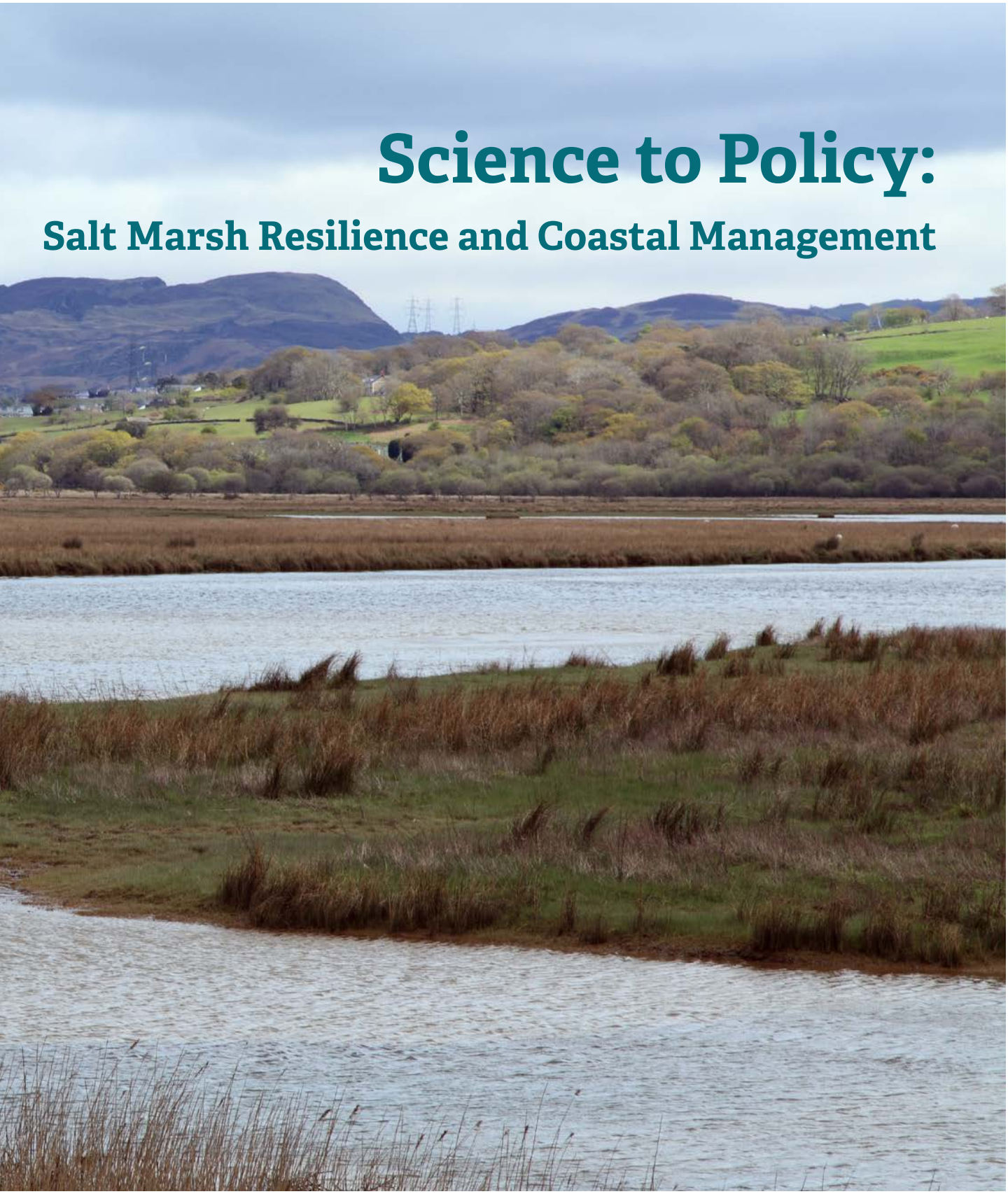
Rhwydwaith Ymchwil Cenedlaethol
i Ynni Carbon Isel a'r Amgylchedd Sêr Cymru

Sêr Cymru National Research Network
for Low Carbon, Energy and Environment

Science to Policy:

Salt Marsh Resilience and Coastal Management



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Resilcoast was a Research Cluster that ran between 2013 and 2018 from the Sêr Cymru National Research Network for Low Carbon, Energy & Environment (see: www.nrn-lcee.ac.uk).

