Managed and unmanaged realignment as a nature-based solution to saltmarsh habitat loss: a sedimentary perspective

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Managed and unmanaged realignment as a nature-based solution to saltmarsh habitat loss: A sedimentary perspective

Jonathan Dale [a,*], Alex Arnall [b]

[a] Department of Geography and Environmental Science, University of Reading, Reading, RG6 6DW, UK
[b] Department of International Development, University of Reading, Reading, RG6 6DW, UK

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ABSTRACT

Managed realignment is the deliberate inundation of the coastal hinterland as a nature-based solution to saltmarsh habitat loss. Managed realignment sites are often designed and landscaped to encourage the development of a mosaic of targeted habitat types. However, despite these pre-breach engineering works, it has been demonstrated that managed realignment sites have a lower abundance and diversity of key plant species, and an increased percentage of bare ground. In contrast, unmanaged realignment is an emerging area of interest and describes sites where no landscaping or engineering works take place prior to site breaching. However, little is known of the evolution and development of unmanaged realignment sites. We argue that from a sedimentary perspective, with emphasis on the centrality of sediment in the evolution of realignment sites, the two approaches should not be classified into distinct categories. Through this sedimentary perspective, we synthesise the scientific evidence on the design and implementation of realignment in terms of the sediment structure, content, movement, and landform evolution. In doing so, we highlight that by adopting a sedimentary perspective a more integrated approach to realignment can be taken. The future research agenda is discussed, concluding that a more managed approach is needed in locations where unmanaged realignment could occur.

1. Introduction

Saltmarshes occupy around 5.1 Mha of the Earth's surface [59] and provide a range of important ecosystem services (e.g. [6]), including habitats for fish and bird species, carbon sequestration and flood defence through wave attenuation (e.g. [17]). However, this habitat is being lost and degraded due to alterations caused by human activities such as land claim, erosion causing marsh fragmentation and creek widening, and reduced sediment supply (e.g. [5,39]). As a result, approximately 50 % of saltmarshes have been lost globally [6]. A number of nature-based solutions exist to (re-)create, restore and compensate for the loss of saltmarsh habitat (e.g. [62]) including transplanting [75], implementing artificial structures to influence hydrodynamics [68] and managed realignment (MR): the process of deliberately breaching, removing or lowering coastal flood defences to allow intertidal inundation of the coastal hinterland, often in locations that have previously been reclaimed for agricultural purposes [35].

MR is considered by many coastal planners and practitioners to be the ideal solution to dealing with saltmarsh loss, but the public at large remain unconvinced of the suitability of the scheme [55,56] and view MR as 'walking away' and 'giving in' to the sea. This is likely to be due to poor communication of the benefits of MR between local authorities, coastal managers and local communities [89], with more efficient and appropriate engagement required to outline the successes of MR elsewhere. Another challenge is that MR frequently results in a lower abundance and diversity of key plant species, and an increased percentage of bare ground, in comparison to pre-existing reference sites [53]. This is despite MR sites regularly being constructed on areas that had previously been intertidal, and should therefore be able to support intertidal habitat, and sites often being designed and landscaped to control vegetation development and the resulting habitat types. These shortcomings have been associated with waterlogging and poor drainage because of changes to terrestrial soil structure [72,77], including compaction caused by the reclamation process and the former terrestrial land use, and the observation that MR sites have lower topographic variability than pre-existing saltmarshes [48].

In contrast to MR, which has been researched extensively with a focus on sites in Europe, USA, Canada and China, an emerging area of interest is unmanaged realignment (uMR). This is where no engineering works are carried out to cause breaching, and no prior landscaping,

* Corresponding author.
E-mail address: j.j.dale@reading.ac.uk (J. Dale).

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alterations or morphological changes take place [85]. uMR has been proposed as an opportunity to evaluate site evolution without the influence of site design features or prescribed targets and required deliverables [21]. However, there is a lack of understanding of the occurrence, evolution or development of uMR sites, meaning there remains uncertainty of benefits of allowing coastal flood defences to fail without any site design or the potential of uMR as a nature-based solution to coastal habitat loss.

