Ocean and Coastal Management 152 (2018) 88–99

Contents lists available at ScienceDirect

Ocean and Coastal Management

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

Delivering sustainable coasts: Monitoring the long-term stability of a breached barrier beach, Porlock Bay, Somerset, United Kingdom

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ARTICLE INFO

Keywords:
Barrier beach
Sustainability
Managed realignment
Geomorphology
Monitoring

ABSTRACT

In many parts of the world, coastal managers have been compelled to make tough decisions about resource allocation, coastal protection and habitat restoration. The creation of habitats through managed realignment initiatives are essential tools for coastal zone managers. Porlock beach is an early example of managed realignment following the decision in the early 1990s to allow natural breaching without repair. Monitoring of these events is essential in understanding geomorphological evolution, but also to reassure the public and inform coastal managers in relation to the long-term stability of the barrier features. The planimetric beach change and inlet development at Porlock beach has been analysed from 1999 to 2014. The study utilised aerial photography and LiDAR datasets to ascertain shoreline positions and barrier width measurements throughout this period and calculate rates of change using linear regression. The results suggest that after some initial significant change, the beach itself and the breached inlet has generally stabilised. The increase in barrier width observed across all datasets is not reflected in the first sample period, spanning 1999 to 2006, which can be correlated with previous findings in the locality. Seaward barrier boundary advancement and landward boundary recession correlate to increased beach width observations, and can be attributed to redistribution and flattening of the barrier following barrier roll-over and breaching. Overall, this research suggests that the barrier beach at Porlock, whilst still exhibiting feature dynamism across shorter time-scales, is indicating relative geomorphological stability in the longer term which is considered important for coastal management.

1. Introduction

Coastal managers in all countries face difficult decisions in relation to improving and maintaining sea defences, as well as meeting other objectives such as the creation of new coastal habitats including salt marsh. Economic imperatives also mean that managed realignment is now seen as an effective tool for sustainable coastal management as well as essential for the creation of, inter-tidal environments which have historically been regarded by authorities as low-value (Doody, 2004; Baily and Pearson, 2007). At the same time, it must be recognised that the general public often perceive managed realignment in a negative way and need reassurance that managed realignment does not simply mean abandonment of coastal areas.

The progressive understanding of geomorphological-ecological coastal processes and quantification of anthropogenic impacts have notably altered the approach of coastal managers whom increasingly recognise saltmarsh value in terms of coastal defence, conservation and recreation (Allen and Pye, 1992; King and Lester, 1995). As a result, coastal national policy and management within the United Kingdom (UK) has encouraged saltmarsh restoration and creation following the EU principles of Integrated Coastal Zone Management (ICZM), (McKenna et al., 2008; Ballinger et al., 2010). Furthermore, the Habitats Directive and the Birds Directives (EC, 1992, EC, 2009) direct the prioritisation of important habitats and provide empirical guidelines to member states concerning sustainable coastal management (Ledoux et al., 2000). Consequently, an increasing number of sites are being left to evolve in response to natural processes which include allowing barrier beaches to breach and new areas of saltmarsh to form behind these breaches. It is important that detailed long-term monitoring is carried out on such schemes to assess the potential implications of further projects of a similar nature and to understand the timeframes over which stability is achieved, if at all. This type of analysis may also reassure the public that allowing a barrier to breach does not lead to a longer-term collapse in the wider coastal system, but is a process of gradual change and new stability. Despite the importance of coastal monitoring and surveying, relatively few sections of UK coastline have been historically consistently monitored, often due to accessibility constraints of inter-tidal regions (Baily and Collier, 2010). Modern

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https://doi.org/10.1016/j.ocecoaman.2017.11.022
Received 13 January 2017; Received in revised form 23 November 2017; Accepted 24 November 2017
0964-5691/

survey methods have increasingly utilised remotely-sensed data for coastal analysis within a GIS, and as such, a similar methodology is applied for this study.

This research assesses the longer-term geomorphological change of the gravel barrier beach at Porlock Bay, Somerset, UK, following the breaching of the shingle ridge after a storm event on 28/29th October 1996. The primary aim of this research is to quantify rates of planimetric shoreline and beach width change, using remotely-sensed data acquired post October 1996. The long-term stability and geomorphological change of a section of coastal barrier are considered in this study, following the decision to allow it to breach.

This research covers the period from 1999 to 2014 and continues the theme of previous work of Jennings et al. (1998), Bray and Duane (2001), Cope (2004), PCO (2009). Jennings et al. (1998) refer to Porlock as a unique "microcosm of the U.K. as a whole" (1998, p. 88). Bray and Duane (2001) provided the most comprehensive analysis of the contemporary geomorphology of the Porlock barrier thus far, supported by historical surveys of gravel volume and breach inlet migration. Importantly, recommendations for future monitoring and management are also provided. Limited historical discussion is available (Carter and Orford, 1993; Orford and Jennings, 1998), whereby past change rates are derived for temporal comparison with contemporary conditions. This research moves on from these previous studies to analyse the longer-term changes which have occurred since breaching. Through the assessment of channel formation, breach inlet and planimetric change of the barrier itself, this analysis critically examines the evolution of the geomorphological system from 1999 to 2014.