Resilcoast's aim was to examine the resilience of salt marshes, a common shoreline habitat and natural flood defence in Wales, to change in climate and land use and the implications for coastal management.

This is a summary of the policy implications of both scientific review and original research undertaken by Resilcoast that fall within the remit of current and evolving Welsh policy.

Key recommendations

- **Include clear consideration of ecosystem services from specific marine and coastal environment**s within high-level national legislation and policy drivers.
- **Include success stories of applications of the ecosystem services approach** to support and inform stakeholders when developing management approaches.
- **Ensure that Welsh legislation considers salt marsh ecosystem services within both marine and terrestrial planning,** given the position of salt marshes at the land-sea interface.
- **Integrate decisions at larger landscape scales in order to deliver multiple-outcome management;** e.g. tailor grazing intensity at a locality according to what outcome is most important there and crosscheck that all services are delivered across multiple marshes at the broader landscape scale.
- **Consider the addition of salt marsh carbon stocks to national and global carbon stock accounting** as carbon stocks in stable salt marshes are substantial and quantifiable.
- **Protection of stable salt marsh areas should be prioritised over dynamic salt marsh areas** if a development needs to be made - as stable salt marshes store >3 times more carbon than dynamic ones.
- **Policy needs to be designed that accounts for the changeability of natural systems in space or time;** e.g. preserving a combination of dynamic and stable salt marshes may maintain estuary-scale resilience of salt marsh habitat, but long term carbon sequestration may be impaired without specific focus on stable salt marsh areas.
- **Biodiversity management legislation needs to outline its aims for specific organisms** as particular management actions may benefit some organisms whilst negatively affecting others.
- **Communicate the evidence underpinning shoreline management plans and associated policy more effectively to non-technical users across Wales** to improve shoreline management planning and optimise the use of available resources.

Credit: Environment Agency

Background

Over 60% of the Welsh population live by the coast, and 75% use the coast for recreation. There are many areas of salt marsh along the coastline of Wales, and most are within protected areas frequently used by the public. However, the integrity of these landscapes and communities is challenged by climate change, via erosion, storm surges, flooding, and sea level rise.

Salt marshes (Fig. 1) deliver many benefits ('ecosystem services') to Welsh society. Firstly, they are a natural flood defence by virtue of taking energy out of waves and reducing both surge severity and extent, even in storm-surge conditions. Secondly, they are important for livestock grazing, wild food collection including hunting and fishing, birdwatching, artistic inspiration, and a sense of place. Knowledge gaps remain, however, which have challenged our ability to manage coastal habitats sustainably. For example, how resilient are they: Will the coastline we see today be the same in 50 years' time? Where and how will climate change and land use threaten their resilience the most? This document summarises the policy implications of knowledge gaps in salt marsh ecology that were addressed by Resilcoast.

Box 1. Relevant policy strands

Well-being of Future Generations (Wales) Act 2015[2]
Outlines seven well-being goals covering resilience (enhancing biodiversity and ecosystems), community health, culture, and action on climate change.

Environment (Wales) Act 2016[3]
Includes key part such as I: Sustainable management of natural resources, and II: Climate change (carbon budgeting, emission targets).

Natural Resources Policy 2017 (Welsh Government)[4]
Statutory policy highlighting importance of coastal habitats and calling for better coastal flood management incorporating natural structures.

National Strategy for Flood and Coastal Erosion Risk Management in Wales (2011)[5]
Under the Flood and Coastal Management Act (2010) the Welsh Government must maintain a Flood and Coastal Erosion Risk Management policy. The most recent briefing stresses the importance of working with, not against, natural processes.

Natural Resources Wales (2017/18) Well-being statement[6]
Sets out well-being objectives of Natural Resources Wales.

Figure 1
Salt marshes are a highly variable habitat due to the wide ranges of environmental conditions they experience, including moisture, salt content, and pH. Ungrazed marshes (top) can have a high abundance of sea lavender (*Limonium vulgare*), while cord grass (bottom) (*Spartina x townsendii*) is tolerant of wide ranges of moisture and salinity and usually extends furthest into the seaward edge. Non-native cord grass species, imported for soil stabilisation for land reclamation, have become invasive (naturalised) in the UK.

