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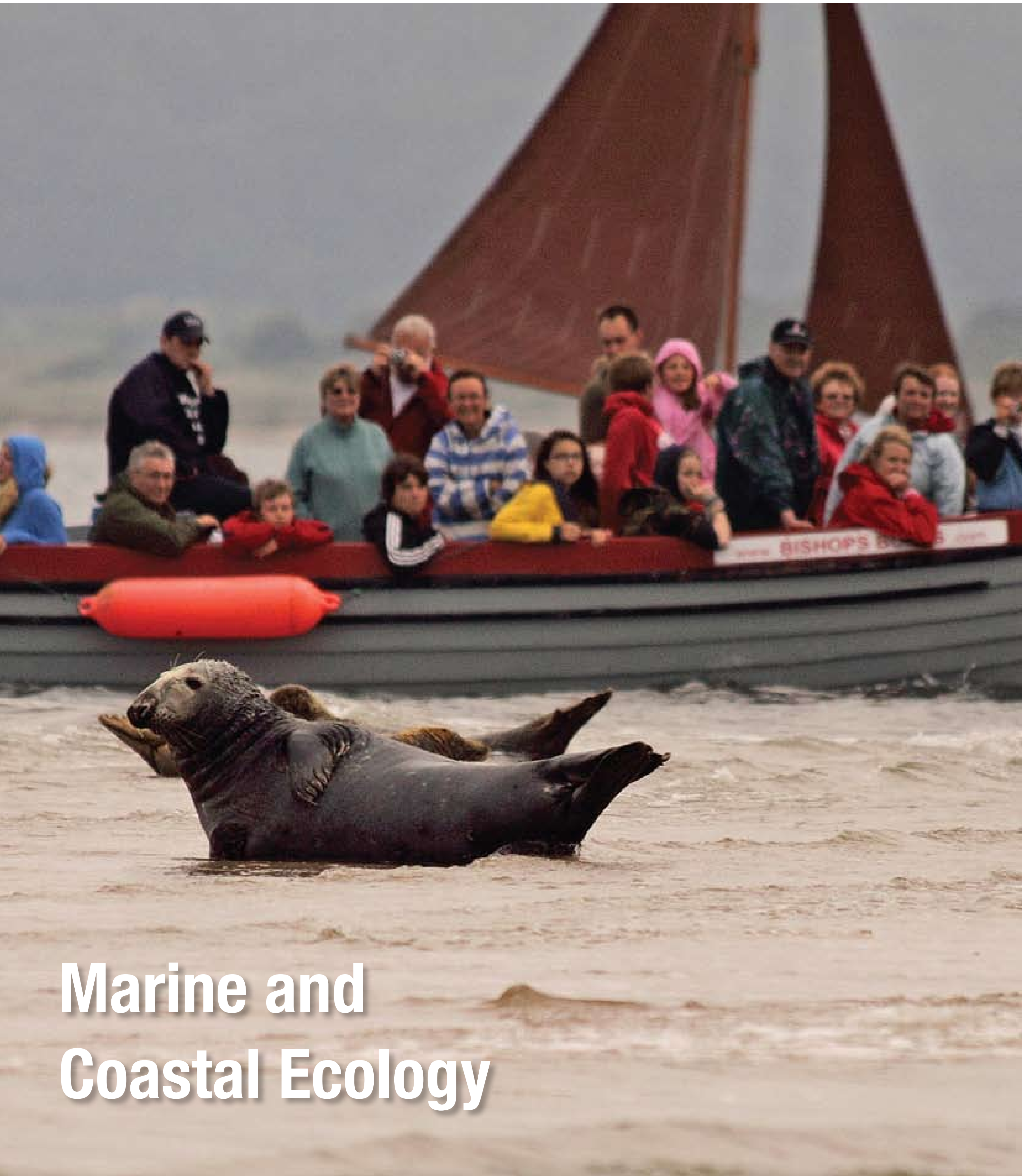

Marine and Coastal Ecology

Sediment - The Coastal Environment's Overlooked Asset

Roger Morris CEnv FIEEM
Bright Angel Coastal Consultants

Introduction

"Put rocks on a beach to stop it eroding - that is how to manage the coast" was the immediate riposte of a friend who learned I was attempting to write a book on coastal management. I am pretty sure that the great majority of the British public if asked about coastal management issues would highlight coastal erosion as a big management issue and would offer similar advice. But, is erosion really the threat, or is it part of the solution?

