

ROLES OF MOSS SPECIES AND HABITAT IN METHANE CONSUMPTION POTENTIAL IN A NORTHERN PEATLAND

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Abstract: In northern peatlands with water tables at or near the surface, the *Sphagnum* moss layer is potentially the only aerobic region where CH₄ oxidation can occur. We hypothesized that mosses with varying physiologies would create different conditions for methane-oxidizing bacteria and, in turn, affect rates of CH₄ consumption. We measured *in-vitro* CH₄ consumption potential of *Sphagnum magellanicum* and *Sphagnum capillifolium* taken from the same habitat and *S. magellanicum* and *Sphagnum majus* across habitats to compare and contrast species and environmental effects. In certain cases, *S. capillifolium* consumed CH₄ more rapidly than *S. magellanicum* taken from identical habitats, although the greatest difference in consumption rates between species was only 29 μg CH₄ g⁻¹ dry moss d⁻¹, compared to a maximum difference of 126 and 415 μg CH₄ g⁻¹ dry moss d⁻¹ in *S. magellanicum* and *S. majus* sampled from different habitats. In most cases, CH₄ was consumed most rapidly in the lower, non-photosynthetic portions of the *Sphagnum* mosses, and consumption potential increased with an increase in the concentration of CH₄ in the habitat. We hypothesize that CH₄ consumption occurred internally, likely in the hyaline cells, as external surface sterilization did not significantly alter CH₄ consumption rates. This work provides evidence that different *Sphagnum* moss species have variable ability to oxidize CH₄, although inter-species differences are small compared to differences across habitats.

Key Words: methane, methane consumption, peatlands, *Sphagnum*

INTRODUCTION

Northern peatlands cover a small area of the earth's surface yet contribute one-tenth of total methane (CH₄) emissions to the atmosphere and thus play an important role in the atmospheric concentration of CH₄ (Gorham 1991, Wahlen 1993, Moore et al. 1998). CH₄ emissions from northern peatlands occur as a result of the activity of anaerobic methanogenic archaea and aerobic methanotrophic bacteria, the boundary of activity of which is roughly defined by the water-table position (Svensson and Sundh 1992, Bubier and Moore 1993). Correlations between mean water-table position and CH₄ emissions have been consistently demonstrated in these sites, yet spatial and temporal variation of CH₄ fluxes at any given water-table position can span 3–4 orders of magnitude (Moore and Roulet 1993). Although many additional controls on

CH₄ production, consumption and emissions contribute to this variability (e.g., Segers 1998, Le Mer and Roger 2001 for reviews), to our knowledge, the role of *Sphagnum* mosses as a habitat for methane-oxidizing bacteria has not been established.

In peatland sites where the water table is close to the surface, the moss layer is potentially the only aerobic region where CH₄ can be consumed before escaping to the atmosphere. In cores removed from hollows of an Estonian bog with a high water-table position dominated by *Sphagnum cuspidatum* Ehrh. ex Hoffm., Frenzel and Karofeld (2000) deduced from CH₄ concentration profiles that most CH₄ consumption was likely occurring immediately below the green photosynthetic region of the moss layer. Vasil'eva et al. (1999) cultured methane-oxidizing bacteria from *Sphagnum* mosses in Russian peatlands and demonstrated that bacteria from presumably different moss species consumed CH₄ at varying rates and with vary-

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ing optimal conditions of pH. They suggested that methane-oxidizing bacteria were harbored within the large water-holding hyaline cells of the lower, non-photosynthetic portions of the moss plants that had begun to lose inner-membrane structure due to decomposition; however, they did not describe CH₄ consumption in intact *Sphagnum* plants in any detail.

In this paper, we describe and contrast the roles of *Sphagnum* moss species and habitat as potential controls on CH₄ consumption. We measured CH₄ consumption potential in three depth segments of the same *Sphagnum* species across peatland habitats and compared inter-habitat differences to those observed between different species present in the same habitat. We tested the hypothesis that the hyaline cells were the principal site harboring CH₄-oxidizing bacteria within the *Sphagnum* plants and that a species with large hyaline cells had a greater CH₄ consumption potential than one with small hyaline cells taken from the same habitat.