In this paper, we assess the implementation of MR and uMR through a synthesis of scientific evidence, arguing that the two approaches should not be classified into distinct categories but rather be understood as two activities on the same intervention spectrum. In doing so, we take what we call a 'sedimentary perspective' (Section 2) which emphasises the centrality of sediment in the implementation and evolution of realignment schemes (whether managed or unmanaged). From this new viewpoint, we provide a novel evaluation of the current sedimentary considerations in MR sites, considering the relevance and context to uMR to advance thinking on the topic of realignment and the impact on the wider coastal environment (Section 3). This is so that a more integrated approach to realignment can be taken that does not rely on distinctions between 'managed' and 'unmanaged'. We then discuss the future research agenda required to further our understanding of the different methods of realigning defences for saltmarsh restoration (Section 4), highlighting the need for a more managed approach in locations where uMR could occur.

2. Implementing realignment from a sedimentary perspective

The hydroperiod (the frequency and duration of inundation) plays an important role in determining the zonation, the distribution of different plant species and habitat types based on their tolerance to saline inundation, in saltmarsh environments. The relationship between the surface elevation and the tidal frame (the range between high and low water level) is consequently one of the most important considerations in MR design [42,62]. The tidal prism (the volume of water flowing in and out of the site) therefore controls the tidal frame and is influenced by the size and design of the breach. Controlling the tidal prism is important as, for example, removing all of the previous flood defences has in some cases resulted in sites having no protection from fast tidal flows, drowning the newly inundated area [3]. However, if the breach is too small the accommodation space (the space available for water and sediment storage) will increase without increasing the cross sectional area of the original channel, increasing the tidal volume of the estuary [60]. This could lead to increased erosion and the loss of external pre-existing saltmarsh and other habitats [80]. Elevation is modified through site landscaping to encourage the development of specific target habitat types by applying additional sediment or excavating areas [73]. This is usually site specific and determined by the defined goals of the scheme (targeted habitat types, consideration of other users such as wildfowl or grazers).

In addition to elevation, vegetation development is reliant on a functional drainage system and creek network to act as a conduit for water, along with sediment, seeds, and nutrients (e.g. [58,67]). Creeks play an important role in encouraging horizontal flow and aerating soils (e.g. [88]), which have been demonstrated to increase plant species richness [64]. However, the design of MR sites usually involves the construction of new drainage channels or the utilisation of agricultural drainage ditches. Often, the use of pre-existing channels results in a drainage system that does not resemble the dendritic creek network typically found in saltmarshes, with the morphology of restored sites having greater similarity to agricultural fields than saltmarshes [47]. Furthermore, pre-existing features such as plough lines have been demonstrated to influence creek development and, in some cases, have become permanent drainage features [8,34].

In contrast, at uMR sites, no engineering works are conducted to influence breach size or position, site elevation or channel networks prior to site breaching. Sites are, therefore, unmanaged in terms of their design, rather than being accidental or unplanned, and should not be viewed as the removal of coastal management. For example, in England, uMR has typically occur in locations that had previously been identified as possible MR sites, or where a policy of no active intervention (NAI) has been set out in the Shoreline Management Plans (SMPs) [85], meaning uMR can be considered the realisation of NAI or early implementation of MR.

Of the two approaches to shoreline management, NAI is considerably more prominent in shoreline management planning for England and Wales in comparison to MR. Specifically, it is intended in the SMPs that by 2056 to 2105 (third epoch) NAI will be the policy for 43 % of the coastline, compared to 17 % for MR (Table 1). Although defence failure through NAI may, in some cases, only results in the shoreline moving landwards by a few meters, in others it could results in the (re-)introduction of intertidal inundation to large areas of the coastal hinterland and the potential creation of hundreds of hectares of habitat. Whilst there have been attempts to identified areas appropriate for saltmarsh restoration (e.g. [52]), the potential extent of habitat that could be created, and subsequent ecosystem service delivery, because of uMR remains unknown. Furthermore, the current extent of MR implementation is much smaller than the intended area set out in the SMPs [15]. Consequently, these coastlines are on a pathway towards increased occurrence of uMR, with defences breaching without the planning, design, and construction phases, or the subsequent evaluation of the suitability of the sediment, the pre-breach landscaping requirements and the potential habitat gains.

