Lessons Learned from 20 Years of Managed Realignment and Regulated Tidal Exchange in the UK

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Introduction

In certain coastal and estuarine locations, the best and most sustainable way to enhance flood protection is to realign the primary sea defences in a landward direction. This typically involves building new sea walls at the back of a site and then either breaching the old wall to fully open up the land to tidal waters ('managed realignment' (MR)) or inserting tidal exchange structures such as sluices into the old wall to enable greater control of the new tidal flows ('regulated tidal exchange' (RTE)). Alongside sediment recharge, such 'soft' engineering measures can be used to respond to sea level rise, improve the cost effectiveness of coastal defences and create new intertidal habitat. Over the last 20 years, some 50 individual MR and RTE schemes have been implemented in the UK. Cumulatively, these have created/restored over 1,300ha of coastal habitat. Therefore, there is now a significant (and expanding) amount of accumulated knowledge about how best to implement these schemes, how habitats develop in these sites and how they provide socio-economic functions beyond their core objectives. This increasingly large evidence base can be used to supplement earlier, fairly generic, design and assessment guidance which was based on relatively few implemented schemes (e.g. Leggett *et al.*, 2004). Ensuring that the practical lessons are communicated and disseminated is essential for underpinning the effective implementation of future schemes. This paper therefore summarises these lessons across six topics, namely: scheme implementation costs, project management and communication, key issues in MR design and assessment, ecological development of the schemes (with particular consideration given to fish and shellfish), and concluding with some consideration of the socio-economic benefits. The paper is informed by the authors' practical experiences, as well as consultation and literature used for the creation and ongoing updating of the Online Managed Realignment Guide (OMReG) database (www.abpmer.net/omreg). The paper also draws upon the main issues raised by delegates at a bespoke MR conference in November 2010 hosted by ABPmer.

Costs of implementation

Frequently, one of the main hurdles to undertaking MR/RTE projects is the cost of their implementation as well as the risk of these costs increasing where obstacles are encountered during the various phases (i.e. scheme design, impact assessment, planning and construction).

Lessons from the past

A review of the implementation cost for 35 of the completed UK schemes has shown that the average cost of a scheme is just under £30,000/ha (2010 prices) (see OMReG). However, these costs have ranged greatly from £6,950/ha for the Pillmouth scheme (Torridge estuary) to just over £100,000/ha for the Trimley Marsh (Orwell) and Paull Holme Strays (Humber) schemes. Such variability is to be expected given the distinct challenges and constraints faced at the individual schemes. In general there has been a clear shift over the course of two decades from initial low-cost, small-scale, and relatively inexpensive trial projects to high-cost, larger, projects that were designed to meet specific targets for habitat creation and flood alleviation. This change is not unexpected, but what is much less intuitive is that many of the recent larger projects were not accompanied by improved unit costs (i.e. 'economies of scale'), and thus did not secure enhanced efficiencies in the light of the lessons learned from previous projects. This is illustrated in Figure 1, which demonstrates that schemes implemented after 2000 had higher unit costs. A contributory factor here will be increasing land prices, but also greater costs are being incurred for licensing, assessment, engineering and mitigation requirements. Project objectives are also a factor, with compensatory scheme costs (e.g. those undertaken to offset impacts from port developments such as Welwick (Humber)) being typically much higher, at £70,000/ha on average, than others. It is furthermore clear that the amount and scale of set-back defences is also a critical consideration; where large new defences needed to be constructed these accounted for a large percentage (c. 44%) of the total cost. Therefore, it is unsurprising that five of the six most expensive MR schemes required extensive new defence construction.