METHODS

Study Sites

We measured moss CH₄ consumption potential and *in situ* CH₄ concentrations during the 2001 growing season at the Mer Bleue peatland complex located 10 km east of Ottawa, Ontario, Canada. The peatland comprised a domed ombrotrophic bog with distinct hummock-hollow topography, a poor fen with less pronounced topography, and beaver pond lags at the margin. Nomenclature is presented according to Anderson (1990) and Garneau (2001). The bog contained *Sphagnum capillifolium* (Ehrh.) Hedw., *Sphagnum magellanicum* Brid., and *Sphagnum angustifolium* (C. Jens ex Russ.) C. Jens. mosses on hummocks and hollows and *Chamaedaphne calyculata* (L.) Moench and *Kalmia angustifolium* L. shrubs and *Polytrichum strictum* Brid. moss present mainly on hummocks. Surface elevation between hummocks and hollows varied by ~10 to 20 cm, and the water-table depth over the 2001 growing season ranged from 10 to 45 cm beneath the surface of the hollows, with an average of 25 cm. The fen at Mer Bleue contained *S. capillifolium*, *S. magellanicum*, *Sphagnum fallax* (Klinggr.) Klinggr., and *Sphagnum papillosum* Lindb. mosses and *Eriophorum vaginatum* (Fern.) sedge in hummocks and hollows. Surface elevation between hummocks and hollows varied by only ~5 to 10 cm, and the fen was wetter than the bog, with an average water-table depth during the 2001 growing season of ~3 to 5 cm beneath the surface of the hollows. The abandoned beaver pond contained floating *Sphagnum majus* (Russ.) C. Jens. in the center and emergent *S. majus* at the edges. We

sampled mosses from bog and fen hummocks and hollows and at three locations from the edge to center of the pond. These environments provided a range of moss habitats with varying water-table positions and thus a range of distances between the surface *Sphagnum* layer and the zone of CH₄ production.

In situ CH₄ Concentrations

In May 2001, we sampled soil air and pond water across sites to determine the range of CH₄ concentrations to which mosses were exposed in the field. Triplicate air samples were taken with 10-ml syringes and needles from 3 cm below the surfaces of three bog and fen hummocks and hollows and from the edge of the pond where *S. majus* was emergent. In the center and margin of the pond where *S. majus* was floating, triplicate 30-ml samples of water were removed from 3 cm below the pond surface in 60-ml syringes, 30-ml of pure N₂ was added to the syringe, and headspace CH₄ concentrations were measured within 24 h. CH₄ concentrations were determined relative to known standards (2, 200, and 2000 ppmv CH₄ in N₂) using a Shimadzu Mini II (Shimadzu, Kyoto, Japan) gas chromatograph equipped with a Poropak Q column with 80/100 mesh (column temp 40° C) and flame ionization detector (detector temp 100° C).

Consumption Potentials

We sampled five mosses from five habitats on May 20, 2001 to initially determine if mosses had potential to oxidize CH₄. We chose *S. angustifolium* from bog hollows, *S. capillifolium* from bog hummocks, *S. fallax* from fen hollows, *S. papillosum* from fen hummocks, and *S. majus* from the center of the pond. Clusters of mosses were removed, placed into plastic bags, stored on ice, and individual stems were separated to ensure that samples for CH₄ consumption potential measurements consisted of only one species. Mosses were cut into three depths according to Vasil'eva *et al.* (1999), who identified top (green), middle (white), and low (brown) segments of *Sphagnum* mosses. The top segment contained all of the photosynthetic material, including moss capitulum. The middle segment had intact structure, although it did not contain chlorophyll, and the low segment had begun to lose structure through decomposition.

On August 28, 2001, we sampled *S. magellanicum* and *S. majus* across a range of habitats to examine the effects of environmental variability on CH₄ consumption. Clusters of *S. magellanicum* were taken from triplicate bog hummocks and fen hummocks and hollows. Triplicate clusters of *S. majus* were taken from the

edge, margin, and center of a pond. Mosses were sampled, stored, and separated as above.

On October 10, 2001, we sampled clusters of mosses from three fen hollows that contained interspersed *S. capillifolium* and *S. magellanicum* to determine the effects of moss species on CH₄ consumption potential. These hollows were chosen because the moss layer was situated immediately above the water table and both species were similar in length, ensuring that both species were exposed to the same *in situ* concentrations of CH₄. Mosses were sampled, stored, and separated as above, except that care was taken to ensure that the three depth segments from the two species were identical with respect to vertical position in the field.