Most studies into uMR have focused on historical sea wall defence failure (e.g. [10,19]), which have been used to contextualise assessments of recent MR sites [72]. Whilst the understanding of uMR evolution is limited, and further research is required to evaluate site development and the impact of uMR on the surrounding marine environment, there is evidence to suggest these sites are accreting sediment, developing morphologically, and halophytic vegetation is becoming established [21,25,85]. However, in uMR sites the terrestrial (agricultural) soil structure will still be present, and it is likely that the drainage network will utilise the pre-existing drainage networks, meaning factors that have been recognised to influence the development of MR may still be present uMR sites. Therefore, beyond site specific geophysical and ecological differences such as tidal range, wave activity and seed availability, the only sedimentological pre-breach difference between MR and uMR is that uMR sites do not have landscaping or design features implemented to encourage a particular habitat type, service, or site characteristic (Fig. 1).

Most MR and uMR sites are allowed to develop through the movement of sediment and the resulting landform development following site breaching, with little intervention or active management. For example, at Paull Holme Stays, Humber Estuary (United Kingdom), post-breach sediment accretion rates were greater than expected. No remedial works were carried out, resulting in the development of upper saltmarsh rather than the targeted mudflat habitat [50]. Furthermore, the Medmerry Managed Realignment Site, West Sussex (United Kingdom) was breached through an inlet cut in the shingle barrier beach flood defences, which prior to site implementation had to be reprofiled at low tide during the winter to maintain the required level of flood defence. Once breached, the inlet widened and the beach rolled back by over 100 m [31], resulting in a second breach forming over the winter 2018–19. Whilst it was always anticipated that the beach would roll back, and

Table 1
Percentage of no active intervention (NAI) and managed realignment (MR) set out in the shoreline management plans of England and Wales.

Policy	Epoch 1 (2005 - 2025)	Epoch 2 (2026 - 2055)	Epoch 3 (2056 - 2105)
NAI	42 %	43 %	43 %
MR	11 %	16 %	17 %