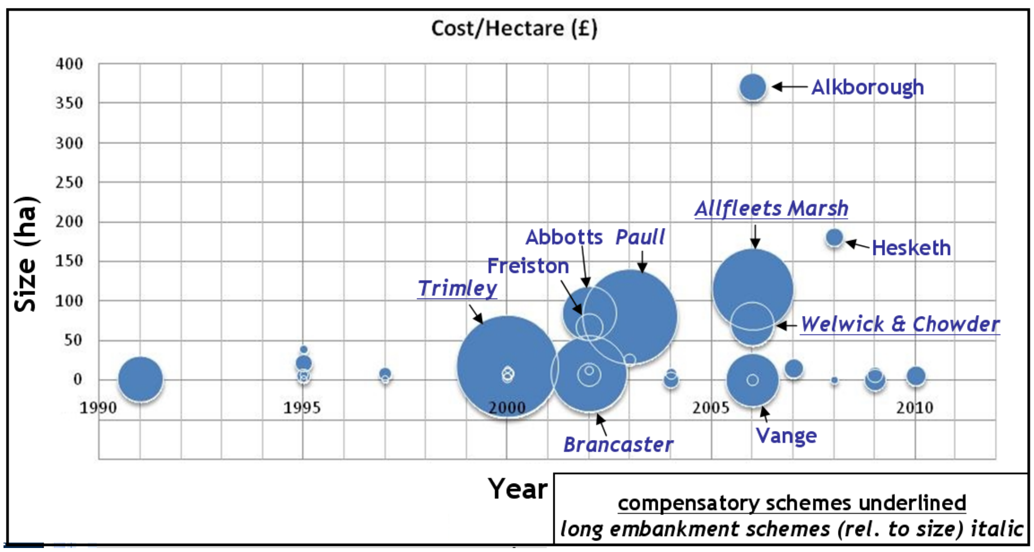

Figure 1: Unit costs of implemented realignments plotted against size and year

The future – need to review and identify cost efficiencies

At this stage there is no sign that the trend of larger projects incurring higher unit costs is likely to change. A number of large-scale projects are in the pipeline at present (e.g. Medmerry (near Selsey) and the Wallasea Island Wild Coast project (Crouch)), which will be relatively high cost projects due to their large size and/or novel complexities associated with their design and build. On an ongoing basis however, there is a need to identify where cost savings can be made with reference to the fees incurred in the past. This could include taking account of the flood protection benefits of intertidal morphology, applying past assessment, mitigation and monitoring regimes to new MRs and designing out the need for future maintenance.

Project management and communication

In general, MR projects should be viewed in the same way as any other engineering development with their implementation requiring careful planning and project management. However, it needs to be noted that, unlike typical infrastructure developments, MRs need to integrate into changing, sensitive, coastal zones and must themselves become adaptive rather than fixed systems.

Lessons from the past

As noted above, there has been a shift from relatively straightforward, smaller MRs to larger, more complex and costly sites that require significant project management to bring them to fruition. For example, the successful realisation of the Allfleet's Marsh site (Crouch; formerly Wallasea) can be attributed to good project management, the competency of the contractors and a clear understanding of the process to be followed (Dixon *et al.*, 2008, p.68). Key documents produced for this project included a clear business case as well as a detailed business plan (setting clear achievable objectives and time lines, outlining robust procurement and cash control). A review of the lessons learned provided for implemented schemes on OMReG also revealed the importance of having committed and enthusiastic implementers on board who learn from previous experience and ensure good cooperation with regulators and wider stakeholders. It is important to note that, once underway, a myriad of issues can cause significant project delays if not completed to specific timeframes. Obtaining planning consent can be a long and complicated process, especially for larger scale projects, and a variety of additional consents/licences are required. Furthermore, construction can be constrained by many factors (weather, tides and protected species windows), and embankments and mitigation habitats may need time to settle and develop. Significant contingencies should be incorporated to allow for aspects such as landowner negotiations, unexpected concerns and issues becoming unexpectedly complex (e.g. the presence of footpaths caused delays at several projects, including at Walborough (Axe)).

