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Peat CO_2 production in a natural and cutover peatland: Implications for restoration

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Abstract. Although studies have shown that peatland drainage and harvesting alter local hydrology, microclimate, and peat characteristics, little is known about the effects of these changes on CO_2 production rates. This study examines the different factors affecting CO_2 production from natural and cutover peatlands. Laboratory peat incubations were performed under aerobic and anaerobic conditions to determine the influence of temperature, soil moisture, and peat depth on CO_2 production rates from peat samples taken from: (1) a natural peatland; (2) a 2-year post-cutover peatland and; (3) a 7-year post-cutover peatland.

CO_2 production rates ranged from 0.21 to 4.87 μmol g^{-1} d^{-1} under anaerobic conditions, and from 0.37 to 15.69 μmol g^{-1} d^{-1} in the aerobic trials. While no significant differences were found between the CO_2 production rates of the two cutover sites, the natural site consistently displayed higher production values. The natural site was also the only site to exhibit strong depth dependent trends, thus indicating the importance of the upper peat layer with respect to substrate quality. Higher production rates were found under aerobic than anaerobic conditions, with the greatest response to oxygen observed at the natural site. Production rates increased with both temperature and soil moisture, with maximum production rates found at 20 °C and 92% moisture content. Temperature responses were generally greater at the cutover sites, while soil moisture had greater effects on the natural site peat.

Results of this work agree with previous studies that suggest that it is essential to begin restoration once a cutover peatland is abandoned. Re-wetting a cutover peatland (through restoration practices) is necessary to prevent an increase in peat temperature and CO_2 production since cutover peat has higher Q_{10} values than natural peat. A decrease in overall peatland oxidation should reduce the persistent source of atmospheric CO_2 from cutover peatlands and the irreversible changes in peat structure that impede *Sphagnum* re-establishment.

Introduction

The main peat-forming vegetation is *Sphagnum* moss, a non-vascular plant that grows in compact, spongy mats in acidic, waterlogged conditions. Waterlogged environments result in slow biomass decomposition, which allows thick layers of peat to accumulate over thousands of years to form peatlands.

Natural peatlands represent an important component of the global carbon balance, storing an estimated 23 g C m^{-2} yr^{-1} (Gorham 1995).

The North American Wetlands Conservation Council (1998) estimates that 700,000 to 800,000 t of peat are mined each year, with almost two-thirds of North America's *Sphagnum* moss and peat mined in Canada (Campeau & Rochefort 1996). Few Canadian peatlands revert back to their natural state after mining (Price 1996; Ferland & Rochefort 1997), as drainage and mining alter the local hydrology, microclimate and physical peat properties, resulting in a harsh environment with insufficient moisture for *Sphagnum* regrowth (Price 1996; Price 1997). Many attempts to restore the hydrology of cutover peatlands have been unsuccessful due to peat compaction and oxidation (Campeau & Rochefort 1996).

An important factor in *Sphagnum* moss regrowth is substrate quality. CO_2 production rates are often used as indicators of substrate quality since they measure how rapidly microorganisms decompose peat. High substrate quality denotes an abundant supply of labile organic matter resulting in a high oxidation rate (Bubier & Moore 1994). Drainage followed by peat oxidation lead to irreversible subsidence with lower specific yield and higher peat bulk density (Price 1996). This higher degree of compaction lowers the ability of peat to retain a high moisture content, with volumetric soil moisture dependent on both the depth of the water table and the structure of the peat mass (Okruszko 1995).

Prévost et al. (1997) and Price (1996) both found volumetric moisture content (VMC) was lower in cutover peatlands than natural peatlands. Studies have also shown that CO_2 production rates are affected by soil temperature and soil moisture. Warmer soil temperatures provide better conditions for decomposing microorganisms, speed chemical reactions, and result in higher rates of gas production (McKenzie et al. 1998). Soil moisture content controls the amount of pore space oxygen, which in turn determines the type of aerobic or anaerobic microbial process that occurs (Orchard et al. 1992).