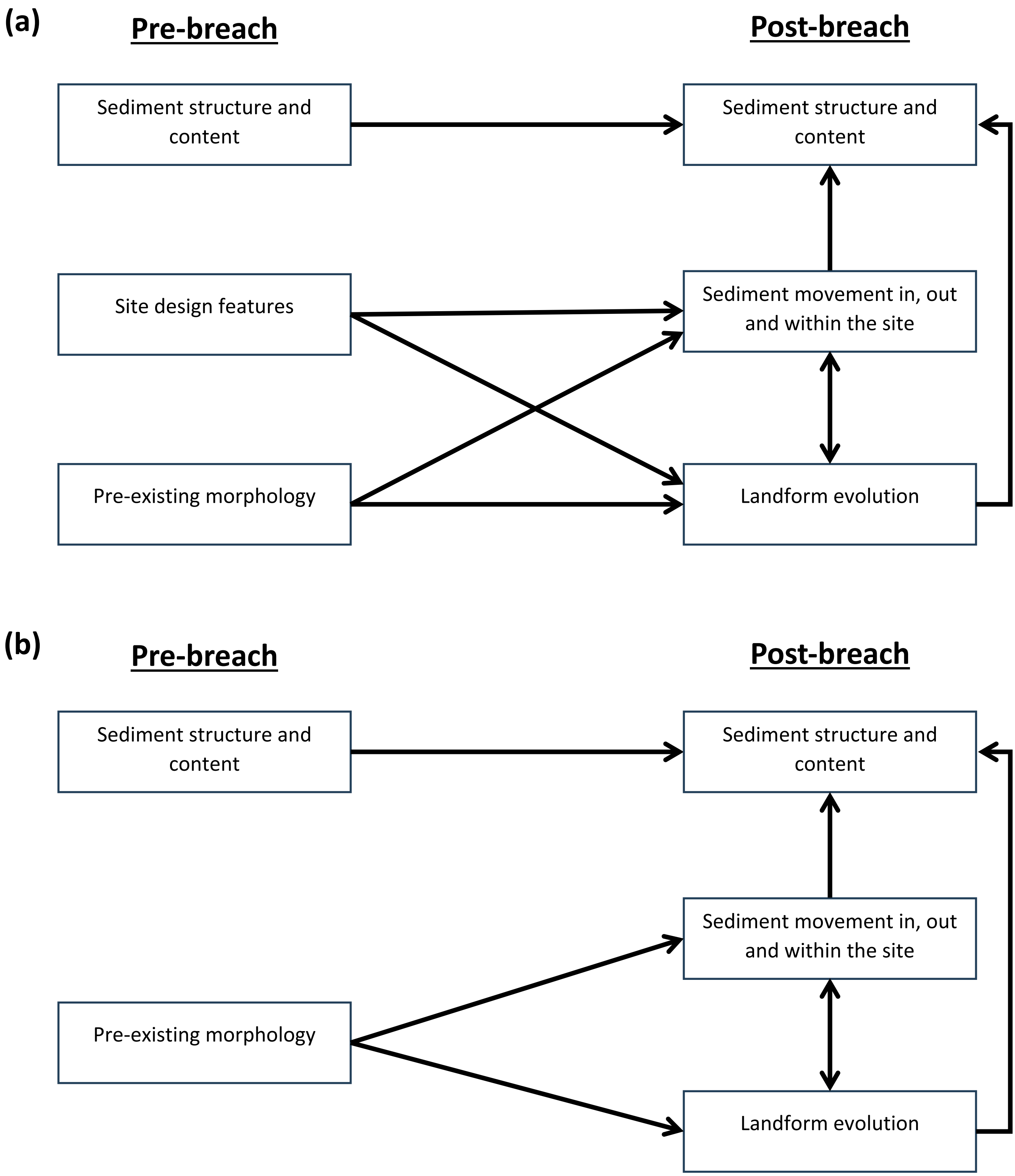

Fig. 1. Sedimentological factors relevant to the evolution of (a) managed realignment and (b) unmanaged realignment sites.

there was no expectation that it would be managed, the rate of roll back was not expected and is likely to have affected the site's hydrodynamics, vegetation colonisation, and level of flood defence provided during storm events. In fact, to our knowledge, the only MR site where large post-breach modifications have been implemented is Freiston Shore, on the east coast of the United Kingdom. Here, scrapes and shallow lagoons were created, and the excavated material used to create raised areas, with the intention of improving biodiversity outcomes [48].

Due to the lack of modifications and interventions to influence site evolution following site breaching, MR sites are arguably unmanaged once intertidal inundation has been introduced. In contrast, some degree of post-breach management may be required in uMR sites and it is important that uMR is not viewed as an abandonment of coastal management. For example, few potential sites are backed by rising ground [61], meaning new defences may still need to be constructed inland. In addition, infrastructure within the site, such as footpaths or assets such as sluices, might need to be considered and changes implemented retrospectively [62], constituting towards management in uMR sites. Consequently, differences in the post-breach evolution of MR and uMR sites may not be as distinct as previously suggested. This is particularly true from a sedimentary perspective, with sediment playing a crucial role in determining the physical condition and ecosystem function, including biotic and abiotic interactions, of the saltmarsh which develops in restored sites (e.g. [7]). Specifically, sediment plays an important role in determining site development because of the inter-relationships between the sediment structure and content, site morphology (pre-existing or constructed) and the post-breach movement of sediment (Fig. 1). As a result, lessons can be learnt from MR sites to make predictions of the sedimentological evolution of sites breached through uMR, whilst uMR provides context to considerations in the design of MR sites including costly landscaping efforts. The next section, therefore, evaluates the sedimentary considerations in terms of the characteristics and movement of sediment in both MR and uMR schemes.

