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Sensitivity of the sediment trapping capacity of an estuarine mangrove forest

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ABSTRACT

Intertidal mangrove forests exist in a dynamic coastal environment that is increasingly impacted by human interference, leading to habitat fragmentation, reduced habitat quality and changing hydrodynamic and geomorphological conditions. Biophysical feedback mechanisms are essential to maintain mangrove ecosystems under such changing conditions, for example by facilitating sediment deposition during periods of tidal flooding to allow for long-term coastal accretion. However, human interferences affect these biophysical interactions. This study investigated the consequences of two widespread anthropogenic intervention scenarios on biophysical interactions in mangroves: sediment starvation (reduced sediment supply) and coastal squeeze (limited landward accommodation space). Field observations of hydrodynamics and sediment dynamics were conducted in Mandai mangrove fringing the sheltered northern shore of Singapore. A process-based numerical model (Delft3D) of this field site was set-up, providing accurate approximations of the observed flow velocities and deposition rates. This model was used for a scenario analysis of the initial response of the sediment trapping capacity in the mangrove system to instantaneous changes related to anthropogenic interventions. This analysis showed increased deposition rates in major parts of the mangrove when sediment supplies increased (up to three times more deposition after 1 tide) or when the landward accommodation space of the mangrove was extended (+17% deposition). A comparison of the outcomes of these scenarios with the current state of the mangrove underlined a lack of short-term sediment trapping capacity, affecting the (longer-term) adaptive capacity of the system. Thus, at present Mandai mangrove is potentially affected by reduced sediment supply and limited landward accommodation space. Importantly, actions to reduce this anthropogenic influence could enhance mangroves' sediment trapping capacity, facilitating increased resilience to future projected changes such as sea-level rise. Understanding this influence of anthropogenic interventions on mangrove resilience is essential if we are aiming to maintain coastal ecosystem stability, especially along rapidly changing and urbanizing tropical shorelines.

1. Introduction

Intertidal mangrove forests provide multiple ecosystem services to coastal populations across the tropics and yet are highly threatened by anthropogenic interventions as tropical coastlines continue to develop rapidly. Conversion of mangroves for aquaculture, agriculture, urban development and subsistence use is causing a rapid decline in their extent (Duke et al., 2007; UNEP, 2014; Webb et al., 2014). Tidal wetlands such as mangroves are also threatened by long-term forcings such as sea-level rise (SLR), in conjunction with decreased sediment supply and reduced landward accommodation space (Thampanya et al., 2006; Kirwan and Megonigal, 2013; Krauss et al., 2014; Lovelock et al., 2015). Mangroves can potentially adapt to such forcings, and such forcings in conjunction with decreased sediment supply and reduced landward accommodation space, as long as species-specific physical and ecological thresholds are not exceeded. This species-specific resilience is facilitated by an array of biophysical interactions operating at a range of different temporal and spatial scales (Cahoon et al., 2006; Friess et al., 2012a).

A key biophysical feedback mechanism in coastal wetlands is the interaction between hydrodynamics (i.e. tidal flows and waves) and above-ground vegetation structures, and the subsequent impact on local geomorphology. Much of the research on coastal wetland biogeomorphology occurred in temperate saltmarshes in Europe and the US from the 1990s onwards, contributing to our understanding of how saltmarsh vegetation can reduce hydrodynamic energy due to breaking and frictional losses (Brampton, 1992; Leonard and Luther, 1995; Möller et al., 1999) and how such attenuation can contribute to

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increased saltmarsh sedimentation (Leonard, 1997). However, while the above-ground vegetation may differ in saltmarshes (grasses and herbs) and mangroves (woody vegetation), they share similarities in their biogeomorphological processes and feedbacks due to their similar positions in the intertidal zone and similar vegetation establishment thresholds (Friess et al., 2012a). Thus, biogeomorphological principles derived from saltmarsh research may be applicable to mangrove systems, and vice versa biogeomorphological principles derived