Proceedings of the International Symposium on Conservation and Eco-friendly Utilization of Wetland in the Three Gorges Reservoir

Study on CO_2 Emission from Newly Created Marshes of Pengxi River in the Three Gorges Reservoir*

WU Yu-yuan[1,2], CHEN Huai[3], LIN Fang-miao[1,2], YUAN Xing-zhong[1,2]

(1. College of Resources and Environment, Chongqing University, Chongqing 400030; 2. Key laboratory of Southwest Resources Exploitation and Environmental Disaster Controlling Project of Educational Ministry, Chongqing University, Chongqing 400030; 3. College of Forestry, Northwest A & F University Yangling Shanxi 712100, China)

Abstract: From early July to late September 2008, we studied CO_2 emissions from 4 different stands in newly created marshes of the Pengxi River, using static opaque chamber-GC techniques. The results showed high spatial variation of CO_2 emissions among the four stands. The greatest CO_2 emission (627.8 ± 335.9 mg · m^{-2} · h^{-1}) was observed in the *Scirpus triqueter* stand. The smallest CO_2 emission (450.4 ± 271.5 mg · m^{-2} · h^{-1}) was observed in the *Juncus amuricus* stand. Standing water depths and above-ground biomass were important factors in explaining these spatial variations in CO_2 emissions. We also found a typical seasonal variation of CO_2 emissions in this area, with maximal emissions ranging from mid-July to mid-August. The seasonality of CO_2 emissions in the newly created marshes was found to be closely related to water temperature and soil temperature ($r = 0.577$, 0.557 (5 cm), $p < 0.001$).

Key words: carbon dioxide emission; newly created marshes; Pengxi River; Three Gorges Reservoir

Chinese Library Classification: X171 **Document Code**: A **Article ID**: 1672-6693(2012)03-0176-05

After the Industrial Revolution, radiative forcing of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrogenous oxide (N_2O) have increased in an unprecedented manner, and information about ancient climates has further demonstrated that climate warming during the most recent 50 years is the most abnormal climate event within the last 1300 years[1]. CO_2 is an important greenhouse gas and its concentration in the atmosphere has increased from 270 ~ 280 ppm (before the Industrial Revolution) to 379 ppm currently, an increase of 36 %[1]. In climate change studies, the sources and sinks of CO_2 have been thought of as "keystones" and "hotspots". Reservoirs were listed as one of the relevant types of land use change by the IPCC[1], but there have been relatively few studies about CO_2 emission from reservoirs. Recently, though, some studies have addressed the importance of mitigating GHGs from reservoirs[2-3]. Researchers have paid attention to CO_2 emissions from reservoir surfaces, turbines and spillways[4-6], but have ignored those from drawdown areas (littoral zones, especially wetlands) of dammed lakes during periods when the water recedes. In recent years, riparian zones of rivers and littoral zones of lakes have been recognized as being important as regions of biogeochemical transformation in the landscape. GHG emissions from these regions, and the associated biological mecha-

* **Received**: 03-02-2012

Foundation: Agricultural Fund Project from the Ministry of Science and Technohgy (No. 2011 GB2F100010); Key Science and Technology programe of Chongqing (No. cstc201120002)

First author biography: WU Yu-yuan, male, graduate student, engaged in researches of environment ecology and biogeochemistry; **Corresponding author**: YUAN Xing-zhong, E-mail: xzyuan63@yahoo.com.cn

nisms, have gradually become of concern [7-10]. Similarly, GHG emissions from the drawdown areas of reservoirs (especially the wetlands) are also important, though rarely studied.

This study is aimed at: 1) understanding spatial and temporal variation of CO_2 emissions during the growing season from the littoral marshes of the Pengxi River (PR) in the Three Gorges Reservoir (TGR), and 2) determining the factors that contribute to the spatio-temporal variation of CO_2 emissions during the growing season.