Although many studies have focused upon the factors affecting decomposition rates in natural peatlands, scarce attention has been paid to cutover sites. In fact, no studies have investigated the differences in CO_2 production rates between natural and cutover peatlands. Furthermore, most studies on CO_2 production in peatlands do not examine the peat profile from the surface to below the water table. Consequently, the objective of this paper was to determine the main controls on CO_2 production from natural and cutover peatlands from the surface layer to below the water. Experiments were performed under a variety of conditions to investigate the influence of temperature, substrate quality, soil moisture, oxygen, and time since abandonment on peat CO_2 production rates from peat samples taken from: (1)

a natural peatland; (2) a 2-year post-cutover peatland and; (3) a 7-year post-cutover peatland.

Materials and methods

Study area

Peat samples were obtained from the Sainte-Marguerite-Marie peatland located in the Lac Saint-Jean region of Quebec (48°47′N 72°10′W). The average annual temperature is 1.7 °C, with average January and July temperatures of –17.1 °C and +17.3 °C respectively. The total annual precipitation for the Sainte-Marguerite-Marie area is 906 mm, of which 32% falls as snow. The Sainte-Marguerite-Marie peatland is a 4315 ha bog-poor fen complex, which is classified as a Plateau Bog (Price 1996). The peat layer is situated on a terrace of deltaic sands, which lie overtop a flat iron pan (Price 1996). The iron pan prevents water drainage, resulting in a high water table characteristic of bogs.

Peat cores were collected from three sites within the bog. The first was an undisturbed site, hereafter referred to as ‘natural’, which served as an experimental control. The natural bog surface is dominated by a variety of mosses such as *Sphagnum fuscum, S. angustifolium, S. magellanicum* and *S. capillifolium* (Campeau & Rochefort 1996). This site is characterized by hummocks, which are typically 30 cm above the moss surface. The second site, hereafter referred to as ‘young’, was drained in the fall of 1996 (2 years before sampling) and the upper 80 cm was block-cut the following year. Drainage ditches 30 m apart were incompletely filled with peat in 1997 in an attempt to reflood the area and restore the water table. The third site, hereafter referred to as ‘old’, was drained in 1990, block-cut in 1991 (7 years before sampling), then had its drainage ditches blocked in the spring of 1992 (Figure 1(a)). Both the young and old sites are essentially devoid of vegetation, resulting in an open surface of bare fibric peat (Price 1997; Campeau & Rochefort 1996). Von Post decomposition values ranged from H1 to H2 and H3 to H4 in the natural and cutover surface peat, respectively (Figure 1(a)). Surface bulk densities were 0.052, 0.084, and 0.109 g cm^{-3} at the natural, young, and old sites, respectively (Figure 1(b)). The mean summer water table in 1998 for the natural, young and old sites was – 11.7, –30.2 and –35.1 cm respectively (Waddington et al., *submitted*).

