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Distribution and deposition characteristics of carbon and nitrogen in sediments in a semi-closed bay area, southeast China

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ABSTRACT

In this study, we analyzed carbon and nitrogen parameters (e.g., total organic carbon (TOC), total nitrogen (TN), stable isotopes of organic matter ($\delta^{13}C$, $\delta^{15}N$), and carbon–nitrogen ratio (C/N)), grain-size parameters and deposition rate, as well as their variations in the surface layer and on the profile of the sediment cores in various ecological zones of Luoyuan Bay. The results showed that the sedimentary type of Luoyuan Bay was clay silt. The TOC, TN, $\delta^{13}C$, and $\delta^{15}N$ were in the range of 0.450–0.955%, 0.054–0.101%, −23.75 to −19.47‰, and 3.57–6.72‰, respectively; the C/N was in the range of 8.80–13.78. The grain-size parameters of the *Spartina alterniflora* marsh and transition zone were similar, whereas a similarity in the carbon and nitrogen parameters between the transition zone and mudflat was observed. The correlation of TOC and TN was different between the fresh organic matter and the obsolete organic matter. The particle size was not the main factor that controlled the TOC and TN contents in the sediments; the $\delta^{13}C$ indicated the organic matter was dominated by marine sources. The average deposition rates in the *Spartina alterniflora* marsh, transition zone, and mudflat were 2.47, 2.79, 1.16 g cm^{-2} y^{-1}, respectively. In the *Spartina alterniflora* marsh, the TOC and TN content increased by 96% and 104%, respectively, from 1955 to the present. Compared with the mudflat, the TOC and TN content in the layer between the surface and the 40-cm depth of the *Spartina alterniflora* marsh were 26% and 13% higher, respectively. The introduction of *Spartina alterniflora* and the metabolism of their roots had a significant effect on the carbon and nitrogen deposition in the layer at 0–40 cm depth. The carbon sequestration rate of the salt marsh wetland in Luoyuan Bay was comparable to the carbon sequestration of global marshes. The deposition rates of TOC and TN in the *Spartina alterniflora* marsh and transition zone were greater than twice that in the mudflat.

1. Introduction

Bay and salt marshes are the transition zones between sea and land, where human activities are concentrated and active. Due to its resources and environment, the bay has become an important area for the social development of human beings (Doody, 1992). The study of sea–land interaction in bay areas is an international forefront, and relevant studies, such as studies on the response of the ecosystem to human activities, the 'source and sink' of biogenic elements and their biogeochemical cycles, record of depositional environment information, and coupling mechanisms of different ecosystems, are popular research topics (Nittrouer, 1999; Crossland et al., 2005; Gao and Wang, 2008; Sousa et al., 2010). Carbon and nitrogen are the most important nutrient elements for the studies on material circulation and energy flow in the sediment–vegetation system of bay areas (Bouillon et al., 2002; Gao and Jia, 2004; Zhou et al., 2007). Tracking the sources of organic matter using C, N, and S isotopes has been widely explored and applied (Carlson and Forrest, 1982; Peterson et al., 1985; Middelburg and Nieuwenhuize, 1998; Liu et al., 2004; Gao et al., 2005; Zetsche et al., 2011). With the strengthening of studies on carbon and nitrogen cycles, studies on organic carbon stock in coastal salt marsh are receiving more attention (Li et al., 2010; Elsey et al., 2011). The predominant vegetation in a salt marsh plays an important role on the carbon and nitrogen cycle of ecosystems (Degan and Garritt, 1997). After more than 20 years of debate on the positive and negative effects, the community has started to pay more attention to *Spartina alterniflora* vegetation and has recognized its typical dual-sidedness (Qin and Li, 2012). However, the contribution of *Spartina alterniflora* vegetation to organic matter in sediments remains controversial (Vernberg, 1993; Howarth, 1993).

In recent years, studies on carbon and nitrogen in sediments of the estuarine areas of China (Chen et al., 2007;Shang et al., 2009; Dong

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et al., 2010; Tong et al., 2010), open salt marshes (Gao et al., 2007), and harbor-type bay areas (Wang et al., 2007) have been reported. However, there are limited studies on closed bays and beaches (Ye et al., 2013). In this study, using sediments from Luoyuan Bay in Fujian Province as an example, we analyzed the total organic carbon (TOC), total nitrogen (TN), stable carbon and nitrogen isotopes ($\delta^{13}C$, and $\delta^{15}N$), carbon and nitrogen ratio (C/N), and Pb-210 (^{210}Pb) dating in the bay surface sediments and the cores of salt marshes. Furthermore, we conducted compositional analysis on the particle sizes and density of the sediments. Based on the obtained data, we investigated the horizontal distribution characteristics of the carbon and nitrogen elements in the sediments of Luoyuan Bay and the profile variation with depth and time. Moreover, we explored the organic matter source of sediments and its influencing factors. This study attempted to provide a basis for research on carbon and nitrogen cycles and environmental record in salt marshes.

