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FORUM

On the loss of saltmarshes in south-east England and the relationship with *Nereis diversicolor*

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Summary

1. Two papers, Hughes & Paramor (2004) and Paramor & Hughes (2004), published in *Journal of Applied Ecology* are discussed. These papers suggest that saltmarsh erosion is linked to bioturbation, and concentrate on the role of the ragworm *Nereis diversicolor*. The authors also suggest that new saltmarsh will not develop in realignment sites because bioturbation will prevent the establishment of saltmarsh plants. We dispute their analysis and offer evidence that inferences derived from their experimental work are erroneous.
2. Experience from the current range of managed realignment sites in the UK shows that saltmarsh communities are developing, and include the lower marsh *Salicornia* communities that they suggest are vulnerable to the effects of bioturbation and grazing by *N. diversicolor*.
3. Further evidence of the benefits of managed realignment, even in situations where realignment sites lie below existing seaward mudflat levels, is provided by the saltmarshes that developed on sites that were not re-enclosed after the 1953 flood in eastern England.
4. We highlight the importance of maintaining positive sediment budgets in order that saltmarshes may continue to adjust to sea level rise and to ensure that sufficient sediment exists to allow realignment sites to warp up to levels at which pioneer saltmarsh may develop.
5. We also draw attention to a range of initiatives that seek to maintain sediment levels within estuaries in south-east England, and highlight the broader conceptual approach that looks upon dredged sediment as an important resource and not a waste material. None of these is designed to change permanently the estuarine tidal prism, as suggested by Hughes & Paramor (2004).
6. *Synthesis and applications.* We present evidence to show that coastal realignment is effective in managing and reversing saltmarsh erosion. We dispute the conclusions presented in the recent papers by Hughes & Paramor (2004) and Paramor & Hughes (2004). We suggest that infauna play an essential role in saltmarsh ecology and that *N. diversicolor* does not play a destructive role in saltmarsh establishment. In the broader context of coastal management, the long-term benefits of managed realignment in sea defence and in delivering nature conservation benefit are quite clear. Sustainable sediment management will play a key role in sustaining saltmarsh habitats in the future.

Key-words: bioturbation, coastal squeeze, managed realignment, saltmarsh erosion, sediment management

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Introduction

Prior to the 1980s, enwalling saltmarsh to secure new agricultural land was commonplace in the UK, especially in southern and eastern England but also in the north-west on estuaries such as the Dee and the Ribble. These land-take projects occurred largely at a time of ongoing saltmarsh accretion but continued until the negative effects on nature conservation interest were obvious and became a matter of concern (Davidson *et al.* 1991).

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Burd (1992) showed that saltmarsh in southern and eastern England was undergoing large-scale erosion. This has continued and is estimated at 25% of saltmarsh extent lost in the past 25 years in Essex (University of Newcastle 2000; Covey & Laffoley 2002). Although these losses continue in many areas, evidence from Kent indicates that the process of erosion in the Medway Estuary is shifting towards accretion and, although some areas continue to erode, the prediction is for a long-term trend of accretion (Living with the Sea 2003).

Continuing saltmarsh loss is a matter of concern not only because it involves the overall diminution of an important range of biotopes, but also because saltmarshes provide cost-effective wave energy attenuation, thereby substantially reducing the cost of flood defence measures required.

Since 1992 the concept of managed realignment has been advanced as a cost-effective solution to the twin problems of biodiversity loss and flood management (English Nature 1992). As Hughes & Paramor (2004) report, it is accepted as the appropriate resolution to ongoing saltmarsh loss by English Nature and a variety of other organizations and agencies, including the Environment Agency, in the UK. Hughes & Paramor (2004) are also correct in reporting that few large-scale trials have been undertaken to date, but are incorrect in asserting that English Nature believes it is conceptually an inadequate response. This misrepresents our position. We acknowledge, however, that the pace of realignment has been disappointing and at the current rate it will not offset current and predicted biodiversity losses.

The slow progress in delivering new intertidal habitat in the UK is often because managed realignment challenges societal preconceptions that coastal land should be defended from the sea, whatever the cost to the exchequer and regardless of the economic benefits. As a result, there has been substantial resistance to a number of potentially beneficial projects. Bigger realignment projects are emerging, however, and will be undertaken in the near future.

