickness of the solid peat increased, similar to the Canwood fen. Moving towards the center of the fen, from the thick solid peat to the floating peat, resulted in lower CH_4 emissions. Floating peat mats can trap CH_4 bubbles released from the submerged peat sediments below. The floating peat, containing plant roots which can transport O_2 to the bottom of the mat, creates an ideal environment for CH_4 oxidation. The open water in the center of the fen has higher emissions (0.25 g CH_4 m^{-2} d^{-1}) presumably because there is no peat on the surface to trap methane bubbles as they move to the atmosphere, decreasing the chance of the CH_4 being oxidized.

Conclusions

The period of methane flux for wetlands in the boreal forest is relatively short, with most CH_4 released between mid-June and the beginning of August. The CH_4 fluxes in the different conformations of peat were similar to rates found in corresponding types of peat throughout the world. The Canwood fen had a mean flux from all profiles of 0.131 g CH_4 m^{-2} d^{-1}, with fluxes reaching as high as 0.337 g CH_4 m^{-2} d^{-1}. Boundary fen had a mean flux of 0.168 g CH_4 m^{-2} d^{-1}, with fluxes reaching 0.547 g CH_4 m^{-2} d^{-1}. The upland basin only released a small amount of methane (0.0081g CH_4 m^{-2}) over the entire

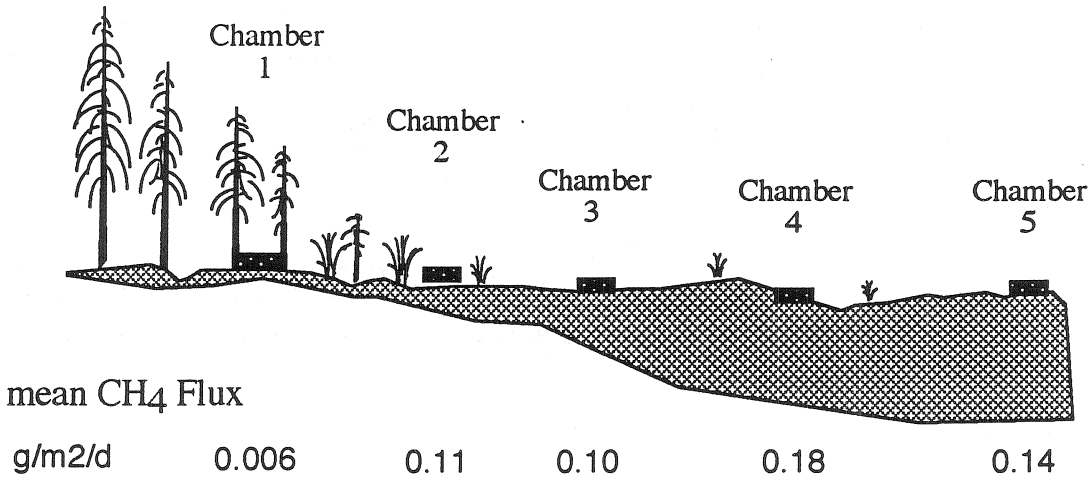

Fig. 4. Mean methane fluxes in Canwood fen from June 24 to August 1

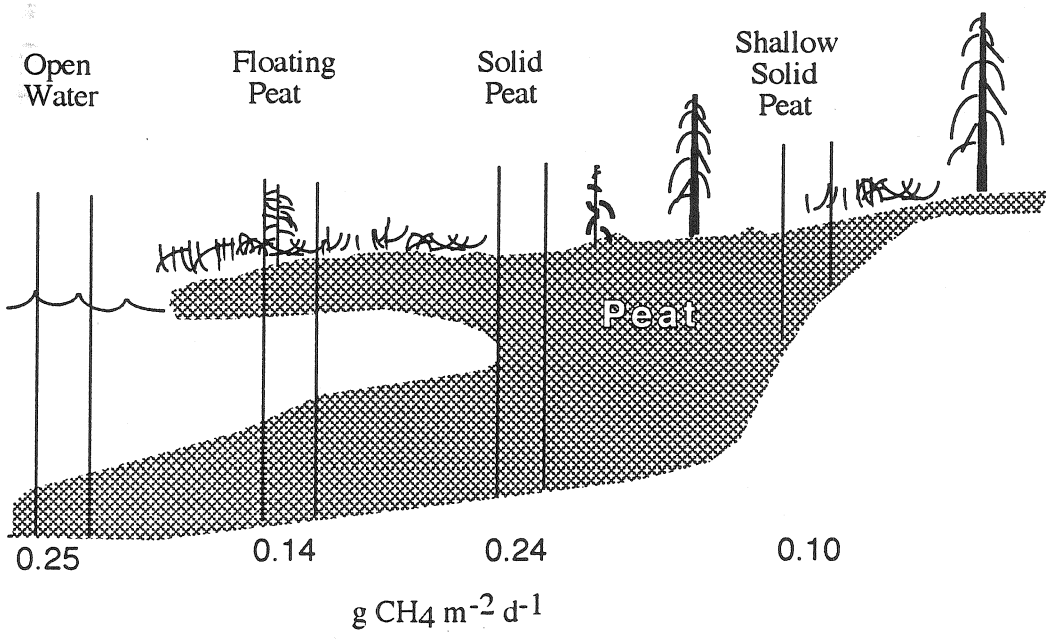

Fig. 5. Mean Methane Fluxes in Boundary Bog from June 24 to July 25

measurement period, mainly during spring thaw. The small amount of CH_4 is attributed to sulfate reduction activity in the peat out competing the methanogens for substrates. Although CH_4 fluxes are only moderate and occur in a short period, the boreal forest wetlands are likely substantial contributors to the atmospheric methane load, because of a large wetland area in the northern hemisphere.

The CH_4 emission rates from different peat conformations are very important if total CH_4 emissions are to be modelled in the boreal forest. The CH_4 fluxes were found to be highest in open water and in deep (> 1m) solid peat profiles. Floating peat mats decrease the CH_4 fluxes considerably because more of the CH_4 is oxidized before getting to the atmosphere. Shallow solid peat found under tree has lower fluxes because of cooler, drier conditions.

References

Baker-Blocker, A., T. M. Donahue & K. H. Mancy. 1977. Methane flux from wetland areas. Tellus 29: 245-250.

Crill, P.M., K.B. Bartlett, R.C. Harriss, E. Gorham, E.S. Verry, D.I. Sebacher, L. Madzar, & W. Sanner. Methane flux from Minnesota peatlands. Global Biogeochem. Cycles. 2: 371-384.

Giani, D., D. Jannsen, V. Schostak & W.E. Krumbein. 1989. Methanogenesis in a saltern in the Bretagne (France). FEMS Micro. Ecol. 62: 143-150.

Harriss, R.C., E. Gorham, D.I. Sebacher, K.B. Bartlett & P.A. Flebbe. 1985. Methane flux from northern peatlands. Nature 315: 652-654.

Harriss, R.C.& D.I. Sebacher. 1981. Methane flux in forested swamps of the southeastern United States. Geophys. Res. Let. 8: 1002-1004.

Lovley, D.R., D.F. Dwyer, & M.J. Klug. 1982. Kinetic analysis of competition between sulfate reducers and methanogens for hydrogen in sediments. Appl. Environ. Micro. 43: 1373-1379.

Khalil, M.A. & R.A. Rasmussen, 1983. Sources, sinks, and seasonal cycles of atmospheric methane. J. Geophys. Res. 88:5131-5144.

Svensson, B.H. & T. Rosswall. 1984. In situ methane production from acid peat in plant communities with different moisture regimes in a subarctic mire. OIKOS 43: 341-350.