We used a method slightly modified from Moore and Dalva (1997) to determine CH₄ consumption potentials. We incubated mosses for 96 h in 50-ml Erlenmeyer flasks sealed with silicone-filled rubber Suba seals (William Freeman Ltd, Barnsley, UK) after injecting 50 µl of pure CH₄ to achieve ~1000 ppmv CH₄ in air in the flask headspace. We chose this headspace CH₄ concentration to achieve a dissolved concentration in moss water of ~1.5 µM (Henry's law constant (K_H CH₄) of 1.5*10⁻³ moles L⁻¹ atm⁻¹) similar to the dissolved concentrations measured near the moss layer in a flooded core of peat from the Mer Bleue bog by Blodau and Moore (2003). The headspace was sampled with 1-ml syringes, and CH₄ concentrations were determined as above; 1 ml of air was added to the flasks immediately after sampling to maintain pressure. We analyzed CH₄ concentrations seven times during the first incubation (samples collected May 20, 2001) and then at least four times in the subsequent incubations. Following the incubations, the headspace volume of each flask was measured by determining the quantity of water required to displace the entire headspace, and flasks were dried at 70° C to measure dry weight of moss tissue and moisture content. Accounting for CH₄ removed during sampling, rates of CH₄ consumption were then calculated as the volume-corrected change in flask CH₄ over time based on the slopes of linear regressions and expressed per mass of dry tissue.

Site of CH₄ Consumption Associated with *Sphagnum* Mosses

To determine if CH₄ was consumed internally in *Sphagnum* mosses, we used a method intended to sterilize the external surfaces of a subset of *S. capillifolium* and *S. magellanicum* sampled from one of the fen hollows in September 2001. Intact individual stems were dipped in a 1% chloramine-t (C₇H₇SO₂NaCl) solution for 1 min and rinsed with distilled water prior

to separating into depth segments and measuring CH₄ consumption potential as described above. This method has been previously used to sterilize external surfaces of forage grass roots (Döbereiner 1980). To investigate the potential role of the water-holding hyaline cells in *Sphagnum* mosses as habitat for CH₄-oxidizing bacteria, we compared the consumption potential of *S. capillifolium*, *S. magellanicum*, and *P. strictum* (which does not contain hyaline cells, J. Buber, pers. comm.) taken from three bog hummocks in August 2001. Mosses were separated according to species, and external surfaces were treated with chloramine-t before separation into depth segments. Because *P. strictum* was shorter than the *Sphagnum* mosses, plants were only separated into photosynthetic and non-photosynthetic segments and only corresponding depth segments of *Sphagnum* mosses were used for comparison. We suspected that CH₄ consumption potential would have been very small in the moss layer of the bog hummocks because of the low water-table position and thus carried out incubations for 1 mo, opening flasks approximately every 4 d to supply O₂, resealing, and adding ~1000 ppmv CH₄ to the flask headspace. This was done to stimulate growth of CH₄-oxidizing bacteria in each of the moss species that may have been limited by low *in situ* CH₄ supply.

Statistical analyses were completed using SYSTAT 10 (SPSS Inc.) We used single *t*-tests to determine if average negative consumption rates among replicates were significantly different than zero and report minimum probabilities of this occurrence for each dataset. Consumption rates by depth segments of moss species in particular habitats and by moss species across habitats were analyzed for significant differences using analysis of variance (ANOVA) with Tukey post-hoc tests. To compare consumption rates in moss species from the fen hollows, we used ANOVA with depth segment and species or depth segment and chloramine-t treatment as factors, respectively, and CH₄ consumption rate as the dependant variable. Resulting residuals were analyzed to ensure even distribution (skewness/standard error and kurtosis/standard error sufficiently near 0), and in certain instances where residual distribution was not normal, data were log-transformed and re-analyzed after replacing negative rates with values of 0.001 µg g⁻¹ dry moss d⁻¹ prior to log transformation. We accepted *P* ≤ 0.05 as indicative of a significant difference.