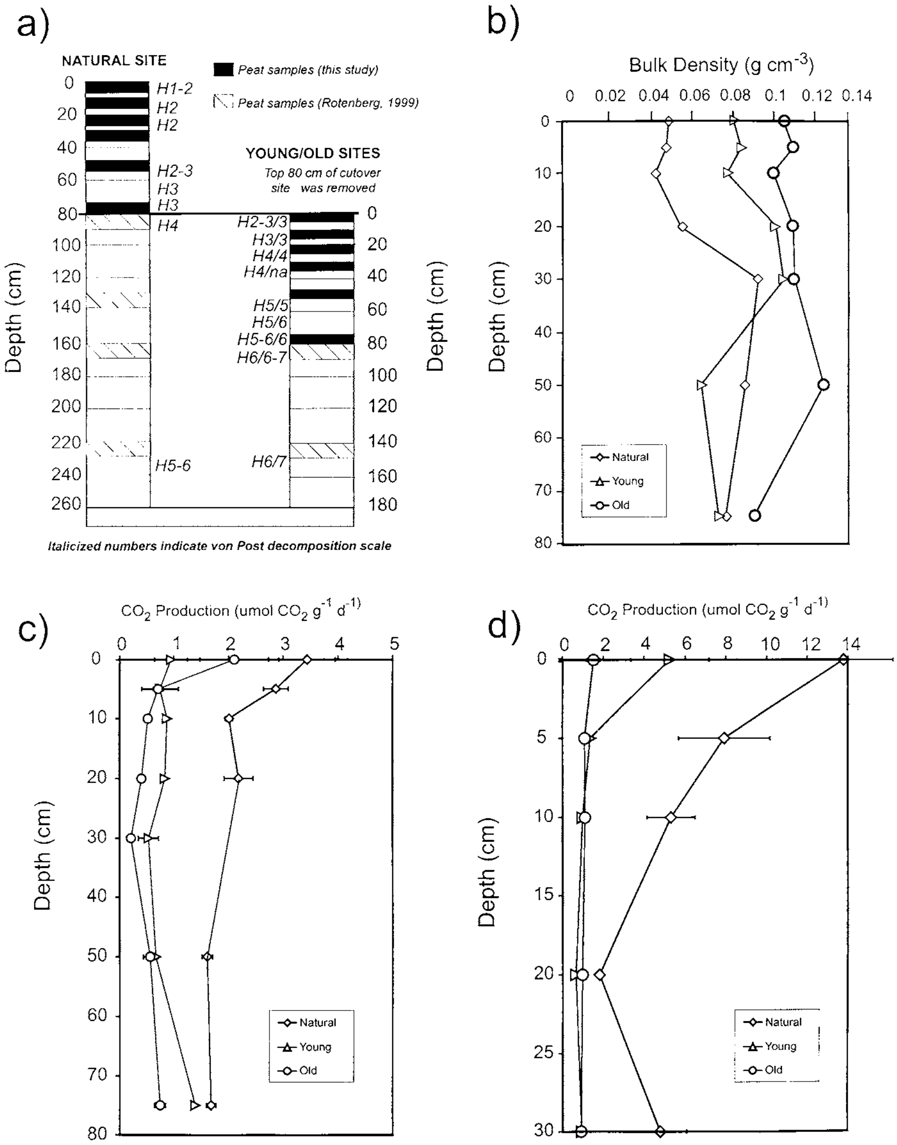

Figure 1. (a) Sample depths and von Post decomposition values for natural and cutover sites; (b) bulk density profile for natural and cutover sites; (c) anaerobic CO_2 production rate and depth at the natural, young and old sites at 12 °C; and (d) aerobic CO_2 production rate and depth at the natural, young and old sites at 12 °C.

Incubation methodology

A Wardenaar peat corer was used to remove a section of peat from the surface to the mineral substrate at each site. The peat core from the natural site was randomly selected and taken through a hummock with the *Sphagnum* surface removed. Both the young and old sites were selectively sampled within 5 m of the drainage ditches. All cores were wrapped in plastic to retain moisture, transported to McMaster University, and frozen. Prior to the experiment, the cores were thawed and subdivided into 5 cm sections at depths of 0, 5, 10, 20, 30, 50 and 75 cm. Deeper cores were extracted in a previous study (see Rotenberg 1999).

Triplicate samples from each 5 cm section (with the exception of the 30 cm section at the natural site) were incubated, for a total of 60 samples (Figure 1(a)). Peat slurries of approximately 35 g were made by the addition of distilled water. Slurries were placed in 250 ml incubation jars, and mechanically agitated for 20 minutes. For the anaerobic experiment, the jars were flushed continuously with nitrogen gas in a glove bag for 15 minutes. The jars were immediately sealed and incubated in a dark Conviron growth chamber for 48 hours. Incubation temperatures for the anaerobic experiments were 4, 12, and 20 °C, while the aerobic experiments were carried out at 12 °C.

Gas samples were taken from each jar initially, then approximately every 12 hours thereafter over a 48-hour period. Prior to sampling, each jar was mechanically agitated for 20 minutes to mix the gases within peat pore spaces and the jar (after McKenzie et al. 1998). Syringes were used to penetrate the septum seal and collect a 3 ml sample from the headspace. Jars were then backfilled with 3 ml of nitrogen gas to ensure constant air volume/pressure. The lid puncture was immediately sealed with silicon and the jars were returned to the incubator. After each sampling period in the aerobic experiment, the jars were placed outside the incubation chamber and the lids were removed to allow 2 to 4 g of water to evaporate. The aerobic sampling procedure was then repeated six times to investigate the effect of decreasing moisture content on CO_2 production.

