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Tormod Lien, Pertti Martikainen, Hannu Nykänen and Lars Bakken

METHANE OXIDATION AND METHANE FLUXES IN TWO DRAINED PEAT SOILS

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Methane production and consumption in drained minerotrophic and ombrotrophic peat was investigated using a combination of field measurement and laboratory incubations. In the field, methane fluxes were measured at intervals over a seven (minerotrophic) and ten (ombrotrophic) month period together with measurements of methane concentrations and temperature at various depths. In the laboratory, aerobic incubations of drained peat samples from various depths were conducted over a range of temperatures to determine rates of potential methane oxidation. The maximum potential methane oxidation rate occurred at a depth close to that of the water table. The oxidation rate was much higher in the ombrotrophic peat than in the minerotrophic peat. However, field measured methane fluxes were lower in the minerotrophic peat. This is attributed to a relatively low water table. Methane oxidation increased over the temperature range 2 to 30°C and decreased at temperatures >34°C. Methane production in the aerobic incubation experiment was measured by inhibition of methane oxidation with dimethyl ether. Production rates were only 1–7% of net oxidation rates. Thus, the measured net rates of methane absorption in aerobic incubations largely reflect gross oxidation rates.

Keywords: Bog, fen, temperature, water level

T. Lien & L. Bakken, Department of Biotechnological Sciences, Agricultural University of Norway, P.O. Box 5040, N-1432 Aas, Norway
P. Martikainen & H. Nykänen, Department of Environmental Microbiology, National Public Health Institute, P.O. Box 95, SF-70701, Kuopio, Finland

INTRODUCTION

Methane oxidation in aerobic layers of soils is apparently minimizing the emissions of methane from moist ecosystems (Conrad 1989, Whalen & Reeburgh 1990). To quantify the role of this methane oxidation in atmospheric methane budgets, we need more information about gross rates and the factors regulating the activity. This paper describes preliminary data from a combination of laboratory and field studies of methane fluxes at two drained peatlands in Finland.

MATERIALS AND METHODS

Field measurements

Methane concentrations in peat profiles and fluxes were measured (Martikainen et al. 1992) during a seven and ten-month period at a minerotrophic (Tall sedge fen, Finnish abbreviation VSN) and an ombrotrophic (Cottongrass pine bog, TR) site, respectively. The sites are located on the drained part of the Lakkasuo mire complex in Central Finland. The fluxes were measured using a static chamber technique. Temperature and water table levels were also monitored.

Laboratory measurements

Methane production and potential methane oxidation rates and the effect of temperature were measured in the laboratory (Norwegian group) using peat samples collected from the same sites as used for flux measurements. The layers sampled were 0–5, 5–15, 15–25 and 25–35 cm below the surface.

The peat samples were drained to a matric tension of 60 cm H_2O on a column of silt. 20 g of peat were then placed in 120 ml serum bottles and incubated for 48 h. The decrease in methane concentration during the first hours of incubation was used to calculate net methane oxidation rates. Thereafter, 1% dimethyl ether, which inhibits methane oxidation, was injected into the vessels to obtain a partial pressure of 1 kPa. The net release of methane during the following incubation period (10 h) was used to estimate methane production. Methane concentrations were measured using a gas chromotograph system described by Sitaula et al. (1991).

Experiments with different initial concentrations of methane demonstrated that the oxidation rate was proportional to the concentration over a wide range (1–100 ppmv). Thus, oxidation rates were first calculated as k values (h^{-1}), estimated by linear regression of ln transformed concentrations values *versus* time. The k values were then used to calculate the oxidation rate (O(1)) in ng methane g^{-1} soil h^{-1}, at a standard concentration of methane (1 ppm):

$$O(1) = (k * D\ CH4 * Vb)/Dm \qquad (1)$$

where D CH4 is the amount of methane in ng CH_4 cm^{-3} at 1 ppmv concentration (= density of methane at 100 kPa, in ng cm^{-3}), Vb is the gas volume in the bottle (cm^3), and Dm is the dry mass of soil. Assuming first order kinetics, oxidation rates at other methane concentrations can be calculated by the equation 1.

