Hunstanton Cliffs, Norfolk.

30. Maritime cliffs and slopes

Climate Change Sensitivity: **High**

Introduction

The Natural Environment chapter of the **UK Climate Change Risk Assessment Evidence Report** (Brown *et al* 2016) highlights that all coastal ecosystems are at high risk from climate change, with increased vulnerability in many locations due to the presence of flood defence and erosion protection structures, which prevent landwards rollback of the intertidal zone as a natural response to sea-level rise. In addition, natural adaptive capacity is limited by reduced sediment supply due to hard coastal defences. Dynamic coastal systems have the potential to be self-regulating in the face of rising sea levels. This can only occur if there is both an adequate supply of sediment and there is landward space for migration and adjustment of the different components relative to the tidal and wave energy frame.

Maritime Cliff and Slope environments will be affected by the consequences of climate change in a range of ways. It is quite natural for sea cliffs to respond to wave energy by releasing rocks and other sediment to the sea: this forms beaches at the cliff foot and is also transported by longshore drift to form sedimentary coastal habitats and beaches elsewhere. Climate change impacts from increased sea levels and wave height, and extremes of rainfall, are likely to alter patterns of both marine erosion and groundwater levels, and the latter will also increase risk of landslides. Where this risk affects built assets, there is likely to be increased demand to stabilise eroding cliffs by drainage and engineering measures. This will affect the environmental quality of the cliff habitats and sediment transfer to other coastal habitats. It is already considered that sediment inputs are reduced because of existing coast protection[12] measures (Lee 2001a).

Geology is the key factor in considering the potential effects of coastal erosion. The older and more resistant rocks are located in north west England and parts of the south west, and are relatively resistant to erosion. Younger sedimentary rocks are less resistant, and areas of glacial sediments are particularly prone to marine erosion and landslides. These areas include the east, southeast and south of England (Zambosky 2011).The greatest climate change impacts, and the most dramatic landslide events, are likely to be on soft cliffs rather than hard rock cliffs (McInnes and Moore 2007).

Climate change could alter the distribution of species through temperature changes, which may encourage non-native invasive species, but this is an area where more research is needed.

Likely changes identified in the Marine Climate Change Impacts Partnership (MCCIP) **Report Card** (Rees *et al* 2010) include:

- Increased marine erosion at cliff toes with higher sea levels and more frequent storms.
- Rocky shore platforms at the foot of hard cliffs may have more marine scour and wave attack at the cliff foot due to beach lowering, and may be lost with sea-level rise as they cannot accrete like beaches.
- Headlands form natural hard points and may promote changes in the shape of intervening bays and beaches.
- High levels of winter rainfall may promote greater risk of landslides, leading to more demands for coast protection.

12 'Coast protection' is defined as engineering measures to prevent or reduce the risk of erosion of the coast, usually in the form of hard structures combined with measures such as drainage to limit landslide risk.

- Old landslide complexes are likely to reactivate more rapidly than expected as groundwater pressure increases.
- Warmer temperatures may favour invasive species e.g. Hottentot fig *Carpobrotus edulis* , but may also promote suitable conditions for other thermophilic species.
- The balance of bare ground to successional vegetation may be altered on soft cliffs, with a potential loss of mosaic habitats important for scarce invertebrates.
- Changes in the intensity of agricultural or recreational use of cliff top land may reduce the potential for colonisation of eroding slopes by semi-natural vegetation.

Beach levels influence cliff erosion rates. As relative sea-level rise results in narrower, shallower beaches this may increase the retreat of soft cliffs in particular. Stabilising cliffs can affect beach sediment volume, further compromising beach levels along the coast and beyond the location of structures. Soft cliff erosion rates are extremely varied within and between years, but the majority of loss occurs in winter months. Excessive rainfall triggers slippages and retreat, so projected winter precipitation increases at a time when conditions promote erosion anyway, will result in higher recession rates. Masselink & Russell (2013) also conclude that it is it is very likely that currently eroding stretches of coast will experience increased erosion rates due to sea-level rise. The episodic nature of cliff recession, which would occur even without climate change, makes it difficult to predict the degree of additional future changes.

