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Short research contribution

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THE EFFECT OF HABITAT ON METHANE EMISSION FROM AN ALPINE WETLAND

ABSTRACT: Alpine wetland is a source for methane (CH_4), an important greenhouse gas, but little is known about how this habitat influences the emission. To understand this wetland habitats were selected at the altitude of 3430 m a.s.l. (in National Wetland Nature Reserve of Zoige, Quingle – Tibetan Plateau) and the methane flux was measured with static chambers in three different sites, including hollows with *Carex muliensis* Hand – Mazz. and *Eleocharis valleculosa* Ohwi f. *setosa* (Ohwi) Kitagawa., grass hummocks composed of *Kobresia tibetica* Maxim, *Cremanthodium pleurocaule* R. D. Good, *Potentilla bifurca* L. and *Pedicularis* sp. We have found that in alpine wetland these habitats significantly affect CH_4 emissions in the onset (April, 2006) and peak (August, 2005) stages of growing season.Hollows covered with *Carex muliensis* and *Eleocharis valleculosa* had higher values of emission than grass hummocks built by several grass species. Slight difference of CH_4 emission was found between two kinds of hollows with *Carex muliensis* and *Eleocharis valleculosa*. These results were consistent with the change of water table, which was found best correlated with CH_4 emissions (r^2 = 0.43, P <0.01) in the peak stage of growing season. Directly measured shoot biomass and plant heights were best related to CH_4 emissions (r^2 = 0.59, P <0.01). However, in the onset stage of growing season, variation of CH_4 emission may not be simply ascribed to changes in water table and vegetation structure.

KEY WORDS: methane fluxes, habitat effects, water table, plant height, alpine meadow, phenology, redox potential

CH_4 is an important greenhouse gas, with a radioactive forcing of 0.48 W m^{-2}, 29% that of CO_2 and about 19% that of all long-lived greenhouse gases (IPCC 2007). Wetlands constitute not only one of the most important sources (70%) of natural CH_4 sources (Khalil 2000), but also the most uncertain one, due to large spatiotemporal variation and data shortage for some specific wetlands (Middelburg *et al.* 2002). Knowledge on CH_4 emissions from alpine wetlands is still limited (Wickland *et al.* 2001, Chimner and Cooper 2003, Hirota *et al.* 2004), and the effects of habitats on CH_4 emission from alpine wetlands remain even unstudied (Oquist *et al.* 2002, Wang *et al.* 2005). The influence of different habitats on the fluxes of greenhouse gases is a critical question in global change ecology and biogeochemistry, given increasing interest in wetland rehabilitation all over the world (Mitsch 2005, Cui and Zhai 2006, Buening *et al.* 2007). In addition, the habitat of alpine wetlands is likely to change in response to climatic change. Thus, a better understanding about habitat effects on soil processes is needed to predict how such natural and human-induced changes in habitat types will alter ecosystem processes, including CH_4 emission.

Water table and vegetation are emphasized as important habitat characteristics for CH_4 emissions (Bubier *et al.* 1993, Kettunen 2003). Water table determines the moisture and oxygen profile in peat matrix and therefore affects CH_4 production and oxidation rates in peat profile. Vascular plants provide methanogenesis with substrates, form a pathway for CH_4 to liberate from peat to the atmosphere and enhance CH_4 oxidation by transporting oxygen to water saturated peat.

The aim of the present research is to determine the effects of wetland habitats of different plant species composition, water table and other soil characteristics on CH_4 emissions in the onset and peak stages of growing season of the alpine meadow.

The investigations were carried out in an alpine wetland of National Wetland Nature Reserve of Zoige, located at the eastern edge of the Qinghai-Tibetan Plateau (33°56′N, 102°52′E, 3430 m a.s.l.). The region is characterized by cold Qinghai-Tibetan climatic conditions with average annual rainfall 650 mm and temperature 1.7°C. Three habitat types, one hummock-type and two different hollow-types were chosen to probe the habitat-related variation to CH_4 flux in such wetland environment. The hummocks are predominantly composed of *Kobresia tibetica* Maxim, *Cremanthodium pleurocaule* R. D. Good, *Potentilla bifurca* L. and *Pedicularis* sp. Scattered in the hollows are two predominant emergent plants, *Carex muliensis* Hand-Mazz. and *Eleocharis valleculosa* Ohwi f. *setosa* (Ohwi) Kitagawa. The size of *Carex muliensis* (CM) and *Eleocharis valleculosa* (EV) hollows is about 5 m^2 on average, with 3 to 7 cm standing water. The size of dry hummocks (DH) is about 0.8 m^2 and their height is from 20 to 50 cm.