The temperature response of methane oxidation was investigated with a flow system. Moistened air (methane concentration of 2.46 ppmv) was pumped (1 ml min^{-1}) by a peristaltic pump into vessels containing peat from the profiles of the ombrotrophic site. The peat vessels were placed in a thermostated water bath in which the temperature could be changed quickly within the temperature range from 2 to 45°C. At regular intervals, methane concentration in the air inlet and outlet was measured. The concentrations of methane reached stable levels after some hours, and this level was used to calculate oxidation rates according to first order kinetics:

$$dCv/dt = (Ci-Cv)/Vv - k*Cv \qquad (2)$$

where Cv is the methane concentration (ppmv) in the peat vessel (and sampling vessel), Ci is the methane concentration in the inlet air, Vv is the total gas volume in the system, and k is the first order rate constant as obtained in equation (1). At steady state conditions (Cv = constant), dCv/dt = 0 and k values can be calculated from the measured Cv according to equation (2). Conversion of k to actual oxidation rates at standard concentration (1 ppm) was done according to equation (1).

RESULTS AND DISCUSSION

Field measurements of methane fluxes

At the ombrotrophic site, the water table was rather high during most of the year (average depth = 8.8 cm), and there was a net flux of methane from peat to the atmosphere (Fig. 1a). The flux was strongly correlated with temperature, but a modifying effect of water table level cannot be ruled out.

In contrast, the minerotrophic site acted as a net sink for atmospheric methane during most of the study period (Fig. 2a). The net flux of methane from the atmosphere to the peat was positively correlated with the water table depth, and also with temperature. In November (last sampling), methane oxidation in the upper layers was apparently limited by the low temperatures and there was a net efflux of methane at this time. A low water table is probably a prerequisite for the high uptake rates during the summer.

Methane concentrations in peat profiles

Methane concentrations were much higher in the profile of the ombrotrophic site than in that of the minerotrophic site (Fig 1c, 2c). The relatively high average value (18 ppm) at a 5-cm depth in the minerotrophic site is due to the samples taken in the autumn (during which a net efflux was registered). During most of the summer period, concentrations were below ambient concentrations (1.71 ppmv). Concentrations below ambient levels were also registered in deeper layers as well (5–15 cm and 15–25 cm), but less frequently than at a 5-cm depth.

At a 5-cm depth in the ombrotrophic site, methane concentrations were above the ambient concentrations throughout the whole period, with a minimum value of 2 ppmv registered in May/ June (week 24). At a 15-cm depth, methane concentrations ranged from 7 to 2 800 ppmv.

Laboratory methane oxidation rates

The ombrotrophic site showed maximum methane oxidation rates for the layers between 5 and 25 cm (Fig. 1b). Much lower activities were found in the samples from the minerotrophic site, and the highest oxidation took place in the deepest layer (Fig. 2b).

The methane oxidation (Figs. 1b, 2b) seems to be related to the concentration of methane in the profiles (Figs. 1c, 2c). The ombrotrophic site had both higher concentrations and higher oxidation rates than the minerotrophic site. The oxidation rate of methane in the different layers of the minerotrophic site was correlated with the methane concentrations. However, despite a high level of methane at the deeper layers of the ombrotrophic site, the potential methane oxidation was low.

We can assume that the potential methane oxidation reflects the biomass of methane oxidizers. The correlation between the methane concentration and potential oxidation of methane in the upper layers would indicate that the growth of methanotrophs was limited by methane availability. At deeper layers in the ombrotrophic site (which had a higher water table than the minerotrophic site), low oxygen availability was probably more important in limiting the activity of methanotrophs.

The *in situ* flux measurements at the ombrotrophic site demonstrated that, despite a high potential for methane oxidation, there was a net flux of methane to the atmosphere. This was probably due to a low availability of oxygen (high water table), which was not the case in the laboratory measurements.

Despite a moderate potential for oxidation at the minerotrophic site, this peat was a net sink for atmospheric methane. The water table was deeper than the deepest sampling layer (i.e., 35 cm) during the summer period (Fig. 2a). Most of the methane oxidation at this site might take place at depths deeper than 35 cm.