In the longer term, the Humber Estuary Shoreline Management Plan (Environment Agency 2000, 2002, 2003) proposes a phased series of substantial realignments to create a morphological solution to flood management on the Humber Estuary. Other estuary shoreline management plans highlight the need for more detailed consideration of managed realignments, through greater understanding of their geomorphological implications. These developments show that there are gradual changes towards a new approach to dynamic coastal management that is being progressed around the English coast.

What lies behind saltmarsh loss?

Analysis of responses to sea level rise in the UK must take account of the fundamental changes in coastal management subsequent to the great storm of 1953, in which many east coast coastal defences were breached, resulting in a substantial loss of life. Prior to this, coastal flood defences and sea walls in the UK conformed to no particular design criteria, having evolved to meet local needs. In subsequent years, walls were designed to counter particular levels of flood risk; they were strengthened and enlarged and were reinforced with various forms of block-work and concrete. The impact of 50 years of enhanced flood and coastal defence is embraced within UK coastal policy-making and forms one of the key findings of the Foresight project (Evans *et al.* 2004). While Hughes & Paramor (2004) highlight rapid erosion in the period 1950–83, they do not make the connection with the extensive storm and sea wall construction programme that followed. Nor do they draw attention to the levels of storminess during parts of the 1970s and 1980s (Pye 2000).

The flood defences of the Crouch and Roach Estuaries in Essex are typical, with extensive sections of block-work and very little saltmarsh. This is a classic example of coastal squeeze, where an estuary with an extensive floodplain has been effectively canalized, giving little room for further saltmarsh development or retention of existing saltmarsh. In these circumstances, wave energy is reflected onto saltmarsh and results in erosion at the foot of the wall and elsewhere within the marsh system. In addition, hard structures such as rock armour and concrete berms, to prevent erosion of soft rock cliffs, have reduced significantly the source of suspended fine material from the open coast that contributes to the sediment budget of many estuaries. This only serves to exacerbate the problem.

These factors, together with sea level rise, combine to influence the evolution of saltmarsh, both on the exposed coast and in estuaries. Any evaluation of saltmarsh adjustment to anthropomorphic and climate change impacts must therefore take account of the sediment sources and the role of saltmarsh and mudflat erosion in supplying sediment that is deposited on upper- and mid-zone saltmarsh. This follows the line of progressive evolution of intertidal sediments in response to relative sea level rise, termed stratigraphic rollover (Allen 1990).

Hughes & Paramor (2004) draw attention to the disparity between estuaries in south-east England and elsewhere, and the concentration of erosion in the south-east. They suggest that regional differences in the physical environment may explain differing rates of saltmarsh erosion. This is of course a possibility, but there are a number of fundamental morphological differences that explain variations in saltmarsh evolution in different parts of the country. For example, the Dee and Ribble estuaries in north-west England have been substantially foreshortened, leading to accretion of coarse sediments. Thus, in these instances, the accreting component of the estuary is relatively wide in comparison to its channel width, promoting flood dominance and net sediment import. Taking the Solway at the borders of north-west England and Scotland as another example, this is a wide funnel-shaped estuary that has extensive saltmarsh and sandflats, and relatively short lengths of flood banks: it is a relatively natural form in comparison with the eroding estuaries of the south-east.

The use by Hughes & Paramor (2004) of the Humber Estuary and Ribble Estuary to argue the deleterious effects of bioturbation by *Nereis diversicolor* (Müller) is in itself misleading because the Humber has lost most of its saltmarsh to land-claim. This makes the Humber noteworthy because the saltmarsh extent is uncharacteristically low for an English estuary (Davidson & Buck 1997). Apart from a small area of sea purslane *Atriplex portulacoides* L. and sea lavender *Limonium vulgare* Mill. marsh, the majority of saltmarsh habitats comprise sea couch *Elytrigia atherica* (Link)-dominated communities in the outer estuary and a mixture of common reed *Phragmites australis* (Cav.), sea club rush *Bulboschoenus maritimus* (L.) and sea aster *Aster tripolium* L. upstream of the most saline influences (Allen *et al.* 2003). In the outer estuary, glasswort *Salicornia anglica* agg. and cordgrass *Spartina anglica* C.E. Hubb. marsh is developing, seemingly a reflection of changing particle size and a trend towards the deposition of fine silts.