1 Methods and Materials

1.1 Study sites

The study was conducted in the PR Wetland Reserve (31°5′37.74″ ~ 31°12′30.26″N, 108°27′45.05″ ~ 108°27′0.05″E), which covers a total area of 36.9 km^2, with 1920 ha of littoral wetlands along the TGR. The PR is one of many secondary branches of the Yangtze River in the Three Gorges Reservoir Region (TGRR). A typical gully marsh was chosen for this study. Four different kinds of wetland plant stands (Tab. 1) had formed there, namely stands of: *Juncus amuricus*, *Typha angustifolia*, *Scirpus triqueter* and *Paspalum distichum*.

1.2 Environmental factors and other sampling

Plant heights, Redox potentials, air temperatures, water temperatures, ground surface temperatures, soil temperatures at depths of 5 and 10 cm, and standing water depths in each stand were recorded, with six replicates on each sampling day. Soil samples were collected at 10 cm soil depth in July, August and September. The total carbon content (TC), total nitrogen content (TN), and total phosphorus content (TP) of soil samples were analyzed according to standard soil chemical methods (Soil Science Society of China).

Tab. 1 Selected plant stands, dominant species of each stand, their standing water depth and aboveground biomass

Plant Stands	Dominant Species	Water Depth/cm	Aboveground Biomass /(g · DW · m^{-2})
Juncus amuricus stand	*Juncus amuricus*	2.2 (0 ~ 7)	288
Typha angustifolia stand	*Typha angustifolia*	3.5 (0.5 ~ 8)	323
Scirpus triqueter stand	*Scirpus triqueter*	8.7 (0 ~ 21)	387
Paspalum distichum stand	*Paspalum distichum*	3.8 (0 ~ 19)	515

1.3 Establishment of sampling plots and CO_2 emission measurements

To minimize disturbance to the marsh, we installed boardwalks in the sampling area. For each plant stand, six plots were established along such boardwalks where CO_2 emissions were measured at 10-day intervals from July to September. Samples were taken at 09:00, Beijing standard time (GMT+8). CO_2 emissions were measured with vented static chambers. Four air samples from each chamber were taken at 10 minute intervals over a 30 minute period after enclosure, and stored in 5 mL air-tight vacuumed vials. The CO_2 concentration was determined by gas chromatography.

The flux J of N_2O was calculated as

$$J = \frac{dc}{dt} \cdot \frac{M}{V_0} \cdot \frac{T_0}{T} \cdot H$$

Where dc/dt is the rate of change of concentration; M is the molar mass of CO_2; P is the atmospheric pressure of the sampling site; T is the absolute temperature at the sampling time; V_0, P_0, T_0 are the molar volume, atmospheric pressure, and absolute temperature, respectively, under the standard condition; and H is the chamber height over the water surface. We accepted the flux data when there was a good linear regression between flux and time ($R^2 \geqslant 0.95$).

2 Results

2.1 Spatial variations in CO_2 emissions from the newly created marshes

The mean CO_2 emission rate of newly created marshes of *PR* was 538.4 ± 324.4 mg · m^{-2} · h^{-1} in the growing season of 2008, which is lower than that of a freshwater marsh of the Sanjiang Plain (range 779.33 to 65.4 mg · m^{-2} · h^{-1})[11] and higher than that of a peatland in the Zoige Plateau 203.22 mg · m^{-2} · h^{-1}[12]. The results showed high spatial variability of CO_2 emissions among the four stands (Fig. 1, Tab. 2). The greatest CO_2 emissions 627.8 ± 335.9 mg · m^{-2} · h^{-1} were from the *Scirpus triqueter* stand. The *Juncus amuricus* stand recorded the lowest CO_2 emissions (450.4 ± 271.5 mg · m^{-2} · h^{-1}). Intermediate CO_2 emissions coming from the *Paspalum distichum* stand and the *Typha angustifolia* stand were 616.3 ± 344.7 mg · m^{-2} · h^{-1} and 459.5 ± 304.7 mg · m^{-2} · h^{-1}, respectively.