2. Materials and methods

2.1. Overview of the research area

Luoyuan Bay, located in the northeastern coast of Fujian Province, is surrounded by mountains on three sides. The Kemenkou on its northeast corner (approximately 2 km) is connected to the East China Sea, making Luoyuan Bay a typical semi-enclosed bay with a large belly and a small mouth. The shoreline of Luoyuan Bay has an overall length of 79 km, and the sea area is 230 km^2, with the beach area accounting for 62% (Cai and Cai, 1989). Luoyuan Bay has a regular semi-diurnal tide, with an average tidal range of 4.98 m, and the average duration of the rising tide is slightly longer than the ebb tide (Compilatory Committee of Chinese Bays, 1994). Currently, there is no river inflow, and the salt marshes are mainly distributed on the southwest and southern side of the bay. The beach is flat, and the slope is generally less than 0.1%; the width is approximately 2–5 km. The sediments are dominated by clay silt. The sedimentary landform does not have distinct zoning, and the form of micro-topography is uniform; the bay hosts the cultivation of clam, oyster, *Porphyra tenera*, and *laminaria japonica* (Wang et al., 2009). The seawater aquiculture area was 8203 hm^2 (Yu, 2012). In 1980, *Spartina alterniflora* that was successfully grown on a trial basis in the botanical garden of Nanjing University was transplanted to Luoyuan Bay (Qin and Jing, 1985; Xu et al., 1989) and has now formed a large area of *Spartina alterniflora* salt marsh in the middle and upper part of the intertidal zone. From 2000 to 2006, *Spartina alterniflora* increased at an annual growth rate of 11%, and the area increased by 17.7 km^2 (Pan et al., 2009).

2.2. Sample collection

In April 2012, we collected samples in Luoyuan Bay and the salt marshes of Fujian Province, including 83 samples of surface sediments in the bay area and 3 cores from the salt marshes. The sampling sites of the cores, which were distributed at different elevations, included *Spartina alterniflora* marsh A, *Spartina alterniflora*-mudflat transition zone (transition zone) B, and mudflat C. The site locations were indicated in Fig. 1. A clam bucket was

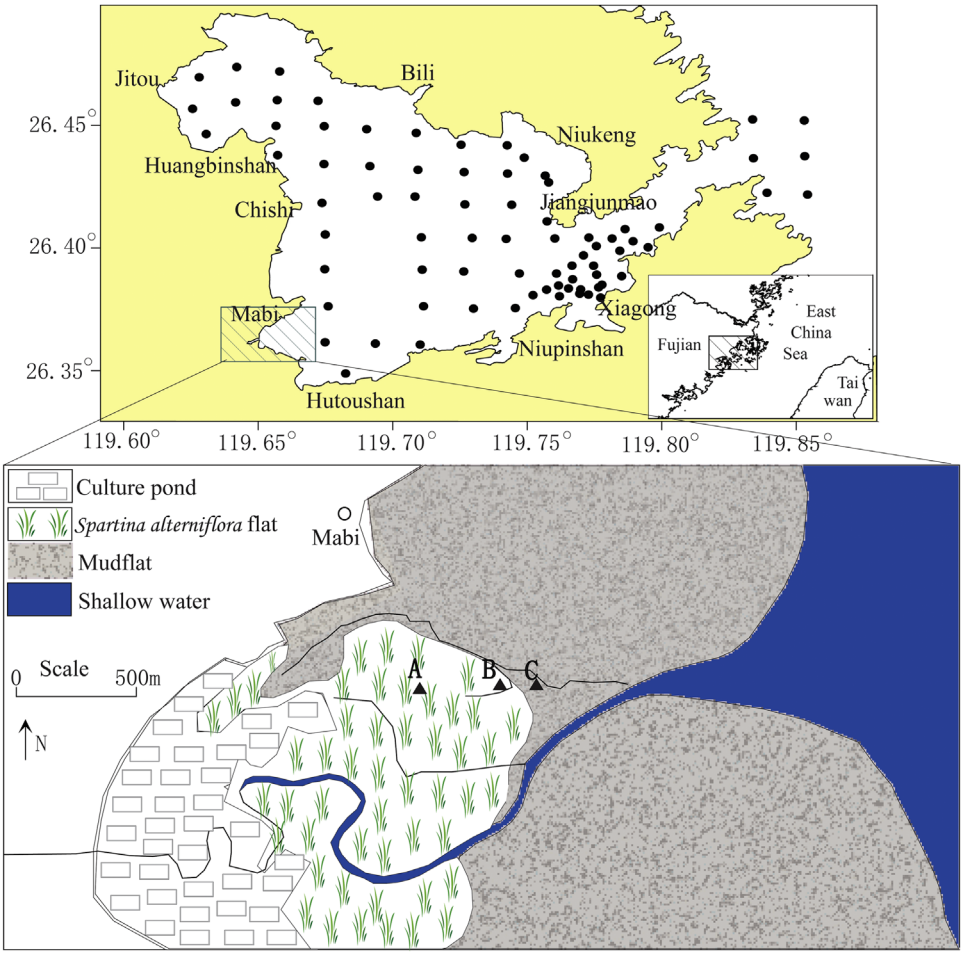

Fig. 1. Map showing the location and the sampling sites. Dots and triangles were the surface sample and core localities, respectively.