3. Sediment in realignment sites

3.1. Sediment structure and content

Differences in vegetation development in MR sites [48,53], in comparison to pre-existing reference sites, have been associated with poor drainage and water logging, resulting in anoxic conditions due to compaction and changes to the soil structure caused by the former land use [72,77]. MR is often carried out on reclaimed land that has previously demonstrated an ability to support saltmarsh habitat [35]. However, following reclamation, the saltmarsh sediments would have been flushed by percolating rainwater, which has a desalinating effect, and subject to soil forming processes [35,72,73,83]. Furthermore, most sites are reclaimed for agricultural purposes, and irreversible disturbances caused by agricultural machinery have been associated with increased compaction [40] and a decrease in porosity [1]. For example, Dent et al. [29] found evidence of changes in soil density, porosity and organic content following reclamation, with ploughing for arable use accelerating the rate of change due to an increased breakdown in sediment structure and enhanced aeration and oxidation of organic matter.

Drainage, generally through macropores, is an important parameter in determining the ecological functioning of a saltmarsh [43,65]. Changes to the sediment structure, and a reduction in the abundance and connectivity of pore space, are therefore likely to result in waterlogging and poor drainage. Despite this, Dale et al. [21] found evidence that the redox profile at Cwm Ivy Marsh, a uMR site in Wales, resembled a ‘natural’ saltmarsh with evidence of anoxia only in non-vegetated mudflat areas. However, these authors attributed this to a lack of intensive arable agricultural activity prior to site breaching, rather than the nature of site breaching. Furthermore, whilst uMR sites may not necessarily occur in locations that have previously been reclaimed, it is more likely that agricultural land would be allowed to flood through NAI. As a result, reduced pore space due to agricultural activity is still likely to be an issue in uMR sites, and may influence the colonisation and establishment of vegetation following site breaching (e.g. [28]). Despite this, sediment structure has only been assessed in historic uMR sites and used as a proxy for the longer-term evolution of MR sites (e.g. [72]). Consequently, further work is required to evaluate water logging and sub-surface drainage in recently breached uMR sites. The appropriateness of implementing any post-breach topographic manipulations, which have been demonstrate to contribute towards changes in redox potential and conditions more suitable for plant growth [48], also requires investigation. This will then inform site management, assessments of site evolution and provide insight into the influence of site design features on drainage in MR sites.

Following breaching and the introduction of saline water in both managed and unmanaged realignment sites, contaminants may be released. These contaminants may originate from sources such as historic landfill sites [41] or could be metals, pesticides and herbicides stored in the agricultural soil and not permanently bound to cohesive sediments [38]. The periodic wetting and drying of the soil as a result of intertidal inundation has also been shown to increase mineralisation of organic matter due to microbial activity and the release of dissolved organic carbon [44]. For example, following inundation at the Glydensteen Coastal Lagoon, Denmark, an algae bloom was observed as a result of the release of dissolved inorganic nitrogen and phosphorus from the terrestrial soil [78]. However, following the initial bloom no further events occurred, suggesting the release of nutrients from the terrestrial soil was relatively short [70]. Furthermore, Sizmur et al. [69] found no evidence of increased bioavailability of mercury following MR in the Bay of Fundy in Nova Scotia, Canada.

