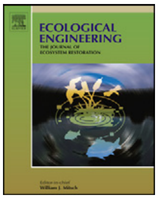
Ecological Engineering 35 (2009) 1685–1692

Contents lists available at ScienceDirect

Ecological Engineering

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



Fine-scale environmental heterogeneities of tidal creeks affect distribution of crab burrows in a Chinese salt marsh

Jin-qing Wang, Long Tang, Xiao-dong Zhang, Cheng-huan Wang,
Yang Gao, Li-fen Jiang, Jia-kuan Chen, Bo Li*

Coastal Ecosystems Research Station of the Yangtze River Estuary, Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, Institute of Biodiversity Science, Fudan University, Shanghai 200433, PR China

ARTICLE INFO

Article history:
Received 15 November 2008
Received in revised form 30 March 2009
Accepted 10 May 2009

Keywords:
Burrows
Crab
Microhabitats
Salt marshes
Sediment properties
Tidal creeks
Yangtze River Estuary

ABSTRACT

Tidal creeks are an important structure of salt marshes in estuarine ecosystems, providing valuable ecosystem services to wildlife in the estuary. To determine the effects of environmental heterogeneities within tidal creeks on the features of crab burrows, we divided a typical creek section into four parts (i.e., microhabitats): bottom, slope, edge and flat, investigated the distribution of crab burrows and sediment properties on creek sections in the Yangtze River estuary, and compared the burrow distribution in tidal creeks with that in non-creek areas. Our results showed that from the creek bottom to flat soil water content declined ($F_{3,60} = 93.8$, $p < 0.001$), and the variations of other sediment physical and chemical properties associated with the change of soil water content were significant among the microhabitats on the creek sections ($p < 0.001$ for pH, conductivity, and grain size). No crab burrows were found at the creek bottom. The burrows on the slope were smaller in size ($p < 0.001$ for burrow opening diameter) while the density was higher than that at the edge and on the flat ($F_{2,45} = 31.2$, $p < 0.001$). Moreover, although the correlations between burrow distribution and sediment properties varied among the microhabitats on the creek sections, crabs generally selected relatively solid sediments to build their burrows. On the slope, there was a significantly negative relationship between burrow density and soil water content ($r^2 = 0.53$, $p < 0.001$). At the edge, the correlation between total burrow opening area and soil water content was significantly negative ($r^2 = 0.44$, $p < 0.002$). The density of small crab burrows (<10 mm) was greater, but that of large burrows (>10 mm) was lower in tidal creeks than in non-creek habitats. Therefore, sediment properties showed a gradual transition from hydrophytic to terrestrial environments on the creek section, which caused significant differences of burrow distribution among the microhabitats. The creeks of tidal salt marshes could affect ecological processes and functioning through affecting crab burrows.

1. Introduction

Salt marshes serve as integral components of coastal ecosystems (Bertness et al., 2004), are considered one of the most productive ecosystems (Mitsch and Gosselink, 1993; Costa et al., 2001), and provide the highest ecosystem service values per unit area (Costanza et al., 1997). Most of salt marshes in world's major estuaries contain numerous tidal creeks (Mallin, 2004; Xie et al., 2006). Compared to non-creek habitats, tidal creeks play important roles in material transfer and other ecological processes due to their great number and high surface-to-volume ratio (Likens and Bormann, 1974; Dame et al., 2000). Moreover, tidal creeks dissect salt marshes, determine the distribution of tidal flooding by complex dendritic networks (Sanderson et al., 2000), and create heterogeneous habitats for various organisms (Desmond et al., 2000; Jin et al., 2007; Mense and Wenner, 1989). The important roles of tidal creeks in determining survival and growth of organisms in salt marshes have been extensively investigated over the last decades, and are recognized as important ecotones in salt marshes, providing habitats for diverse animals moving between and among these habitats (Mallin, 2004).

Although the importance of tidal creeks in the salt marshes has received increasing attention, most studies have considered tidal creeks as a whole and little attention has been paid to the fine-scale abiotic and biotic heterogeneities on the creek sections. To fully understand the roles of the tidal creeks in the maintenance of biodiversity, it is necessary to examine the environmental heterogeneities related to the frequency and duration of tidal inundation on the tidal creek sections. Previous studies suggest that a creek section can be geomorphologically divided into three parts: bottom,

---

* Corresponding author. Tel.: +86 21 65642178; fax: +86 21 55664990.
E-mail address: bool@fudan.edu.cn (B. Li).

0925-8574/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecoleng.2009.05.002

bank and flat, on which variations of macrobenthic life form and functional groups are considerable from the bottom to flat in a creek system of estuarine salt marshes (Naiman and Decamps, 1990; Yuan and Lu, 2001). Moreover, a refined division of a creek section is needed to consider the slope separately, i.e., a creek section has four functional parts (or microhabitats): bottom, slope, edge and flat. The four microhabitats, including the important transitional "edges", are considered to be more representative in reflecting the variations of habitat characteristics caused by hydrodynamic differences on the creek section.

