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Evaluation of the combined threat from sea-level rise and sedimentation reduction to the coastal wetlands in the Yangtze Estuary, China

Heng Wang[a], Zhenming Ge[a,*], Lin Yuan[a], Liquan Zhang[a,b,*]

[a] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, 3663 Zhongshan Road North, Shanghai 200062, China
[b] Shanghai Key Laboratory of Urbanization and Ecological Restoration, East China Normal University, 3663 Zhongshan Road North, Shanghai 200062, China

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ABSTRACT

In recent decades, the prospect of climate change, in particular sea level rise (SLR) and its impacts on low-lying coastal areas has generated worldwide attention. The coastal wetlands located in the Yangtze Estuary, with their low elevation and decreasing sediment loading, are susceptible to both SLR and anthropogenic activities. Taking the Chongming Dongtan wetlands as a study area, two scenarios of SLR were evaluated: the present trend (1980–2010) of SLR 2.6 mm/yr (PSLR) and the IPCC A_1F_1 scenario of 5.9 mm/yr (HSLR). In addition, two scenarios of sedimentation rate were adopted for the Yangtze Estuary: the current sedimentation rate (CSR) and a reduced sedimentation rate of half of the present rate (1/2CSR). The combined effects of SLR and sedimentation reduction were evaluated by projection of the combinations of these phenomena for 2025, 2050 and 2100, using a Sea Level Affecting Marshes Model (SLAMM). The results showed that the combined effects of sea-level rise, reduced sedimentation and land subsidence could result in a considerable decrease in or even complete loss of the coastal wetland habitat in the Chongming Dongtan nature reserve, particularly under the medium-term (2050) and long-term (2100) scenarios. Without proper mitigation measures, the potential decrease in and loss of habitats and ecosystem services is inevitable. Such mitigation measures should be considered in the future for securing the coastal wetland ecosystems, which include the management of sedimentation, the rehabilitation and re-creation of wetland habitat and the control and limitation of reclamation.

1. Introduction

In recent decades, the prospect of climate change, in particular sea level rise (SLR) and its impacts on low-lying coastal areas has generated worldwide attention (IPCC, 2007; Nicholls et al., 2007; Stralberg et al., 2011). According to a report from the Chinese State Oceanic Administration (SOA), SLR in the Yangtze Estuary has been occurring at a rate of 2.6 mm per year over the past 30 years (1980 to 2010) and is predicted to accelerate to 40–50 cm per year by 2050 (SOA, 2012). Due to its low elevation and slope, the coastal zone of the Yangtze Estuary is particularly vulnerable to this accelerating rate of SLR (Nicholls et al., 2007; SOA, 2012).

The coastal wetlands in the Yangtze Estuary, located at the junction of the Yangtze River, the Yellow Sea and East China Sea, represent one of the largest estuarine alluvial wetlands in the world. The coastal wetlands are dynamic and provide valuable ecosystem services, including habitats for biodiversity, primary production, water purification, carbon sequestration and coastal protection (Mitsch and Gosselink, 2007; Craft et al., 2008; Fourqurean et al., 2012). With an abundant sediment supply from the Yangtze River, the coastal wetlands of the estuary have prograded rapidly in recent centuries. However, following construction of the Three Gorges Dam (TGD), presently the world's largest dam, 185 m in elevation above mean sea level, there has been a marked decrease in the progradation rate. Consequently, the dam has now exerted a huge impact on the eco-hydro-morphological setting of both the river and the estuary. The sediment discharge at Datong station, in the Yangtze River, fell from ~490 Mt/yr in the 1950s and 1960s to ~150 Mt/yr after the closure of the TGD in 2003 (Yang et al., 2011). This dramatic decrease in

* Corresponding authors at: East China Normal University, 3663 Zhongshan Road North, Shanghai, 200062, China. Tel.: +86 21 62232599; fax: +86 21 62546441.
E-mail addresses: lqzhang@sklec.ecnu.edu.cn, lzhang88us@hotmail.com (L. Zhang).

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sedimentation rate could further exacerbate the impacts of SLR and result in coastal erosion and loss of coastal habitats.

Chongming Dongtan Nature Reserve, one of the largest nature reserves on coastal wetlands in East Asia, is located at the mouth of Yangtze Estuary and is highly susceptible to SLR and sedimentation reduction, due to its low elevation and the lack of resources to mitigate such threats. Tian et al. (2010) conducted an inundation spatial analysis to evaluate the possible impacts of various SLR scenarios on the coastal wetlands in the Yangtze Estuary. However, this initial study had many limitations, as the bathymetric model employed did not simulate realistically the feedbacks of wetland habitats on critical processes, such as accretion/erosion rate and subsidence. The responses of coastal wetlands were not incorporated and the impacts of sedimentation reduction in relation to anthropogenic activities such as the TGD were not considered. In recent years, a number of methodologies have been developed to evaluate quantitatively the impacts of SLR on coastal regions. Numerical modelling is a key tool for the understanding of the dynamics of the boundaries and progradation or regression of coastal wetlands under conditions of SLR (Fagherazzi et al., 2012). Landscape elevation modelling can also be used to forecast the dynamics of coastal wetlands within a suitable elevation range (Rogers et al., 2013). A 3-dimensional model can depict tidal marsh accretion and creek network development explicitly, coupling physical sediment transport processes with vegetation biomass productivity (Fagherazzi et al., 2012). The Sea Level Affecting Marshes Model (SLAMM) (Clough et al., 2010) simulates the major processes pertinent to coastal wetland dynamics, providing detailed information about coastal habitats in response to SLR. In addition, the SLAMM has focused on landscape-scale patterns, combining high resolution, process-based models with broad-scale spatial models, which make forecasting possible and more realistic (Craftet al., 2008; Clough et al., 2010).