RESULTS

CH₄ concentrations in air or water below the moss capitula spanned nearly two orders of magnitude (Figure 1). They ranged from 2 to 3 ppmv at the pond edge, bog hummocks and hollows, and fen hummocks

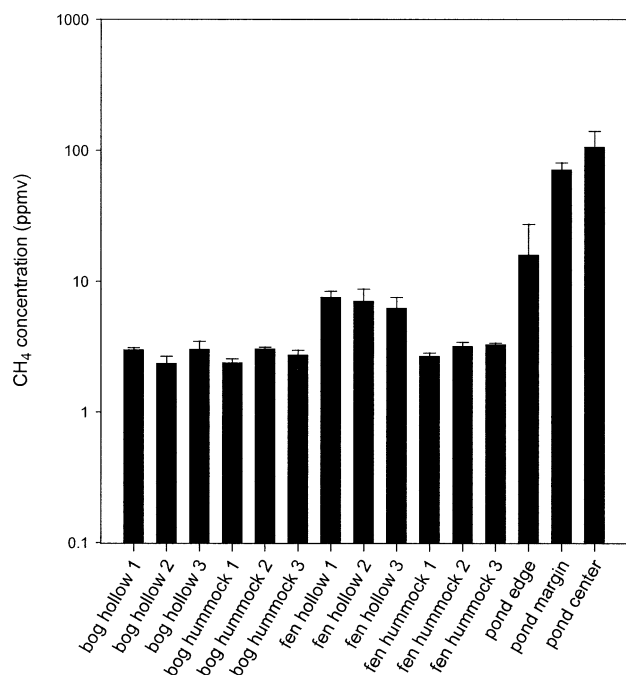


Figure 1. *In situ* CH₄ concentrations sampled immediately below *Sphagnum capitula* in sets of bog hummocks, bog hollows, fen hummocks, and fen hollows and along a pond-edge transect in the Mer Bleue peatland complex. Error bars represent the standard deviation of three replicates.

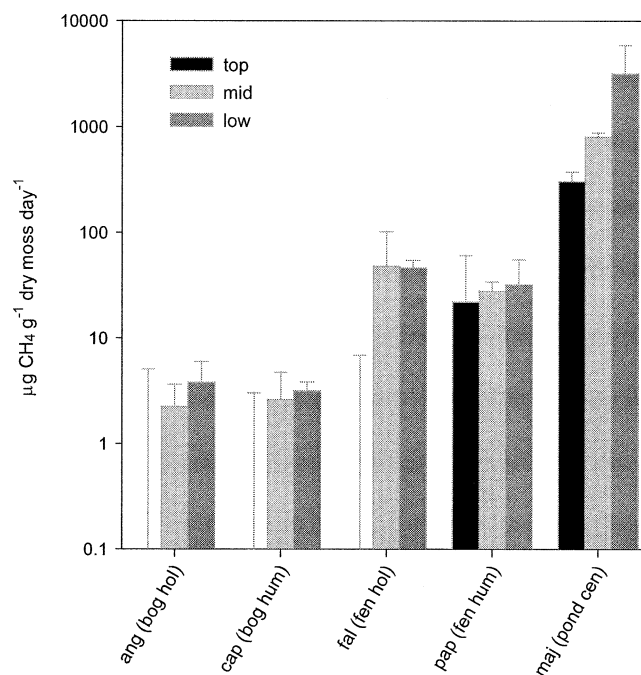


Figure 3. *In vitro* CH₄ consumption rates in three depth segments of five *Sphagnum* moss species from five distinct habitats at the Mer Bleue peatland complex: *S. angustifolium* (ang) from bog hollows, *S. capillifolium* (cap) from bog hummocks, *S. fallax* (fal) from fen hollows, *S. papillosum* (pap) from fen hummocks, and *S. majus* (maj) from the center of a pond. Error bars represent the standard deviation of three replicates.