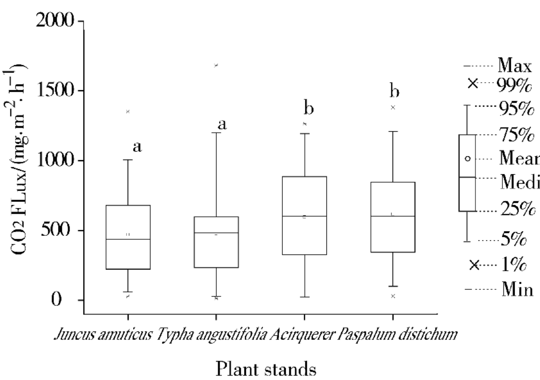

Fig. 1 CO_2 emissions in different plant stands from July to September, 2008

Tab. 2 Significance of impacts of stand type, season, and their combined effect on CO_2 emission and environmental factors in growing season

	Stand Type	Season	Combined Effect
CO_2 emission /(mg · m^{-2} · h^{-1})	*	*	ns
Air temperature / ℃	* *	* *	* *
5 cm soil temperature / ℃	* *	* *	* *
10 cm soil temperature / ℃	* *	* *	* *
The standing water depth / cm	* *	* *	* *
Plant height / cm	* *	ns	* *
Soil water content / %	* *	ns	* *
C-total / (g · kg^{-1})	* *	ns	* *
N-total / (g · kg^{-1})	* *	ns	* *
P-total / (g · kg^{-1})	*	ns	ns
DOC / (mg · kg^{-1})	* *	* *	* *
NO_3^-/ (mg · kg^{-1})	* *	* *	* *
NH_4^+/ (mg · kg^{-1})	* *	ns	* *

* $\alpha<0.05$, * * $\alpha<0.01$; ns, no significant impact.

2.2 Seasonal variations in CO_2 emissions from the newly created marshes

Significant seasonal variation of CO_2 emissions were found during the growing season in our study (Fig. 2), with maximal emissions ranging from mid-July to mid-August. There were similar seasonal patterns of CO_2 emissions in each of the four different kinds of wetland plant stands.

3 Discussion

CO_2 emissions as measured here using the static opaque chamber method are caused by total ecosystem respiration, including the respiration of vegetation, roots and soil microorganisms [13]. The high level of ecosystem respiration is partly related to the subtropical climate of the site, as well as the effects of the special condition of periodic transition between terrestrial and aquatic ecosystems. Research conducted on ecosystems of the Sanjiang Plain and Qinghai-Tibet Plateau [11-12, 14] found that wetland ecosystem respiration was lower than that of its terrestrial counterparts. We think that ecosystem respiration in the marshes of PR may, however, be similar to its terrestrial ecosystem counterparts because of the similar physical-chemical characteristics of the soils of the two systems. Thus the high ecosystem respiration in the marshes of PR appears to play a unique and significant role in the regional carbon cycle and related dynamic processes.

In this study we found that marshes with higher standing water depths (*Scirpus triqueter* stand and *Paspalum distichum* stand) emitted more CO_2 than marshes with lower depths of standing water (*Juncus amuricus* stand and *Typha angustifolia* stand), which differs from results of other studies. We similarly found that both soil water content and standing water depth influenced spatial variations of CO_2 emissions when the soil water content ranged widely. However, when soil water content is comparatively abundant, it will not be an important factor controlling the process of soil respiration [15-16]. Our results also showed that there were higher CO_2 emissions in the *Scirpus triqueter* stand and the *Paspalum distichum* stand, when above-ground biomass was higher, and lower CO_2 emissions in the *Juncus amuricus* stand and the *Typha angustifolia stand which had less above-ground biomass. Therefore, we understand that respiration of above-ground* biomass is also a factor influencing spatial variations of CO_2 emissions in the marshes of PR [17], indicating that ecological factors correlated with plant respiration [18] may explain variations of CO_2 emissions among different plant stands.

