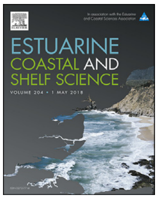
Estuarine, Coastal and Shelf Science 204 (2018) 202–211

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss



Comprehensive effects of a sedge plant on CH_4 and N_2O emissions in an estuarine marsh

Yangjie Li [a, b], Dongqi Wang [b, *], Zhenlou Chen [b], Hong Hu [b]

[a] Key Laboratory of Marine Ecosystem and Biogeochemistry of State Ocean Administration, Second Institute of Oceanography, State Ocean Administration, Hangzhou 310012, China
[b] School of Geographic Sciences, East China Normal University, Shanghai 200241, China

ARTICLE INFO

Article history:
Received 14 November 2017
Received in revised form
24 February 2018
Accepted 5 March 2018
Available online 7 March 2018

Keywords:
Brackish marsh
Blue carbon
Methane emission
Nitrous oxide absorption
Nitrous oxide consumption

ABSTRACT

Although there have been numerous studies focusing on plants' roles in methane (CH_4) emissions, the influencing mechanism of wetland plants on nitrous oxide (N_2O) emissions has rarely been studied. Here, we test whether wetland plants also play an important role in N_2O emissions. Gas fluxes were determined using the in situ static flux chamber technique. We also carried out pore-water extractions, sedge removal experiments and tests of N_2O transportation. The brackish marsh acted as a net source of both CH_4 and N_2O. However, sedge plants played the opposite role in CH_4 and N_2O emissions. The removal of the sedges led to reduced CH_4 emissions and increased accumulation of CH_4 inside the sediment. Apart from being a conduit for CH_4 transport, the sedges made a greater contribution to CH_4 oxidation than CH_4 production. The sedges exerted inhibitory effects on the release of N_2O. The N_2O was barely detectable inside the sediment in both vegetated and vegetation-removed plots. The denitrification measurements and nitrogen addition (the addition rates were equal to 0.028, 0.056 and 0.112 $g\,m^{-2}$) experiments suggest that denitrification associated with N_2O production occurred mainly in the surface sediment layer. The vascular sedge could transport atmospheric N_2O downward into the rhizosphere. The rhizospheric sediment, together with the vascular sedge, became an effective sink of atmospheric N_2O.

1. Introduction

Methane (CH_4) and nitrous oxide (N_2O) are important greenhouse gases (GHG) that contribute to global warming by 20% and 6%, respectively (Forster et al., 2007). The present global CH_4 and N_2O concentrations in the atmosphere are 1803 ppb and 324 ppb, respectively (IPCC, 2013). Minor variations in these trace GHG can exert significant influences on global warming due to the significant impact of the gases on the atmospheric radiation balance. Methane is 28–34 times and N_2O is 265–298 times more potent than CO_2 as a GHG over a 100-year period (IPCC, 2013). Wetlands can store carbon in the long-term due to their wetter conditions (Yang et al., 2017). However, the anaerobic underground environment of wetlands, caused by prolonged waterlogging, unavoidably leads to the emissions of GHG (George et al., 2015). Wetlands are considered to be the largest and second largest natural source of CH_4 and N_2O, respectively (Denman et al., 2007).

The estuarine marsh is one of the most important wetland types for understanding GHG dynamics due to the high spatio-temporal variations involved with water conditions, sedimentation characteristics, astronomic tidal fluctuations and vegetation types (Sun et al., 2013). The intertidal zones between terrestrial and aquatic coastal ecosystems are considered to be important sources of CH_4 and N_2O. Thus, they are important from a global climate change perspective (Hirota et al., 2007). The net CH_4 and N_2O fluxes from estuarine wetlands are the results of production, consumption and transportation of gases from both the reduced and oxic zone to the atmosphere (Lai, 2009; Butterbach-Bahl et al., 2013). Considerable efforts have been made to investigate the CH_4 fluxes and key controlling factors (such as water table, temperature, vegetation, salinity, sulfate concentration, substrate availability for methanogens and redox condition) in different natural wetland ecosystems (Allen et al., 2007; Ganguly et al., 2008; Pennock et al., 2010; Danevčič et al., 2010; Sun et al., 2013; Chen et al., 2016). Despite being an important byproduct of nitrogen cycles, which are also widespread in estuarine wetlands, N_2O dynamics and emission mechanisms, especially in the vegetated marshes, have been rarely

---

* Corresponding author. School of Geographic Sciences, East China Normal University, Shanghai, 500 Dongchuan Road, Shanghai 200241, China.
E-mail address: dqwang@geo.ecnu.edu.cn (D. Wang).

https://doi.org/10.1016/j.ecss.2018.03.008
0272-7714/

studied. Most studies show that wetland plants prove to be the dominant regulators of CH_4 emissions in vegetated marshes and often act as net promoters of global warming, if the effects of CH_4 oxidation, providing fresh organic carbon for CH_4 production and the transportation effects on CH_4 emissions, are considered (Baruah et al., 2010; Koebsch et al., 2013). However, this conclusion was not considered for the more radiative N_2O. Although the N_2O production mechanism and emission fluxes in soil or sediment have been identified by many studies (Song et al., 2009; Stewart et al., 2012; Philippot et al., 2011; Morley and Baggs, 2010), the presence of wetland plants adds a large degree of uncertainty to N_2O emissions. To obtain accurate estimates of the contribution of wetland plants to global warming, the effects of plants on CO_2, CH_4 and N_2O should all be taken into consideration.