In the above, it is assumed that the methane production in the deeper anaerobic layers was similar at both sites. It is possible that this is not true. Ombrotrophic peat types may produce much more methane per volume unit than minerotrophic ones (Nilsson 1992). Thus, the net flux of methane from the ombrotrophic peat may be due to both a high gross production and the high water table.

Temperature response of methane oxidation

The samples from the 5–15 and 15–25-cm layers of the ombrotrophic site had similar methane oxidation activities at low temperatures (2–10°C). At higher temperatures, however, the activity in the samples from the 0–15-cm layer was higher than that of the samples from the 15–25-cm layer (Fig. 3). This indicates that the deeper peat layers had a methanotrophic flora which had a more "psychrophilic" temperature response profile than the flora of the upper peat profile. This would make sense, since the amplitudes of temperature variations are negatively correlated with depth. However, maximum methane oxidation rates for the both layers were obtained at 31°C, which is in good agreement with the results of Whalen et al. (1990).

Gross rates of methane production and consumption

The measured methane consumption is a net result of methane oxidation and a possible methane production. If these processes occur simultaneously, accurate methane oxidation rates can not be determined by measuring the net consumption of methane. This might explain the apparent plateau in methane consumption over a wide temperature range (10–30°C, Fig. 3). However, preliminary results from experiments where samples from the ombrotrophic site were incubated at room temperature with and without dimethyl ether did not indicate that methane production significantly affected consumption. In the presence of dimethyl ether, production ranged from 0.1 to 0.3 ng CH_4 g^{-1} peat hr^{-1}, which was only 1–7% of the methane consumption rate at 1 ppm concentration. The results suggest that dimethyl ether can be used to block methane oxidation without affecting methane production (Oremland & Culbertson 1992).