Sustainable management of salt marshes: insights from the Ecosystem Services concept

The Ecosystem Services (ES) concept has, since the 1970s, emerged as a valuable tool to inform policy and decision-making (e.g. UK National Ecosystem Assessment[1]). It highlights crucial links between nature and society through causal flows between processes such as soil formation, primary production and nutrient cycling, and societal benefits such as livelihoods, food production, and physical and mental well-being. The different ecosystem services fall into three categories: regulating (e.g. climate change mitigation), provisioning (e.g. livestock production) and cultural (e.g. aesthetics) services.

The ES framework is highly applicable as a tool to achieve targets outlined in Welsh policy. For example, the Well-being of Future Generations (Wales) Act 2015[2] (hereafter referred to the 'Future Generations Act') stresses the innate connection between the health of the environment and that of humans, which the ES flows between natural processes and societal benefits can illuminate. The Future Generations Act also outlines well-being goals that have their counterparts in ES language: for example, the cultural ES provided by salt marshes align with the 'cultural well-being', 'physical health', 'cultural heritage' and 'natural heritage' that the Future Generations Act outlines.

Salt marshes and ecosystem services in current policy and implementation

Using salt marshes as a lens to examine recent additions to Welsh national legislation, Resilcoast reviewed the consideration given to ecosystem services (ES) within 5 Welsh Acts, including the Environment (Wales) Act 2016[3] and the Future Generations Act. They found that, despite a growing emphasis on the ES framework within natural resource management, there was little explicit consideration of services, benefits or processes more generally, and even less that could be directly attributed to salt marshes, or indeed other coastal fringe environments[7].

The omission of ES in the majority of Welsh Acts, in combination with the absence of specific examples relating to goals such as resilience, has repercussions on both setting and achieving management targets. For example, the Future Generations Act outlines the importance of achieving ecological resilience, without referring to the ecosystem services that might support this in any environment.

Stakeholders echo the importance of clear examples and definitions in policy. Resilcoast interviewed representatives from the Crown Estate, Natural Resources Wales, Local Planning Authorities and various NGOs plus local consultants on how they view the Acts and advice therein. While encouraged by the call for more joined-up thinking in tackling natural and societal challenges, they expressed uncertainty due to the absence of explicit links between environmental and societal targets, as well as guidance on how to attain them[8]. For example, win-win situations are not the norm, and so it is important to know how to plan when targets are mutually exclusive (see next section).

In contrast, Resilcoast found that coastal and marine stakeholders who implement policy predominantly strongly agree that: 1) ES makes communication easier and more effective; 2) ES is a useful management tool; 3) ES supports integrated management and plans of marine and coastal environments[9]. 85% of those interviewed for this research have already used the ES concept in their work.


Credit: iStock

Trade-offs and multiple outcome management: salt marsh grazing, biodiversity, and resilience

Livestock grazing illustrates trade-off situations that can arise from different management options. Conservation grazing is widely used to improve habitats for certain wildlife, including birds, and boost plant diversity. Yet, grazing is not good for all salt marsh wildlife and ecosystem services. For instance, nesting success by threatened red shanks (amber UK conservation status; reflecting declining numbers) drops dramatically at even low livestock densities, and flood mitigation by marshes is reduced if livestock graze vegetation to a short height.

Biodiversity of what?

Environmental management plans need to be clear about their aims for salt marsh ecology to avoid confusing and contradictory implementation. For example, Resilcoast reviewed over 90 published studies to clarify the biodiversity tradeoffs within different groups of organisms in response to grazing[10]. Grazing increased the biodiversity of grass-like plants at the expense of others, and decreased both the biodiversity and abundance of invertebrates. Spiders particularly benefited from a combination of plant heights typical of low or zero grazing.

Does grazing increase erosion?

Grazing by domestic herbivores (e.g. cattle and sheep) has consequences for salt marsh resilience that may act in opposition to each other. On the one hand, soil compaction, resulting from movement of heavy animals, stabilises soil and reduces marsh erosion. On the other hand, by reducing plant cover and thus increasing the amount of bare soil, animals may increase the amount of creek edge breakage (i.e. slumping). Results from Resilcoast research comparing ungrazed with grazed marshes suggest that for conditions typical in Wales, compaction from moderate sheep grazing has a net positive impact on salt marsh resilience[11]. However, only one site in this case had cattle and only at low densities, so results could be different under cattle grazing.