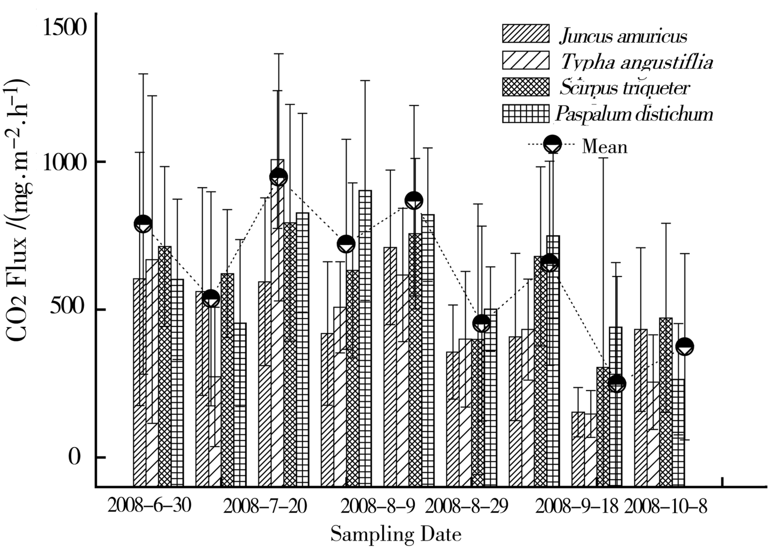

Fig. 2 Seasonal variation of CO_2 fluxes from July to September, 2008

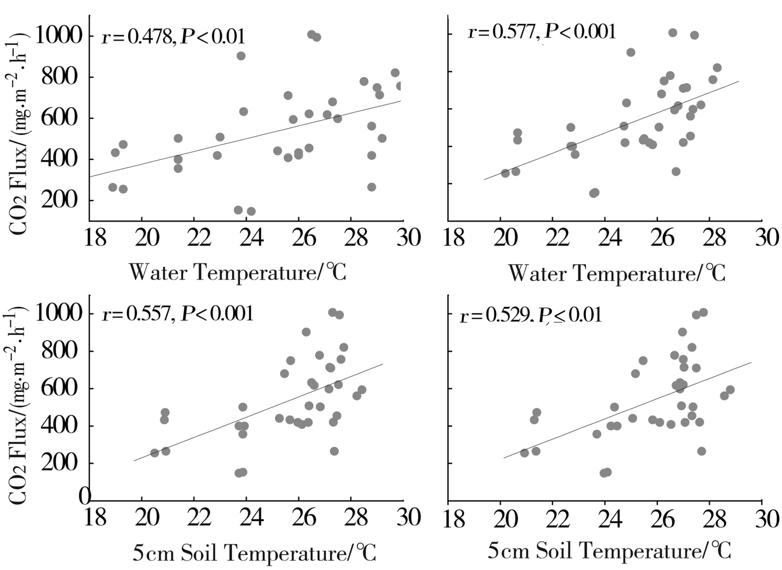

Fig. 3 The relation between CO_2 fluxes and air , water and soil temperatures

The seasonal pattern of CO_2 emissions which we found was similar to those reported for natural marshes, including alpine wetlands in the Qinghai-Tibet Plateau [12, 14, 19-20], the plain wetlands in Sanjiang [11, 17], and others, with peak emissions being recorded in the peak growing season. Seasonal variations of temperature may explain these variations in CO_2 emissions [11, 19]. Like many other studies, the present study also showed a positive correlation between CO_2 emissions and temperature. Moreover, the seasonality of CO_2 emissions was found to be closely related to water temperatures and soil temperatures at 5 cm depths (Tab. 2, Fig. 3). Therefore, the seasonality of CO_2 emissions in the marshes of PR can probably be explained by the seasonal variation in ground water and soil temperatures. Continuing studies will delve more deeply into this subject in order to better understand the factors that influence CO_2 emissions in the marshes of the TGR drawdown zones.

References:

[1] IPCC. Summary for Policymakers, in Climate Change 2007: The Physical Science Basis [M]. Cambridge: Cambridge University Press, 2007.

[2] Abril G, Guerin F, Richard S, et al. Carbon dioxide and methane emissions and the carbon budget of a 10-year old tropical reservoir (Petit Saut, French Guiana) [J]. Global Biogeochemical Cycles, 2005, 19: GB40074.

[3] Giles J. Methane quashes green credentials of hydropower [J]. Nature, 2006, 444(7119): 524-525.