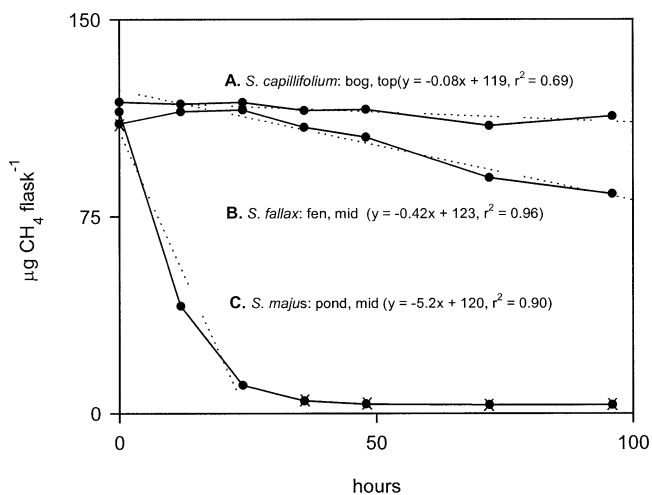


Figure 2. Representative CH₄ depletion (after subtraction of CH₄ removed in sampling) in individual flasks containing: A. top segments of *S. capillifolium* from a bog hummock, B. mid segments of *S. fallax* from a fen hollow, and C. mid segments of *S. majus* from the pond. Linear equations based on data points used for rate calculation and *r*² values are given in parentheses and represented graphically with dotted lines. Points removed prior to linear regression calculation are marked with X. Periods of maximum rates of consumption over the course of the incubation for each flask are indicated with dashed lines.

to 7 to 16 ppmv in the fen hollows and to 71 to 106 ppmv at the margin and center of the abandoned beaver pond.

Typical CH₄ consumption in selected individual flasks is illustrated in Figure 2. In most *Sphagnum* mosses, maximum rates of CH₄ consumption usually occurred during the middle of the 96 h incubation (e.g., Figure 2 A and B), and occasionally during the initial phase of the incubations (0 to 24 h), CH₄ content increased in the flasks (e.g., Figure 2 B). *Sphagnum majus* taken from the margin and center of the pond, however, consumed nearly all of the CH₄ added within the first 24 h of incubation. To compare CH₄ consumption potentials between habitats and species, we use the linear rates over the 96 h incubations, with the exception of *S. majus* where we use the rate over the first 24 h, and in instances where there was substantial initial (0 to 12 or 0 to 24 h) increases in CH₄, where we calculated rates from 12 or 24 to 96 h.

Rates of CH₄ consumption by five *Sphagnum* mosses taken from different habitats in May 2001 varied from slightly negative to 3164 µg g⁻¹ dry moss d⁻¹ (Figure 3). Negative consumption rates were calculated from slight increases in CH₄ over the course of the incubation, although among replicates, average values

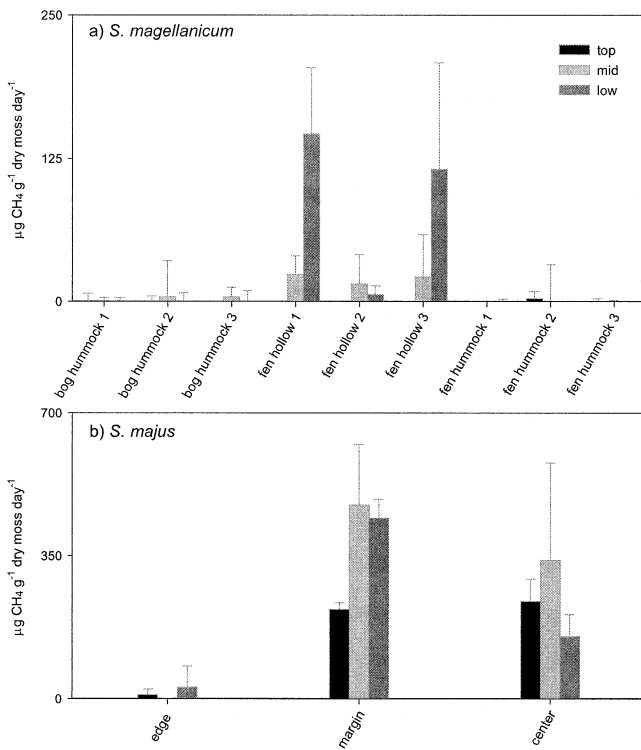


Figure 4. *a)* *In vitro* CH_4 consumption rates in three segments of *S. magellanicum* from three distinct habitats: bog hummocks, fen hollows, and fen hummocks. Error bars represent the standard deviation of three replicates each taken from the same hummock or hollow. *b)* *In vitro* CH_4 consumption rates in three segments of *S. majus* across a pond-edge transect. Error bars represent the standard deviation of three replicates.

were not significantly different from zero ($P \geq 0.36$). In all cases, the smallest rates were observed in the top photosynthetic segments of the plants, although rates were only significantly different from those in lower segments in *S. fallax* (F-ratio = 148, df = 2) and *S. majus* (F-ratio = 13, df = 2). Across habitats, CH_4 consumption potential increased as distance between the moss layer and the water table decreased. The smallest potentials were observed in bog hummocks and hollows and increased across fen hummocks and hollows; the highest potentials were in the center of the pond, with rates up to 100-fold greater than in the fen hollows (Figure 3). Across species/habitat, significantly smaller rates were observed at all depth segments between *S. majus* taken from the pond and all others and also between the lowest segments of *S. angustifolium* or *S. capillifolium* and *S. fallax* or *S. papillosum* (top: F-ratio = 42, df = 4, mid: F-ratio = 190, df = 4, low: F-ratio = 62, df = 4).

