Extended abstract No. 23

TITLE OF THE PAPER: METHANE DYNAMICS OF UNDISTURBED FENS IN OIL SANDS REGION OF ALBERTA, CANADA

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SUMMARY

Peatlands account for 40-70% of planned oil sands development areas and reclamation strategies will be required for these ecosystems. In order to evaluate reclamation success, baseline data from undisturbed peatlands of the region are required. We used the closed chamber technique to measure the surface CH_4 flux and pore water samplers to collect pore water for determination of sub-surface CH_4 concentration. Results indicate that poor fen had the highest pore water CH_4 concentration and CH_4 flux, followed by rich fen and saline fen. The CH_4 flux of the saline fen was almost zero likely due to high pore water sulphate concentration. However, the sub-surface CH_4 analysis found that a small amount of CH_4 is produced. As reported in literature, we found significant correlation between water table position and CH_4 flux. Results from this study suggest that CH_4 flux and sub-surface CH_4 concentration at reclaimed peatlands will be mostly controlled by vegetation, water table and soil chemistry.

KEY WORDS: Methane Dynamics, Fen, Oil Sands, Reclamation.

INTRODUCTION

Peatlands play important roles in the global cycling of carbon as they are net sinks of atmospheric carbon dioxide (CO_2) and a large source of atmospheric methane (CH_4) (Gorham, 1991). These ecosystems are estimated to store over 550 million tonnes of carbon, or 30% of all land-based carbon (Wetlands International, 2008). In Alberta, near Fort McMurray where most of the oil-sands are located, peatlands comprise about 65% of the landscape, most of which are fens (Vitt and Chee, 1989). The oil sands operation, which will remove large areas of undisturbed peatlands, is expected to cover approximately 1400 km^2 by 2023 (Alberta Environment, 1999). According to Price *et al.* (2009) fen creation is feasible and the concept has been adapted into the Alberta Environment Protection & Enhancement Act (AEPEA). As part of their operation all oil sands operators must restore their leased lands to a state with similar ecosystem capabilities of the undisturbed landscape. Thus, information about ecosystem function in baseline reference ecosystems is needed to compare to the reclaimed landscape. This study focused on methane (CH_4) flux and pore water CH_4 concentration of three different natural undisturbed peatland ecosystems (poor fen, rich fen and saline fen) in the oil sands region near Fort McMurray, Alberta, Canada. The main objective of this study was to understand the surface and sub-surface

CH_4 dynamics which can be used for success monitoring of reconstructed fen ecosystems. The specific objectives were to – (i) measure CH_4 flux and pore water CH_4 concentration of different representative fen ecosystems of the oil sands region, and (ii) investigate the controlling factors for CH_4 flux and pore water CH_4 concentration at these sites.

METHODS

Study Site

The study selected three undisturbed peatlands around Fort McMurray, Alberta Canada. These are (i) Pauciflora poor fen (PF), located about 50 km south (56°22.610' N, 111°14.164' W) of Fort McMurray and we divided this site into two categories namely open poor fen (OPF) and treed poor fen (TPF), (ii) Saline fen (SF), located about 25 km south of Fort McMurray (56°34.398' N, 111°16.518' W), and (iii) Poplar creek rich fen (RF), located about 40 km NW (56°56.330 N, 111°32.934 W) of Fort McMurray. Ecologically (vegetation characteristics), chemically (EC, pH) and physically (topographic characteristics) these three sites were different. The mean EC (± standard deviation) from water table wells was 440.3 ± 144.3 µS/cm, 26.1 ± 16.3 mS/cm, and 123.3 ± 105.6 µS/cm; and mean pH (± standard deviation) was 7.0 ± 0.2, 6.4 ± 0.3, and 5.6 ± 0.7 for PPF, SF and PCF respectively.

CH_4 Flux and Pore Water CH_4 Concentration Measurement

Data for this study were collected during the growing season (May - August) in 2011.We used chamber techniques described by Alm *et al.* (2007) to measure CH_4 flux. At the beginning of the growing season we installed six replicate plots at each site– three of which were hollow plots and three of which were hummock plots. CH_4 samples were collected using dark chambers over a 35-minute sampling period and stored in pre-evacuated Exetainers (Labco Ltd, UK). Pore water samples were collected from within 10 cm below the water table using sub-surface samplers (see Strack *et al.,* 2004), consisting of a 20 cm length of 2.5 cm inner diameter (i.d.) PVC pipe slotted at the middle 10 cm, covered in Nitex screening to prevent clogging, and sealed at both ends with stoppers. Later the samples were analysed using Varian Gas Chromatograph (GC) equipped with a flame ionization detector in the laboratory. Water table depth, air temperature inside the chamber and peat soil temperature were measured at each plot during each CH_4 measurement.

