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Interactions between the range expansion of saltmarsh vegetation and hydrodynamic regimes in the Yangtze Estuary, China

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ABSTRACT

Over the last 15 years, rapid invasion of large areas of the saltmarshes of Chongming Island, in the Yangtze Estuary, China by the exotic species *Spartina alterniflora* has occurred. Two types of advancing fronts are found: the *S. alterniflora*–mudflat (S–M front) and the *S. alterniflora* – *Scirpus mariqueter* – mudflat (S–S–M front). In this study, both the range expansion in terms of seedling recruitment and tussock development at these two advancing fronts and the accretion/erosion dynamics used as a proxy for comparable hydrodynamic regimes were investigated. The results showed that the mean number of seedlings of *S. alterniflora* recruited at the S–M front was much higher than that at the S–S–M front. The rate of range expansion after one growing season at the S–M front was much faster than the S–S–M front. The different colonisation behaviours on the two types of advancing front was related to the differences in hydrodynamic regimes. At the site with a regime of autumn/winter erosion and spring/summer accretion, the original pioneer species of *S. mariqueter* was replaced by *S. alterniflora* and a pattern of range expansion at the S–M front developed. In contrast, at the site with a relatively stable accretion regime, the original pioneer species of *S. mariqueter* remained within the advancing front and a pattern of range expansion at the S–S–M front developed. The impact of abiotic and biotic factors governing the range expansion of *S. alterniflora* and its implications on the spatial structure of tidal wetlands is discussed.

1. Introduction

Estuarine mouth bars and associated submerged delta features represent major locations of sedimentation resulting from the large amount of silt brought down the Yangtze River in eastern China. The range expansion of saltmarsh in the Yangtze Estuary depends on accretion of dynamic mudflats (Huang et al., 2008; Xiao et al., 2010). *Spartina alterniflora* (smooth cordgrass) is a perennial and deep-rooted saltmarsh pioneer plant, native to the Atlantic and Gulf coasts of North America (Simenstad and Thom, 1995). As a species for ecological engineering (Callaway and Josselyn, 1992; Chung et al., 2004), this exotic plant was introduced to the Yangtze Estuary in 1995 and expanded rapidly thereafter, accounting for almost one quarter of the total area of intertidal saltmarshes in the Shanghai region by 2008 (Huang et al., 2007; Li and Zhang, 2008).

Spartina aterniflora maintains a fast rate of geographic spread through both sexual reproduction by seeds and asexual propagation by tillering and rhizome production (Daehler and Strong, 1994; Davis et al., 2004; Xiao et al., 2010). The long-distance spread of nascent populations along the USA Pacific coast has been driven primarily by seedling recruitment and to a lesser extent by the dispersal of vegetative fragments (Sayce et al., 1997; Ayres et al., 2004; Lambrinos and Bando, 2008). Long-distance dispersal of *S. alterniflora* seeds by floating wracks can facilitate germination at suitable habitats. Once germination has occurred, *S. alterniflora* forms tussocks by vegetative tillering and rhizome production, which finally merge into dense continuous meadows (Davis et al., 2004). Seedling recruitment and establishment during the spring has been shown to be crucial to the colonisation of the new habitat and the fast rate of range expansion of *S. alterniflora* at the saltmarshes in the Yangtze Estuary (Xiao et al., 2010). *S. alterniflora* in the Yangtze Estuary has also been reported to have a great capacity

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for asexual propagation, by which its expansion rate could reach 1.07–2.63 m after one growing season (Zhang et al., 2006).

A cellular automata model for population expansion on the saltmarshes in the Yangtze Estuary revealed that the range expansion of the saltmashes depends on the dynamic accretion of mudflats and on a large scale, *S. alterniflora* showed a pattern of simple advancing wave fronts (Huang et al., 2008). In the pioneer zone, two types of advancing fronts of *S. alterniflora* along an elevation gradient are found: the *S. alterniflora* – mudflat (S–M) front and the *S. alterniflora* – *Scirpus mariqueter* – mudflat (S–S–M) front (Xiao et al., 2010). By both seedling recruitment and vegetative growth, *S. alterniflora* at the S–M front has been shown to achieve a more rapid expansion rate than at the S–S–M front, that occurs mainly through lateral advancement of vegetative propagules The colonisation behaviour of *S. alterniflora* at the advancing fronts was shown to differ as a reaction to various external and internal factors by Xiao et al. (2010). However, the dominant factors structuring the range expansion patterns and associated bio-physical processes, as well as the mechanisms underlying the range expansion of *S. alterniflora* at the advancing fronts, are poorly understood.