Do Welsh salt marshes provide significant carbon storage?

'Blue carbon' is carbon stored in the world's oceans and in coastal ecosystems such as salt marshes, seagrass meadows and mangrove forests. Mangroves have been researched more exhaustively than salt marshes, and are involved in global carbon trading initiatives. Carbon storage by salt marshes is less well researched and it is uncertain how long-lasting these stores are, given the propensity of marshes to sometimes rapidly expand or erode. For example, within one estuary we typically find that marshes erode and expand cyclically as a result of the movements of the main channel[12]. It has generally been assumed that the net balance is that a salt marsh area is resilient to these local changes at the estuary scale. However, we do not know how past temporal stability/dynamics influence salt marsh ecosystem services delivery.

In pioneering studies tracking carbon accumulation through time across marshes from three Welsh estuaries[13], Resilcoast found that those marshes that had been identified as stable using aerial photography spanning the last 150 years, had been so for thousands of years. This analysis also revealed that stable salt marshes can store approximately three times more carbon than dynamic salt marshes (Fig.2) (an average of 150 tons of carbon can be stored per hectare in a stable salt marsh); an important finding that needs to be considered for inclusion into global carbon storage estimates. This study is a clear example illustrating how ecosystem service provision today is affected by long-term disturbance legacies (100-1000's of years).

Resilience

The long-term function of salt marshes as flood defence, or landscape components more widely, is inherently related to their resilience. Resilcoast used historical maps and images, models, and surveys to determine the patterns and underlying mechanisms of the waxing and waning of UK salt marshes. With this research, we are now better able to predict how resilient salt marshes are against climate change and sea level rise, and how changeable they are.

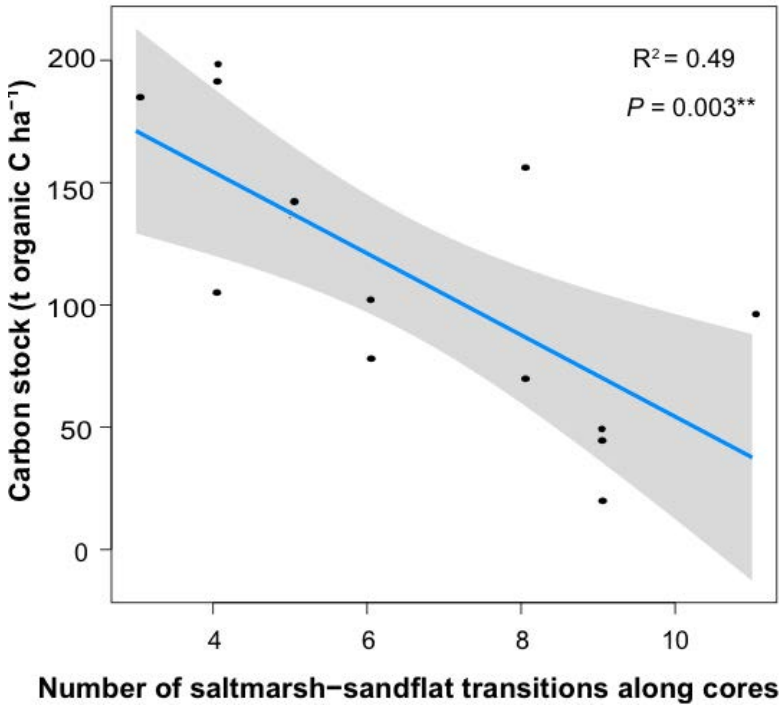


Figure 2
Relationship between the number of transitions between salt marsh and sandflat conditions (as shown by salt marsh soil core analysis) and ecosystem carbon stock. This relationship shows that the more stable an area of salt marsh is (i.e. the fewer transitions between salt marsh and sand flat conditions) the greater the ecosystem carbon store.