In their attempt to counter the coastal squeeze argument, Hughes & Paramor (2004) quote the seaward expansion on the Dengie Peninsula subsequent to enwalling some 200 years previously. They omit to mention that currently the saltmarsh on the Dengie Peninsula is in retreat and that it is rapidly eroding, graphically described by Pye (2000). This trend, among others, provides evidence that circumstances on the Essex coast have changed over the past 50 years. We suggest that the key reasons relate to relative sea level (RSL) rise, increased storminess and reductions in available sediment owing to interruption of coastal processes.

Hughes & Paramor (2004) argue that relative sea level rise has been no greater in recent decades than in the past, and that one might expect loss of upper-zone saltmarsh plants in the first instance if coastal squeeze was a reality. While there are examples where monitoring does not agree with quoted predictions of sea level rise, others correlate more closely with predictions, albeit towards the lower end of global predictions but nonetheless consistent with trends obtained elsewhere in Europe (Woodworth *et al.* 1999). Importantly, the impact of sea level rise on nature conservation is considered sufficiently severe that it is the subject of a major modelling programme funded by the UK conservation agencies and other partners to investigate responses to a variety of climate change scenarios (Harrison, Berry & Dawson 2001).

Hughes & Paramor (2004) also argue that saltmarsh losses are related to 'relatively recent and regional-scale increases in bioturbation and herbivory by the invertebrate infauna'. Using matting to exclude infauna, they demonstrate accretion and conclude that it is the infauna that inhibits accretion within saltmarsh creeks (Paramor & Hughes 2004). Through reference to these experimental results, they reject the concept of managed realignment as a practical response to coastal squeeze. In the absence of an adequate explanation of how the experimental design took account of the physical impact of the matting itself on accretion , we have doubts about the conclusion that infauna prevents colonization by halophytes. It is also noteworthy that Hughes & Paramor (2004 overlook the role of managed realignment as a response to predicted increased storminess and storm surges, especially in south-east England. Delivery of economically sustainable flood defence is an issue recently tackled by Defra in their recent policy paper (Defra 2004).

In highlighting some of the problems in delivering managed realignment, Hughes & Paramor (2004) imply that the process seeks to deliver instant saltmarsh creation. This has never been the case. Various demonstration projects have been undertaken (Covey & Laffoley 2002) and some important lessons have been learnt. These projects refute Hughes & Paramor's (2004) assertion that saltmarsh generation on newly accreted sediments will not happen because of earlier infaunal development; the evidence points to the contrary.

Managed realignment schemes, such as the Tollesbury example used by Hughes & Paramor (2004), have in fact developed pioneer saltmarsh, including *Salicornia europaea* agg. (L.). Garbutt *et al.* (2003) describe this project in detail and report that by 2001 (realignment occurred in August 1995) some 6 ha of the 21-ha site was vegetated, largely by *Salicornia*. They show that colonization depends upon a wide range of local factors, including topography, sediment supply and position within the tidal frame. Garbutt *et al.* (2003) also highlight the importance of creek systems in draining and consolidating newly accreted sediment such that it has greater shear strength and is the first to be colonized by *Salicornia*. Apart from the published evidence, we draw attention to the realignment site at Freiston Shore in the north-west corner of the Wash in Lincolnshire. This site, breached in 2002, not only accreted rapidly but also developed extensive *Salicornia* marsh in the first spring following the breach.

In the absence of longer term examples arising from managed realignment, we suggest that the best examples of saltmarsh regeneration can be seen where the flood banks breached in 1953 were not repaired. In these cases, upper zone saltmarsh had developed prior to the study period used in Burd (1992). For example, the extensive saltmarsh at Lion Creek on the Crouch Estuary includes a network of former sea walls that lie slightly above the *Atriplex portulacoides* marsh and contribute higher ground with extensive areas of sea wormwood *Seriphidium maritimum* (L.). There are also extensive saltmarshes on the Alde Estuary in Suffolk that derive from a breach event.