Each 3 ml sample was analyzed by a Varian 3800 gas chromatograph (GC) equipped with a flame ionization detector (FID), thermal conductivity detector (TCD) and Porapak Q packed column to analyze CO_2 concentration. The GC was standardized using a CO_2 standard gas after approximately every six samples.

To calculate the production of CO_2, the measured concentrations were corrected for standard pressure and temperature and multiplied by the headspace volume. Dry weight of peat was determined by oven drying the sample at 55 °C for 24 hours at the end of the experiment. Production was calculated by dividing the CO_2 concentration by the final dry peat weight (g). Overall gas production rates (μmol CO_2 g^{-1} d^{-1}) were calculated from the slope of the gas concentrations versus incubation time. Slopes with r^2 values less than 0.8 were discarded, resulting in the loss of 9% of the anaerobic data and 3% of the aerobic data. CO_2 production for the peat profile was calculated by integrating gas production rates from the upper 75 cm, assuming linear changes between measured depth increments. Values from different sites and depths were tested using t-tests with statistical significance assigned for $p < 0.05$. Values of Q_{10} were calculated as the change in production rate for a ten-degree change in temperature. Q_{10} values were calculated for 4 to 12 °C and 12 to 20 °C in the anaerobic experiment.

Results

Anaerobic experiment

Peat samples from the natural site consistently displayed higher CO_2 production rates at 12 °C (median: 2.82), than the young (median: 0.84) and old (median: 0.83) sites. T-tests revealed that the production rates from the natural site peat were significantly greater than those of the cutover sites, both throughout the peat profile, and at the different temperatures. However, the production rates were similar between the two cutover sites, with few significant differences measured. At the lower temperatures (4 and 12 °C), CO_2 production rates were slightly higher from the old site peat compared to the young site. The greatest differences were observed in the middle peat layers during the 20 °C run, where the production rates at the old site were significantly higher than from the young site.

Figure 1(c) illustrates the relationship between the anaerobic CO_2 production rate and depth at each site during the 12 °C run. At the natural and the old site, the highest production rates were measured in the surface layer. Production rates at the natural site declined with depth, leveling off to reach a minimum in the deeper layers. In contrast, apart from the initial decrease in CO_2 production over the first 5 cm at the old site, no depth dependent trend was observed. Likewise, there was no apparent relationship between depth and CO_2 production in the peat from the young site. In fact, the highest production rates from the young site were measured in the deepest peat layers (Figure 1(c)).

The highest CO_2 production rates were measured at 20 °C, with production generally increasing with temperature (Figure 2). Only the old site deviated from this trend, as CO_2 production declined as the temperature rose from 4 to 12 °C. To examine the effect of increasing temperature between the three sites, Q_{10} ratios were calculated for each temperature increase