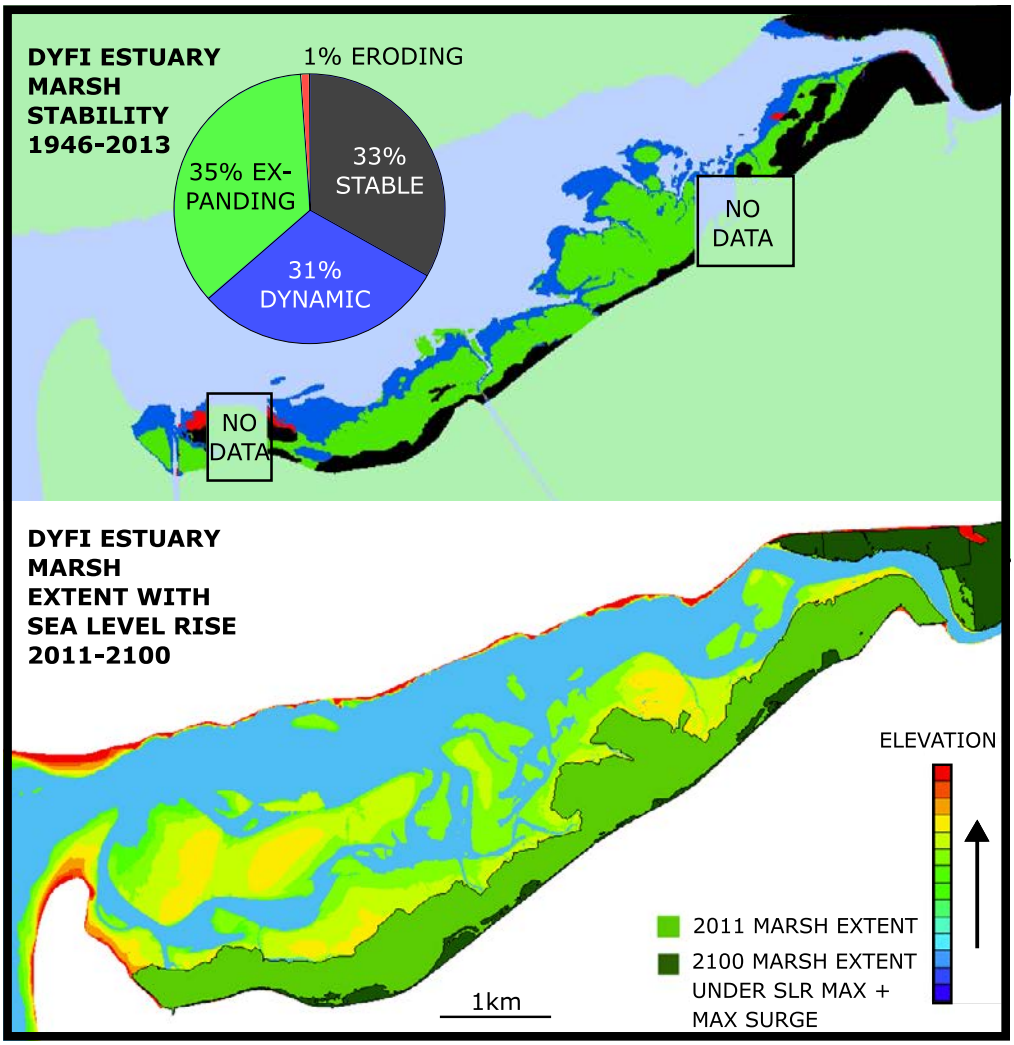


Figure 3
The Dyfi estuary contains many stable salt marshes which provide significant carbon stores. Marsh expansion at the seaward edge has been driven by colonisation by invasive/ naturalised *Spartina* species. However, sea level rise (SLR) will lead to a loss of salt marsh area between 58% (minimum SLR) and 77% (maximum SLR plus storm surge) by 2100 according to Resilcoast models. Sea walls limit the landward migration of salt marsh habitat[11].

Natural variability

Studying 25 estuaries across the UK from the 1850s to the present, Resilcoast found that the balance between sea level rise and sediment supply was the biggest factor determining salt marsh extent through time[14]. Sediment supply enables marshes to grow and counters the otherwise negative effect of sea level rise. Therefore in UK areas where the land is still rising due to post-glacial uplift, and sediment supply is high (e.g. Scotland, North Wales), salt marshes have expanded in contrast to southern - southeastern UK which has experienced a decline in sediment supply combined with the land still sinking.