To find the answer we need to look to the way that our coastline has responded over the past 8,000-10,000 years since the end of the last glaciation to understand how the coast works, and how it responds to sea level rise. At the peak of the last glaciation some 18,000-20,000 years ago sea levels were as much as 120 m below current levels and the British Isles were effectively part of the European mainland, albeit with a tundra-like climate. Glacial melt-waters together with isostatic adjustment and thermal expansion of sea water combined to elevate seas to modern levels at a fairly rapid pace, so that by the time our recorded history emerged from the Iron Age the coastline largely resembled its modern form.

Our modern coastline has benefitted from the huge volumes of material deposited by the retreating glaciers. The melt-waters helped to sort the material and to transport it towards the sea, whilst the sea itself contributed to the sorting process by moving sediments of differing weights over sometimes considerable distances. Much of the sediment was pushed landward by the sea to form sand dunes, mudflats and shingle ridges, very large volumes of sediment were also deposited in deeper water to form sandbanks in the southern North Sea and the Irish Sea, whilst finer fractions may have been drawn offshore and deposited in deeper water where re-mobilisation is less likely. In addition, substantial sections of the eastern and southern English coastlines have eroded to feed sediment into the evolving coastline.

These processes provide an important explanation about how the coast evolves in the face of sea level rise: it rolls back, with mobile sediments pushed landwards by the rising seas. On the open coast, these sediments are bigger and heavier cobbles, shingle and sand, whilst upstream in estuaries the finest clay and silt particles coagulated as flocs in response to particular chemical and physical parameters. Thus, whilst some of the UK's coastal evolution is driven by fluvial sources, the vast majority arises from re-working of existing material or from the legacy of the last ice-age.

Most of the historic supplies of sediment have been used up (Orford and Pethick 2006) or are in the process of re-working. In addition, substantial sections of the coast have been defended to arrest erosion, leading to reduced sediment supplies from the one remaining viable resource. Saltmarsh erosion in south-eastern England is one of these responses. Sea level rise leads to increased energy inputs on the outer face of the mudflats and saltmarshes and re-mobilises sediment. The question is what happens to this re-mobilised sediment?

Roll-Over - A Theory Borne Out By Geological History

Using the idea that as sea levels rise sediment is pushed landwards, a conceptual model (Figure 1) can be constructed in which eroded sediment will be pushed inland until it achieves a lower level state of entropy. This is readily apparent when wash-over fans on shingle beaches are examined (Photograph 1). Each episode of wash-over pushes the shingle inland, with the broad estimated rate equating to 1 m of lateral movement for every metre of sea level rise. Thus, it can be expected that barrier beaches such as Chesil Beach will eventually over-run freshwater features to their rear. Apart from Chesil Beach there are many others such as Cley-Salthouse and the Walberswick to Minsmere coast.

For roll-over to work, however, there must be somewhere for this sediment to go. This coastal space is known as 'accommodation space' which is absolutely crucial to coastal evolution. In estuaries for example, it is the land in the floodplain that has been annexed to form some of our most important and productive agricultural land. If there is no space, the sediment is likely to be transported offshore: often into deeper water offshore where it cannot be re-mobilised.

Where roll-over does happen in muddy environments, eroded sediment will be deposited on saltmarshes, making them gain vertical height, whilst their lateral position may still adjust landward. For example, in the Blyth Estuary in Suffolk, despite