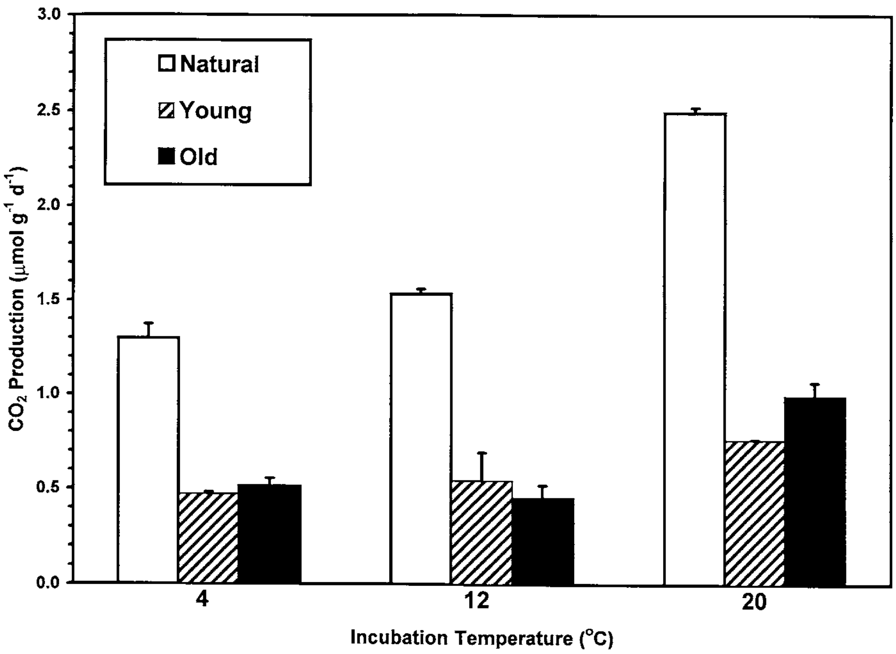

Figure 2. Total anaerobic CO_2 production rates in the peat profile at 4, 12 and 20 °C at the natural, young and old sites.

Table 1. Q_{10} ratios at the natural, young (2-year post cutover), and old (7-year post cutover) sites

Depth (cm)	Natural		Young		Old	
	4 to 12 °C	12 to 20 °C	4 to 12 °C	12 to 20 °C	4 to 12 °C	12 to 20 °C
0	1.09	1.77	1.41	2.05	2.77	1.01
5	1.12	1.68	0.91	2.65	1.07	2.61
10	1.15	1.92			0.78	4.11
75	2.33	2.43	3.70	1.11	2.09	1.62
Median	1.14	1.85	1.41	2.05	1.58	2.11

(Table 1). In most cases, the Q_{10} values for the 12–20 °C temperature change exceeded those of the 4–12 °C increase. At the natural site, Q10 ratios were low compared to the other sites (median 1.85) and tended to increase with depth. Both the young (median 2.05) and the old (median 2.11) cutover sites exhibited a greater temperature dependence than the natural site. However, it

Table 2. CO_2 production rates (μmol g^{-1} d^{-1}) under aerobic (Ae) and anaerobic (An) conditions at the natural, young (2-year post cutover), and old (7-year post cutover) sites

Site	Depth (cm)	Anaerobic (An)	Aerobic (Ae)	An/Ae (%)
Natural	0	3.44	13.79	24.9
	5	2.87	7.92	36.2
	10	2.01	5.31	37.9
	20	2.19	1.82	120.2
Young	0	0.95	5.26	18.0
	5	0.74	1.36	54.8
	10	0.87	0.99	88.7
	20	0.84	0.65	128.1
	30	0.53	0.95	56.4
Old	0	2.11	1.52	138.6
	5	0.71	1.09	65.2
	10	0.52	1.10	47.3
	20	0.40	0.97	41.6
	30	0.21	0.91	22.8

should be noted that t-tests revealed that the differences between sites were not significant.

Aerobic experiment

At the natural and the young site, the effects of oxygen varied with depth (Figure 1(d)). In the upper peat layers (0–10 cm), CO_2 production rates were greater under aerobic conditions, with anaerobic production rates ranging from 18 to 88 percent of the aerobic rates. In two circumstances, CO_2 production was higher under anaerobic conditions than under aerobic in deeper layers (Table 2). At the old site, production rates were higher in the surface layer peat under anaerobic conditions, while in the lower layers; production rates under anaerobic conditions were 23 to 65 percent of the aerobic rates.

CO_2 production was significantly higher in the natural site peat than the young and old sites, while the production rates were not significantly different between the two cutover sites. These patterns were observed under both wettest and driest conditions. CO_2 production tended to decrease with depth at the natural and the young site, and the highest production rates were