On 15th and 29th of August, 2005 and April, 2006, CH_4 flux was measured at 09:00 in Beijing standard time (GMT+8). These two months are important in terms of phenology. August is the peak of the growing season (PG); April is the start of growing season (SG). Thirty plots were established to measure CH_4 flux in PG, 10 for hummocks, 9 for *Carex muliensis*, and 11 for *Eleocharis valleculosa*. Eleven plots were established in SG, 5 for hummocks, 3 for

Table 1. Mean values and SD of biotic and abiotic factors in each of the three habitats: Grass hummock –site (DH), and two hollow sites covered with *Carex muliensis* (CM) and *Eleocharis valleculosa* (EV) in the two phenological stages of growing season. PG: the peak stage of growing season (August, 2005); SG: the onset stage of growing season (April, 2006).

	DH	*CM*	*EV*	*Sampling date*
Water or surface temperature, °C	19.3±2.4	20.1±4.5	21.4±5.1	PG
Water or surface temperature, °C	5.2±0.8	3.6±2.0	3.7±2.8	SG
5 cm soil temperature, °C	18.3±2.8	16.5±3.1	15.8±3.1	PG
10 cm soil temperature, °C	16.6±1.9	14.5±1.8	13.9±4.0	PG
5 cm soil Eh, mV	n.d.	-155.8±35.8	-186.6±57.4	PG
10 cm soil Eh, mV	n.d.	-156.9±30.7	-200.8±62.3	PG
15 cm soil Eh, mV	n.d.	-160.7±33.9	-203.5±58.9	PG
N-total, g kg^{-1}	18.1±1.6	12.4±3.0	9.0±2.2	PG
C-total, g kg^{-1}	392.6±49.7	226.3±104.1	179.2±44.1	PG
P-total, g kg^{-1}	1.21±0.44	0.65±0.13	0.63±0.20	PG
Standing water depth, cm	-20.9±10.1	4.7±3.1	8.3±5.0	PG
Plant height, cm	13.8±4.2	30.7±7.9	32.2±9.2	PG
Ice thickness, cm	n.d.	0.68±0.12	1.13±0.54	SG
Water depth below the ice , cm	n.d.	3.7±3.1	8.5±5.4	SG
Thaw depth, cm	4.3±2.9	n.d.	n.d.	SG

n.d.- no data.

Table 2. Results of impact of habitat on CH_4 emission, environmental factors and soil properties by ANOVA. PG: the peak stage of growing season; SG: the onset stage of growing season.

	PG		*SG*	
	F	*P*-level	*F*	*P*-level
CH_4 emission, mg CH_4 m^{-2} h^{-1}	10.597	0.000**	4.634	0.024*
Water or surface temperature, °C	1.383	0.259	1.705	0.210
5 cm soil temperature, °C	3.816	0.028*	n.d.	n.d.
10 cm soil temperature, °C	13.482	0.000**	n.d.	n.d.
5 cm soil Eh, mV	3.831	0.058	n.d.	n.d.
10 cm soil Eh, mV	7.288	0.011*	n.d.	n.d.
15 cm soil Eh, mV	7.279	0.011*	n.d.	n.d.
N-total, g kg^{-1}	26.357	0.000**	n.d.	n.d.
C-total, g kg^{-1}	42.594	0.000**	n.d.	n.d.
P-total, g kg^{-1}	7.743	0.005**	n.d.	n.d.
Standing water table, cm	107.001	0.000**	n.d.	n.d.
Plant height, cm	40.744	0.000**	n.d.	n.d.
Ice thickness, cm	n.d.	n.d.	14.000	0.000**
Water depth blow the ice , cm	n.d.	n.d.	4.121	0.033*
Thaw depth, cm	n.d.	n.d.	4.376	0.029*

*Significant impact *P* <0.05, **highly significant impact, *P* <0.01
n.d.- no data.

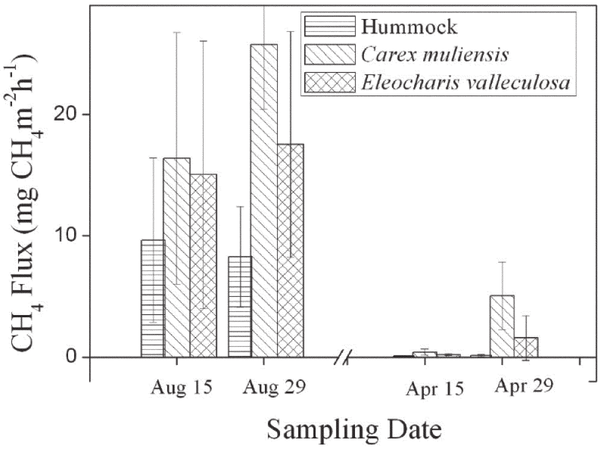

Fig. 1. Average values of CH_4 emission in each of the three habitats: Grass hummock-site (DH), and two hollow sites covered with *Carex muliensis* (CM) and *Eleocharis valleculosa* (EV) in the onset and peak stages of growing season (August is the peak of the growing season (PG); April is the start of growing season (SG).