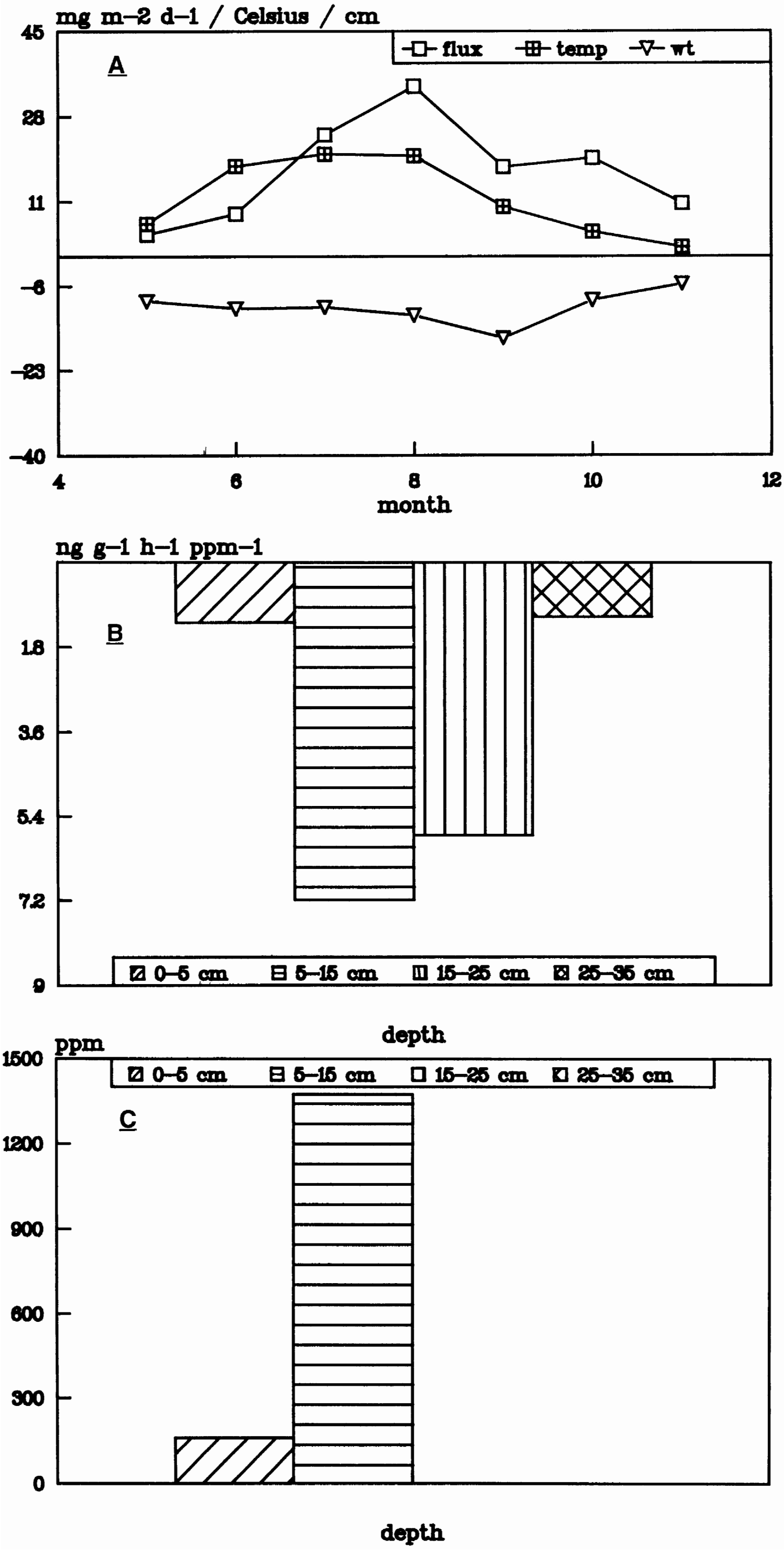

Fig. 1A–C. Field and laboratory data for the **ombrotrophic site.** — A: Methane flux (mg $m^{-2}d^{-1}$), air temperature (°C), and water table level (wt, cm below surface). — B: Methane oxidation rates as measured in the laboratory. — C: Methane concentrations at different depths in the peat profile.