The Yangtze Estuary is the third largest estuary in the world and large quantities of sediment are carried to the estuary and deposited there. In the last 40 years, nitrate and soluble reactive phosphorus concentrations increased from 11 to 97 μM and from 0.4 to 0.95 μM, respectively (Chai et al., 2006). Currently, approximately 1.1×10^6 t of inorganic nitrogen is annually transported into the estuary and its adjacent coastal areas (Dai et al., 2010). Chongming Island lies in the middle of the estuary and features well-developed high, middle and low tidal flats, referring to elevation, within the tidal frame. The dominant plants in the high and middle tidal flats are *Phragmites australis* and *Scirpus mariqueter*, respectively. The sedge plant *S. mariqueter* is the endemic wetland plant in Yangtze Estuary and belongs to the Cyperaceae plants. The most active growth period of *S. mariqueter* is May to August. This study was performed to: (1) Identify the fluxes of CH_4 and N_2O across the sediment-atmosphere interface in the most active season of the sedge plant in an estuarine brackish marsh; (2) Explore the mechanism of sedge plant effects on both CH_4 and N_2O emissions through pore-water extraction and an indoor simulation experiment; and (3) Comprehensively quantify the role that the wetland sedge plant plays in global warming based on its influences on both CH_4 and N_2O.

2. Materials and methods

2.1. Study sites

The study was performed in the eastern intertidal zone of Chongming Island in the Yangtze Estuary, which is located in the subtropical monsoon climate zone. The marshes of Chongming Island are the largest and most completely developed wetlands in the Yangtze Estuary, which has approximately 100 km^2 of intertidal lands, composed of high, middle, and low tidal flats. In contrast to the high marsh that is mainly covered by reeds, the sampling site in the lower middle marsh (Fig. 1) is mainly covered by the endemic sedge plant (*S. mariqueter*) and experiences a higher flood frequency due to regular astronomic tidal fluctuations. During the tide movement, the salinity of the tide water emerging in this area exhibited a large variation. It varied from 0.60‰ (July) to 21.1‰ (December) throughout the year (Wang et al., 2009). The wetter conditions are more likely to promote the production and emission of trace gases. The dominant vascular sedge in the middle marshes is a rhizomatous and corm-forming perennial herb (Sun et al., 2002). In general, the underground corm begins to sprout, forming a new shoot, in April, and it grows quickly from May onwards when the temperature and solar radiation significantly increase. The rapid growth period lasts until August when the plant reaches its largest aboveground biomass. Since then, both the aboveground and underground tissues begin to wilt. The aboveground leaves and stems gradually lie down to the sediment surface and are buried by the sediment depositions. Except for the seeds and corm, the rest of the parts of the plants would be decomposed in the anaerobic conditions.

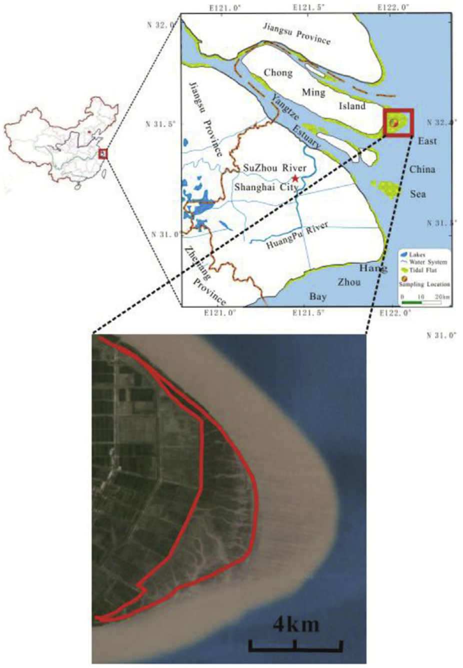


Fig. 1. Map of sampling location. The surrounded area by red lines is the vegetated area, most of which belongs to the middle tidal flat. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

2.2. Gas sampling and flux measurement

Gas sampling campaigns were performed in the middle brackish marsh in the Yangtze Estuary from May to August 2012 using the static closed chamber-chromatography technique (Wang et al., 2009). For each sampling campaign, measurements were taken at 6:00, 7:30, 9:00, 10:30, 12:00, 13:30,15:00 and 17:00 (Beijing standard time) when the sediment was exposed during neap tide. Each sampling campaign consisted of six chambers, which could be divided into two groups. The triplicate chambers of the first group were used to collect the gas samples in vegetated plots. The triplicate chambers of the second group were used to collect gas samples in the sedge-removed plots. The sedge removal was performed very carefully in early April when the sedge was still in the bud, and the uprooting treatment caused very little disturbance to the sediment. The sediment condition can fully recover from the little disturbance caused by the bud uprooting. Thus, the artificial and physical disturbances to the sediment condition were minimized.

On a sampling day, we first inserted stainless-steel collars into the sediment to a depth of 15 cm. Then, transparent Perspex cylinders that were 3 mm thick (50 cm net height × 30 cm ID) were placed on the corresponding notched collars, and an airtight closure was ensured by water sealing. Small electric fans and kerosene thermometers were fixed inside the chambers (Wang et al., 2009; Sun et al., 2013). The fans were used to mix the air in the chamber, and the thermometers were used to measure the final temperature of the chambers. Additionally, a balance pipe was used to equalize the inner-outer air pressure. Every chamber was connected to a polyethylene pipe via a clinical three-way valve on the top of the chamber for sampling. All the connections and gaps were sealed with silicone gel to keep the chambers airtight. Immediately