A saltmarsh is the result of interactions between biological and physical processes (Dijkema et al., 2001). In saltmarsh pioneer zones, hydrodynamic stress, as the main abiotic force, is highly variable in both space and time and has been suggested as being a possible cause for the generation of distinct patterns (van Wesenbeeck et al., 2008). The dominant factor structuring the spatial structure of range expansion for *S. alterniflora* in the saltmarshes at Chongming Dongtan wetlands is believed to be the variations in hydrodynamic regimes and the accretion of dynamic mudflats (Xiao et al., 2010). The dynamic and natural characteristics of the eastern fringe of Chongming Island, both in terms of sediment deposition, saltmarsh succession and biological invasion, make it an ideal study area for studying the interaction between the range expansion of saltmarsh vegetation and the hydrodynamic regimes. Such information is of great importance for saltmarsh management and conservation, and is also essential for the development and improved parameterisation of models for forecasting changes in vegetation dynamics and estuarine morphology, particularly in response to climate change and sea-level rise (Widdows and Brinsley, 2002).

In this study, both the range expansion in terms of seedling recruitment and tussock development of *S. alterniflora* at these two advancing fronts and the accretion/erosion dynamics used as a proxy for comparable hydrodynamic regimes were investigated. The research aims were to: 1) test whether and how the hydrodynamic regimes govern the spatial structure of range expansion at two advancing fronts; 2) determine the interactions between the range expansion and hydrodynamic regimes, and 3) understand the mechanisms underlying the range expansion of *S. alterniflora* in the Yangtze Delta and their implications for the spatial structure of tidal saltmarshes.

2. Materials and methods

2.1. Study area

The Chongming Dongtan nature reserve, one of the largest nature reserves for migratory birds in Eastern Asia, is located on Chongming Island in the mouth of the Yangtze River, between 31°25′ ~ 31°38′N, 121°50′ ~ 122°05′E (Fig. 1). The eastern fringe of the nature reserve is the major locations for sedimentation of the huge amount of silt brought by the Yangtze River and has been growing rapidly (Gao and Zhang, 2006). The Dongtan wetlands were listed in the Chinese Protected Wetlands in 1992, were designated as internationally important under the Ramsar Wetlands Convention in 2001 and became a national nature reserve in 2005 (Gao and Zhang, 2006).

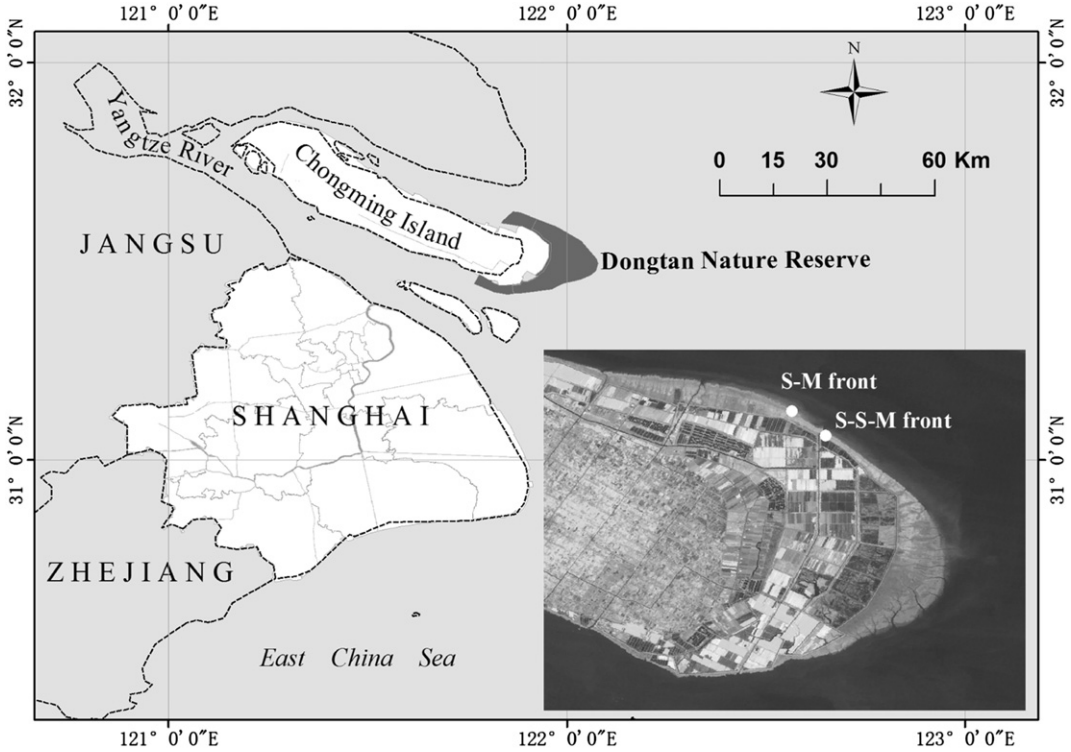

Fig. 1. The location of the Chongming Dongtan nature reserve as well as the measurement and sampling sites at the *Spartina alterniflora* – mudflat (S–M) front and the *S. alterniflora* - *Scirpus mariqueter* – mudflat (S–S–M) front.