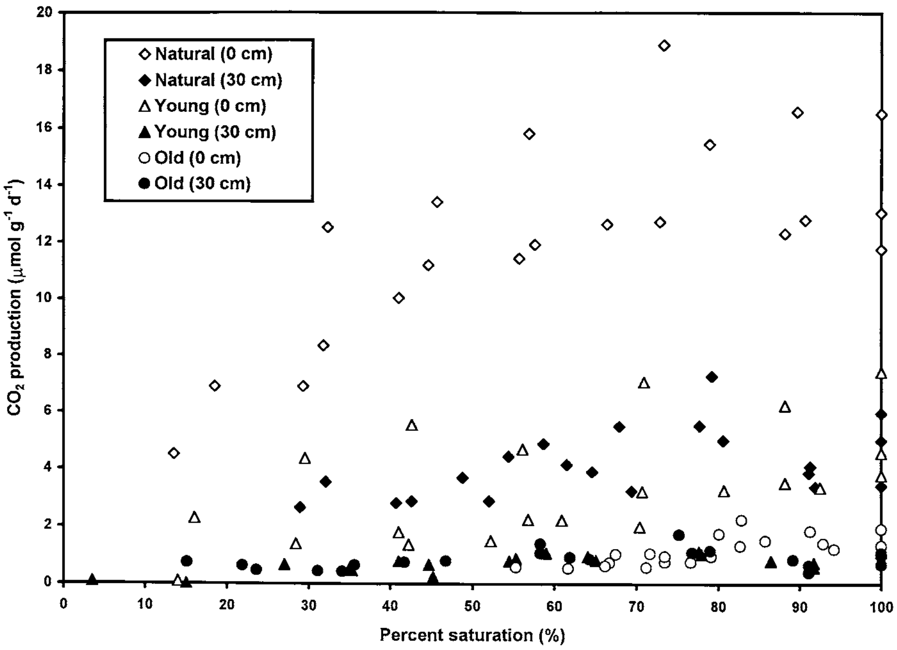

Figure 3. CO_2 production rates versus percent soil saturation at the natural, young and old sites (0 and 30 cm peat samples only).

recorded in the surface layers (Figure 1(d)). At the old site, production rates were consistently low, and did not appear to be affected by depth.

Figure 3 illustrates the influence of soil moisture (expressed as percent saturation) on CO_2 production at each of the three sites. In the surface peat of the natural site, CO_2 production rates increased with soil moisture, reaching peak values of 18.9 μmol g^{-1} d^{-1}, at a percent saturation amount of 73%. Production rates then began to decrease with moisture. In the deeper peat of the natural site, although production rates fluctuated, they generally increased under wetter conditions, reaching maximum values of 7.3 μmol g^{-1} d^{-1}, at a percent saturation amount of 79%.

The young site was generally characterized by low soil moisture contents and CO_2 production rates (Figure 3). Production rates from the surface layer peat increased with percent saturation, reaching an optimum at about 70%, similar to the natural site peat. CO_2 production rates in the deeper peat were relatively constant, displaying no trends with soil moisture. Although there was a peak in production at a percent saturation value of 83% in the surface layer peat of the old site, the production rates were generally low, and not affected by soil moisture.

A comparison of the CO_2 production rates under wettest and driest conditions indicates that soil moisture significantly affected CO_2 production at the natural and the young sites. The greatest effects were seen in the surface layer peat of the natural site. Production rates from the old site were not significantly affected by soil moisture content.

Discussion

CO_2 production rates ranged from 0.2 to 4.9 μmol g^{-1} d^{-1} in the anaerobic experiment and from 0.4 to 15.7 μmol g^{-1} d^{-1} in the aerobic experiment. These values are slightly lower than those documented in other peat incubation experiments (e.g., McKenzie et al. 1998; Magnusson 1993; Moore & Dalva 1993). However, studies present a wide range of production rates, which is in part due to experimental methods, but also due to differences in peat characteristics and substrate quality. For example, Magnusson (1993) found surficial (0 to 50 cm depth) *Sphagnum* peat CO_2 production rates ranged from 2.5 to 3.6 μmol g^{-1} d^{-1} at 16 °C incubation temperatures, whereas McKenzie et al. (1998) found boreal forest wetland peat production ranged from 4.7 to 21.1 μmol g^{-1} d^{-1} at similar depths and incubation temperatures.

Variation between sites

Throughout each experiment it was generally found that the natural site exhibited higher CO_2 production rates than the two cutover sites, while the number of years post-mining did not significantly affect production rates. The high CO_2 production rates at the natural site can be explained by the fact that the fibric surface layer contains a substantial supply of labile carbon. In contrast, the lack of vegetation at the cutover sites, along with the removal of the upper 60 to 70 cm of peat during mining, resulted in a surface layer of recalcitrant peat with a low substrate quality. The high production rates from the upper layers at the natural site suggest that undisturbed peatlands have a higher potential for CO_2 emissions to the atmosphere. However, it must be noted that the natural peatland is vegetated with *Sphagnum* moss, whose uptake of CO_2 during photosynthesis offsets the CO_2 emissions from the underlying peat.

