JOURNAL OF ENVIRONMENTAL SCIENCES XX (2016) XXX–XXX

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/jes

JES JOURNAL OF ENVIRONMENTAL SCIENCES

www.jesc.ac.cn

Response of gaseous carbon emissions to low-level salinity increase in tidal marsh ecosystem of the Min River estuary, southeastern China

Minjie Hu[1,2,3], *Hongchang Ren*[1,2,3], *Peng Ren*[1,2,3], *Jiabing Li*[1,4], *Benjamin J. Wilson*[5,*], *Chuan Tong*[1,2,3,*]

1. *School of Geographical Sciences, Fujian Normal University, Fuzhou 350007, China. E-mail:* mjhu0014@163.com
2. *Key Laboratory of Humid Sub-tropical Eco-geographical Process of Ministry of Education, Fujian Normal University, Fuzhou 350007, China*
3. *Research Centre of Wetlands in Subtropical Region, Fujian Normal University, Fuzhou 350007, China*
4. *School of Environmental Sciences, Fujian Normal University, Fuzhou 350007, China*
5. *Department of Biological Sciences, Florida International University, Miami, FL 33199, USA*

ARTICLE INFO

Article history:
Received 17 January 2016
Revised 19 May 2016
Accepted 20 May 2016
Available online xxxx

Keywords:
Greenhouse gases
Salinity gradient
Global warming
Tidal marsh
Min River estuary

ABSTRACT

Although estuarine tidal marshes are important contributors to the emission of greenhouse gases into the atmosphere, the relationship between carbon dioxide (CO_2), methane (CH_4) emission, and environmental factors, with respect to estuarine marshes, has not been clarified thoroughly. This study investigated the crucial factors controlling the emission of CO_2 and CH_4 from a freshwater marsh and a brackish marsh located in a subtropical estuary in southeastern China, as well as their magnitude. The duration of the study period was November 2013 to October 2014. Relevant to both the field and incubation experiments, the CO_2 and CH_4 emissions from the two marshes showed pronounced seasonal variations. The CO_2 and CH_4 emissions from both marshes demonstrated significant positive correlations with the air/soil temperature ($p < 0.01$), but negative correlations with the soil electrical conductivity and the pore water/tide water Cl^- and SO_4^{2-} ($p < 0.01$). The results indicate no significant difference in the CO_2 emissions between the freshwater and brackish marshes in the subtropical estuary, whereas there was a difference in the CH_4 emissions between the two sites ($p < 0.01$). Although future sea-level rise and saltwater intrusion could reduce the CH_4 emissions from the estuarine freshwater marshes, these factors had little effect on the CO_2 emissions with respect to an increase in salinity of less than 5‰. The findings of this study could have important implications for estimating the global warming contributions of estuarine marshes along differing salinity gradients.

Introduction

Carbon dioxide (CO_2) and methane (CH_4) are significant active greenhouse gases (GHGs) that contribute to the warming of the surface of the Earth. Therefore, it is essential to measure the GHG emissions from the major ecosystems to estimate their effect on global warming (IPCC, 2013). The coastal and estuarine marsh ecosystems have relatively high net primary productivity and have been recognized as important contributors to GHG emissions (Magenheimer et al., 1996; Middelburg et al., 2002; Tong et al., 2014). Considerable efforts have been made to quantify the CO_2 and CH_4 emissions from tidal

* *Corresponding authors.*
E-mail addresses: mjhu0014@163.com (M. Hu), bwils034@fiu.edu (B.J. Wilson), tongch@fjnu.edu.cn (C. Tong).

http://dx.doi.org/10.1016/j.jes.2016.05.009
1001-0742/

freshwater and brackish marshes, as well as salt marshes (Van der Nat and Middelburg, 2000; Avery et al., 2003; Hirota et al., 2007; Bastviken et al., 2011), including those in wetlands along salinity gradients in estuarine areas (DeLaune et al., 1983; Smith et al., 1983; Bartlett et al., 1987; Nyman and DeLaune, 1991; Poffenbarger et al., 2011; Weston et al., 2014; Wilson et al., 2015). In general, wetlands are important ecosystems for carbon storage because of the high productivity and low decomposition rates. The decomposition rates (gaseous efflux) are of more concern in subtropical estuarine areas, where large quantities of gaseous carbon (CO_2 and CH_4) are produced and emitted into the atmosphere. These large emissions are ascribed to the warmer conditions and much longer growing seasons in such environments (Turetsky et al., 2014). However, in China, few studies have measured simultaneously the emissions of CO_2 and CH_4 from freshwater and brackish marshes, especially from those situated in subtropical estuaries. To predict the future atmospheric CO_2 and CH_4 concentrations, accurate estimations of such emissions from subtropical estuarine ecosystems are required. Furthermore, most previous studies have focused on the plant communities of *Phragmites australis* and *Spartina alterniflora*, whereas scant attention has been paid to *Cyperus malaccensis*, a native species that is widely distributed throughout the southeastern coastal region of China.

