

## NET ECOSYSTEM CO<sub>2</sub> EXCHANGE OF TWO PEATLANDS WITH CONTRASTING VEGETATION IN NORTHERN ALBERTA, CANADA

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### 1. INTRODUCTION

Peatlands are terrestrial ecosystems that play a major role in the global carbon (C) cycle and associated climatic feedbacks (Gorham, 1991; Moore et al., 1998). In Canada, peatlands have been defined as wetland ecosystems with a minimum organic soil depth of 40 cm (NWWG, 1988). They form when net primary production consistently exceeds decomposition due to cool and anaerobic subsurface conditions (Vitt et al., 1995; Szumigalski and Bayley, 1996a; Thormann and Bayley 1997). Peatlands can be divided into bogs and fens, with bogs influenced by water input derived only from precipitation, whereas fens are also influenced by groundwater that has come in contact with mineral soils (Vitt et al., 1995). Peatlands are further classified along a bog-rich fen gradient, based on variation in plant species composition and water chemistry characteristics (Sjörs, 1952; Vitt et al., 1995; Szumigalski and Bayley, 1996a; Thormann and Bayley 1997). The water of bogs and poor fens has low pH, low electrical conductivity, and low base cation concentrations, and these three chemical components increase along the gradient to extreme-rich fens, which have water that is more alkaline with high electrical conductivities. Peat moss (*Sphagnum* spp.) dominates bogs and poor fens, while sedge (*Carex* spp.) and "brown moss" species are the dominant vegetation in rich fens (Vitt et al., 1995).

Bog and fen ecosystems are very important because they contain approximately one-third of the world's soil C pool and represent the largest pool of C in the Canadian terrestrial biosphere. Canada contains between 30-40% of the world's peatlands, covering 10-14% of the country's entire land surface (NWWG, 1988; Gorham, 1991).

The carbon dioxide (CO<sub>2</sub>) exchange between an ecosystem and the atmosphere is the net result of the competing flux processes of gross primary

production (GPP, photosynthetic CO<sub>2</sub> uptake) and total ecosystem respiration (TER, autotrophic and heterotrophic CO<sub>2</sub> production). Like all terrestrial ecosystems, a number of environmental factors play important roles in governing the rate of net CO<sub>2</sub> exchange in peatlands and projected climate change can be expected to affect these regulating factors (Bubier et al., 2003). Accurately predicting the consequences of global climate change, as well as potential interactions and feedbacks with the atmosphere, requires a broader comprehension of the mechanisms influencing net ecosystem CO<sub>2</sub> exchange (NEE) in various types of peatlands.

Northern Alberta, Canada is a region that has greater than 20% peatland cover (Vitt et al., 1998), with wetland types spanning the bog to rich fen gradient readily accessible by road, providing a convenient opportunity for conducting comparative ecological studies among contrasting peatland types experiencing a similar climate. Comparison studies of peatland water chemistry (Vitt et al., 1995), net primary production (Szumigalski and Bayley, 1996a; Thormann and Bayley 1997) and decomposition (Szumigalski and Bayley, 1996b) have been performed by others in the region and it was the aim of the present study to extend the comparative approach to analyses of NEE measurements.

Two peatlands in northern Alberta were selected for this study, a peat moss dominated poor fen and a sedge dominated extreme-rich fen. It was hypothesized that rates of GPP and TER would differ between the peatland sites because of variation in nutrient availability and the dominant plant functional types present. Based on net CO<sub>2</sub> flux measurement campaigns and supporting meteorological measurements made at the two peatlands in northern Alberta during the 2004 growing season (May 1 – October 31), the following research objectives were addressed: (1) to determine if peak season rates of NEE were different between the two ecosystems; (2) to determine if growing season (6 month) CO<sub>2</sub> budgets were different between the sites; and (3)

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to examine how the contributing flux processes of GPP and TER influence NEE at the two temporal scales investigated with objectives (1) and (2).

## 2. MATERIALS AND METHODS

### 2.1 Peatland Site Descriptions

The peatlands studied during the 2004 growing season consisted of a poor fen and an extreme-rich fen that were located in north-central Alberta, Canada. These two peatland sites were auxiliary sites to the Western Peatland flux station of the Fluxnet-Canada Research Network (FCRN), one of seven ecosystem research stations located in a longitudinal transect across the southern boreal forest of Canada (FCRN, 2006).