Average rates of CH_4 consumption by *S. magellanicum* sampled across habitats in August, 2001 ranged from slightly negative in bog and fen hummocks to

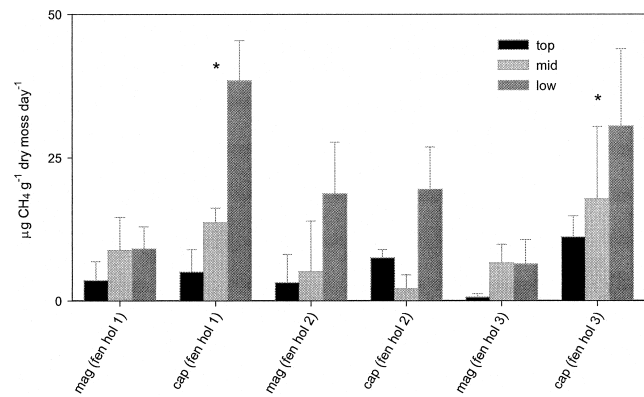


Figure 5. *In vitro* CH_4 consumption rates in three segments of *S. magellanicum* (mag) and *S. capillifolium* (cap) in three fen hollows. Error bars represent the standard deviation of three replicates taken from the same hollow and * indicates significant difference between species (ANOVA, $P \leq 0.05$).

$146 \mu\text{g g}^{-1} \text{ dry moss d}^{-1}$ in the low segments from a fen hollow (Figure 4a). With the exception of the top segments from one fen hummock, average negative values among replicates were not significantly different from zero ($P \geq 0.18$). Significant differences in consumption rates were observed between the low sections from the fen hollows and low sections from fen and bog hummocks (F-ratio = 1028, df = 2). Average rates of CH_4 consumption in *S. majus* were slowest in the location along the edge of the pond and fastest in the waterlogged margin between the edge and the center of the pond (Figure 4b). Rate differences were significantly smaller in all depth sections at the edge of the pond than at the margin or center and in the low section at the center relative to the margin (top: F-ratio = 42, df = 2, mid: F-ratio = 7, df = 2, low: F-ratio = 52, df = 2). In *S. magellanicum* taken from fen hollows, rapid rates of consumption were observed in the low segments of the plants, while in *S. majus* taken from the margin and center of the pond, rapid rates were observed in all three segments (Figure 4). *Sphagnum capillifolium* sampled in October, 2001 had significantly greater consumption potential than *S. magellanicum* taken from the same locations in two out of three fen hollows (Figure 5, F-ratio = 26, df = 1 and F-ratio = 16, df = 1), and differences between species were largest in the low depths. The two species removed from these sites both had average moisture contents of ~95%.

Treating external surfaces of *S. magellanicum* and *S. capillifolium* from a fen hollow with chloramine-t did not significantly alter rates of CH_4 consumption compared to untreated controls across all segments (Table 1 A, $P = 0.34$ and 0.89 , respectively). After 1 mo incubation, CH_4 was consumed by both *S. magellanicum* and *S. capillifolium*; the low segments of both

Table 1. A) *In vitro* CH₄ consumption rates in three segments of *S. magellanicum* and *S. capillifolium* from a hollow at the Mer Bleue fen. One set of samples for each species was treated in chloramine-t solution prior to incubation, and B) Potential CH₄ consumption rates in two depth segments of *S. capillifolium*, *S. magellanicum*, and *P. strictum* from a hummock, with external surfaces treated with chloramine-t, after one month incubation in ~1000 ppmv CH₄ in air. Rates are $\mu\text{g g}^{-1}$ dry moss d^{-1} . Standard deviations of three replicates are in parentheses.