Salinity is an important driving force of ecosystem processes in estuarine areas, especially of CO_2 and CH_4 production and emission. It is generally acknowledged that coastal salt marshes have high concentrations of sulfate (SO_4^{2-}). The presence of SO_4^{2-} in marsh soils is conducive to sulfate-reducing bacteria (SRB) that outcompete methanogens for energy sources, consequently inhibiting methane production (Bartlett et al., 1987; Middelburg et al., 2002). Considerable efforts have been made to investigate the relationship between CO_2 and CH_4 emissions and the salinity in different coastal marsh ecosystems. In Chesapeake Bay, Virginia (USA), the annual atmospheric CH_4 emission was indicated as 5.6 g/(m^2 year) at the most saline site, 22.4 g/(m^2·year) at an intermediate saline site, and 18.2 g/(m^2·year) at the least saline site (Bartlett et al., 1987). Poffenbarger et al. (2011) have concluded that CH_4 emission from freshwater tidal wetlands (salinity range 0‰–0.5‰) was greater than that from mesohaline marshes (salinity range 5‰–18‰), although the difference was non-significant. Smith et al. (1983) found that the CO_2 emissions were highest (618 g/(m^2·year)) from a freshwater marsh, lowest (180 g/(m^2·year)) in a brackish marsh, and that a salt marsh demonstrated intermediate CO_2 emission (418 g/(m^2·year)). In addition, Nyman and DeLaune (1991) found that the CO_2 emissions from brackish and salt marshes were lower than those from freshwater marshes. Wilson et al. (2015) found no significant differences in the CH_4 emissions across the sites despite the salinity differences; however, the net CO_2 emission was highest at the freshwater site, followed by the saline and brackish sites. Consequently, gaseous carbon emissions from estuarine marsh ecosystems are likely to be affected by the soil salinity. However, the relationship between salinity and gaseous carbon emissions remains unclear, especially in subtropical estuarine marshes. This subject is particularly important in the context of sea-level rise and saltwater intrusion.

The Min River estuary has a long macrotidal course, with the extent of the saltwater intrusion upstream affecting the compositional character of the marshes. Despite the large variation in marsh types, research on GHG emissions from freshwater and tidal marshes is lacking. Therefore, the current study was undertaken to compare the spatiotemporal variations in CO_2 and CH_4 emissions from a freshwater *C. malaccensis* marsh and a brackish *C. malaccensis* marsh in the Min River estuary, southeastern China. The primary objectives of this study were (1) to establish whether there were significant differences in CO_2 and CH_4 emissions from tidal marshes within a relatively narrow salinity range, and (2) to quantify the relationship between CO_2 and CH_4 emissions, salinity, and other environmental factors in subtropical estuarine marshes.

1. Materials and methods

1.1. Site description

This study was conducted in the Min River estuary area, southeastern China. The climate of the area is defined as warm and wet, with an annual mean temperature of 19.85°C and precipitation of 1905 mm. The main vegetation types include the native species *C. malaccensis* and *P. australis*, and the invasive species *S. alterniflora* (Tong et al., 2012). To study the effect of low-level salinity increase on greenhouse gas emissions in tidal wetlands, two marshes, approximately 28 km apart, were selected as the freshwater and brackish marshes (Fig. 1). The brackish site (26°01′46″N, 119°37′31″E), located at the mouth of the Min River estuary, is affected by tidal saltwater intrusion, with a monthly average salinity of 3.79‰ ± 1.35‰. The entire freshwater site (25°57′21″N, 119°24′25″E) has freshwater throughout the year, with an average salinity of 0.20‰ ± 0.02‰. The maximum height of *C. malaccensis* in the two marshes is approximately 1.3 m.

At each marsh site, on a line parallel with the coastline or riverline, four sampling plots (four replicates) were established at intervals of 3 m in the selected freshwater and brackish marshes. The sites exhibited uniform characteristics relevant to vegetation, soil, and hydrology. At both sites, the tides were semidiurnal over a 24-hr cycle. At the brackish marsh site, the average total duration of the two submerged periods of tidal flooding and ebbing during the day and night was approximately 7 hr. The duration of both the exposed-before tidal inundation and the exposed-after tidal inundation periods was 8.5 hr, respectively. Normally, there was between 20 and 150 cm of tidal water above the soil surface at high tide (Tong et al., 2014). However, at low tide, the soil surfaces of both marshes were completely exposed. The physical and chemical properties of the soil, from 0–15 cm deep in the two sampled marshes, are shown in Table 1.

1.2. Gas sampling

The enclosed opaque static chamber technique (Magenheimer et al., 1996; Hirota et al., 2004; Tong et al., 2012; Datta et al., 2013) was used to measure simultaneously the CO_2 and CH_4 emissions from the two marshes. In this study, the sampling chambers comprised two parts, namely, a stainless steel bottom collar (35 cm × 35 cm × 30 cm) and a polyvinyl chloride