Crabs' burrowing activities and burrow architectures can significantly modify microtopography, improving soil aeration (Warren and Underwood, 1986), oxidation, drainage (Bortolus and Iribarne, 1999), penetrability (Botto and Iribarne, 2000). Crab burrow distribution has strong associations with the functions of salt marshes because of strong effects of the burrows on both biotic and abiotic components in the salt marshes. Consequently, burrowing crabs play important roles in ecosystem processes that are associated with the matter transfer and energy flow, and have generally been considered as ecosystem engineers in the salt marshes (Lee, 1998; Gutierrez et al., 2006). On the other hand, burrows are basic sites for intertidal crabs to accomplish many important life activities, such as molting, courtship, breeding, overwintering (Reaney and Backwell, 2007). Burrows also serve as refuges from predators and harsh environmental conditions such as high temperature and dehydration (Warren, 1990). Previous studies have investigated the relationships between crabs and their burrow distributions, and evaluated the accuracy of inferring crab distribution through using burrow density and size (Nobbs and McGuinness, 1999; Skov et al., 2002; Kent and McGuinness, 2006). Burrow counting has been used by many researchers to estimate crab distribution (e.g., Bertness and Miller, 1984; Mouton and Felder, 1996), which significantly facilitate field studies related to crab distributions.

Soil properties (for example, soil hardness, silt and clay content, water content) are the important factors determining crab's burrowing processes and burrow density (Takeda and Kurihara, 1987; Mouton and Felder, 1996). Teal (1958) suggests that three species of fiddler crabs in Georgia marshes prefer substratum with certain grain sizes. Ashton et al. (2003) suggest crab community structure is linked with topographical height and surface water pH and salinity. Gradient variations of elevation and corresponding frequency and duration of tidal inundation on the tidal creek section can alter soil properties, and thus exert strong effects on burrow distributions.

In this study, we assumed that fine-scale environmental heterogeneities within tidal creeks have significant effects on the distribution of crab burrows, and investigated the distribution of crab burrows on the creek sections in Dongtan Wetland of International Importance in the Yangtze River Estuary. The hypotheses tested in this study included: (1) sediment properties are different among different parts of a creek section, which results in fine-scale variation of crab burrow distribution and crab zonation; (2) burrow distributions are determined by soil properties within tidal creeks; (3) spatial distributions of crab burrows in tidal creeks are different from those in non-creek areas.

2. Materials and methods

2.1. Study sites

This study was conducted in Dongtan Wetland of International Importance on Chongming Island in the Yangtze River estuary (located at 31°25′–31°38′N and 121°50′–122°05′E) (Fig. 1). Dongtan wetland occupies an area of about 230 km^2, which is affected by semidiurnal tides with maximum tidal height ranging from 4.62 to 5.95 m, and average tidal height ranging from 1.96 to 3.08 m (Huang et al., 1993; Sun et al., 2001). The average annual precipitation is 1123.7 mm, concentrating in the summer (Sun et al., 2001). Soil temperature varies between 19.7 and 31.5 °C during the growing season of 2005 (Chen et al., 2007).

Dominant plant species include native plants *Phragmites australis* and *Scirpus mariqueter* and introduced plant *Spartina alterniflora* in the salt marshes (Li and Zhang, 2008). The dominant crab species in the tidal creeks of the marshes are *Uca arcuata* and a small-sized species *Ilyoplax deschampsi*, both of which extensively burrow on tidal creek banks, while numerous grapsid crabs largely reside in non-creek habitats (Wang, 2008).

Tidal creek formation has been affected by several large-scale reclamations over the last decades (Huang et al., 1993; Ma et al., 2004). The exotic plant *S. alterniflora* also greatly modifies morphologies of tidal creeks through affecting sediment deposition (Li et al., 2009). Tidal creek systems are well developed in Dongtan marshes, and display dendritic distribution with good meander development above neap high tidal level (Huang et al., 1993). Tidal creeks mainly serve as draining channels collecting fine sediments from marsh surface during the ebbing phase (Xie et al., 2006), and can be divided into three classes. First-order creeks with a width of tens of meters pass through high tidal marshes and low tidal mudflats, and enter subtidal zone. The width of second-order creeks is smaller but may be up to 10 m, ending at outer margin of high tidal flats. Third-order creeks with a width of only about 1 m are mainly distributed in the mudflats. Mudflat banks exist in first- and second-order creeks, but not in third-order creeks (Huang et al., 1993).

2.2. Sampling transects

Five parallel second-order tidal creeks with a width of 5–10 m were selected from north to south in Dongtan marshes. One creek section (treated as a transect) was established in each tidal creek, from which the distance was about 2 km to the dyke built in 1998 (Fig. 1).

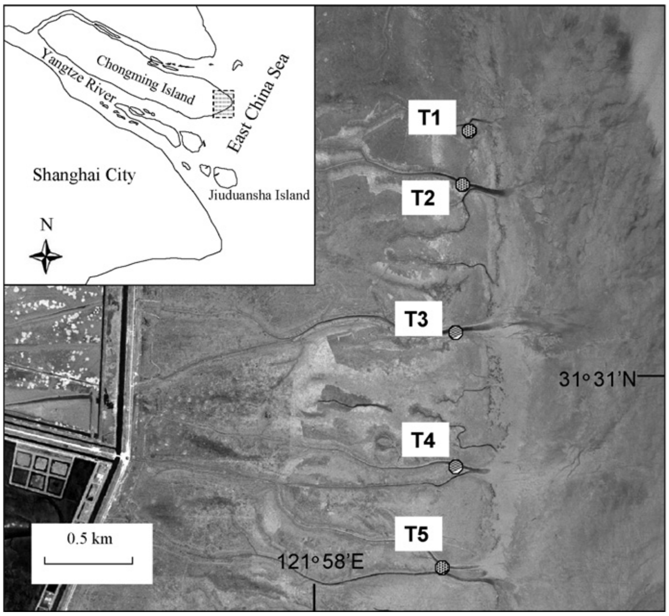


Fig. 1. The location of study area. The grey block in the inset shows the study area in the Yangtze River estuary. Five grey points (T1, T2, T3, T4, T5) marked in satellite image indicate transects selected from five parallel tidal creeks in the salt marshes.