Although the natural site had the greatest production rates overall, the amount of production was not significantly different from the other sites when corrected for differences in depth due to peat removal and subsidence. According to this standpoint, the substrate quality of the present day surficial peat at the young and old site is roughly equivalent to the substrate quality of the deep (70 cm) peat at the natural site. This is further supported by the similarities between the production rates at the young and old sites. A previous study indicated no significant differences in CO_2 production between the natural and cutover sites at greater depths (160 cm) (Rotenberg 1999).

According to the data in this study, there were no significant differences in CO_2 production between a peatland 2 and 7 years post-cutover under aerobic and anaerobic conditions. This demonstrates the ecological importance of the top fibric peat layer removed during mining, and shows that there is little difference in deep peat substrate quality.

Influence of depth on CO_2 production

It has been found repeatedly that CO_2 production decreases with depth under aerobic and anaerobic conditions (Bridgham & Richardson 1992; McKenzie et al. 1998; Nadelhoffer et al. 1991). This finding has been attributed to the lower proportion of readily available organic carbon (Nadelhoffer et al. 1991), the accumulation of recalcitrant humic compounds (Hogg et al. 1992) and unavailability of suitable electron acceptors at depth. During this experiment, the natural site displayed the greatest change in production rate with depth, thus displaying the highest range in substrate quality. This illustrates the importance of the top 60 cm peat layer, which presumably has a higher substrate quality due to its proximity to organic matter inputs and more access to oxygen. The low production rates in the deep peat layers at the natural site are characteristic of old peat, whose labile carbon compounds had been consumed over time by microbes (Updegraff et al. 1995). A further explanation for the decrease in production may be due to the accumulation of compounds unfavourable to microbial activity such as lignins, phenolic or humic substances (Hogg et al. 1992).

In the deepest layers at the natural site and throughout most of the peat at the cutover sites, depth dependent trends were slight under anaerobic conditions (Figure 1(c)). This can be attributed to the age of the peat, as studies have found that inter or intra-community samples of well humified peat show no significant variation in CO_2 production (Bridgham & Richardson 1992). The similar production rates for all three sites 35 cm below the surface imply that substrate quality is comparable beneath this depth for all three sites. Since the enclosure of peat samples in sealed jars prevented CO_2 removal by gas movement through the peat profile, the low gas production at greater depths was more likely caused by decreased substrate quality than gas transport through peat layers. The lack of significant difference in CO_2 production with depth at the old and young site reinforces the uniform nature of substrate quality.

Variations in peat age and species of *Sphagnum* moss may occur with depth, thus accounting for differences in production rates (McKenzie et al.

1998). As there were irregularities at similar depths in the profile of each site, this may have been due to differences in peat age or species of moss. Nilsson and Bohlin (1993) showed that variability in peat composition can affect CO_2 concentration in bogs, and Bubier and Moore (1994) also found high spatial variability in production rates.

Influence of temperature on CO_2 production

The high CO_2 production rates at the maximum incubation temperature of 20 °C agree with results of several previous studies that warmer temperatures enhance CO_2 production (e.g. Christensen et al. 1999; Grosvernier et al. 1995; McKenzie et al. 1998; Moore & Dalva 1993). When the temperature was increased from 4–12 °C, the Q_{10} ratios ranged from 0.78 to 3.70 (median 1.15). These values are comparable to those documented by McKenzie et al. (1998), who found Q_{10} ratios ranging from 0.62 to 3.06 over a similar temperature increase. When the temperature was increased from 12 to 20 °C, the Q_{10} ratios were generally higher (median 1.92).

The higher Q_{10} values at the cutover sites suggest that CO_2 production rates from cutover peatlands are more responsive to rising temperatures than undisturbed sites. This finding disagrees with previous studies, which have shown that older, recalcitrant peat is less sensitive to temperature changes (Christensen et al. 1999; Updegraff et al. 1995), and suggests that factors other than substrate quality could have facilitated the strong response. For instance, cutover sites are characterized by more extreme temperature fluctuations (Prévost et al. 1997). As a result, microbial populations may adapt better to changing conditions and warmer temperatures. This is supported by studies that have shown that microbial efficiency is affected by the response of the micro-organisms to temperature (Lekkerkerk et al. 1990) and that different microbial communities dominate CO_2 production as temperatures increase (Zak et al. 1999).