Storms

Based on a systematic review, Resilcoast found that storms have short-term negative effects on salt marsh resilience by reducing plant cover but longer-term positive effects by increasing deposition rates of marine-derived sediment, potentially helping salt marshes against sea level rise[15].

Credit: Jordi Pages (Resilcoast)

Sea level rise (SLR)

Using hydrodynamic numerical models[16], Resilcoast found that marshes near the mouth of estuaries will be more vulnerable to sea level rise (SLR), given higher local SLR rates and the fact that marshes naturally occur at lower elevations near the mouth. In contrast, marshes at the back of estuaries will be more resistant to SLR, given that they naturally occur at higher elevation, and simultaneously will be subjected to lower SLR rates. The projected increases in SLR will require marshes to migrate inland. In many cases, this recession will be impeded by sea walls. This 'coastal squeeze' is likely to be critical in Wales where much of the soft coastline has dikes or human construction (Fig. 3).

Coastal erosion

Sandy coastlines, such as those in Wales, are more erosion-prone than clay-rich ones due to sandy sediment being less dense and more poorly bound[17]. Resilcoast researchers have shown species-rich plant communities to bind soil together, protecting coastlines from erosion. Thus, safeguarding plant diversity might be particularly important along sandy regions such as Wales[18].

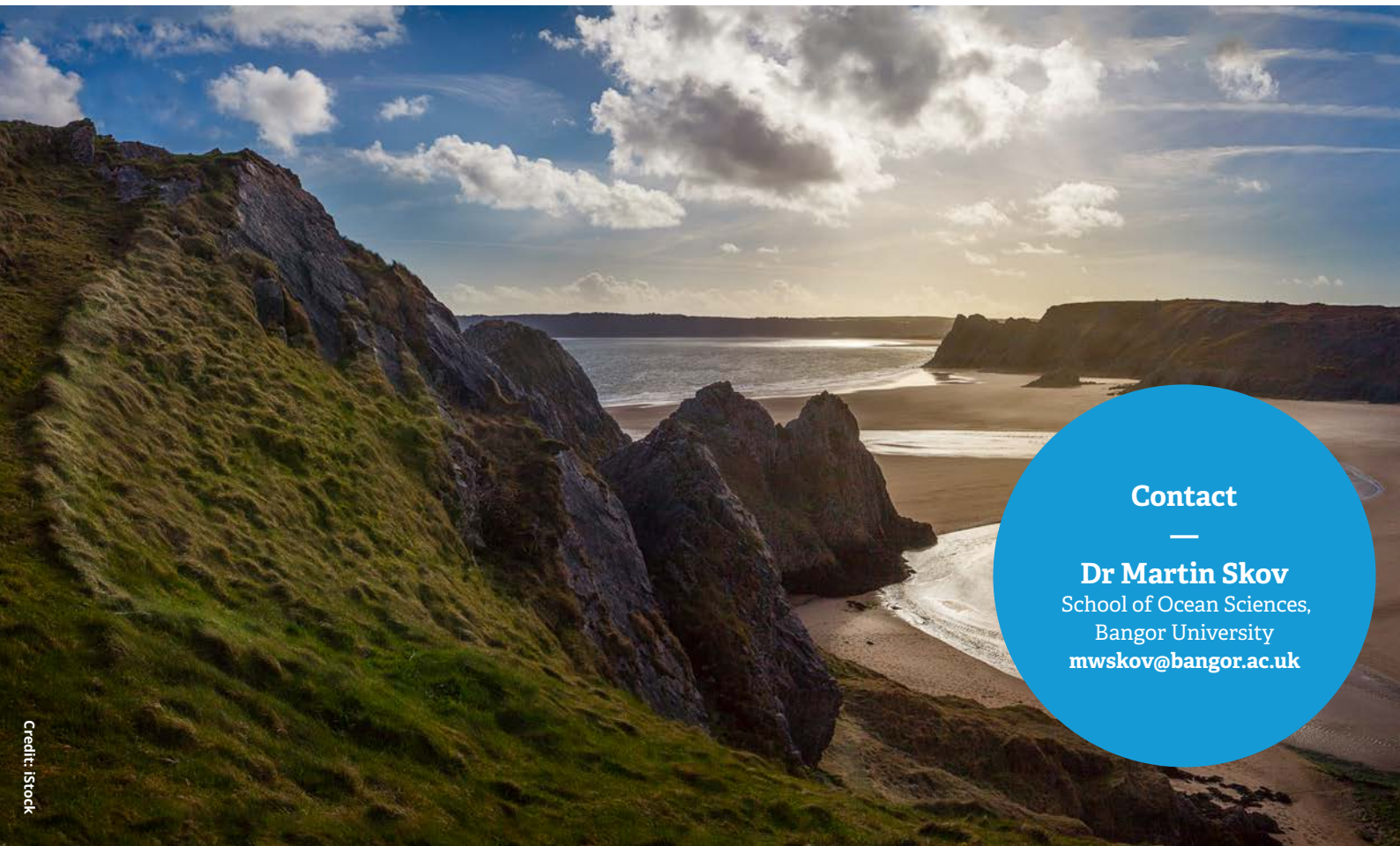
Evidence gaps

The projected increase in both the frequency and intensity of storms due to climate change[19] is based on observations of the same trend over the latter half of the 20th century. However, the effect of the trend on storm surges (specifically storm-driven rising of the sea) are still uncertain as SLR has been the dominant pattern behind observed increases[20]. Therefore, their combined effect on salt marshes, especially during extreme events, is still to be ascertained. Research in this respect is challenged as by definition, extreme events are rare, and so capturing them in any window of research or observation opportunity is unlikely, especially at timescales which would allow adequate comparison with before and after conditions.

Scientific underpinning of shoreline management plans

Shoreline management plans (SMPs) are non-statutory policy documents for coastal defence management, which have been continually developed in the UK to improve the scientific evidence base for coastal (risk) management across England and Wales. SMPs include the management and future planning of flood defence, which has traditionally consisted of building 'hard' defences such as sea walls. These are expensive to maintain and do not necessarily work with natural processes - a key, long-recognised principle of Integrated Coastal Zone Management. Indeed, over the last few decades there has been a gradual recognition that the location and design of many 'hard' engineering structures have been based on short-term decision making with limited understanding of geomorphological processes at local and regional scales.

