Wetlands May Change Tallgrass Prairie from a Sink to a Source for Atmospheric Methane

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Abstract. The belief that tallgrass prairie is a small but measurable sink for atmospheric methane (CH4, a greenhouse gas) has not considered the role of wetlands that tend to be strong sources of atmospheric CH4. We measured CH4 emission from cattail (*Typha latifolia*) dominated marshes to the atmosphere in northeastern Kansas, focusing on the flow of sediment-derived CH4 into, through, and out of the plant to the atmosphere. Emission rates were negligible at night, but rates were 0.1 to 0.5 ¦mol m-2 [leaf] s-1 from noon to sunset, with maximum rates of 1.7 ¦mol m-2 [leaf] s-1 at midday. The emission rate per unit of ground area was as high as 1000 mg CH4 m-2 d-1, which is a relatively high rate for wetlands. Assuming wetlands cover just 1% of the prairie landscape, CH4 emission from the wetland is large enough to offset CH4 consumption in the uplands. The results show that even minor components of landscapes are important in local and regional budgets for atmospheric CH4.

Key words: atmospheric methane, cattail, climatic change, greenhouse gas, Kansas, prairie wetland, *Typha latifolia*

Introduction

Prairie wetlands have important roles in determining water quality and water quantity, as waterfowl habitat, and as sites of biodiversity (cf., Van der Valk 1989). The persistence of these wetlands is threatened by human activities, including drought induced by projected climatic change (Poiani and Johnson 1993, Larson 1994). In this study, we address a possible role of prairie wetlands as agents of climatic change by emitting more CH4 (a +greenhouse+ gas) to the atmosphere than is consumed by upland soil. Methane is an odorless, colorless gas that plays a fundamental role in the chemistry and radiation budget of the earth+s atmosphere (Ramanathan et al. 1985). Currently, atmospheric CH4 accounts for a significant portion of the earth+s greenhouse effect, and the changing atmospheric concentration of CH4 will have a profound effect on the projected climatic change (Prinn 1994). Atmospheric CH4 comes entirely from the earth+s surface. The major sources include microbial production of CH4 anaerobically (i.e., in the absence of oxygen) in natural and constructed wetlands, in landfills, and in ruminant animals, as well as the emission of natural gas to the atmosphere (Crutzen 1991). The largest sink is chemical oxidation in the atmosphere (Crutzen 1991); however, several studies have found a small but significant sink for atmospheric CH4 in well-drained soil containing aerobic CH4-oxidizing bacteria (cf., King 1992, Ojima et al. 1993, Dorr et al., 1993).

In a recent study, Tate and Striegl (1993) found consumption of atmospheric CH4 by soil in tallgrass prairie, which continued even after the land was converted to agriculture. Given the prominence of grasslands on the earth+s surface, especially in North America, the authors speculated that tallgrass prairie and associated agricultural land could play an important role in a regional budget for atmospheric CH4. This is an important consideration as countries work towards limiting their emissions of greenhouse gases to the atmosphere (Houghton et al. 1992). However, the study by Tate and Striegl (1993) did not consider the diversity of land use across the prairie landscape, including wetlands as sources of atmospheric CH4 that might offset consumption by soil in the uplands.

We specifically studied wetlands dominated by the emergent macrophyte *Typha latifolia* because (i) it occurs widely across the prairie region (McNaughton 1966) and, in particular, (ii) it facilitates CH4 emission to the atmosphere by serving as a conduit for CH4 transport from wetland sediment to the atmosphere (Sebacher et al. 1985).

Methods

Sampling was done at two sites in northeastern Kansas. One small wetland, covering about 300 m2, occurred downstream from a spring on the Konza Prairie Natural Area near Manhattan, Kansas (39o11.0+N, 96o34.5+W) and was sampled in July 1992 and again in August 1993. The second site was a larger wetland, covering about 0.1 ha, located at the inlet end of Pottawatomie #2 reservoir also near Manhattan and was sampled in July 1994. Each site had a monospecific stand of *T. latifolia* established on a silty-clay sediment.

There is compelling evidence that CH4 produced microbially in wetland sediments can flow into aquatic emergents such as *T. latifolia* and then escape to the atmosphere through pores or stomatal openings on leaf surfaces (Knapp and Yavitt 1992). Therefore, we estimated rates of CH4 emission directly from *T. latifolia* as well as the CH4 diffusing directly from the sediment to the atmosphere.