The poor fen site (55.54°N, 112.33°W; 730 m a.s.l.) had a distinct microtopography, consisting of alternating hummocks (elevations in the peat surface), and hollows (depressions in the peat surface). The pH of the poor fen surface water was 4.0 in July, 2004 (Glenn et al., *in press*). In contrast to the poor fen, the microtopography of the extreme-rich fen site (54.47°N, 113.32°W; 670 m a.s.l.) was mainly flat, with occasional small hummocks. The pH of the extreme-rich fen surface water was 6.5 in July, 2004 (Glenn et al., *in press*).

The plant community of the poor fen was dominated by a continuous ground layer of peat moss (*Sphagnum*) species, which comprised approximately 66% of the total photosynthetic leaf area of the peatland at the peak of the 2004 growing season (Glenn et al., *in press*). Evergreen shrubs, herbs, sedges were present in much lower abundance, as were dwarf (average height < 0.75 m) black spruce (*Picea mariana*) and tamarack (*Larix laricina*) trees along hummocks. The plant community of the extreme-rich fen mainly consisted of sedge (*Carex lasiocarpa*), accounting for approximately 60% of the total photosynthetic leaf area of the peatland at the peak of the 2004 growing season (Glenn et al., *in press*). A discontinuous mat of brown moss species (*Drepanocladus aduncus* and *Aulacomnium palustre*) was present at the base of the sedge plants. Shrubs (average height < 0.5 m) covered approximately 5% of the fen and consisted primarily of willow (*Salix pedicellaris*) and the occasional dwarf birch (*Betula pumila* var. *glandulifera*). Detailed study site descriptions, as well as vegetation and surface water sampling methods, analyses and results are given by Glenn (2005).

### 2.2 Meteorological and Flux Measurements

Two triangular, aluminum instrumentation towers (3 m tall) were installed at each of the peatland sites prior to the 2004 field season. One tower at each site was equipped with a package of meteorological instruments that continuously monitored environmental conditions (including air temperature, relative humidity, net and photosynthetically-active radiation, precipitation and water table depth). The second instrumentation tower at each of the sites was used to support a mobile eddy covariance system during intermittent flux measurement campaigns conducted over the growing season. Power was supplied to the two instrumentation towers at each site by an array of 12 V deep-cycle batteries that were charged solar panels.

The eddy covariance (EC) technique (Baldochi et al., 1988; Moncrieff et al., 1997; Aubinet et al., 2000; Baldochi, 2003) was used to measure net ecosystem fluxes of CO<sub>2</sub>, water vapour, and sensible heat (*H*) at the two peatland sites. The EC system consisted of a three-dimensional sonic anemometer-thermometer (SAT; CSAT3, Campbell Scientific, Inc.), and a fast response open-path infra-red gas analyzer (IRGA; LI7500, LI-COR Inc.). Output signals from the SAT and IRGA were sampled at a frequency of 10 Hz by a programmed data logger (CR5000, Campbell Scientific, Inc.) and recorded to a flash memory storage card. The EC system was initially installed at the poor fen site on April 30, 2004, and then moved back and forth between the two peatland sites every 12 to 18 days throughout the 2004 growing season, for a total of five flux measurement campaigns at each ecosystem. The final EC flux campaign of the season concluded on October 30, 2004 at the extreme-rich fen. The IRGA was calibrated in a temperature-controlled hut between measurement campaigns.

Peatland fluxes of CO<sub>2</sub>, H<sub>2</sub>O, and *H* were calculated as the mean covariance of vertical wind velocity and scalar fluctuations, with the appropriate density corrections applied (Baldochi et al., 1988; Aubinet et al., 2000). Coordinate rotations were performed to align the mean vertical velocity measurements normal to the mean wind streamlines prior to scalar flux calculations. A storage term was added to the calculated CO<sub>2</sub> fluxes for the determination of NEE and was estimated using the single level measurements of CO<sub>2</sub> concentration with the open-path IRGA. The meteorological notation was adopted, where a

positive value for NEE represents net CO<sub>2</sub> flux into the atmosphere and a negative value indicates net CO<sub>2</sub> uptake by the ecosystem. A filtering algorithm was applied in a series of two passes to remove outliers from the flux data set. During each pass all half-hourly NEE values greater than 3 standard deviations from the mean were rejected and excluded from further analysis and calculations. A flux footprint analysis was conducted at both sites using the parameterization of Kljun et al. (2004). Results from the footprint analyses conducted under a variety of atmospheric conditions indicated that there was adequate fetch for representative fluxes for the majority of EC measurements made at each of the peatland sites during the 2004 growing season.