A)

Depth	Moss species			
	<i>S. magellanicum</i>	<i>S. magellanicum</i> (sterilized)	<i>S. capillifolium</i>	<i>S. capillifolium</i> (sterilized)
top	3.5 (3.3)	5.0 (3.0)	5.0 (3.9)	4.0 (1.6)
mid	8.8 (5.8)	8.6 (8.0)	14 (2.6)	28 (24)
low	9.1 (3.9)	10 (7.4)	38 (7.0)	28 (15)

B)

	<i>S. capillifolium</i>	<i>S. magellanicum</i>	<i>P. strictum</i>
0-3 cm	8.0 (6.4)	6.6 (23)	-13 (14)
3-8 cm	68 (60)	309 (60)	-4.1 (8.3)

S. magellanicum and *S. capillifolium* consumed CH₄ most rapidly and *S. magellanicum* had higher average rates (Table 1 B). The slightly negative average CH₄ consumption rates for both segments of *P. strictum* were not significantly different from zero among replicates (single *t*-test, $P \geq 0.45$).

DISCUSSION

In vitro incubations have commonly been used to determine potential CH₄ consumption rates, as a rapid measure of relative methanotroph biomass and as a proxy for relative *in situ* activity (e.g., Moore and Dalva 1993, Sundh *et al.* 1995, Moore and Dalva 1997, Frenzel and Karofeld 2000). Consumption potential is the potential of a sample to consume CH₄ at a given concentration in a controlled, aerobic environment. We exposed mosses to artificially high CH₄ concentrations representative of those that may occur after prolonged flooding in our study site, although because we measured consumption in controlled conditions, rates of consumption likely do not represent absolute *in situ* rates. However, we assume that consumption measured *in vitro* corresponded to consumption *in situ*, providing a relative measure of CH₄ consumption across habitats and species. This assumption would fail if substantial enrichment of CH₄ consumption had occurred, and although we occasionally observed slower initial rates in the incubations, linear models not indicative of microbial growth best predicted consumption rates. In other work, we have found that measuring CH₄ consumption in mosses or peat using water slurries and rapid shaking eliminates this lag or slight initial increase in flask CH₄; however, we chose not to use this method because it would have physically dis-

rupted the mosses. In certain flasks, we observed slight increases in CH₄ concentration throughout the incubation, representing negative net uptake in our rate calculations. These increases may have resulted from CH₄ present in room air we used to maintain flask pressure following sampling, calculation errors when accounting for loss due to sampling, or biological CH₄ production from anaerobic microsites in the mosses. Although certain individual flasks experienced increasing CH₄ concentration over the incubations, across environmental replicates, this occurrence was only significantly different from zero (i.e., no net consumption or production occurring) in one case. This suggests that if, for example, CH₄ production was occurring in mosses under generally aerobic conditions, it may not be of major biogeochemical importance in these sites.

The range of CH₄ consumption rates (up to 146 $\mu\text{g g}^{-1}$ dry moss d^{-1}) by *Sphagnum* from the bog and fen was similar to those observed in peat slurries by Moore and Dalva (1993, 1997). Because nearly identical methods for determining consumption potentials were used, we suggest that, given adequate conditions, *Sphagnum* mosses can oxidize CH₄ at rates equivalent to peat sediments. Consumption rates in *S. majus* taken from the pond, however, were up to 30 times greater than those determined in peat slurries.

CH₄ consumption occurs largely as a function of CH₄ and O₂ supply, and thus, rapid rates in peatlands usually occur at the aerobic-anaerobic boundary where methane-oxidizing bacteria are exposed to both CH₄ substrate and O₂ required for consumption (Svensson and Sundh 1992). In many northern peatlands, the water-table position roughly defines this boundary and correlates with the rate of CH₄ emission (e.g., Moore and Roulet 1993). In this study, *in situ* CH₄ concen-

tration measured in the moss layer appeared to be dependant on the relative water-table position at each site. The bog hummocks and hollows and fen hummocks had the lowest water table and the smallest concentrations of CH₄. Fen hollows and the edge of the pond had intermediate concentrations and water tables near the surface. The margin and center of the pond had highest concentrations and a water surface close to the top of the *Sphagnum*. CH₄ consumption potentials of five mosses taken from five habitats were generally positively related with *in situ* CH₄ concentrations: *Sphagnum* from bog hummocks and hollows and fen hummocks had the smallest consumption potentials, fen hollows were intermediate, and center of the pond was the largest.