At each site, CH4 emission from *T. latifolia* was measured periodically during the day and at ambient temperature, humidity, and sunlight. We studied three to nine shoots at each site, and separate measurements were made on 6-10 cm2 parts of two leaves per shoot. *Typha latifolia* leaves grow as high as 2 m, although we consistently sampled the upper 1/3 of the canopy. The emission estimate was made with a field-portable, closed flow system (LI-COR model 6200, Licor Inc., Lincoln, NE) and a 1/4 l plexiglass cuvette. Leaves were sealed into the cuvette, and the emission rate was measured during a 3-min enclosure time by taking 10-ml gas samples with plastic syringes (i) just before closing the cuvette, thus sampling ambient air at the same place in the plant canopy where the cuvette was placed and (ii) from the cuvette headspace (405 ml total volume) 1, 2, and 3 min after closure. The syringes served as storage vessels until gas analysis within 72 h of collection. While in the field, we filled several

syringes with CH4 standards of known concentration and analyzed them along with the *T. latifolia* samples to correct for leakage from the sample syringes. Humidity within the cuvette was maintained close to the ambient level by directing flow through a desiccant in the LI-COR system. Leaf temperature was not regulated but remained within 2ÑC of ambient during the relatively short incubation period. The leaf was removed from the cuvette following the emission estimate and reinserted for subsequent measurements.

Following each individual gas-exchange measurement, we collected separate <5-ml gas samples from within the part of the leaf enclosed by the cuvette using plastic syringes and a 25 gauge needle (about 16 mm long). Leaves typically have an air-filled volume of 450 cm3 (cf., Tornbjerg et al. 1994); hence, our gas sample was <1% of the total volume. Additional samples taken from plant bases below the waterline collected air and no water, suggesting that ambient air did not mix with samples collected from emergent leaves.

We also sampled gases dissolved in sediment pore waters (n = 3 per site at 1 and 7.5 cm depth). Dissolved gases were extracted from the water sample by shaking it vigorously for 2 min. The total amount of dissolved CH4 (C in ¦l liter-1) in the water sample was calculated using transfer equations given by Flett et al. (1976):

$$C = x\,(1 + °Vw/Vg)$$

where x is the mixing ratio in the gas phase (ppmv = ¦l liter-1), ° is the temperature-dependent Bunsen adsorption coefficient (cf., Yamamoto et al. 1976), Vw is the volume of the water extracted, and Vg is the volume of the gas phase. We express the final CH4 concentration as a partial pressure (i.e., 1 ¦l liter-1 = 30 ¦atm pCH4 at 19ÑC) to compare directly to CH4 concentration in ambient air and within *T. latifolia* plants. Sediment temperatures were measured with a thermistor.

Methane in air samples was analyzed with a gas chromatograph (Perkin Elmer, Inc., model Sigma 3B) equipped with a flame ionization detector and a 3-m Poropak-Q (80/100 mesh) column. We quantified CH4 concentrations by comparing peak areas for samples and several standards (1.09 to 10,300 ¦l liter-1 CH4 in N2; Scott Specialty Gases, Plumsteadville PA), which bracketed every 5-10 samples. Analytical precision was <0.2% for the lowest standard and was always within 2%. With this system, we could measure a minimum rate of CH4 emission of 0.01 ¦mol m-2 [leaf] s-1.

Results

During the day, the mean rate of CH4 emission was 0.25 ¦mol m-2 [leaf] s-1. Individual estimates ranged from detection limit to a high rate of 1.7 ¦mol m-2 [leaf] s-1. Figure 1 shows that the mean emission rate of 0.40 ¦mol m-2 [leaf] s-1 at the Pottawatomie site was significantly higher ($p < .05$) mean emission rate than the mean rate of 0.08 ¦mol m-2 [leaf] s-1 at Konza. Diurnal measurements of CH4 emission revealed maximum values from 1000 h to about 1400 h, with lower values in the early morning and later afternoon (Fig. 1).

At the Konza site, we measured CH4 emission from *T. latifolia* to the atmosphere on two dates during the growing season. The mean emission rate during the day was somewhat higher in July 1992 (0.25 ¦mol m-2 [leaf] s-1) than in August 1993 (0.08 ¦mol m-2 [leaf] s-1).

Methane concentrations within *T. latifolia* plants (Table 1) were always greater than the atmospheric concentration of about 1.7 ¦l liter-1, indicating a leaf-to-air gradient for CH4. Likewise, CH4 concentrations in sediment pore waters were relatively high. The mean values of pCH4 at the sediment/water interface were 23,000 ¦atm at the Konza site and 181,000 ¦atm the Pottawatomie site. Within the sediment (7.5 cm depth), the pore water CH4 was similar at both sites (ca., 200,000 ¦atm).