### 2.3 Carbon Budget Calculations

Non-linear, least squares regressions were used to model net CO<sub>2</sub> exchange for each peatland ecosystem. Mean diurnal patterns (bin-averages by time of day) of NEE, photosynthetic photon flux density (*PPFD*) and air temperature (*T*) were used to parameterize the model:

$$NEE = -\frac{A_{max}\alpha PPF D}{A_{max} + \alpha PPF D} + R_{10}Q_{10}\left(\frac{T-10}{10}\right) \quad (1)$$

where  $A_{max}$  is the maximum GPP ( $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) at infinite *PPFD* ( $\mu\text{mol m}^{-2} \text{s}^{-1}$ );  $\alpha$  is the initial slope of the ecosystem light-response curve or the apparent light-use efficiency ( $\text{mol CO}_2 \text{ mol}^{-1} \text{PPFD}$ );  $R_{10}$  is total ecosystem respiration rate (TER) at 10°C ( $\mu\text{mol m}^{-2} \text{s}^{-1}$ );  $Q_{10}$  is the temperature sensitivity coefficient for TER for a 10° change in temperature; and  $T$  is air temperature (°C). Estimates of the  $A_{max}$ ,  $\alpha$ ,  $R_{10}$  and  $Q_{10}$  parameters were obtained using non-linear, least squares regressions and the Gauss-Newton method in Systat10 (SPSS Inc., 2000). The calculations were done with the parameters bound over the following ranges:  $A_{max}$  between 0.1 and 40,  $\alpha$  between 0.01 and 0.08,  $R_{10}$  between 0.1 and 6.0, and  $Q_{10}$  between 1.8 and 2.2.

Equation 1 was used, along with meteorological measurements (*PPFD* and *T*), to model NEE so that integrated growing season carbon budgets could be determined. This required information on seasonal variation in each of the equation parameters ( $A_{max}$ ,  $\alpha$ ,  $R_{10}$ ,  $Q_{10}$ ). The parameter estimates calculated from data during the measurement campaigns were plotted as a function of time (day of year (DOY), the center of

each modelled time period). Only the model parameters derived from time periods when the  $r^2$  value of the regression model was greater than 0.20 were plotted. Polynomial relationships were fit to each of the model parameters as a function of DOY. The polynomial equations were then used to determine values for the model parameters each day over the course of the 2004 growing season (May 1 through October 31). Comparisons were made between modelled NEE values and corresponding EC measurements using geometric mean regressions (Sokal and Rohlf, 1995) and the modelling efficiency statistic (Janssen and Heuberger, 1995; Reichstein et al., 2002),

The influence of friction velocity ( $u_*$ ) on the CO<sub>2</sub> flux measurements by the EC system and modelled values of NEE was assessed. The EC measurements were grouped into 6 classes (from  $u_* > 0.0$  to  $u_* \geq 0.25 \text{ m s}^{-1}$ ) based on  $u_*$  increments of  $0.05 \text{ m s}^{-1}$ , prior to the calculation of mean diurnal trends of NEE and the subsequent fitting of parameters to Eq. 1. Separate comparisons were then made between modelled NEE and all available EC measurements that satisfied a particular  $u_*$  criteria (Table 1). From analysis of the slope and  $r^2$  values of the regressions between modelled and measured NEE (Table 1), a  $u_*$  threshold was selected ( $0.15 \text{ m s}^{-1}$ ) and applied to screen EC measurements before the comparison of NEE values or the calculation of growing season CO<sub>2</sub> budgets for the two peatlands. The slope and  $r^2$  values increased substantially with the  $u_*$  threshold from 0 to  $0.15 \text{ m s}^{-1}$  at both sites, but did not differ significantly at more stringent levels ( $0.20$  and  $0.25 \text{ m s}^{-1}$ , Table 1). Since it was important to retain the highest number of EC observations ( $n$ ) as possible, we considered the  $u_*$  threshold of  $0.15 \text{ m s}^{-1}$  as the most appropriate for both peatland sites. This procedure for selection of a  $u_*$  threshold was consistent with analysis of the relationship between friction velocity and nocturnal NEE measurements. We observed much greater variability in nighttime EC measurements at  $u_*$  values below  $0.15 \text{ m s}^{-1}$  (data not shown), consistent with other peatland studies (Lafleur et al., 2001).