RESULTS

Environmental Characteristics

The mean water table (± standard deviation) was -7.64 ± 8.53 cm, -2.32 ± 3.42 cm, -9.94 ± 9.98 cm and -14.2 ± 4.82 cm for RF, OPF, TPF and SF, respectively. The mean (± standard deviation) soil temperature at 5 cm depth was similar at RF (16.53 ± 2.46 ºC), OPF (17.19 ± 0.56 ºC) and OTF (16.36 ± 1.23 ºC) but relatively warmer at SF (19.07 ± 0.90 ºC).

CH_4 Flux and Pore Water CH_4 Concentration

The study found significant variation in CH_4 flux (ANOVA – F = 3.74, $p < 0.01$; Figure - 1) and pore water CH_4 concentration (ANOVA – F = 9.69, $p < 0.01$; Figure - 2) between hummocks and hollow plots at different sites. The highest average seasonal CH_4 flux was observed at OPF hummock with large standard deviation (56.46 ± 42.17 mg CH_4 m^{-2} day^{-1}) followed by hollow (40.09 ± 13.89 mg CH_4 m^{-2} day^{-1}) plots (Figure 1). At TPF this value was about 14 times lower for hummocks and two times lower for hollow plots (Figure 1). RF hollow plots had a similar flux (39.72 ± 24.06 mg CH_4 m^{-2} day^{-1}) as OPF but RF hummock plots had a mean CH_4 flux of only 2.57 ± 3.15 mg CH_4 m^{-2} day^{-1} (Figure -1). SF showed small consumption of CH_4 at both hummock (-0.68 ± 1.28 mg CH_4 m^{-2} day^{-1}) and hollow (-0.9 ± 1.15 mg CH_4 m^{-2} day^{-1}) plots during the study period (Figure -1).

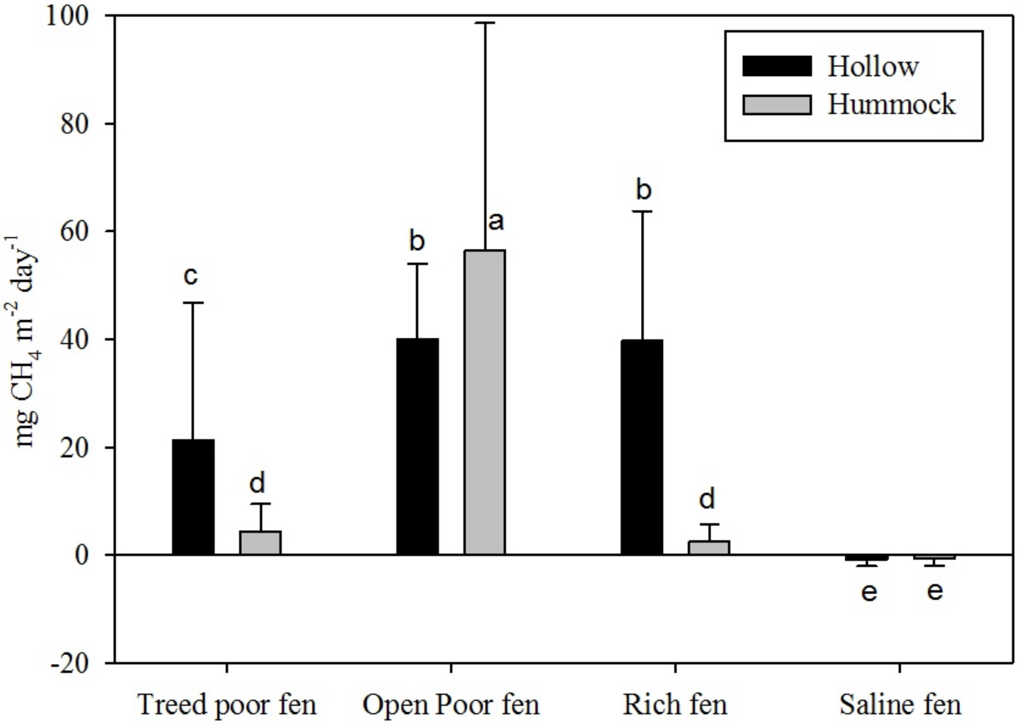

Figure 1. Mean seasonal CH_4 flux from hummocks and hollows at different fen ecosystems. Error bars are showing ± standard deviation. Sites are significantly different ($P < 0.05$) from each other if no letters are in common.