2. Study area

The coarse clastic gravel barrier beach at Porlock Bay, Somerset, UK is located on the macro-tidal Bristol Channel coastline and extends approximately 5 km from Gore Point to the headlands at Hurlstone Point (Fig. 1). Historically, the barrier has been subject to variable relative sea level rise since (RSLR) c. 8,000 cal yrs BP, and has experienced landward retreat resulting from berm formation and overwashing cycles (Bray and Duane, 2001). Further exacerbation by human reclamation of the hinterland is also cited (Jennings et al., 1998, Bray and Duane (2001).

Management of the barrier beach at Porlock can be traced back to the mid-nineteenth century to prevent breaching and flooding of the grazing land behind the beach (Cope, 2004). In the 1990s management agencies adopted a policy of non-intervention leading to an eventual breaching of the barrier in 1996 (Fig. 2). Previously, management of the site has promoted hard engineering approaches including groyne construction immediately east of the breach channel inlet and at Porlock Weir, in addition to Porlock ford sea wall (Bray and Duane, 2001; Blathwayt, 2010) (Fig. 2). Geometric design modification of the groynes west of Porlock Weir, supported privately by Porlock Manor Estate, has increasingly considered geomorphological trends and sediment supply in protecting the western barrier region (Blathwayt, 2010). However, groyne construction at Gore Point, indicated in Fig. 2, has reduced shingle input to the ridge, limiting the barrier's capacity to attenuate wave energy (English Nature, 2002). Furthermore, a policy of managed retreat has been adopted and is anticipated for at least the next 50 to 100 years, from Porlock Weir to Hurlestone point, within which the study area is situated (Fig. 1) (NDASCAG, 2009). Nevertheless, cessation of engineering in this region has helped to provide a 'natural' monitoring context for developing understanding of barrier response to breaching and formation of saltmarsh habitat. Since the abandonment of artificial defence maintenance, environmental and economic incentives for establishing a managed realignment site with Special Site of Scientific Interest (SSSI) designation have assisted with fulfilling national and EU sustainability targets. Following breaching, the defence policy adoption at Porlock Bay and subsequent monitoring of environmental change can provide a useful analogue for geomorphological and ecological feedbacks in similar contexts.

The predominantly single-ridge barrier is formed upon Mercia Mudstone, a calcareous clay and mudstone sequence deposited in the Triassic period (Hobbs et al., 2002). The barrier material mostly comprises locally-sourced clays, silts, sands and gravels, formed as head or river terrace deposits and eroded locally from cliffs (BGS, 2013). Due to changes in sea level, a domain shift from drift to swash-alignment of the barrier was initiated, contributing to natural 'roll-over' and enhanced by increasing sediment depletion (Jennings et al., 1998). The region is subject to prevailing westerly winds influencing longshore sediment transport processes.

Contemporary tidal range at Porlock has been recorded at 9 m (PCO, 2009) and a unique tidal regime has developed, establishing an equilibrium between the seaward edge of the lagoon substratum and local regimes within the Bristol Channel (Bray and Duane, 2001). Combined with RSLR, this process has resulted in periodic inundation of the lagoon behind the barrier at high water, and draining of the intertidal zone, sustaining saltmarsh formation (Fig. 3).

3. Method

A suite of coastal imagery datasets were utilised for this research covering the period 1999–2014 to follow on from the work of Bray and Duane (2001), who analysed the period up to 1999. This study makes use of aerial photography and LiDAR datasets between 1999 and 2014, available from Channel Coastal Observatory and the Department of Geography, University of Portsmouth (UOP). Initially, unrectified 1:4000 photography captured in 1999 was acquired from UOP and georeferenced to associate points of the historical configuration with locations on the modern barrier. In addition, orthorectified aerial photography was downloaded from the Channel Coast Observatory's (CCO) online data catalogue for 2006, 2010 and 2013 for temporal comparison. Unfiltered 1 m resolution LiDAR data was also downloaded from CCO's database for 2007a,b, 2009a,b, 2012 and 2014. The LiDAR datasets were utilised as proxies for planimetric shoreline position, and provided a positional accuracy of ± 0.3 m (CCO, 2015a,b).

Overall, assessment of barrier width change and planimetric migration of the shoreline and breach inlet was undertaken using a combination of ArcGIS 10.3 and USGS's Digital Shoreline Analysis System (DSAS) v.4. In order to capture planimetric shoreline positions from each dataset, manual 'heads-up' digitisation of shoreline positions from all dataset years was undertaken. Following the review of similar studies (Thieler et al., 2005; Kuleli et al., 2011), the USGS Digital Shoreline Analysis System (DSAS v.4) was utilised as an appropriate tool for baseline and transect generation to quantify shoreline change. Transect generation from the baseline was then undertaken, specified at 115 m baseline-perpendicular intervals before minor geometric modification was undertaken to enhance clarity for measurement. The transects were divided in to three groups representing the western, central breach and eastern zones of the study area. Group 1 includes transects 1–6 (western region); group 2 transects 7–10 (central breach area) and group 3 transects 11–16 (eastern region), presented in Fig. 3.

Change rate calculation was then undertaken in DSAS, outputting intersection and statistical rate tables to a personal geodatabase. These rates were then processed and are presented in graphic form within the results section of this paper. The requirement by DSAS for the inclusion of uncertainty values associated with each shoreline facilitated expression of change, whilst considering variable error sources and values across the datasets.

Further to analysing planimetric migration of the landward and seaward barrier boundaries, the original shapefiles digitised from each dataset were converted to polygons. The purpose of this was to derive values for the variation in beach width across the sample period, to provide qualitative discussion of correlation between these observations and those of planimetric change. These were further correlated with observations from breached and eroded barrier regions in order to