### 2.4 Estimation of Uncertainty in CO<sub>2</sub> Budgets

The uncertainty associated with EC measurements consists of both random and systematic errors (Goulden et al., 1996; Baldocchi, 2003). In the present study, the composite random error ( $E_R$ ) of the EC measurements was estimated by evaluating the differences between EC

Table 1. The effect of applying various friction velocity ( $u^*$ ) thresholds on eddy covariance (EC) measurements and modelled values of NEE. The slope of the regression between modelled and measured NEE is given for each  $u^*$  threshold, with the 95% confidence intervals in parentheses.  $r^2$  is the coefficient of determination for the regression, and  $n$  is the number of half-hourly EC observations over the 6 month study which satisfy the  $u^*$  threshold criteria.

		$u^*$ threshold (m s <sup>-1</sup> )					
		0.0	0.05	0.10	0.15	0.20	0.25
Poor Fen	slope	0.50 (0.49-0.52)	0.61 (0.58-0.63)	0.83 (0.81-0.86)	0.93 (0.90-0.96)	0.95 (0.92-0.97)	0.93 (0.90-0.96)
	$r^2$	0.26	0.26	0.60	0.74	0.76	0.73
	$n$	2971	2565	2047	1708	1399	1065
Extreme-rich Fen	slope	0.77 (0.75-0.80)	0.77 (0.75-0.80)	0.80 (0.78-0.82)	0.98 (0.96-1.00)	0.98 (0.96-1.00)	1.07 (1.04-1.10)
	$r^2$	0.36	0.50	0.59	0.79	0.82	0.80
	$n$	2965	2585	2172	1760	1405	1029

measurements and corresponding modelled values (Aurela et al., 2002):

$$E_R = \sqrt{\sum_{i=1}^n \frac{(NEE_{obs} - NEE_{mod})^2}{(n-1)n}} \quad (2)$$

where  $NEE_{obs}$  represents all available half-hourly measurements of NEE ( $u^* \geq 0.15$  m s<sup>-1</sup>),  $NEE_{mod}$  are the corresponding modelled values calculated with Eq. 1, and  $n$  is the number of half-hourly NEE measurements ( $u^* \geq 0.15$  m s<sup>-1</sup>) during the 2004 growing season. To estimate the systematic error ( $E_{SYS}$ ) of NEE measurements we examined the effect of changes in the  $u^*$  threshold on the growing season carbon budget calculations. Separate 6-month CO<sub>2</sub>-C budgets were calculated using  $u^*$  thresholds of 0.10, 0.15, 0.20 and 0.25 m s<sup>-1</sup>, and the derived NEE model (Eq. 1) parameters for each. The relative difference in the carbon budgets among the four  $u^*$  thresholds was used to estimate the systematic uncertainty. To obtain the total uncertainty of the growing season CO<sub>2</sub>-C budgets for the two peatland sites we took the root-sum-square of the random and systematic uncertainty components ( $\sqrt{E_R^2 + E_{SYS}^2}$ ).

### 3.0 RESULTS AND DISCUSSION

With the exception of July, the 2004 growing season in northern Alberta had cooler than normal average daily temperatures at both peatland sites (Glenn et al., *in press*). However, the 6-month mean daily temperatures at both sites were not significantly different from the average conditions

at Athabasca, AB (54.82°N, 113.52°W), the location of the nearest W.M.O standardized meteorological station. During May – October, 2004 the poor fen received slightly above-average precipitation (449.6 mm) while the extreme-rich fen had near-normal accumulation (394.0 mm) compared to the 30-year mean ( $\pm$  SD) of 370.4  $\pm$  80.7 mm. The monthly precipitation totals exhibited variability between the sites, as well as deviation from the 30-year normals at Athabasca during many months of this study. However, the water table was relatively high at both sites throughout the 2004 growing season, always < 40 cm below the average hummock height at the poor fen, and < 30 cm beneath the average hummock height at the extreme-rich fen (Glenn et al., *in press*).