The mean seasonal (± standard deviation) pore water CH_4 concentration was relatively low at all the sites. It was similar at TPF hummock and hollow plots (Figure 2). The highest pore water CH_4 concentration was observed at OPF hollows (4.14 ± 1.16 mg CH_4) followed by OPF hummock (3.24 ± 1.06 mg CH_4) plots (Figure 2). At RF pore water concentration was higher than SF but lower than PF hummock-hollow plots (Figure 2).

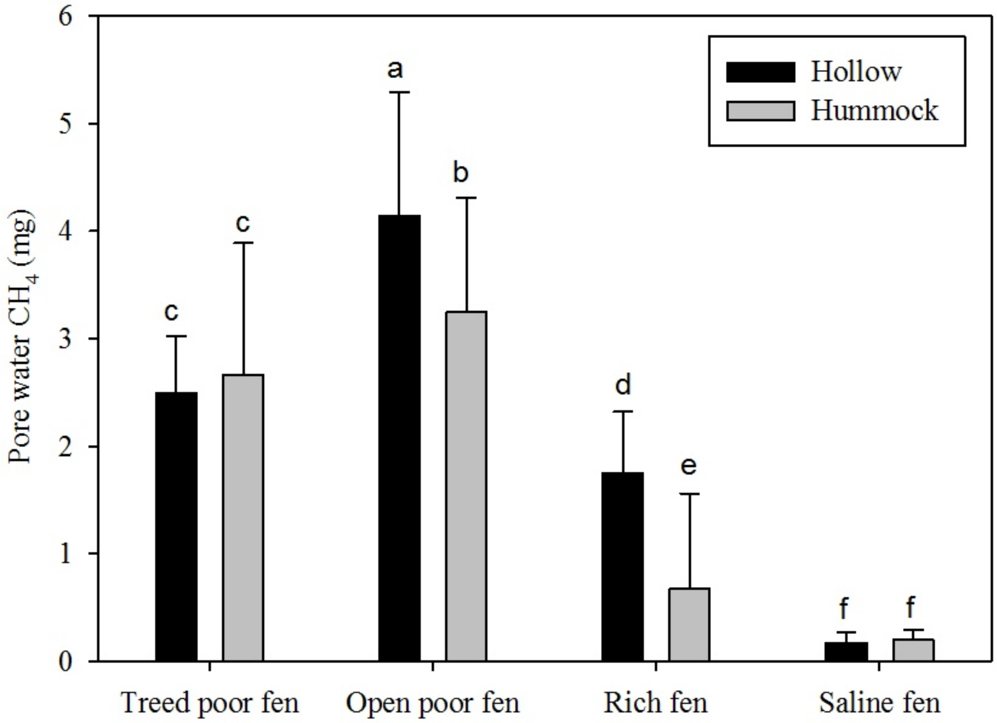

Figure 2. Mean seasonal pore water CH_4 concentration at hummocks and hollows at different fen ecosystems. Error bars are showing ± standard deviation. Sites are significantly different ($P < 0.05$) from each other if no letters are in common.