Table 1. Mean concentrations of CH4 in ambient air and in *Typha latifolia* plants (¦l liter-1) and pCH4 in sediment pore water (¦atm) of two *Typha*-dominated wetlands in Kansas.

	Konza		Pottawatomie
Location	July1992	August 1993	July 1994
Ambient air	1.72	1.77	1.77
Typha latifloia leaves	2.84	2.93	3.63
stem below waterline	150.0	191.0	234.0
Sediment			
1 cm depth	18,000	29,000	181,000
7.5 cm depth	190,000	202,000	204,000

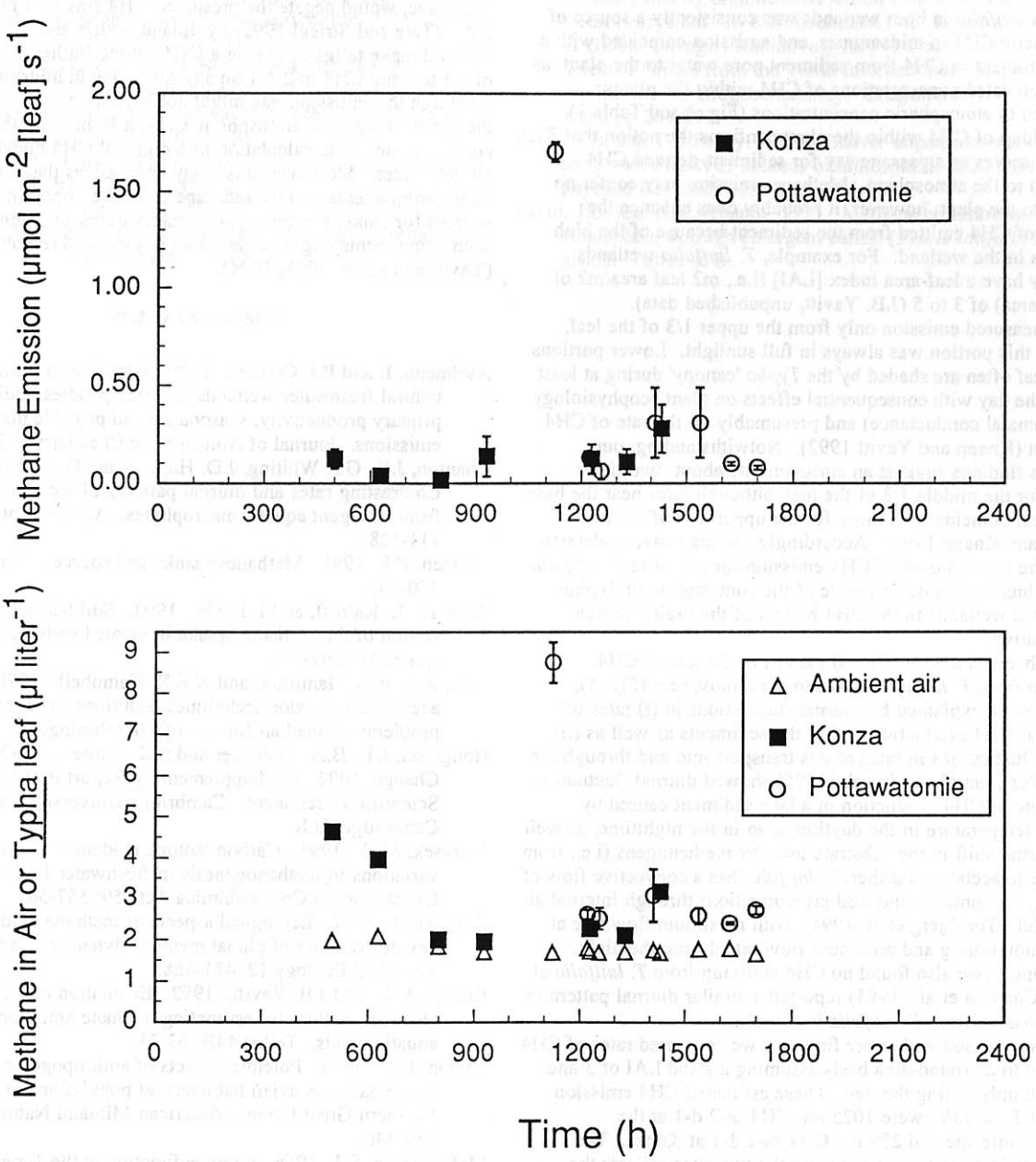

FIG. 1. Diurnal pattern of CH4 emission to the atmosphere (top panel) and CH4 concentrations in ambient air and in *Typha latifolia* leaves (bottom panel) for two sites in northeastern Kansas.