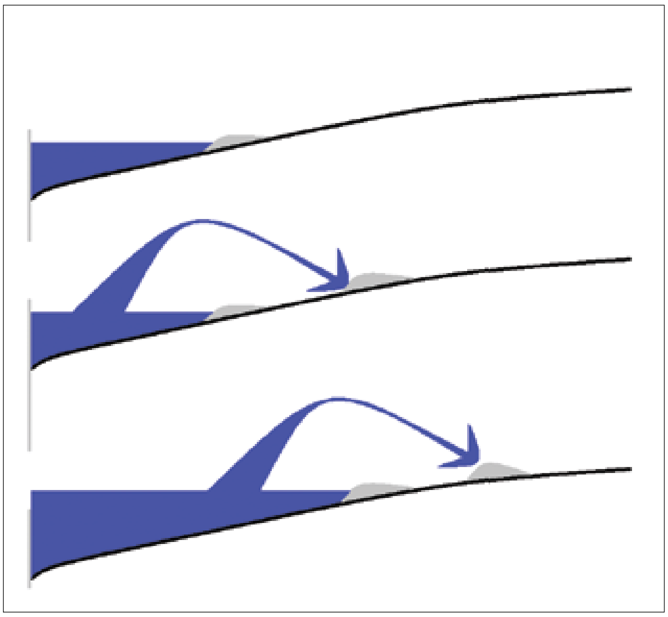

Figure 1. A simple model of sediment roll-over in response to sea level rise. This particular model represents barrier beaches of heavier pebbles forming shingle banks.

Photograph 1. Wash-over fan behind the shingle barrier beach at Porlock, Somerset. At this site, the sea has been allowed to breach the shingle barrier beach in order to allow the evolution of a more stable coastline.

there being lateral erosion, the saltmarshes continue to accrete vertically (French and Burningham 2003). The problem is that there is now insufficient accommodation space in many estuaries which have now been effectively canalised or their form is such that they export rather than import sediment. What is more, the upper ends of estuaries have lost the majority of their tidally inundated freshwater marshes (Van den Bergh *et al.* 2009) that would have been the most important accommodation space and also provide the chemical and physical parameters that facilitate flocculation.

The Role of Accommodation Space

Where accommodation space is lacking, saltmarsh erosion continues and is followed by mudflat loss too. This leads to exposure of sea walls to ever increasing levels of wave energy because mudflats and saltmarshes are natural energy interceptors (Morris 2010). This in turn leads to sediment exported into offshore locations whilst structural stability of sea walls declines and they require increasing levels of engineering to maintain them. (Photographs 2-3). A useful additional indicator of shortfalls in accommodation space is the paucity of saltmarsh in estuaries that have had much of their former saltmarshes converted to agriculture so that very little saltmarsh remains. Estuaries that face these problems invariably have sea walls that have to be armoured and that require strengthening of the toe of the wall to prevent undercutting (Photograph 4).

If, on the other hand, there is sufficient accommodation space, mudflats and saltmarshes will continue to recede laterally but they will gain elevation and hence they will maintain their value as energy absorbers. This means that there is a need to create accommodation space in estuaries, *i.e.* managed realignment. One of the enduring problems facing coastal managers is the tendency for the public at large to regard realignment as unacceptable retreat - allowing the sea to take back hard-won resources. In addition, realignment has been largely promoted as a conservation tool and consequently it is associated with wildlife management rather than a necessary part of flood risk management.

Lack of accommodation space starts to equate as a monetary value, because as the coastline erodes, the costs of maintaining sea walls increases to the point where further efforts are too difficult or too costly. But, it is just half of the challenge. Not only is there a need to create accommodation space for saltmarshes and mudflats to roll back over, there is a need for sediment to be available in sufficient volumes to allow mudflats and saltmarshes to keep pace with sea level rise. Erosion of the foreshore alone is not sufficient as tides and currents inevitably lead to leakage. Some of the sediment eroded from the coast of eastern England is believed to end up on the Dutch and German coasts (HR Wallingford *et al.* 2002), so coastal managers need to take this into account when planning coastal adaptation programmes.

Valuing Sediment - A Paradox

At the end of the last glaciation the landscape had much greater plasticity. There were ample supplies of mobilisable sediments and plenty of water to undertake the engineering required. Today the landscape has evolved so that very little material is mobilised from terrestrial sources even during major storm events. Woodlands and grasslands largely bind the sediment and the volumes of water passing over the land surface differ considerably from those arising from melt waters. Consequently, estuaries and the open coast are hugely dependent on various forms of re-mobilisation by the sea. This is well-illustrated by the sediment budget for the Humber Estuary, which has been estimated to comprise less than 5% from fluvial sources (Townend and Whitehead 2003) with the remainder arising from re-mobilisation, cliff erosion on the Holderness coast and erosion of associated wave-cut platforms.