Having an effective, clear, honest and early, stakeholder communication strategy emerged as the most important lesson learned from schemes contained in OMReG. This is especially the case as MR is relatively complex and entails largely irreversible land use and visual change. The issue of change from arable land to intertidal has become a more prominent one over recent years, and in 2010, the Donna Nook MR on the Humber was denied planning consent largely for this reason. Based on experience at recent large-scale projects, including Alkborough Flats (Humber) and Medmerry, stakeholder engagement incorporating liaison groups, public exhibitions and individual meetings with interested parties is highly beneficial. This should enable genuine input into areas the public can actually influence and extol the wider benefits of schemes beyond the immediate objectives (focussing on aspects people can relate to, e.g. flood protection).

The future

The requirements and resources needed for project management and consultation are unlikely to diminish in the future, particularly as in some areas, more straightforward sites may have already been realigned. Also, local communities and authorities increasingly demand significant planning gains from MR implementers (e.g. improved flood protection and public access). Cuts in government spending may also make obtaining funding more difficult, so project managers may need to allocate more time to obtaining resources from more diverse sources. Factors which have proven useful during recent consultation experiences, and which are recommended for future schemes, include the ‘marketing’ of a scheme by providing information on the multiple benefits of MR, and using photorealistic 3D Geographical Information System (GIS) visualisations to demonstrate how a site will look and function.

Design and assessment

It is important at the very earliest stages of implementing a MR to understand the hydrodynamic functionality of a site and the physical interaction it will have with the adjacent estuary or coastal zone. Indeed this element needs to underpin the process of selecting a site in the first instance before then also forming the cornerstone of the majority of the design and assessment work that follows. There is a need to consider both short-term effects likely to arise from introducing a new inundation area as well as longer-term effects given that estuaries can take decades to centuries to respond. However, short-term considerations often dominate the consulting process, with immediate impacts a prominent issue when seeking the necessary consents.

Lessons from the past

Designing and assessing MR projects is a complex process, and can vary greatly in scope between projects. Two issues are crucial to the successful design of MR sites. Firstly, the hydrology and hydraulics within the site have to be designed to support the target habitats. Secondly, the physical changes which occur along adjacent estuaries or coasts following the introduction of a new inundation area need to be assessed; particularly as these can in turn affect other interests, such as designated habitats or flood protection. Understanding such changes often requires detailed hydrodynamic, sediment and wave modelling/assessment exercises. Listing each of these considerations is beyond the scope of this review. However, it is instructive to focus briefly on three of the best-understood and most accurately-quantifiable aspects of the physical changes which occur. These are:

- the amount by which a scheme increases an estuary’s tidal prism (which is a simple surrogate indicator of the scale of a scheme’s potential near-field and far-field effects);
- the channel formations that occur in front of a site as an indication of its near-field effects;
- the anticipated rate of accretion of sediments within a site, which influence how a site functions and also the rate at which the tidal prism effect reduces over time.

The available guidance on MRs suggests that changes in tidal prism amounting to more than 5% are likely to have significant impacts on the morphology of the adjacent system (e.g. Leggett *et al.*, 2004). However, this has not actually been tested and any schemes implemented to date have at most had a minor effect on the adjacent estuary’s prism. For example, the Allfleet’s Marsh MR led to a 2% change to the Crouch estuary prism and evidence from this and other projects with comparable changes (incl. Abbotts Hall, Blackwater/Salcott Creek) indicate that this has not led to significant external hydrodynamic effects. With respect to near-field morphological changes, some changes will always necessarily occur along the drainage channel from a site. However, such effects can be minimised by effective site and breach design, drawing on lessons from sites where the breach design was perhaps sub-optimal and thus led to unwanted (largely temporary) effects on fronting habitats (e.g. Freiston, Wash; Symonds & Collins, 2007). Experience from UK sites is that they tend to accrete, thus leading to a gradual reduction in tidal prism over time. The accretion rates differ greatly depending on site design and location. In the turbid Humber estuary initial lower-elevation accretion has been rapid at more than 10cm per year at all of the four Humber MRs. At Allfleet’s Marsh, accretion was less rapid at 3-5cm per year; in the four years since implementation, this accretion has already led to a 10% prism reduction. It is interesting to note that at flood storage RTE projects such as Lippenbroek (Belgium), accretion and the consequent reduction in prism are seen as negative. This demonstrates that it is critical that these sites are not seen as static environments but as evolving and changing from day one.