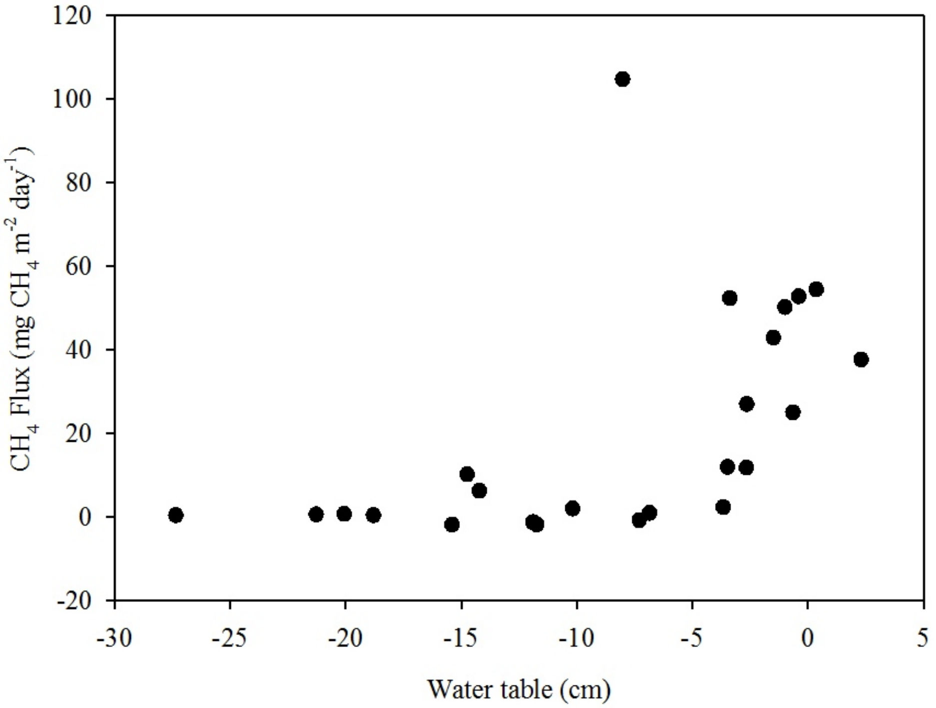

Figure 3. Relation between mean seasonal CH_4 flux and water table at all the sites.

Factors Controlling CH_4 Flux

This study did not observe any statistically significant relation between average seasonal soil temperature at various depths (2, 5, 10, 15, 20, 25, and 30 cm) and CH_4 flux. However, we found a significant correlation between mean water table and CH_4 flux ($P < 0.001$) in Pearson's correlation test. But, when we looked at the distribution of the data points at the scatter plots in Figure 3 we found that the water table relationship is non-linear with very low fluxes when water table is deeper than 5 cm below the surface. The study also found statistically significant relation between CH_4 flux and pore water CH_4 concentration.

DISCUSSION AND CONCLUSION

The CH_4 flux varies between the peatland types as well as within the peatland as a function of microtopography i.e. hummocks and hollows (Lai, 2009). In general fens are stronger CH_4 producers than bogs as the anoxic zone is on average close to the surface (Moore *et al.*, 1990). According to literature, peatland CH_4 fluxes vary from slight uptake to efflux of more than 1040 mg CH_4 m^{-2} day^{-1} (Klinger *et al.*, 1994) and hollows are generally higher emitter than hummocks (Lai, 2009).The mean seasonal CH_4 flux from this research study was within the range reported previously.The result for hummock – hollow variation was also consistent with other studies except for open poor fen (OPF) where the water table was shallow at both microform types. This pattern arises because the main cause of the variation in CH_4 fluxes between microtopography is the water table position as a deep oxic zone supports methanotrophs and more CH_4 oxidation, and vice versa (Lai, 2009). The lower CH_4 flux at SF was mainly due to high sulphate concentrationin the soil (> 120 mg/L; Stewart and Lemay, 2011), as well as deep water table position. The relation between water table and CH_4 flux in our study also support our findings. The pore water CH_4 concentration below the water table in our study is similar to other findings (Blodau *et al.,* 2007; Strack and Waddington, 2008; Mahmood and Strack, 2011).The correlation between pore water CH_4 concentration and flux suggests that the rate of CH_4 production as controlled by the physiochemical characteristic of each fen are important for controlling total CH_4 emissions.

In conclusion CH_4 flux from the three undisturbed fen ecosystems in northern Alberta were within the peatland range previously reported. However, we need to study more years to confirm this result. During the study period water table was one of the driving factors for CH_4 flux. Thus from this research we can assume that the CH_4 flux and sub-surface CH_4 concentration at the reclaimed site will be mostly controlled by vegetation, water table and soil chemistry.

ACKNOWLEDGEMENT

We would like to thank Peter Macleod, Tahni Phillips, Corey Wells, and Jonathan Goetz for helping with field data collection and laboratory analysis. The funding for this project was supported by Canadian Oil Sands Network for Research and Development – Environmental and Reclamation Research Consortium (CONRAD-ERRG).

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