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Sedimentation rhythms and hydrodynamics in two engineered environments in an open coast managed realignment site

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ABSTRACT

Managed Realignment (MR) schemes are considered by many coastal managers and engineers to be a preferable method of coastal flood defence and compensating for habitat loss, by creating new areas of intertidal saltmarsh and mudflat habitat. Monitoring of MR sites has tended to focus on short term ecological factors, resulting in a shortage of high frequency, high resolution long term measurements of the evolution of the sediment erosion, transportation, deposition and consolidation cycle (ETDC) in newly breached sites. This is particularly true of analysis of the formation and preservation of sedimentary rhythmites and evaluations of sedimentation rates (and their variability) in newly inundated intertidal environments. This study provides an evaluation of sedimentation rhythms and hydrodynamics from two contrasting sites within the Medmerry Managed Realignment scheme, the largest open coast realignment in Europe (at the time of site inundation). Bed sediment altimeter data highlighted different sedimentation patterns at the two sites; near constant deposition of sediment occurred near the breach resulting in 15.2 cm of sediment being accreted over the one year monitoring period, whereas periodic accretion and erosion of sediment occurred inland leading to 2.7 cm of net accretion. Differences in the relationship between suspended sediment concentrations and site hydrodynamics were observed on a semi-diurnal to annual scale. This study highlights the need for further consideration of the sedimentation processes in MR schemes in order to enhance the design and construction of these sites. Advancements in the understanding of these processes will increase the success of MR schemes in terms of the evolution of the sediment regime and the ecosystem services provided, particularly as they are more widely accepted as a form of coastal flood defence and intertidal habitat creation method.

1. Introduction

Large areas of saltmarsh have been drained and reclaimed over the past millennium for agricultural, industrial or urban development under the misunderstanding that they were of no value to society (Pethick, 2002). As a result, many European and North American coastal wetland environments have become severely degraded (Wolters et al., 2005). The international importance of intertidal saltmarshes and mudflats has only been realised in recent decades (Rotman et al., 2008). These environments provide a range of ecosystem, economic and cultural services such as wildlife habitat, carbon sequestration, immobilisation of pollutants, water quality improvements, social and recreation opportunities and protection from coastal flooding (Costanza et al., 1997; King and Lester, 1995; Moller et al., 2014; Moller et al., 1999, 2001; Tempest et al., 2015). Furthermore, these environments also protect (and reduce the cost of maintaining) engineered defences such as sea walls (e.g. King and Lester, 1995), which are becoming a growing concern due to questions over their medium to long term integrity under predicted sea-level rise scenarios (French, 2006).

Intertidal habitats remain under significant pressure and continue to be lost and degraded; approximately 50% of saltmarshes are estimated to be lost or degraded globally (Barbier et al., 2011) due in large part to alterations and influences caused by human activities (e.g. Gedan et al., 2009). These losses result from coastal squeeze caused by climate change and sea level rise, the construction of coastal defences, reduction in water and sediment quality, land reclamation for agriculture, industry and recreational use, and coastal development through the construction and expansion of ports and marinas (e.g. Doody, 2004; Jacobs et al., 2009; Kennish, 2002).

Recognition of the importance of, and the threats to, intertidal habitats have resulted in calls for an approach to coastal management that protects and allows for the sustainable use of these environments, via an ecosystem services approach (e.g. Balmford et al., 2002; Bockstael et al., 2000; Costanza et al., 1997; Turner and Daily, 2008). The ecosystem services approach provides a collective framework for coastal managers to consider the options available and to effectively communicate the consequences to various stakeholder groups (Granek et al., 2010). Environmental regulations (such as the European Habitats Directive

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92/43/EEC) now enforce mitigation and compensatory measures for habitat loss (van Loon-Steensma and Vellinga, 2013). Several techniques have been used to compensate for intertidal habitat loss including increasing suspended sediment concentrations and decreasing current velocities (Boorman and Hazelden, 1995) through sediment recharge projects and the construction of offshore breakwaters (Doody, 2008), controlled reduced tide schemes (e.g. Jacobs et al., 2009) and de-embankment or managed realignment (e.g. French, 2006).

This paper focuses on managed realignment (MR), the technique of re-locating the land/sea border in-land by lowering, removing or breaching the previous defences and constructing new or maintaining previous secondary defences. MR allows tidal inundation of the formerly defended low-lying coastal hinterland (e.g. Tempest et al., 2015) which usually consists of land that had previously been reclaimed for agricultural use. Many coastal managers advocate MR as a preferred management strategy (French, 2006) as it provides new areas of intertidal habitat and improves the standard of coastal flood defence. Despite the growing popularity of MR there remains however a shortage of data regarding its success (or otherwise). This has been explained by a lack of long-term monitoring (Spencer and Harvey, 2012) with the monitoring that has been carried out focusing on vegetation changes, which occur on a comparatively short timescale (Kentula, 2000), as a measure of success.