When approaching the assessment and design of MR projects, an iterative and phased process is recommended, whereby there is a building up of evidence about the scale of changes and the functioning of a site. A site visit should be seen as an essential first step in this process. During the next phase, a preliminary design should be developed and its implications assessed on a high level. At the same time, the Environmental Impact Assessment (EIA) process should be commenced, and relevant ecological surveys undertaken to ensure on-site constraints are known (and mitigated for). The final phase should involve the detailed assessment of the scheme’s hydrodynamic effects, which will then inform both the finalisation/enhancement of the design and the assessment of the individual EIA topics. This may need to be supported by wave and sediment transport modelling. Design aspects requiring the most careful consideration include tidal prism, breach design (and breach flow speeds), the role of site morphology in delivering particular habitats, and how future accretion may influence site development. Breach placement should be based on insights gained from a site visit, and a review of historic charts, current elevation maps and estuarine/coastal processes. For example, at Allfleet’s Marsh, the breaches were largely placed in locations that minimised the losses of fronting saltmarsh habitat. The optimum breach dimensions can be calculated using recognised equations outlined by Townend *et al.* (2010), with a key input being a site’s tidal prism. A breach needs to be sufficiently large and deep to avoid unwanted stability issues, a lesson learned from implemented schemes such as Freiston and Hesketh Out Marsh (Ribble). At Allfleet’s Marsh, the breaches were deliberately over-designed to ensure that they were in ‘regime’ with the volumes of water exchanged and, to date, no morphological changes to the breach channels have been observed. Regarding site morphology, the extent of any landform manipulation must be justified with due consideration to project objectives, the potential gains and the likely cost. It has often been the case that materials for new walls need to be sourced on site (e.g. at Medmerry), which provides valuable opportunities for environmental optimisation (e.g. on-site fish lagoons or landward ditches enhanced for freshwater species). At the majority of the implemented MR sites, internal creeks were excavated to facilitate the effective flooding and draining of the site which, in turn, helps to ensure effective habitat creation. In some instances, field drains were already available for this function (e.g. Alkborough, Allfleet’s Marsh) whilst, in others, tidal waters were allowed to create their own creek network (e.g. Tollesbury (Blackwater)).

The future

Future projects need to follow and further develop best practices established in the past, particularly with respect to following an iterative approach in which key questions are addressed early. It is recommended that early feasibility studies are carried out that address the key hydrodynamic issues but also begin the EIA scoping process by identifying the relevant impacts based on past experience. Where possible the guiding principles of scheme design work should be to minimise land manipulation and work with the existing topography. However, interventions should be undertaken to facilitate the efficient drainage of a site, maximise the stability of the breach(es) and optimise a site's ecological value from the opportunities presented by wall build excavations. These design principles were for instance applied to design the consented Medmerry scheme (breach anticipated in 2012).

Ecological development (benthos, saltmarsh and birds)

The ecological development of MRs is well studied, particularly where these were implemented as compensatory measures under the EU Habitats Regulations. For these sites there is a requirement to understand whether the created/restored habitats have offset the impacts of the plan or project which they have been designed to compensate. This monitoring usually focuses on mudflat benthos, marsh vegetation and overwintering birds. Some key findings from this work are set out below.