Taking the Chongming Dongtan wetlands in the Yangtze Estuary as the study area, the possible impacts of SLR and decreasing sedimentation were evaluated using the SLAMM model. The specific objectives were:

(1) to simulate the spatio-temporal outcomes under various scenarios of SLR, combined with differing sedimentation regimes;
(2) to predict how the tidal saltmarshes in the study area would respond to different scenarios of SLR, sedimentation regimes and related phenomena; and
(3) to propose mitigation measures in terms of ecological engineering for the coastal wetlands in the Yangtze Estuary.

2. Materials and methods

2.1. Study area

The Chongming Dongtan wetlands and nature reserve is located at the eastern end of Chongming Island, which lies between 31°25′–31°38′N and 121°50′–122°05′E (Fig. 1). The area has an eastern Asian monsoon climate with an average annual temperature of 15.2–15.8 °C. The average winter temperature is 3 °C, while the summer is hot and wet with an average temperature of 26 °C and with 60% of annual precipitation falling in summer months. Average annual precipitation is approximately 1022 mm and the average humidity is 82% (Gao and Zhang, 2006). According to data obtained over a 30-year period (1978 to 2008) at the nearby Waigaoqiao tidal gauge station the local mean sea level is 2.17 m, the mean 'high' water height is 3.5 m and the mean 'low' water height is 1.03 m in relation to the local Wushong bathymetric benchmark. The mean tidal level was 2.5 m and the mean tidal range was 2.47 m (Wang et al., 2012).

The total area of the Chongming Dongtan nature reserve is 21,315 ha. The wetland habitats in the nature reserve include tidal saltmarshes (mainly occupied by communities dominated by *Scirpus mariqueter*, *Phragmites australis* and *Spartina alterniflora*), tidal mudflats and shallow open waters. Zonation of the coastal wetlands occurs in relation to elevation above sea level. The tidal mudflats, with an elevation of less than 2 m, are characterized by mudflats without any vascular plants. The intertidal zone, between 2.2 m and 2.9 m, is dominated by a pioneer community of *S. mariqueter*. Above 2.9 m, the saltmarsh is dominated by the *P. australis* plant

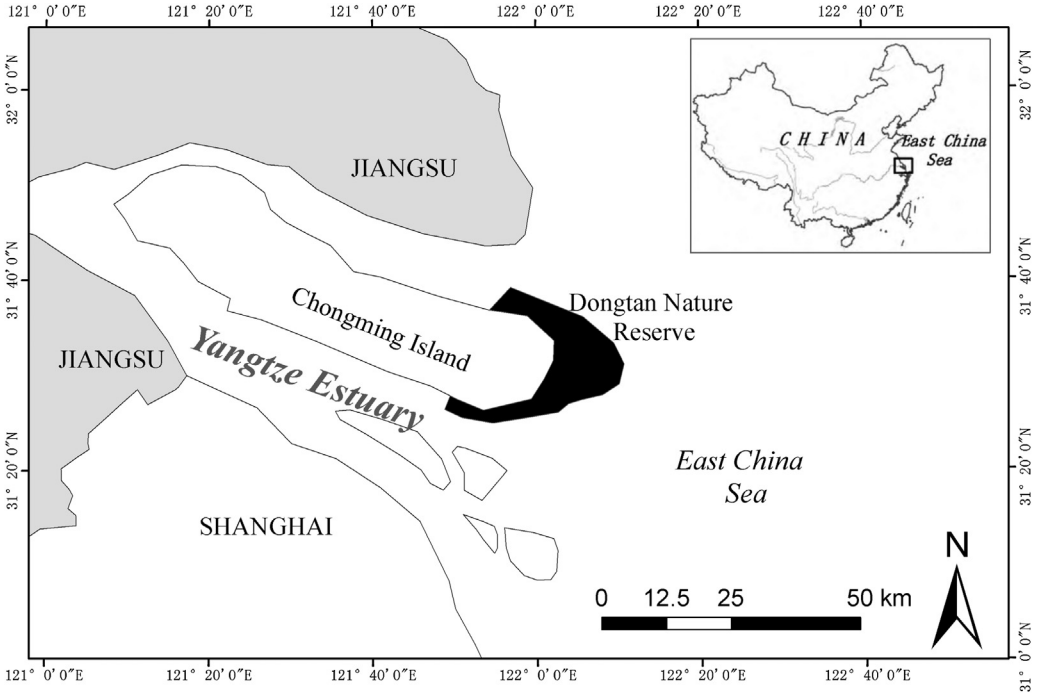

Fig. 1. Location of the Chongming Dongtan nature reserve in the Yangtze Estuary.