In addition to contaminants, the terrestrial soils in breached sites are likely to contain other evidence of anthropogenic activity. For example, the Medmerry Managed Realignment Site, on the south coast of the United Kingdom, was constructed in an area used as a bombing range during the Second World War. Following site breaching, large quantities of unexploded ordnance have regularly been flushed out and deposited on the surround shingle beach, which has subsequently been labelled as one of the most dangerous beaches in Britain by the media. Furthermore, many reclaimed intertidal areas contain infrastructure such as pylons and utility supplies, which can be expensive to remove. For instance, it was proposed that MR could be conducted at Southmoor in Langstone Harbour, United Kingdom [9], but the project did not go ahead due to the excessive costs of adjusting the utility supplies and facilities within the site. However, the external sea wall failed on 22nd September 2020, resulting in site inundation without the adjustments to the utility supplies, forming an uMR site [85]. It remains to be seen what the impact of intertidal inundation on the facilities within the site is, and the response if any facilities fail or require maintenance. Nonetheless, in cases where breached sites contain significant quantities of anthropogenic contaminates, debris and infrastructure, there is a strong case to be made for ongoing management and monitoring, regardless of whether the initial inundation was planned or unintentional.

The content of the sediment is also important for site functioning and the development of saltmarsh following site breaching, for both managed and unmanaged realignment. For example, Dale et al. [27] presented evidence that the accretion of intertidal sediment exacerbates issues associated with the terrestrial soil structure. Whilst the sediment structure might inhibit plant colonisation and growth, saltmarsh ecosystem functioning is also driven by the fauna found within the sediment [87]. Traditionally, macroinvertebrate composition was considered to be an important parameter in determining the success of MR, although in recent years the importance of microbial communities has been increasingly recognised as drivers of organic matter decomposition, productivity and carbon storage [7].

Maximising the potential blue carbon benefits of realigned sites is necessary if carbon finance mechanisms are to be developed [11,49,57], in addition to quantifying variations due to differences in the age, design and history of MR sites [51,54]. For instance, McMahon et al. [51] highlighted the importance of elevation in maximising carbon storage in MR sites, finding greater carbon stocks in sites of higher elevation. It was recommended by these authors that site elevation should be above MHWN prior to breaching, or sites should have a readily available supply of sediment to encourage rapid sedimentation, to ensure suitable conditions for the establishment of plant communities known to produce and store large quantities of carbon. In contrast, ensuring an appropriate elevation for maximum carbon storage is not possible in uMR sites, although any differences in carbon storage remains unquantified and requiring further study to inform assessments of the potential blue carbon benefits. However, there has been a lack of consistency in approach to quantifying carbon accumulation, with estimates differing by over an order of magnitude [12,54,71,86] and the sources of the carbon remaining unclear. There is, therefore, a need for greater understanding of the sources and mechanisms of carbon storage in both managed and unmanaged realignment sites, and greater consistency in measuring approach. This will provide confidence in a quantitative carbon budget and the integration of restored sites in carbon markets [11,36,49], which in turn could provide justification for future site implementation.

3.2. Sediment movement and landform evolution

Following site breaching, rapid accretion of sediment would initially be anticipated according to predictive models (e.g. [2]) and measurement data (e.g. [14,23,30]). This could be material being re-distributed internally [24], providing sediment is readily available, or material transported from the wider coastal environment if there is sufficient accommodation space within the site. However, it has been reported at both MR and uMR sites that the change in hydrodynamics following site breaching has resulted in erosion of pre-existing external marsh (e.g. [21,37]). This has been associated with the increase in tidal prism, and the water exchange between the site and external intertidal environment being constrained to the breach area [37]. Arguably, if the sediment eroded from the external marsh is deposited in the MR site the implications could be minimal, although the habitat net gain from the scheme would be lower than anticipated. If this sediment is transported into the estuary and open coast, then there is the potential for carbon and contaminants such as heavy metals stored in the sediment to be released back into the wider coastal environment (as described in Section 3.1). Sediment may also be introduced to the wider coastal environment from the scheme itself [66], increasing the turbidity and reducing light and dissolved oxygen levels, impacting negatively on the surrounding ecosystems and habitats.