Discussion

Typha latifolia in both wetlands was consistently a source of atmospheric CH4 in midsummer, and emission coincided with a strong gradient in CH4 from sediment pore water to the plant, as well as elevated concentrations of CH4 within the plants compared to atmospheric concentrations (Fig. 1 and Table 1). The buildup of CH4 within the plant confirms the notion that *T. latifolia* serves as a passageway for sediment-derived CH4 emission to the atmosphere. Methane emission may confer no benefit to the plant; however, it probably does enhance the amount of CH4 emitted from the sediment because of the high leaf area in the wetland. For example, *T. latifolia* wetlands typically have a leaf-area index [LAI] (i.e., m2 leaf area/m2 of ground area) of 3 to 5 (J.B. Yavitt, unpublished data).

We measured emission only from the upper 1/3 of the leaf, because this portion was always in full sunlight. Lower portions of the leaf often are shaded by the *Typha* 'canopy' during at least part of the day with consequential effects on plant ecophysiology (i.e., stomatal conductance) and presumably on the rate of CH4 emission (Knapp and Yavitt 1992). Notwithstanding, our previous findings suggest an emission rate about two times higher for the middle 1/3 of the leaf, although rates near the base of the leaf coincide with those for the upper part of the leaf (Yavitt and Knapp 1995). Accordingly, we may have underestimated the total amount of CH4 emission for an entire *T. latifolia* plant, which makes our estimate of the contribution of *Typha*-dominated wetlands to the CH4 budget of the prairie region conservative.

We observed a weak diurnal pattern in the rate of CH4 emission from *T. latifolia* leaves to the atmosphere (Fig. 1), which can be explained by diurnal fluctuations in (i) rates of microbial CH4 production within the sediments as well as (ii) diurnal fluctuations in rates of gas transport into and through the plant. For example, Jedrysek (1995) showed diurnal fluctuation in the rate of CH4 production in a lake sediment caused by warmer temperature in the daytime than in the nighttime, as well as a diurnal shift in the substrate used by methanogens (i.e., from H2/CO2 to acetate). Further, *T. latifolia* has a convective flow of gas (i.e., by humidity-induced pressurization) through internal air spaces (cf., Tornbjerg et al. 1994), with maximum flow rate at about midmorning and minimum flow rate during the night. Accordingly, we also found no CH4 emission from *T. latifolia* at night. Chanton et al. (1993) reported a similar diurnal pattern in CH4 emission from *T. latifolia* in Florida.

For comparison with other findings, we converted rates of CH4 emission to a ground-area basis assuming a stand LAI of 3 and emission only during the day. These estimated CH4 emission rates for *T. latifolia* were 1025 mg CH4 m-2 d-1 at the Pottawatomie site and 220 mg CH4 m-2 d-1 at Konza. The difference in emission rates among the two sites reflects the heterogeneity that characterizes *Typha*-dominated wetlands across the prairie landscape. For example, we sampled the Pottawatomie site because it had more organic matter in the sediment than the Konza site to fuel higher rates of microbial CH4 production (i.e., higher pore water CH4 concentration) and the higher emission rates.

The highest values confirm the notion that marshes dominated by *T. latifolia* are extraordinary sources of CH4. For example, the global mean rate for CH4 emission from marshes dominated by aquatic emergents is 238 mg CH4 m-2 d-1, as summarized by Aselmann and Crutzen (1989). Chanton et al. (1993) reported emission rates of 400 to 1500 mg CH4 m-2 d-1 for a *T. latifolia* wetland in Florida.

To further put these values into perspective, the CH4 emitted from prairie wetlands, assuming they covered just 1% of the landscape, would negate the presumed CH4 sink of 1 mg CH4 m-2 d-1 (Tate and Striegl 1993) by upland prairie and agricultural soil and make tallgrass prairie a CH4 source (rather than a sink) of 1.5 to 7 mg CH4 m-2 d-1 on any given day in midsummer. Although this emission rate might not have much of an impact on the global budget for atmospheric CH4, it is an important consideration in the calculation of a regional CH4 budget for the United States. Moreover, this study emphasizes that seemingly minor components on the landscape can have important roles as sources (or sinks) for atmospheric traces gases, and neglecting such components might cause errors in local and regional budgets (Yavitt and Fahey 1993, 1994).

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