Lessons from the past

With regards to benthos, mudflat invertebrate monitoring undertaken at several MR sites has shown that, where the tidal elevation and physical conditions are appropriate, benthic invertebrates can colonise the accreting mudflat fairly rapidly (e.g. Tollesbury, Allfleet's Marsh and the Humber sites). Site species composition generally becomes more complex and stable over time. Early colonisers such as ragworm, mud snail and mud shrimp often dominate the biomass over the first few years. For example, rapid colonisation was observed at Allfleet's Marsh where there have been 10,000 to 20,000 organisms/m^2 in each year since its breaching. The species composition, abundance and diversity can vary greatly with differences in site elevation and location, and this makes comparison between schemes very difficult. At Chowder Ness for instance, between 500-15,000 organisms/m^2 have been observed, while at the Welwick site, ca. 37km downstream on the Humber, numbers ranged from 700-7,000 organisms/m^2. However, the species diversity at Welwick is still typically lower when compared to fronting, pre-existing mudflats, whereas at Chowder Ness, these figures are already very similar (three years post realignment). Judging assemblages in the context of fronting habitats provides an interesting context but will not necessarily allow the effectiveness of the schemes to be determined given how different the internal conditions can be from those outside (e.g. Nigg Bay (Cromarthy Firth) and Allfleet's Marsh).

Saltmarsh plant colonisation follows a similar successional pattern as that observed for mudflat invertebrates. Rapid colonisation occurs if the conditions are right, especially in relation to drainage and elevation (e.g. Welwick, Chowder Ness). Pioneer vegetation such as glasswort typically colonises within one year, and it may then take several years or decades to achieve a species composition similar to that of adjacent mature marshes. At Freiston, particularly rapid pioneer colonisation was observed; 70% of the area was covered in vegetation within three years. A similar 'exponential' rate was observed at Allfleet's Marsh, where the percentage plant coverage increased over four years from 1% to 6% to 60% and then 100%. At Freiston, the expectation was that the site's species abundance and community types would be equivalent to those outside the site within 10 years of breaching (Brown *et al.*, 2007).

MR sites can rapidly develop into important roosting and feeding sites for waterbirds. At Freiston, Badley and Allcorn (2006) concluded after four years that the site supported 'large numbers of wintering waterbirds, several species in nationally important numbers' (p. 105).

Some sites (e.g. Welwick, Allfleet's Marsh) may initially mainly be utilised as roost sites but, as prey diversity and biomass increases, so should the proportion of feeding birds. Allfleet's Marsh for example supported very good, increasing, numbers of waterbirds in the first three years of its existence; with some 7,000, 10,000 and 12,000 waterbirds observed respectively. At the Tollesbury and Orplands MRs (Blackwater), communities were found to be largely similar to those of surrounding mudflats within five years of the initial breach (Atkinson *et al.*, 2001).

The future –need to clarify site success criteria

With regards to compensatory MRs, one of the most important future objectives will be to clarify the issues associated with measuring a site's ecological performance and, where relevant, addressing the extent to which it has offset the predicted and actual impacts arising from the project which it has compensated. Clearly, appropriately-designed MRs can deliver high ecological and biodiversity value even in a short space of time (weeks/months) alongside a wide range of other gains. However, the process of achieving full equivalency with mature habitat, saltmarsh in particular, may take much longer. The relevance of this needs to be better understood, agreed and communicated amongst coastal managers. In this context it should be noted that measuring value is not simple and different approaches are often taken to review monitoring data. It is also clear that most sites accrete sediments, often very rapidly, and their habitats are therefore inherently adapting from day one. Hence, quantitatively measuring the value and extent of the created habitats will never be a simple task. Each case will probably need to be judged on its own merits, but some kind of auditable framework that addresses the role that new sites play in maintaining the coherence of the Natura 2000 network may be warranted. The most obvious issue is whether designation requirements are met. However, it may be more useful to evaluate the 'functional equivalence' of the new habitats using ecosystem services analysis, particularly given that judgements are made in a non-stationary climate. In 2011, several major schemes will reach the end of their first five-year monitoring cycle and conclusions on their success will need to be reached in the context of these dynamics (and lessons disseminated).