Many species of *Sphagnum* mosses are quite specific with regards to habitat and particularly moisture conditions (Crum 1992), and their distribution shows a strong relationship to field fluxes of CH₄ (Bubier et al. 1995). Large standard deviations within replicates of *S. magellanicum* taken from the same hummock or hollow and large differences in rates between the fen hollows (Figure 4a) indicated that there was a high degree of spatial variability in CH₄ consumption at small and large scales, presumably due to environmental heterogeneity. Both *S. magellanicum* and *S. majus* had even larger ranges in consumption potentials across habitats, with maximum differences in average rates of consumption in the same depth segment of mosses sampled at the same time from different habitats of 152 and 415 μg g⁻¹ dry moss d⁻¹, respectively. Although water-table position is usually the principal determinant of the site of CH₄ consumption in northern peatlands, CH₄ consumption is also potentially affected by N concentrations (Crill et al. 1994, Kravchenko 2002), temperature (Moore and Dalva 1993, Crill et al. 1994), and the presence and type of vascular vegetation that can both supply oxygen to otherwise anoxic depths (Bubier and Moore 1994) and/or transport CH₄ rapidly to the surface before consumption can occur (Waddington et al. 1996). We cannot exclude factors other than the distance between the *Sphagnum* layer and the water table in controlling CH₄ consumption potentials across habitats.

Control of CH₄ consumption by *Sphagnum* species in peatlands is difficult to assess because *Sphagnum* mosses are often adapted to exist only in particular habitats (Crum 1992), and habitat exerts a strong control over CH₄ consumption. In the Mer Bleue fen, however, we encountered two species from two distinct taxonomic sections with different morphological and physiological characteristics present in the same habitat. *Sphagnum capillifolium* and *S. magellanicum* were interspersed among each other in hollows and closely aligned regarding position of the three depth

segments defined by Vasil'eva et al. (1999) in relation to the water table. This allowed us to compare differences in CH₄ consumption potential between the two species in the absence of confounding environmental variability. In certain cases (two out of three hollows examined), *S. capillifolium* CH₄ consumption potential exceeded that of *S. magellanicum* at the same depth by up to 29 μg g⁻¹ dry moss d⁻¹ compared to differences of up to 152 and 415 μg g⁻¹ dry moss d⁻¹, respectively, for *S. magellanicum* and *S. majus* across habitats. The two species from the fen hollows had identical water content, although because they were morphologically different, inter-species differences in gas-water transfer of CH₄ may have affected rates of CH₄ consumption. Differences in CH₄ consumption could have also resulted from plant physiology constraining CH₄-oxidizing bacterial biomass. Although our findings consider only two species of moss sampled at one time, we suggest that different *Sphagnum* moss species can consume CH₄ at different rates, although differences are small compared to the effects of environmental variability, particularly water-table position.

In nearly every habitat and species, the smallest CH₄ consumption potential was measured in the top photosynthetic segment of *Sphagnum* mosses, which may result from being furthest from the source of CH₄ production, providing less suitable habitat for CH₄ oxidizing bacteria, or a combination of both. Although we cannot properly assess this question, we did observe rapid rates of CH₄ consumption (>300 μg g⁻¹ dry moss d⁻¹) in the top segments of *S. majus* from the center of the pond, an indication that living, photosynthetic portions of *Sphagnum* may not have been an inherently unsuitable habitat for CH₄-oxidizing bacteria. Chloramine-t treatment of external moss surfaces did not significantly decrease consumption potential of *S. capillifolium* or *S. magellanicum* from a fen hollow, and one-month aerobic incubation of *P. strictum* in CH₄ could not stimulate CH₄ consumption. This might indicate that the hyaline cells present in *Sphagnum* yet absent in *Polytricum* were the site of consumption. We observed, however, higher rates of consumption in *S. capillifolium*, which has smaller hyaline cells than *S. magellanicum* (J Bubier, pers. comm., Crum 1992). We also did not repeatedly treat the mosses with chloramine-t throughout the one-month incubation or verify absence of bacterial cells on the moss surfaces after the incubation to ensure prolonged surface sterilization. We confirm Frenzel and Karofeld's (2000) report of high rates of CH₄ consumption likely occurring just below the photosynthetic portions of *Sphagnum* layer by demonstrating that consumption can occur internally, perhaps in the hyaline cells. Although we did not measure methanotroph biomass, our findings also

appear to agree with assumptions made by Vasil'eva *et al.* (1999), suggesting that the large partially decomposed cells of the lower segments of *Sphagnum* mosses contained the greatest biomass of CH₄ oxidizing bacteria.

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