As the sediment is moved either in or out of, or is redistributed around, the site, morphological features will develop. Creek networks play an important role in the functioning of intertidal environments (e.g. [45,76]), forming the main transport pathways for water, biota and nutrients [81] and contributing to site drainage (e.g. [73,74,84]). The timescale for creek development is also influenced by factors such as the drainage characteristics, tidal energy, and marsh gradient [16,18,20,73]. However, investigations into the formation of creek networks within intertidal marsh environments have relied on morphodynamic models (e.g. [33,45,76]), with few studies providing empirical field data on creek formation and evolution [13,21,22,26,82]. Consequently, further work is required to examine how differences in pre-breach channel morphology (constructing channels vs. utilising the pre-existing channel network) influences site evolution, including site drainage and subsequent site development, which could lead to improvements to site design and implementation. This includes assessing the possible benefits of reinstating the pre-reclamation channel network prior to breaching, as implemented at Hesketh Out Marsh East and West Managed Realignment Sites [79], in order to maximise ecosystem service delivery and ecosystem functioning. The influence of constructing additional morphological features and adding topographic manipulations to a site following breaching, as implemented at the Freiston Shore Managed Realignment Site [48], also requires further study in both managed and unmanaged realignment scenarios.

4. Future research agenda

MR is viewed as the best solution to dealing with saltmarsh habitat loss by many coastal managers and practitioners and has been subject to extensive scientific investigation. In comparison, uMR has been relatively understudied. This is despite that fact that we are likely to see a considerable increase in the extent of uMR in the coming decades. However, given that the only difference between MR and uMR from a sedimentary perspective is that MR sites contain pre-breach landscaping, we argue that the two approaches should not be considered as distinct categories, and that lessons can be learnt from both managed and unmanaged realignment to inform the other approach. Whilst further work is required to assess the validity of this argument beyond a sedimentary perspective, this approach provides two opportunities: (1) uMR sites provide an opportunity to evaluate site development without the influence of site landscape and design features, which can inform assessments of MR evolution following site breaching, and (2) MR sites can be used to validate predictions of the evolution of uMR sites following site breaching. Furthermore, maintaining the sedimentary perspective presented herein will ensure sediment maintains a central position and is not overlooked in the planning, designing and communication of realignment sites (both managed and unmanaged).

Whilst there have been attempts to use uMR sites to assess site evolution without site design features, these are limited to historically breached sites and a small number of recently breached sites (e.g. [19,21,72,85]). Given the extent NAI is outlined in SMPs, there is a need to assess where uMR is likely to occur to allow for predictions of the potential increase in intertidal habitat. The preparedness of coastal managers and communities for increased implementation of uMR also needs to be evaluated to ensure stakeholders have the tools to manage sites following breaching, to effectively communicate the benefits, and to maximise ecosystem service delivery. For example, whilst there may be little difference between managed and unmanaged realignment from a sedimentary perspective, predictions of habitat delivery utilising the pre-existing elevations and morphology (e.g. [46]) and assessments of vegetation development post-site breaching are still required. Arguably within an unmanaged system these assessments should not consider or target a specific habitat type, but instead focus on the rate and extent of saltmarsh development, and the resulting benefits to the coastal ecosystem.

It important that no negative impacts come about because of site breaching. The suitability of the site is considered an important factor when selecting where to implement MR [4], including the potential release of contaminates following site breaching. MR may not be implemented if initial investigations indicate high levels of contamination in the terrestrial soil, due to concerns over the impact to the wider coastal ecosystem. However, if uMR were to occur and the site subsequently breaches anyway, there is the possibility that contaminates may still be introduced to the wider coastal environment. Little is known of the potential release of contaminates through uMR, especially as sites are not assessed prior to breaching. Research is therefore required to evaluate the potential impact of uMR on coastal habitats and communities, including the duration of any pollution events and the level of contamination relative to the wider ecosystem. There is also a need to consider the impact of an increase in turbidity due to sediment being released to the wider coastal environment.

