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Methane emissions from wetlands: An *in situ* side-by-side comparison of two static accumulation chamber designs

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ABSTRACT

This study examined whether changing the design of a non-steady-state flux chamber accounted for an increase in methane emission rates from two 15-year-old constructed wetlands in central Ohio, USA. An increase in methane emission rates has been observed year to year in these created wetlands since 2004 with the greatest increase from 2008 to 2009 when a change of static field sampling chambers occurred from a PVC frame/bag design to a rigid plastic container design. Bimonthly gas samples were taken over a year in 2009–2010 comparing these different chamber methods previously used at this study area while recording several environmental influences on methane production. A multi-variate regression of the environmental influences determined soil temperature, water level, and dissolved organic carbon concentration of the surface water are weak predictors of methane emission rate (R^2 = 0.286) during the growing season. There was no significant difference in averaged methane emissions between the original PVC frame/bag method and the later rigid plastic container method in the planted wetland (3.4 and 2.3 mg-C m^{-2} h^{-1} respectively) and in the naturally colonized wetland (4.9 and 6.0 mg-C m^{-2} h^{-1} respectively). This comparison suggests the large increase of methane emissions in the wetlands from 2008 to 2009 was not an artifact of changing sampling chamber design.

1. Introduction

Wetlands produce about 25% of the world's naturally produced methane (Whalen, 2005; Mitsch and Gosselink, 2007). The high organic carbon concentrations and anaerobic conditions found in most wetlands support methanogenic microorganisms (Mitsch and Gosselink, 2007). An accurate estimate of methane emissions from wetlands is important because methane has a global warming potential approximately 25-times greater than CO_2 after 100 years (IPCC, 2007). Determining an accurate estimate of wetland methane production is important to understand the role wetlands have in both global warming potential and carbon budgets.

Detailed suggestions of chamber designs encompassing steady state verse non-steady state, venting, volume to basal area ratio, temperature control, and sampling ports to deployment and sampling techniques have been made by Livingston and Hutchinson (1995). The many different designs are needed to ensure the most accurate estimation of methane emission rates for varied environments studies (Livingston and Hutchinson, 1995). Therefore there have been many different chamber designs (Levy et al., 2012; Pihlatie et al., 2013), but until recently there have been few comparisons of those designs (Trégourès et al., 1999; Christiansen et al., 2011; Juszczak, 2013; Pihlatie et al., 2013). Of those comparisons only Juszczak (2013) conducted the study *in situ*, but the different chambers were in neighboring wetlands and not conducted side by side. Additionally the study by Trégourès et al. (1999) was of a landfill where methane emission rates of three different chamber methods were compared, although they failed to describe geometric design in detail, any of the materials, data analysis, or the sampling procedure(s) used. As far as we know there has not been a side by side comparison of two chambers, nor an *in situ* comparison of non-steady state vented chambers.

Two basic static chamber designs were used to estimate annual methane production at the 20-ha Olentangy River Wetland Research Park (ORWRP) in central Ohio over the period 2004–09 (Altor and Mitsch, 2006, 2008; Nahlik and Mitsch, 2010, 2011a; Sha et al., 2011). A methane emission increase of 4 g CH_4-C m^{-2} y^{-1} was observed between 2004 and 2008 (Nahlik and Mitsch, 2010, 2011a), but an increase of 11 g CH_4-C m^{-2} y^{-1} was recorded over just one year from 2008 to 2009. The increased methane emissions between the two years correspond to a change from the previously used PVC frame/bag chamber by Altor and Mitsch (2006, 2008)

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and Nahlik and Mitsch (2010, 2011a) to the rigid plastic container (Sha et al., 2011). Two possible causes for the increased emission rates while using the rigid method were disturbances. For example, the top of the chamber is pressed down onto the base with a petroleum jelly at the interface to ensure an airtight seal, and the pressure exerted on the base could have disturbed the soil, releasing methane bubbles from the soil. Another source of disturbance is the short height of the rigid chambers that forced the researcher to manipulate vegetation to fit within the chamber. This manipulation could also disturb the soil, and at times damage the vegetation, creating methane shunts and thereby increasing emission rates.

This study is a side-by-side comparison of the two methods to determine if they yield similar results and emissions truly increased over the years, or if the difference noted is an artifact of different chamber designs. Because the large increase of methane emission rates occurred when the ridged chamber was used, we hypothesized that the rigid plastic container design will result in higher emission rates. The study also allowed us to determine the validity of comparing other studies at this specific site in Ohio, as well as to legitimize comparisons among separate studies at other sites for decades. Additionally, the study added to a growing database of wetland methane emissions from created wetlands.