Influence of soil moisture

Soil moisture content was found to significantly affect the CO_2 production rates from the natural and the young site, with greater effects seen in the upper layers. As documented by Silvolva and Ahlholm (1989), there appeared to be an optimum soil moisture content for CO_2 production. At each of the three sites, there was a peak in the production rate at approximately 92% saturation. This means that production rates generally increased with soil moisture. This is in sharp contrast to studies that show an increase in CO_2 emissions from peat following water table drawdown (e.g. Silvolva et al. 1996; Moore & Dalva 1993). However, this may be due to the fact that the water table position only indicates 100% saturation, and does not account for the range of soil moisture content characteristic of peatlands. Other work (e.g. Orchard et al. 1992), has shown a positive linear relationship between respiration rates and gravimetric water content. Orchard et al. (1992) attributed this relationship to the effects of water content on soil microbial communities. They believe that water content acts as a selective force, allowing different microbial populations to succeed under different moisture conditions.

Oxygen appeared to have the greatest effects on the shallow peat from the natural site, as anaerobic CO_2 production rates ranged from 25 to 37% of the aerobic rates. These values fall within the range of 25 to 40% documented in past studies (Bridgham & Richardson 1992; Johnson et al. 1990; Updegraff et al. 1995). In the deeper layers at the natural site, and at the cutover sites, the anaerobic to aerobic production rate ratios tended to be higher, suggesting that this peat was less affected by oxic conditions. In many cases, the anaerobic production rates were actually higher than the aerobic rates. Other studies have similarly shown that older, recalcitrant peat is less sensitive to the presence of oxygen (Updegraff et al. 1995), likely due to the fact that labile carbon and electron acceptors are less available in older peat (Magnusson 1993).

Implications for restoration

The low CO_2 production rates from the cutover peatlands indicate that the peat remaining after mining is highly decomposed, and thus of low substrate quality. Low substrate quality has been shown to affect not only gas production, but also the fiber content, bulk density, water holding capacity and hydraulic conductivity of peat (Price 1997). Schotorst (1977) suggested that peat oxidation should be greatest in the first few years post-harvest and then decrease with time since abandonment because of a decrease in substrate quality. However, the similarities between the CO_2 production rates of the cutover sites and the deep peat layers at the natural site in this study suggest that time post-harvest may not be so important in determining substrate quality. Moreover, this suggests that substrate quality is not decreasing with time (2 vs. 7 years). This refutes Schotorst's (1977) findings and suggests that once the upper layer of peat is removed, there is generally low substrate quality and decomposition/gas production is slow. In fact, Waddington et al. (submitted) found soil respiration rates followed the trend: old > young > natural suggesting that differences in environmental conditions (e.g., volumetric moisture content and peat temperature) are more important than substrate quality in controlling overall peat oxidation. Consequently, the results of this study suggest that because substrate quality does not decrease post-harvest as rapidly as initially thought, older abandoned peatlands might still be suitable for *Sphagnum* restoration.

If the goal of restoration is to minimize further losses of carbon to the atmosphere, we agree that it is essential to begin restoration once a cutover peatland is abandoned. Cutover peat responds differently to controlling factors such as temperature, soil moisture, and oxygen availability. For example, given the high Q_{10} values of the cutover peat, a wetter cutover peatland (through restoration practices) is necessary to reduce peat temperature warming, subsequent oxidation and subsidence/compaction. Thus, Price (1997) advocates beginning the restoration process immediately following abandonment. A decrease in overall peatland oxidation not only has important implications for reducing the persistent source of atmospheric CO_2 from cutover peatlands (Waddington et al. submitted), but also for reducing the irreversible changes in peat structure that impede *Sphagnum* re-establishment (Campeau & Rochefort 1996). By further grasping how mining affects peatland function, an improved understanding of cutover sites will be possible, which in turn will help achieve the goal of restoring abandoned peatlands to a net carbon sink.

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