In addition to contaminate release, efforts should be taken to ensure uMR does not result in the erosion of pre-existing external marshes (e.g. [21,37]). Consequently, the breach width and location need to be appropriate for the tidal prism and the channel networks within the site. New inland defences may also be required to limit the extent of tidal inundation [61]. As a result, it may be necessary to adopt a more managed approach to NAI. Specifically, the location, timing, and size of the breach and site could be controlled and, whilst this will increase the cost of uMR, could maximise the benefits of the scheme. Alternatively, in preparation for site breaching, small-scale interventions and topographic manipulations could be implemented, such as the construction of scrapes and lagoons, to provide sufficient heterogeneity and enhance marsh diversity [48].

Public perceptions have frequently been negative towards MR [32,55,56], and are likely to be less accepting of uMR due to the uncertainty of when and where a site will breach and the negative connotations associated with the term “unmanaged”. Whilst adopting alternative terminology to describe these sites such as ‘non-engineered’ managed realignment or restoration [21,62] could be beneficial, it is important that interlinked social barriers, including economic, governance, institutional, and psychological obstacles, are managed [63]. Whilst efficient and appropriate communication and community engagement will also help [89], adopting managed NAI will help to provide confidence in the approach and ensure the delivery of benefits and the provision of ecosystem services through realignment. There is, therefore, scope for research to investigate public perceptions of uMR and how the 'unmanaged' part of the term affects propensity to support or resist such schemes. Nonetheless, adopting a managed NAI approach will hopefully ensure that uMR is not viewed as an accident or the abandonment of coastal management, and will allow uMR to be fully incorporated into shoreline management and planning.

5. Conclusion

MR has been implemented as a nature-based solution to saltmarsh habitat loss and degradation, although sites have been recognised as having a lower abundance of key plant species and more areas of bare ground. Despite many MR sites being implemented on previously reclaimed intertidal areas and being landscaped prior to site breaching to encourage a range of habitat types, they have been associated with water logging and poor drainage due to compaction and changes to the sediment structure because of reclamation. In contrast, uMR sites are understudied, but provide an opportunity to assess site development without any pre-breach landscaping or construction of design features. However, we argue that, from a sedimentary perspective, this is the only distinction between MR and uMR, with many MR sites being unmanaged following site breaching and uMR often requiring some degree of management.

Lessons can be learnt and applied from both types of realignment, with sediment playing an important role in determining ecosystem functioning in restored sites in terms of its content, movement, and the resulting landform evolution (reviewed in Section 3). The sedimentary perspective presented in this paper helps to ensure that sediment is not overlooked in the planning, designing and communication of both managed and unmanaged realignment. However, further research is required to evaluate the preparedness for increased uMR implementation from a sedimentary perspective due to the extent of NAI in shoreline management planning. This includes predictions of the potential habitat gains and losses and assessments of vegetation development when utilising the pre-existing elevation and site morphology. The potential impact of realignment also requires investigation, especially for uMR where the timing, location and size of the breach is not controlled. It may, therefore, be necessary to introduce more control and management in areas of the coast that have a policy of NAI. Introducing managed NAI could potentially improve public perception of realignment, and would also ensure schemes do not impact negatively on the wider coastal environment and maximise the delivery of ecosystem services and potential benefits of uMR.

NBS impacts and implications

- Managed realignments sites have a lower abundance and diversity of key plant species despite pre-breach site landscaping to encourage the developed of targeted habitat types.
- In contrast, in unmanaged realignment sites there are no pre-breach landscaping or engineering works, although little is known of the evolution and development these sites.
- From a sedimentary perspective managed and unmanaged realignment should not be divided into two distinct categories leading to a more integrated approach to realignment.
- A more managed approach is needed in locations where unmanaged realignment could occur to ensure public engagement, reduce the potential impact on the wider coastal environment and maximise ecosystem service delivery.

CRediT authorship contribution statement

Jonathan Dale: Writing – original draft, Conceptualization. **Alex Arnall:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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