Fish and Shellfish

In general, intertidal habitats are known to be valuable feeding and nursery grounds for many fish species such flounder, herring and bass (Dixon *et al.*, 2008). Hence, the value of managed MR for fish and shellfish populations, as well as for associated commercial and recreational fishing activities, is an important consideration when seeking to understand the socio-economic and ecological gains/benefits that can be achieved. In the UK to date, this has never been a key motive for habitat creation and is typically no more than a tertiary consideration if it is addressed at all. However, there is increasing recognition of the potential importance of MR sites for commercial fishing and food-production in their own right as well as in mitigation for losses of at-risk arable land and as a means to enhance the recruitment of fish and shellfish stocks.

Lessons from the past

Work undertaken at several MRs has confirmed that they are capable of providing suitable habitat within a relatively short space of time. At Allfleet's Marsh, fish sampling undertaken just 1 and 2 months after breaching showed that even though plants and algae had yet to colonise, the lagoonal scrapes in the developing mudflat had high numbers of crustacea and were refuge and feeding areas for juvenile sea bass and herring (amongst others). Fish were feeding on marine zooplankton, crustacea and polychaetes and were leaving the site with fuller stomachs than when they entered (L. Fonseca PhD, pers comm). Longer term surveys undertaken at Freiston and Paull Holme Strays confirmed the value of MRs as nursery areas for economically important fish. At Freiston, high numbers of bass, sprat and herring were observed (Brown *et al.*, 2007). At Paull, eel, flounder, bass and sand goby were abundant, and species composition and density was judged to be largely similar to that of adjacent areas (Hemingway *et al.*, 2008). Of particular note is that sites are of higher value if they provide fish habitat throughout the entire tidal cycle by including channels and ponds which remain flooded at low water. The value of such deep ponds/lagoons has been demonstrated at Abbotts Hall where up to 2000 herring/sprat were once found in one pool alone (along with 10 other species including bass, flounder and eel) (Colclough *et al.*, 2005). Comparative surveys at Brancaster (Norfolk) and Freiston confirmed the value of both sites for fish with the former site having a greater species diversity that was attributed to more diverse habitats and the presence of deep channels (Deaney, 2010). It is also known that fish use RTE areas. At Goosemoor (Exe), for instance, mullet pass through the control device to graze within the site; at Beltringharder Koog (Germany) fish pass through a culvert where average speeds are 4m/s; and at Lippenbroek, fish mostly utilise the outlet sluice.

Increasing work is also being done to understand the use of MRs by shellfish species and the potential for their commercial exploitation. Environment Agency-funded trials of cockle growth undertaken at Allfleet’s Marsh demonstrated that this species grows as well within the site as it does outside (Dirt Consultants, pers. comm.). Subsequent RSPB-funded trials at Allfleet’s Marsh concluded that MR sites could be used for the initial growing on of juveniles/spat. Benthic monitoring in this site has also shown that bivalve species are thriving more generally. The breach areas now have large rock oyster aggregations as well as occurrences of native oyster and mussels, while the mudflat supports high numbers of clams and occasional cockles. It seems likely that shellfish are feeding on both autochthonous nutritional inputs (internally generated from marsh and algae) and allochthonous organics (imported from external sources).

The future – the importance of environmental optimisation and commercial trials

There is now evidence that MR s are valuable for fish/shellfish populations and certainly that they are important places for the development of juveniles. However, the commercial potential of these sites has yet to be fully realised. In large part this is because these sites are not designed with this as a core objective. Adopting a process of ‘environmental optimisation’ when designing projects should allow this deficiency to be addressed. It is clear that even modest design changes, often undertaken at limited (if any) extra cost, enable a site to be enhanced in biodiversity terms. The inclusion of ponded areas retaining water at low tide is particularly valuable and also brings about additional benefits for bird species. It will be important to further investigate the commercial exploitability of MRs and to understand how the fish objective can be elevated as part of future scheme design work. This has particular resonance when dealing with the loss of productive (but often at risk) agricultural land and addressing how this can be offset by opportunities in new coastal habitat creation projects.