Temporal variation in the diurnal magnitudes and patterns of measured net CO<sub>2</sub> exchange were similar between the two peatland sites. Large seasonal variation was observed for photosynthetic parameters ( $A_{max}$ ,  $\alpha$ ) at both sites while smaller seasonal variation was observed for respiratory capacity ( $R_{10}$ ) and sensitivity ( $Q_{10}$ ). Calculations of  $A_{max}$  and  $R_{10}$  at the peak of the 2004 growing season were higher at the extreme-rich fen ( $A_{max} = 12.1$ ;  $R_{10} = 1.9$ ) than at the poor fen ( $A_{max} = 9.2$ ;  $R_{10} = 1.6$ ). The higher photosynthetic and respiratory capacities at the extreme-rich fen appeared to offset each other, since both peatland sites exhibited nearly identical peak season, mean mid-day NEE values of approximately -5  $\mu$ mol CO<sub>2</sub> m<sup>-2</sup> s<sup>-1</sup> (Fig. 1). The greater maximum photosynthetic capacity at the extreme-rich fen was consistent with higher total nitrogen (N) content of the aboveground biomass (3.0 g m<sup>-2</sup>)

compared to the poor fen ( $2.3 \text{ g m}^{-2}$ ) and the total N content of the dominant plant species at each of the sites ( $7.8 \text{ mg g}^{-1}$  for active peat moss tissues at the poor fen and  $19.3 \text{ mg g}^{-1}$  for sedge leaves at the extreme-rich fen).

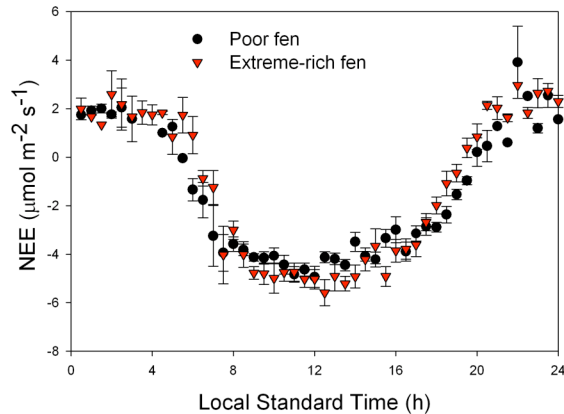


Fig. 1. Mean diurnal patterns of NEE ( $u^* \geq 0.15 \text{ m s}^{-1}$ ) at the peak of the 2004 growing season for the two peatland ecosystems in northern Alberta. Data for the poor fen is from eddy covariance measurements made during July 7 to July 25. Data for the extreme-rich fen is from eddy covariance measurements made from July 27 to August 13. Values represent the mean  $\pm$  SE.

Temperature standardized ecosystem respiration rates ( $R_{10}$ ) were higher during midseason at the extreme-rich fen than at the poor fen, consistent with chamber respiration measurements made in these ecosystems (Glenn, 2005). Variation in water table depth was not a significant factor influencing the differences in calculated respiratory capacity, as the water table level was similar between the sites during the growing season. This suggests that biological differences between the two fens were responsible for the contrasting respiratory capacities. There are a number of possible factors that could result in higher ecosystem respiration at the extreme-rich fen compared to the poor fen. First, a correlation between photosynthesis and respiration rates exists because of growth and maintenance requirements in plants (Amthor, 2000). Ecosystem-level studies have also shown strong positive relationships between GPP and TER (Griffis et al., 2003; Flanagan and Johnson, 2005). Therefore, the higher photosynthetic capacity ( $A_{max}$ ) at the extreme-rich fen suggests that TER would be higher than at the poor fen. Second, it has been estimated that 30-70% of total peatland respiration was due to plant roots or root-derived microbial respiration (Frolking et al., 1998). Although belowground (root) biomass was not measured in this study, previous studies have shown that up to

90% of sedge species biomass production was belowground (Sjörs, 1991; Thormann and Bayley, 1997) while *Sphagnum* moss species lack roots. It therefore follows that belowground respiration should be higher at the extreme-rich fen than the poor fen. Third, sedge tissue and its derived peat is a higher quality substrate than peat moss tissue (Verhoeven and Toth, 1995; Szumigalski and Bayley, 1996b), so decomposition would have been greater at the extreme-rich fen than the poor fen. Previous studies have demonstrated a negative correlation between the rate of decomposition and C:N ratios, and a positive correlation between decomposition rate and tissue total N content (Updegraff et al., 1995; Szumigalski and Bayley, 1996b). The peat moss at the poor fen site had a total N content that was less than half ( $7.8 \text{ mg g}^{-1}$  compared to  $19.3 \text{ mg g}^{-1}$ ), and a C:N ratio that was more than two times greater than that of the sedge at the extreme-rich fen ( $57.4$  compared to  $23.6$ ). Furthermore, the lower pH of the surface water at the poor fen compared to the extreme-rich fen ( $4.0$  compared to  $6.5$ ), and the presence of phenolic secondary metabolites, may have also further inhibited the decay rate of *Sphagnum* peat (Verhoeven and Toth, 1995).