The Humber is an important model because it lies down-drift from one of the largest uninterrupted sources of new sediment in the UK. The exceptionally high sediment loading of this estuary gives it the appearance of a river of mud at times, but the importance of this sediment is well illustrated by accretion rates at realignment sites such as Paull Holme Strays on the north bank (Richardson 2004) which accreted by as much as 5 cm per month in the first year. By comparison the Tollesbury realignment in the Blackwater Estuary accreted at least an order of magnitude more slowly.

Sediment shortfalls along the coasts of Suffolk, Essex and Kent, combined with lack of accommodation space mean that development of more sustainable defence lines along realigned boundaries is much more challenging. The same holds in the Solent, where defences along the coast between Selsey and East Head have influenced the evolution of the spit at East Head and have given rise to concern that it might breach at its neck. Similarly, much of the coastline between Christchurch Harbour and the Lymington Estuary is now defended against erosion, reducing sediment availability in the Lymington River and elsewhere in the Solent.

Photograph 2. Foreshore erosion in front of the sea wall at North Killingholme, North Lincolnshire. This illustrates the loss of fine muddy sediment and exposure of harder consolidated sediments.

Photograph 3. Saltmarsh erosion exposing the toe of the sea wall at Wallasea Island, Crouch and Roach Estuary, Essex. This photograph shows classic coastal squeeze features: cliffed saltmarshes, lowered mudflats and undermining of sea walls.

Problems of sediment shortfall and the need to create sediment sinks to minimise loss must eventually lead to significant policy changes. At the moment, for example, Government is unwilling to consider compensation for people whose homes and land are eroded away. This is of course understandable from one perspective, but perhaps an alternative view is to consider high profile erosion hardship cases reinforcing the public perception that coastal erosion is something that must be countered? Each time more coastal protection is installed there is less sediment entering a system that is gradually moving towards a rate of sea level rise analogous to the rates following the last glaciation. Surely, therefore, there is a case for looking at ways to maintain or even increase sediment supplies?

Sediment Husbandry: The New Coastal Paradigm?

Taking the long view of coastal evolution, it is clear that our attempts to hold the line all along the coast are doomed to failure. It may be possible to continue current levels of defence for perhaps a further generation, but when the defences cannot be maintained the problem this will cause will be of a far greater magnitude than we might experience today. The most critical point is that whilst we fail to create adequate accommodation space to absorb eroded sediment, non-renewable supplies will be leaked into deeper water where they can only be retrieved in comparatively small volumes at very high monetary and carbon costs. Such an approach cannot be sustained and so the cost to future generations will be much higher than they might be if action is taken now.

This means that a monetary value can be placed on sediment. The calculations have not been done as far as I am aware, but bearing in mind that 1 cm of accretion over 1 ha of a saltmarsh requires a sediment input of 100 m^3 of wet clay and silt, the volumes required simply to warp up realignments to the height required to support mid- and high-level saltmarsh are phenomenal. This means that eroding cliffs start to have a very real value if one also takes into account the conversion ratio of eroded material to sediment reaching the target site.

A similar approach can also be taken towards dredged sediment from navigation channels. Far from being a waste product, it is a valuable resource that has more value in the coastal environment than either being disposed of far offshore or being landed for use as fill. Offshore disposal does confer one possible benefit however: providing the disposal site is sufficiently close to the coast, dispersed material may be returned to the coastal environment and absorbed elsewhere. The crucial issue is to create the necessary sinks to prevent loss.

Following this sequence of thoughts, the concept of managed realignment could and probably should be re-packaged as creating sediment sinks to improve adaptation to sea level rise. Meanwhile, coastal erosion needs to be re-branded as a positive contribution to adaptation to sea level rise and not as a threat to people and property: the real threat is insufficient erosion.

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Correspondence: brightangel.coastal@googlemail.com

Photograph 4. Armouring at the base of the sea wall at the eastern end of Wallasea Island, Crouch and Roach Estuary, Essex. This illustrates how foreshore recession has led to piecemeal attempts to maintain the integrity of the sea wall.