An important yet poorly understood issue is the evolution of the sediment Erosion, Transportation, Deposition and Consolidation (ETDC) cycle within MR sites. ETDC processes vary temporally and spatially, and significantly impact on the development of newly inundated intertidal environments and their associated habitat (Rotman et al., 2008) and therefore site ecosystem services. Whilst sufficient sediment accumulation is required for habitat creation (e.g. raising bed elevation sufficiently to allow colonisation by salt marsh flora) excess sedimentation could prevent the desired habitat from becoming established. An understanding of the sediment source and supply is also required. For example the saltmarsh neighbouring the Freiston Shore MR site (UK) experienced rapid erosion (Symonds and Collins, 2007) following site inundation. Eroded material were transported into the MR site, building in the newly inundated area at the expense of the adjacent saltmarsh and undermining the success of the habitat creation scheme (Rotman et al., 2008).

Research elsewhere has provided high frequency analysis of intertidal sediment erosion and accretion processes, particularly the formation and preservation of rhythmic intertidal sedimentation patterns (henceforth referred to as rhythmites), to evaluate ETDC processes and sedimentation rates in more established estuarine and coastal areas (e.g. Deloffre et al., 2007). This paper presents an investigation of sedimentary rhythmites and ETDC processes in a recently breached and inundated estuarine environment: the Medmerry Managed Realignment site, West Sussex, UK. Specifically, we evaluate:

(a) Local hydrodynamics and its influence on sediment supply, and erosion/accretion.
(b) Differences in the rates of sedimentation and erosion, patterns of sediment accumulation and sediment supply and sources between two engineered sites at varying distances from the breach.

These differences in pattern and rate of sedimentation may have long term implications for the evolution of the ETDC processes and the sediment regime, and therefore the ecosystem services provided.

2. Study site

The Medmerry Managed Realignment Scheme (Fig. 1), the largest open coast MR site in Europe at the time of site inundation (occupying 450 ha), is located at the eastern end of the Solent (the stretch of water between Hurst Spit, Hampshire and the Needles on the Isle of Wight in the west and the Manhood Peninsular in West Sussex to the east, including the north coast of the Isle of Wight). Coastal flood defence at Medmerry was formerly provided by a shingle barrier beach, which was managed by the Environment Agency (UK). To maintain the necessary defence standard to protect the coastal hinterland constant work was required each winter to raise, recycle and re-profile the shingle bank. Nevertheless, the defences remained vulnerable during storm events; the bank was breached 14 times between 1994 and 2011, flooding homes, local holiday caravan parks and agricultural land. The coastal flooding and erosion risk was reviewed in the Pagham to East Head Coastal Defence Strategy (Environment Agency, 2007), which concluded that the existing defences were unable to prevent flooding and would no longer be effective beyond the short-term. MR was endorsed, after a review of the available options, as the most suitable method of managing the risk from coastal flooding.

The MR scheme at Medmerry was designed not only to provide a sustainable and cost effective method of coastal flood and erosion risk management, but also to compensate for the loss of saltmarsh and mudflat habitat elsewhere in the Solent. Over 80% of the Solent's coastline is designated for its nature conservation interest (Foster et al., 2014) yet 40% (approximately 670 ha) of saltmarsh in the region were lost through erosion between 1971 and 2001 (Cope et al., 2008). It was estimated that up to 184 ha of new intertidal habitat would be created over the hundred years following construction of the Medmerry site (Pearce et al., 2011). The surrounding land drains through four drainage outlets into the realignment area, which consists of previously reclaimed land formerly used for both arable and pastoral agriculture. Construction of 7 km of new defences, reaching 3 km in land, began in autumn 2011. The site was breached on 9th September 2013 through a single opening in the shingle bank, forming a semi-diurnal, mesotidal estuarine system.

3. Materials and methods

Five monitoring sites were initially investigated at Medmerry and described by Burgess et al. (2016). In this study measurements were taken at Sites 3 and 5 (Fig. 2), two sites of similar design and construction but contrasting in spatial position within the Medmerry site. Both of these sites were heavily disturbed and altered by heavy plant machinery during site construction as material was extracted to construct the new defences creating borrow pits; areas of lowered elevation designed to encourage the development of a range of different intertidal habitats.

Site 3 (Fig. 2a), situated at the centre of the inundated site, historically was an area of pastoral land with vegetation growth increasing during the 20th century. The site is located in an excavated channel that gently slopes up to the borrow pit behind the remnants of a row of trees. The channel was cut through the eastern bank of a pre-existing terrestrial drainage channel which now forms the main drainage network through the site, draining both tidal waters and freshwater from the wider catchment flowing from upstream through two tidal gates. Up to 1.5 m of soil was excavated during construction of the borrow pit and access channel exposing soils compacted by the removed large overburden, with the heavy construction machinery causing additional compaction. The monitoring site is inundated at high water during every tide.

Site 5 (Fig. 2b) is located towards the back of a borrow pit in a remnant barley field near the breach area, which is inundated during every tide and is exposed to the prevailing wind from the south west. The barley field was harvested the week before the site was breached and had previously been used consistently for agricultural purposes.

3.1. Hydrodynamic analysis

Hydrodynamic variations at both sites were measured by YSI EXO2 Sondes fitted with conductivity, temperature, depth and turbidity probes, deployed in near bed scaffolding rigs (Fig. 2) at 0.46 mOD