Good agreement was observed between modelled NEE and measurements over the 6 month study period at both sites. There was a slightly better fit between modelled and observed NEE ( $u^* \geq 0.15 \text{ m s}^{-1}$ ) at the extreme-rich fen than the poor fen, as indicated by the higher slope ( $0.98$  compared to  $0.93$ ) and  $r^2$  values ( $0.79$  compared to  $0.74$ ; Table 1). Calculation of the modelling efficiency statistic gave similar patterns of correspondence between modelled and measured NEE at the two sites as the  $r^2$  values for the linear regression results. At the poor fen the modelling efficiency was calculated to be  $0.73$ , while at the extreme-rich fen site it was  $0.78$  (for  $u^* \geq 0.15 \text{ m s}^{-1}$ ).

When integrated over the entire 6 month study, the poor fen was shown to be a net  $\text{CO}_2$ -C sink (NEE) that was approximately three times greater than the extreme-rich fen (Table 2).

Table 2. Cumulative growing season  $\text{CO}_2$ -C budgets ( $\text{g C m}^{-2} \text{ 6 months}^{-1}$ ) for the two peatlands. The NEE error term was calculated as described in section 2.4 and was 8% for the poor fen and 58% for the extreme-rich fen.

	Poor fen	Extreme-rich fen
GPP	-340	-358
TER	250	327

<b>NEE</b>	$-90 \pm 7$	$-31 \pm 18$
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The poor fen had lower cumulative totals for GPP and TER than the extreme-rich fen, but the difference between competing CO<sub>2</sub> fluxes was greater at the poor fen resulting in a larger net CO<sub>2</sub> sink (6 month NEE value) over the growing season. The ratio of cumulative TER:GPP was approximately 0.7 (250:340) at the poor fen and 0.9 (327:358) at the extreme-rich fen for the entire 2004 growing season.

Monthly CO<sub>2</sub>-C budgets calculated illustrated a distinctly different seasonal pattern for NEE between the two sites, as net uptake of CO<sub>2</sub> occurred earlier in the growing season at the poor fen (Fig. 2). In addition, our calculations showed the poor fen to be a net sink for CO<sub>2</sub> during four of the six months (peaking at 44 g C m<sup>-2</sup> for July), while only slight net losses of CO<sub>2</sub> (3 g C m<sup>-2</sup>) occurred in May and September. In contrast, the extreme-rich fen was a significant net sink for CO<sub>2</sub> only during two months of the growing season (peaking at 30 g C m<sup>-2</sup> in August), while significant net losses of CO<sub>2</sub> occurred in May (8 g C m<sup>-2</sup>) and in October (13 g C m<sup>-2</sup>).

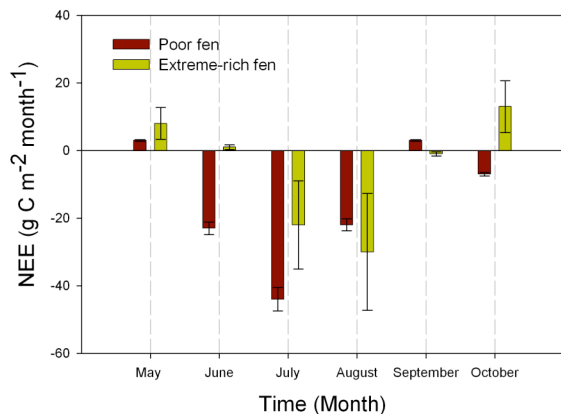


Fig. 2. Comparison of monthly CO<sub>2</sub>-C budgets for the contrasting peatland ecosystems in northern Alberta during the 2004 growing season. Error bars for monthly sums were calculated as described in section 2.4 and were 8% for the poor fen and 58% for the extreme-rich fen.