There are exceptions, however, where saltmarsh has not developed. In such cases, the explanation often lies in the physical profile of the estuary. At sites characterized by strong ebb currents derived from a large internal tidal prism passing through a very narrow mouth, sediment deposition is limited and there is little opportunity for the breach site to accrete to saltmarsh. An example is the 1953 breach on the Blyth Estuary in Suffolk, which is upstream of extreme canalization that seriously affects the relationship between the cross-section of the mouth of the estuary and the tidal prism.

Finally, Hughes & Paramor (2004) imply that the generation of saltmarsh is the key success criteria for managed realignment; this is not so. Success is better judged by considering the improved sustainability of flood defences, both at the site and in the estuary as a whole. While the creation of new intertidal habitat (not just saltmarsh) is an important outcome for nature conservation, the contribution that strategically planned realignments make to helping sustain estuarine systems, and the suite of biological interests they support, is more important.

Beneficial use of dredged material

Hughes & Paramor (2004) also raise the possibility that dredged materials could be used to reduce tidal volumes. As their hypothesis states that bioturbation prevents saltmarsh development, it is difficult to see why such sediment deposition would be any less affected by bioturbation effects and would therefore develop as saltmarsh. Where recharge material is placed without dewatering and vegetation development, it is unlikely to remain *in situ* and will rapidly erode away unless it is of a consistency of geological clays. The latter form is largely unavailable from dredging activities except in special circumstances relating to the nature of the dredge (capital rather than maintenance) and the type of dredger (backhoe rather than cutter-suction).

Even though we reject the suggested use of dredged materials to restore saltmarshes in the way proposed by Hughes & Paramor (2004), it is helpful that they have raised the issue of beneficial use of dredged materials; this is an important area of research and is undergoing development at a number of sites.

In a broader context of estuary management, there are great merits in keeping dredged materials within the estuarine system. This is already practised on the Humber Estuary, where the entire dredging output is returned to the system. Such an approach means that the Humber has sufficient sediment to allow mudflats and saltmarshes to keep pace with sea level rise. The recent Paull Holme Strays managed realignment site on the north side of the Humber, created by the Environment Agency as compensation for necessary flood defence works, demonstrates the importance of sediment load. At this 80-ha site, accretion rates monitored by the Institute of Estuarine and Coastal Studies during the first winter (December 2003–April 2004) varied from 10 to 20 cm across the main body of the site, with localized rates up to 35 cm (H. Richardson, personal communication). This scale of accretion in the absence of exclusion mats amply demonstrates the importance of sediment availability and estuarine morphology as limiting factors.

Implications for coastal management

If, as we contend, there is sufficient evidence that managed realignment sites are developing saltmarsh communities, then Hughes & Paramor's (2004) arguments that new saltmarsh cannot be created by managed realignment should be rejected. Likewise, there seems to be no reason to suppose that saltmarsh will develop before infaunal colonization in the scenarios proposed where creeks are attenuated or filled with dredged material. The interpretations presented both in Hughes & Paramor (2004) and in Paramor & Hughes (2004) include inconsistencies that undermine any argument there might be about the relationship between saltmarsh generation and bioturbation. As a consequence we believe that the coastal management conclusions they present must also be disregarded: realignment works, managed or otherwise.

Bioturbation is a natural aspect of healthy mudflat ecology and is responsible for ensuring sufficient oxygenation for infaunal communities (Gribsholt & Kristensen 2002). It is these communities that support bird populations, which are themselves of international importance and to which the UK has international obligations. The importance of the same infaunal communities to fish is often overlooked and is a further reason for seeking to ensure that the extent of saltmarsh and mudflat habitat is increased. However, the role of infauna in oxygenating and draining newly established mudflats also needs to be considered. Far from having a detrimental impact on colonization by saltmarsh species, it is probable that their presence is essential, and that *N. diversicolor* is an integral component of the assemblage. For example, Gribsholt & Kristensen (2002) show that *Nereis* and other infauna are responsible for limiting the development of algal mats (*Voucheria* spp.) on the sediment surface. Not only do these algal mats lead to benthic respiration dominated by sulphur reduction, they may also limit macrophyte propagation if they develop early enough in the spring.

In the broader context of coastal management, there is a need for attention to focus on the long-term benefits of managed realignment and the role of adequate sediment supplies in determining the long-term sustainability of saltmarsh habitats. Sustainable sediment management, in addition to other aspects of coastal management, is fundamental and needs to take a high profile in the engineering and environmental world.

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