Carex muliensis, and 3 for *Eleocharis valleculosa*. Soil samples were collected at 10 cm soil depth on August 15.

The methane flux is measured with vented closed chambers. The chambers (30 cm in diameter, 50 cm in height) were made of cylindrical polyvinyl chloride (PVC) pipe. Details about the chambers were described in Chen *et al.* (2008). Four air samples from each chamber were taken at 10-minute intervals over a 30 minute period after enclosure, stored in 50 ml air-tight vacuumed vials.

The CH_4 concentration was determined by a gas chromatography (PE Clarus 500, PerkinElmer, Inc., USA), equipped with a flame ionization detector (FID) operating at 350°C and a 2-m Porapak 80–100 Q Column. The column oven temperature was 35°C; the carrier gas was N_2 with a flow rate of 20 cm^3 min^{-1}. The minimum detectable concentration is 1×10^{-3} μL^{-1} (ppb). Certified CH_4 standard in 4.9 μl L^{-1} (China CH_4 National Research Center for Certified Reference Materials, Beijing) was used for calibration.

Related data including redox potentials (Eh), soil temperatures, standing water depths, hummock heights, plant heights, thaw depths and ice thickness were recorded after the air sampling. Total carbon, nitrogen and phosphorus content were measured in the lab of Chengdu Institute of Biology, Chinese Academy of Science.

In Table 1, we listed mean values of measured biotic and abiotic factors in each of the above-mentioned three habitats. According to Table 2, habitats had profound effects on hydrological regime, nutrient availability, plant species distribution and productivity.

CH_4 emission varied from 8.9 to 21.1 mg CH_4 m^{-2} h^{-1} during PG and from 0.1 to 2.7 mg CH_4 m^{-2} h^{-1} over SG (Fig.1). Habitats significantly affected CH_4 emission in both PG and SG periods (Table 2). Overall, hollows covered with *Carex muliensis* and *Eleocharis valleculosa* had higher values of emission than grass hummocks. The values of *Carex muliensis* were slightly higher than those of *Eleocharis valleculosa* (Fig.1).

Like Van den Pol-van Dasselaar *et al.* (1999), we also found that habitats with a high instantaneous CH_4 emission always showed a high annual CH_4 emission and habitats with a relatively low instantaneous emission always had a relatively low emission throughout the year. These results were consistent with the change of water table (Table 1), which was found best correlated with CH_4 emissions ($r^2 = 0.43$, $P < 0.01$) in PG. It was suggested that a slight decrease in water depth would only have marginal effect on CH_4 emission (Grünfeld and Brix 1999). Therefore, the slight variation of water table resulted but marginally in the above-mentioned slight difference of CH_4 emission between *Carex muliensis* and *Eleocharis valleculosa*. However, taking into consideration lack of data in SG, variation of CH_4 emission may not be simply ascribed to changes of water table.

Correlation between CH_4 emissions and plant biomass has been proven by many studies (Chanton *et al.* 1993, Van den Pol-Van Dasselaar *et al.* 1999, Ding *et al.* 2003). Different from the above-mentioned papers, however, the present study chose plant height, which can directly indicate shoot biomass, as the predictor of plant biomass (Ding *et al.* 1999). In PG, plant heights were best related to the CH_4 emissions ($r^2 = 0.59$, $P < 0.01$). Wetland vegetation was influenced by water table, nutrient and climate, etc. It has been suggested that vegetation may have predictive value for CH_4 emissions among different habitats (Bubier *et al.* 1995). In SG, it is more difficult to explain variation of CH_4 emission in response to habitats due to (a) the lack of a relationship between CH_4 emission rate and litter biomass or (b) difference in mechanisms of CH_4 transports from those in PG.

These results provide evidence that an accurate estimate of the strength of alpine wetlands as a global methane source should take into consideration changes in habitat types together with changes in water table and vegetation cover. However, if, as predicted, global warming causes wet meadow to replace emergent plant hollows, potential CH_4 emission will become lower.

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