[4] Guerin F, Abril G, Richard S, et al. Methane and carbon dioxide emissions from tropical reservoirs: Significance of downstream rivers [J]. Geophysical Research Letters, 2006, 33: L2140721.

[5] Fearnside P M. Greenhouse gas emissions from a hydroelectric reservoir (Brazil's Tucurui Dam) and the energy policy implications[J]. Water, Air and Soil Pollution, 2002, 133(1-4): 69-96.

[6] Fearnside P M. Do hydroelectric dams mitigate global warming? The case of Brazil's Curua-Una Dam[J]. Mitigation and Adaptation Strategies for Global Change, 2005, 10(4): 675-691.

[7] Hefting M M, Bobbink R, de Caluwe H. Nitrous oxide emission and denitrification in chronically nitrate-loaded riparian buffer zones[J]. Journal of Environment Quality, 2003, 32(4): 1194-1203.

[8] Huttunen J T, Alm J, Liikanen A, et al. Fluxes of methane, carbon dioxide and nitrous oxide in boreal lakes and potential anthropogenic effects on the aquatic greenhouse gas emissions[J]. Chemosphere, 2003, 52(3): 609-621.

[9] van den Heuvel R N, Hefting M M, Tan N, et al. N_2O emission hotspots at different spatial scales and governing factors for small scale hotspots B-8834-2011 B-9514-2011[J]. Science of the Total Environment, 2009, 407(7): 2325-2332.

[10] Wang H J, Wang W D, Yin C Q, et al. Littoral zones as the "hotspots" of nitrous oxide (N_2O) emission in a hyper-eutrophic lake in China[J]. Atmospheric Environment, 2006, 40(28): 5522-5527.

[11] Song C C, Zhang L Y, Wang Y Y, et al. Annual dynamics of CO_2, CH_4, N_2O emissions from ereshwater marshes and affected by nitrogen fertilization[J]. Chinese Journal of Environmental Science, 2006, 27(12): 2369-2375.

[12] Wang D X, Song C C, Wang Y Y, et al. CO_2 fluxes in mire and grassland on Zoige Plateau[J]. Chinese Journal of Applied Ecology, 2008, 19(2): 285-289.

[13] Turetsky M R, Wieder R K, Vitt D H. Boreal peatland C fluxes under varying permafrost regimes[J]. Soil Biology and Biochemistry, 2002, 34(7): 907-912.

[14] Wang D X, Song C C, Wang Y S, et al. Carbon dioxide flux from peat mire in Ruoergai plateau[J]. Ecology and Environment, 2005, 14(6): 880-883.

[15] Soegaard H, Nordstroem C. Carbon dioxide exchange in a high-arctic fen estimated by eddy covariance measurements and modelling[J]. Global Change Biology, 1999, 5(5): 547-562.

[16] Li Z F, Li X G, Yang Q, et al. Soil surface CO_2 fluxes of deyeuxia angustifolia wetland in sanjiang plain[J]. Journal of Nanjing Forestry University (Natural Science Edition), 2003, 27(3): 51-54.

[17] Lu Y, Song C C, Wang Y Y, et al. Influence of plants on CO_2 and CH4 emission in wetland ecosystem[J]. Acta Botanica Boreali-Occidentalia Sinica, 2007, 27(11): 2306-2313.

[18] Sun W J, Huang Y, Chen S T, et al. CO_2 Emission from soil-crop system as influenced by crop growth and tissue N content[J]. Chinese Journal of Environmental Science, 2004, 25(3): 1-6.

[19] Wang J F, Wang G W, Wang Y B, et al. Effects of degraded alpine meadow and marsh in Qinghai-Tibet Plateau on CO_2 flux during growth season[J]. Chinese Science Bulletin, 2007, 52(13): 1554-1560.

[20] Zhang F W, Liu A H, Li Y N, et al. CO_2 flux in alpine wetland ecosystem on the Qinghai-Tibetan plateau[J]. Acta Ecologica Sinica, 2008, 28(2): 453-462.

(Editors: Martin WILLISON, OU Hong-ye)

(English translator: WU Yu-yuan)