2. Materials and procedures

2.1. Study site

The study was conducted at the two 1-ha experimental wetlands of the Olentangy River Wetland Research Park (ORWRP) at the Ohio State University in Columbus, OH (Fig. 1). The ORWRP is located on a historic floodplain of the fourth-order Olentangy River in central Ohio. The floodplain was converted to experimental farm fields at the beginning of the 20th century for university agricultural studies. The experimental wetlands were excavated in 1993 and water was introduced using a controllable pump system beginning in March 1994 (Mitsch et al., 1998, 2005, 2012). The two wetlands are identical in initial morphology and in hydrologic inflow except the western wetland (W1) was planted with 13 native macrophyte species in 1994 while the eastern wetland (W2) was left unplanted (Mitsch et al., 1998, 2005, 2012). Pumps draw water from the Olentangy River to the wetlands, and the pumping rate is adjusted several times per week based on a flow *vs.* river stage relationship. The Olentangy River is influenced by urban and agriculture runoff and stream flow, and by the retention and discharge of the Delaware Dam located approximately 42 km upstream of the ORWRP.

Sample sites included permanently flooded open water sites with little to no floating or submerged aquatic plants, partially flooded transitional zones dominated by emergent plants, and dry upland sites dominated by trees and herbs (Fig. 1). Each site was sampled in duplicate for each method. The sample site placement tested the methods across a water level gradient, and between emergent vegetation verse open water. Sampling over seasons allowed us to compare methods across a hydrologic and temperature gradient, and to estimate annual methane fluxes. The side-by-side comparison of each method allowed us to evaluate the legitimacy of comparing or combining results from separate studies with separate methods.

2.2. Chamber design

The two methods used in this study will be called the PVC frame/bag (bag) (Altor and Mitsch, 2006, 2008; Nahlik and Mitsch, 2010, 2011a, 2011b) and the rigid plastic chamber (rigid) (Sha et al. (2011) (Fig. 2). Sha et al. (2011) used the rigid method to reduce small volume variability the bag method inherently had from construction imperfections and flexing due to wind. Also the rigid chamber method is more manageable, and thought less likely to be compromised with holes or failed taped corners. There are two designs for each method, one a permanent installed base for sites with <15 cm of standing water, and the other a floating design for sites >15 cm of standing water.

The frame method at both the partially flooded transition site (<15 cm) and upland sites used a 53 cm × 37 cm (0.20 m^2) rectangular HDPE (high density polyethylene) base open both on the top and bottom. The bottom was permanently sunk approximately 10 cm into the soil. A polyvinyl chloride (PVC) frame with the same basal dimensions as the HDPE base with 120 cm PVC legs was placed just inside the HDPE base and permanently inserted into the soil approximately 2–3 cm for stability. The total volume was approximately 0.24 m^3, although changes in waters level affected volume calculations. A thermometer was hung from the top of the PVC frame using a metal hook. Chamber temperature is needed to calculate gas density, and the chamber acts as a greenhouse slowly increasing temperature during daytime sampling periods. A thick clear plastic bag was cut and taped to the same dimensions of the PVC frame, and fitted with a gray butyl seal and a 3 m vent of 1.6 mm (i.d.) Tygon tubing. At the time of sampling the bag was slid over the PVC frame, and tied closed at the base with a 3-cm elastic tie to create a seal.

For open water sites with water depths >15 cm a framed floating chamber was used that was otherwise similar to the framed chambers described above. A cubed (40 cm × 40 cm × 40 cm) chamber with a surface area of 0.16 m^2 and volume of 0.07 m^3 was constructed with PVC pipe. The same material used for the plastic bag in shallow water sites was fitted permanently to the cubed frame along with a butyl seal and vent. One-inch (2.5-cm) pipe foam insulation was fitted on the bottom of the frame allowing the frame to float on the surface of the water. The effective surface area was only 0.12 m^2. The only change to the previous studies was fully extending the foam around the basal corners of the frame, and fully sealing the foam with duct tape. This prevented the foam saturating with water and tipping the chamber, which previously was a problem. A string was attached to the chamber so it could be tethered during windy conditions.

The rigid chamber method at both the shallow water (<15 cm) and upland sites used a rectangular HDPE (high density polyethylene) base open both on the top (57 cm × 41 cm) and bottom (55.5 cm × 39.5 cm) for an approximate basal area of 0.21 m^2. The bottom was permanently sunk approximately 10 cm into the soil, giving the chamber an approximate volume of 0.08 m^3. Another HDPE container was used to cap the sunken base with an identical open base but with a closed top of 46 cm × 30 cm fitted with a butyl seal, a 3-m vent of 1.6 mm (i.d.) Tygon tubing, and a thermometer taped to the ceiling. A 1-cm foam insulation strip covered in duct tape was placed along the edge of the base of the top container. At the time of sampling petroleum jelly (Vaseline, Unilever) was spread across the duct taped foam insulation bottom of the cap and secured to the base with six 2.5-cm paper clamps. The air tight seal was so strong care had to be taken not pull the permanent base out of the ground when removing the cap after sampling due to the suction created by the seal. With water depths >15 cm, a rigid floating chamber was used. The floating chamber is identical to the cap used to seal the permanent bases for shallow water sites except it was fitted with 2–5-cm pipe insulation covered with duct tape for buoyancy. The approximate volume of the chamber design is 0.06 m^3. A string was attached to the chamber so it could be tethered during windy conditions.