Variation in the monthly NEE between the sites was primarily due to differences in the dominant plant functional types found at the contrasting peatlands. The poor fen was dominated by peat moss and other 'evergreen' plant species while the extreme-rich fen was dominated by deciduous, perennial sedge. The plant species present at the poor fen site had lower total N contents and photosynthetic capacities than the sedge at the

extreme-rich fen, but they were active earlier and later in the growing season. It took longer for the sedge at the extreme-rich fen to develop leaf tissue, and leaf senescence and reduction in photosynthetic activity occurred earlier in the fall. This contrasting seasonality in net CO<sub>2</sub> exchange between the two peatland sites was especially pronounced in June when the poor fen was a significant carbon sink (greater than 20 g C m<sup>-2</sup> month<sup>-1</sup>) and the extreme-rich fen was essentially carbon neutral (Fig. 2), indicating that the sedge leaf area was not yet fully developed.

These growing season (May - October) carbon budgets determined in this study were comparable to the results obtained for other peatlands in North America. For example, a boreal minerotrophic fen in central Saskatchewan was a net sink of approximately 88 g C m<sup>-2</sup>, during mid-May to early October in 1994 (Suyker et al., 1997). Other studies have shown significant interannual variability in net CO<sub>2</sub> exchange at peatland sites. A fen in northern Manitoba was a net CO<sub>2</sub> source in 1994 of approximately 30 g C m<sup>-2</sup> between the months of April and September (Lafleur et al., 1997), while in 1996 it was a net sink of approximately 92 g m<sup>-2</sup> (Joiner et al., 1999). From May to October in 1991, an open peatland in north-central Minnesota was estimated to be a net source of CO<sub>2</sub>, emitting approximately 71 g C m<sup>-2</sup> to the atmosphere, while in 1992 the same ecosystem was a net C sink, sequestering 32 g C m<sup>-2</sup> over the course of the growing season (Shurpali et al., 1995). Although both peatland sites from the present study were calculated to be CO<sub>2</sub> sinks during the growing season in 2004, this may not be case in years with different environmental conditions.

It is important to note that the present study only included NEE measurements and CO<sub>2</sub> budget calculations during the 6 month growing season. Although the growing season has the highest biological activity and ecosystem CO<sub>2</sub> fluxes, other studies have noted the importance of wintertime CO<sub>2</sub> effluxes for annual C budgets in peatland ecosystems (Lafleur et al., 2001; Aurela et al., 2002). Slow but steady rates of CO<sub>2</sub> loss from peatlands during the winter months can have a significant effect on cumulative net CO<sub>2</sub> balances. For example, it was calculated that the annual C budget of a subarctic fen in northern Finland would be overestimated by 150% if the winter emissions from the site were not included (Aurela et al., 2002). The importance of wintertime fluxes noted in other studies highlights the need for more

measurements during non-growing season periods to further elucidate the complete C balance of our study ecosystems, especially with the trend toward warmer winter temperatures in western Canada.

Although net CO<sub>2</sub> fluxes dominate the overall C balance of peatlands, exports of C from these ecosystems can also occur through methane (CH<sub>4</sub>) emissions (Bubier et al., 1995) and the leaching of dissolved organic carbon (DOC), which may have a significant influence on annual C budgets (Moore et al., 1998; Aurela et al., 2002). Further measurements of these additional components contributing to net C cycling in peatlands should be incorporated in future studies in order to estimate complete C budgets. In the context of the present study, CH<sub>4</sub> emissions may have a pronounced effect on the net C budget of the extreme-rich fen site. The high water table during the growing season would cause anaerobic conditions conducive to CH<sub>4</sub> production (Moore et al., 1998). In addition, high root exudate production by the sedge-dominated plant community and high rates of methane diffusion through the vascular plant stems could contribute to potentially high methane fluxes at the extreme-rich fen (Bubier et al., 1995).

#### 4.0 CONCLUSIONS

The peatland ecosystems exhibited similar mean diurnal patterns of NEE at the peak of the 2004 growing season. However, the extreme-rich fen had higher photosynthetic and respiratory capacities than the poor fen at this time, which appeared to offset each other according to net CO<sub>2</sub> flux measurements. When integrated over the 6 month growing season, the poor fen was shown to accumulate approximately three times as much CO<sub>2</sub>-C as the extreme-rich fen. The difference between the peatland ecosystems in cumulative NEE over the growing season study was largely influenced by contrasting seasonal patterns in monthly CO<sub>2</sub> budgets between the sites. The dominant vegetation at the sites was believed to be the main determinant dictating differences in monthly and 6 month NEE sums calculated for the two peatlands.

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