Socio-Economic Benefits

As discussed above, the main reasons for MR are to enhance flood defences and/or create new coastal habitat. In addition to these objectives, which need to be clearly laid out, secondary benefits can accrue providing additional socio-economic benefits. These can relate to tourism, recreational and commercial fisheries, carbon sequestration and water quality improvements.

Lessons from the past

Although the potential and theoretical benefits of MR have always been well understood, new lessons are being learned about the socio-economic gains that can realistically arise and also, in the light of new guidance from Defra (2007), about how to value ecosystems generally. The RSPB site at Freiston is a good practical example of a site that has been justified on economic and social grounds, having led (among other aspects) to reduced sea wall maintenance and increased visitor numbers (56,000 in 2003) that have boosted the local economy. Anecdotally, businesses near the site have reported increased trade from the visitors to the site and a guesthouse has opened immediately adjacent to the reserve. Separate, ecosystem services review work has also informed the Alkborough scheme (Everard, 2009) as well as projects that have not yet been completed such as the Medmerry and the Wallasea Island Wild Coast projects during their developmental phases. The Alkborough review identified an approximate aggregate benefit of £23m. The Wallasea Island Wild Coast scheme was predicted to lead to the creation of 16 to 21 full-time equivalent jobs in the local economy, and to flood defence-related cost savings of between £0.5 and 10million over the next 10 years (Eftec, 2008).

The future

Projects such as Freiston indicate the clear economic gains that can arise from a scheme, while ecosystem valuation also regularly demonstrates that these projects can have a sound economic rationale. There is a need to obtain more accurate valuation data on the ecosystem services to better understand and quantify these benefits. There is also a need for clarity on how ecosystem valuation will influence future coastal management decisions, because were it to do so, it could shift the balance in favour of coastal habitat creation. In the near future, however, it seems more likely that project valuation will need to be based primarily on the more obvious market services (e.g. reduced defence cost or greater tourism) that are more easily evaluated and communicated to local communities. However, less tangible services (such as local ‘sense of place’) must mot be overlooked as they can be a source of friction with local residents. Separately, there is a need to use these findings to seek out new funding sources, for instance from commercial organisations that can use such schemes as part of their carbon budgeting or from other as yet unexploited ‘paying for ecosystem services’ markets. This, if achieved, would help to address one of the key problems of funding MR implementation.

Conclusion

Our understanding about how to implement schemes has been greatly advanced through practical experience. This includes aspects such as how to design MRs, assess their impacts, secure planning consents and construct them, as well as how to engage stakeholders. Knowledge sharing has yet to be achieved adequately, and some projects still do not build upon well-known design opportunities. Major problems still exist in moving from the strategic level (shoreline management planning), which says what should be done, to ground-level implementation which indicates what can be done. Key difficulties include: securing landowner involvement, obtaining appropriate funding (especially when the costs of schemes increase) and communicating the potential socio-economic benefits (carbon sequestration, commercial fisheries productivity, green tourism, etc.). Ultimately, a long-term vision for scheme implementation is required in which a ‘conveyor-belt’ of future schemes is identified, some of which may not be implemented for decades. Within such a long-term vision there may well be a need to consider whether very large–scale (>>1000ha) projects can now be implemented to help achieve national habitat creation targets and provide services of economic value. It will, however, continue to be difficult to communicate the rationale for this work and to convey the relevant principles of future site and shoreline evolution, when shorter-term visions inherently prevail.

Key References

Large sections of this review are based on the primary and secondary data contained in the OMReG database (incl. many references). This site can be accessed at: www.abpmer.net/omreg

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