To evaluate the trends in the evidence base of coastal management, Resilcoast reviewed the scientific underpinning supporting policies within a range of previous and current SMPs across England and Wales[21]. Focusing on the transparency as well as the clarity and appropriateness of the science communication was deemed essential: a large proportion of the potential users of these plans, particularly land use planners and local communities, do not have a detailed technical background of coastal processes and engineering. The results pointed to improved evidence and understanding at the regional scale, but indicated issues associated with the transparency of the science informing shoreline management policy options at local levels. The study also revealed inconsistencies in climate change science and its use across plans. The authors attributed their findings to a combination of factors, including the limited availability and the poor online communication of both the plans and their supporting evidence base and the varying approaches of consultancies previously tasked with developing the plans.



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This science to policy briefing is based on the findings from the Sêr Cymru National Research Network for Low Carbon, Energy & Environment (www.nrn-lcee.ac.uk). Financial support was provided by the Welsh Government and Higher Education Funding Council for Wales.

Ariennir yn Rhannol gan **Lywodraeth Cymru**
Part Funded by **Welsh Government**

Cyngor Cyllido Addysg Uwch Cymru
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The Sêr Cymru National Research Network for Low Carbon, Energy and Environment (NRN-LCEE) was funded by Welsh Government (WG) and the Higher Education Funding Council for Wales (HEFCW) as part of the Sêr Cymru 1 funding initiatives.

The over-arching mission of the Network was to promote excellent research within Wales into the sustainable use of natural resources for the provision of energy, water, food, and other ecosystem services. The Network was the catalyst to bring a diverse set of talented researchers and partners into new collaborations, in order to conduct innovative research that was highly pertinent on an international research agenda.

Four themes tie together all research funded by the Network:
1. Sustainable Intensification
2. Low Carbon Energy Pathways
3. Developing the Bio-Economy
4. Impacts & Mitigation of Climate Change and Human Activities

The core of the Network research was centred around 8 Research Clusters (supporting 18 Research Fellows and 12 PhD students) and 10 Returning Fellowships. The latter were individuals returning from extended career breaks. It also supported STEM outreach opportunities, public lectures and a diverse range of workshops and events on topical science issues. **www.nrn-lcee.ac.uk**

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