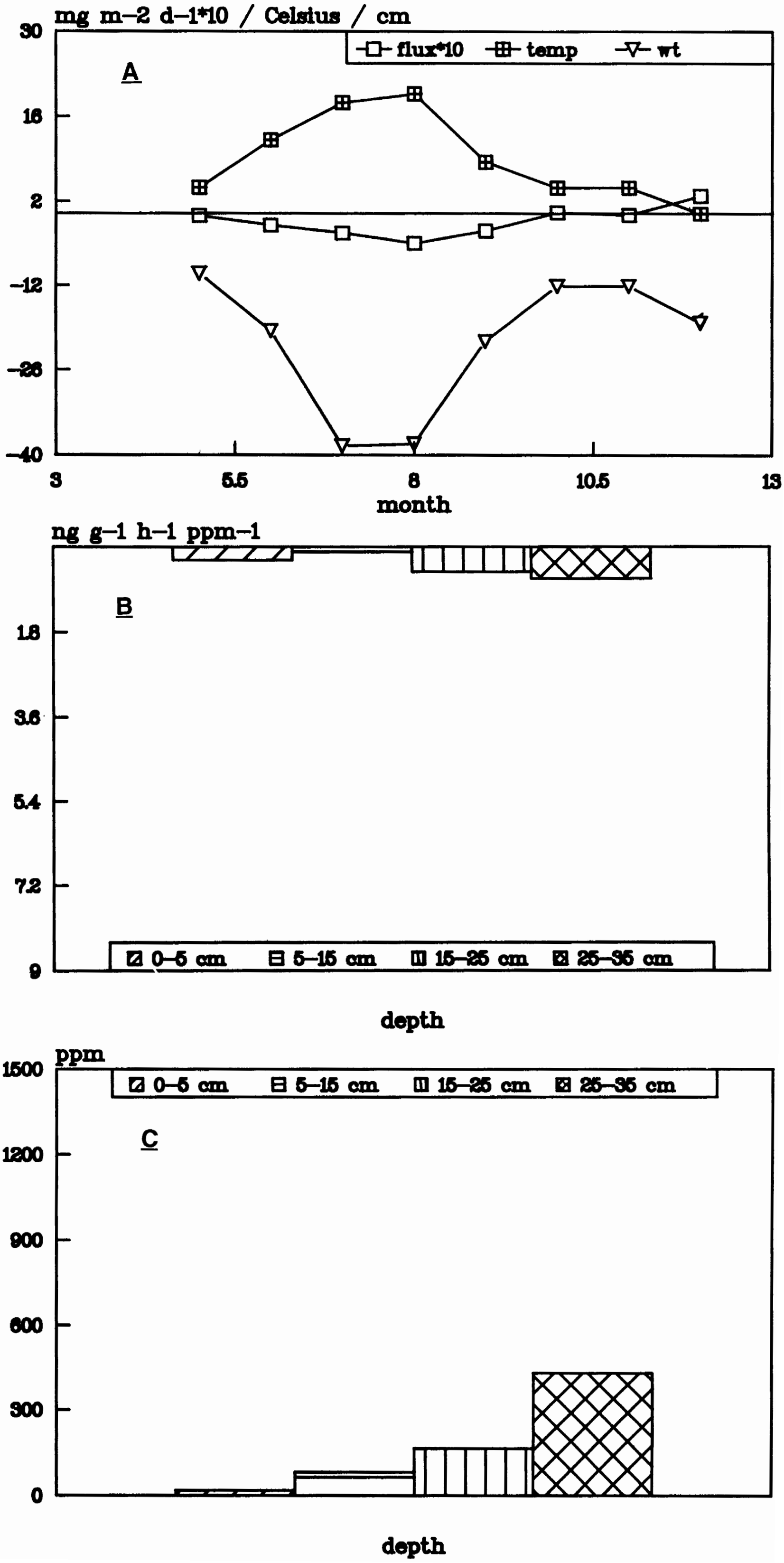

Fig. 2A–C. Field and laboratory data for the **minerotrophic site.** — A: Methane flux (mg $m^{-2}d^{-1}$ multiplied by 10) air temperature (°C), and water table level (wt, cm below surface). — B: Methane oxidation rates as measured in the laboratory. — C: Methane concentrations at different depths in the peat profile.

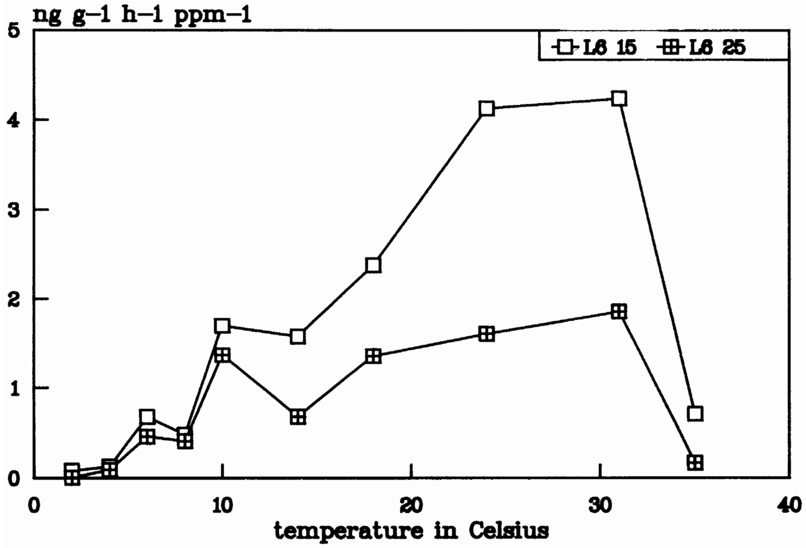

Fig. 3. Temperature response of methane consumption in samples from a 5–15-cm depth and a 15–25-cm depth at the ombrotrophic site.

CONCLUSIONS

The flux data together with the methane concentrations in peat profiles and laboratory measurements of methane consumption indicate that most methane consumption takes place near or below the water table. Methane fluxes in drained peatlands appear to be largely regulated by methane consumption which is strongly affected by water table levels and temperature. However, variations in methane production rates may also be important.

The use of dimethyl ether in the field to block methane consumption may enable methane oxidation rates in the field to be determined. Thus, gross rates of methane production and methane consumption could be measured.

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