The habitat is very sensitive to the human response to coastal erosion, although more rapid recession could impact on the balance of vegetation and bare surfaces. Coastal erosion risk management attempts to stabilise these processes through a combination of toe protection, drainage, and other engineering methods. It is estimated that in the 100 years up to the 1990s, 860km of coast protection works were constructed to reduce erosion (Lee, 2001a), reducing sediment input by an estimated 50%. Schemes to extend or replace coast protection are still being proposed, often in response to the reactivation of landslides. Recently, high levels of rain have reactivated landslides on the Dorset coast at Lyme Regis, and Cayton Bay, Yorkshire

Soft cliff erosion is an important source of sediment. The areas with the most rapid rates of recession are on the south and east coasts of England. For example, at Holderness in Yorkshire cliff erosion is estimated to supply 3 million m^3 a year of fine sediment into the marine system, most of which is transported to the Lincolnshire coast and the Humber estuaries, contributing to the estuary environment (HR Wallingford 2002).

Habitat Description

Geology

It is estimated that there are approximately 1100 km of maritime cliffs and slopes in England (Rees *et al* 2010), and it is a relatively scarce habitat with a linear nature. Vegetated sea cliffs in England are very variable due to differences in geology, geomorphology, slope angle, abiotic processes, exposure and level of naturalness. It has been suggested that a minimum height for cliffs can be between 3 - 5m above the shore platform or beach (Barron *et al* 2011). In England the highest sea cliff is Great Hangman in Exmoor, Devon at 244 m, with the highest east coast cliff at Boulby in Yorkshire at 203 m.

Maritime cliffs and slopes have a series of steep or vertical faces as a result of slippage and erosion by marine processes (JNCC 2008). Wave action is the most important coastal process that drives change in sea cliffs. Changes in water depth and wave energy, and factors affecting long-shore drift and current movements, together with groundwater conditions, will determine the rate of sea cliff erosion and landward recession. The foot and tops of cliffs are also part of the overall ecosystem. At the foot, there can be a reef platform extending from the cliff foot into the intertidal and subtidal areas. This may also be covered by beach deposits. Cliff top habitats can have a maritime influence from blown salt spray and wave splash. This is greater on more exposed coastlines such as the south west. The type of cliff top habitat can influence the slope ecology, providing a source of plant seeds for the slope and additional habitat or food sources for a range of fauna, such as nectar for invertebrates.

Maritime cliffs can broadly be classified as 'hard cliffs' or 'soft cliffs', although in reality there can be complex mosaics and intermediate types.

Hard cliffs are found around the exposed coasts of the UK, mainly in the west. They have vertical or steeply sloping faces and thus support few higher plants, other than on ledges and in crevices or where a break in slope allows soil to accumulate. They tend to be formed of rocks resistant to weathering, such as granite, sandstone and limestone, but can be formed of softer rocks, such as chalk, which erode to a vertical profile. Vegetation types are well-described in the NVC (Rodwell 2000) as these have been well-studied.

Soft cliffs are found mainly on the east and south coasts of England. These are formed in less resistant rocks such as shales or in unconsolidated materials such as boulder clay or 'drift'. Their instability means seaward faces are less steep, sometimes with a series of steps, and can be colonised by vegetation. Soft cliffs experience frequent slumping and landslips, particularly where water percolates into the rock and reduces its effective shear strength (JNCC, 2008).

While different processes affect hard and soft cliffs, they are not entirely distinct; for example some hard rock types, such as chalk, may sporadically experience massive collapses (Hill *et al* 2002). These changes occur in a sequence of stages, with slope processes and marine erosion as the key influences.

Ecological variation

Maritime cliff and slope habitats are not uniform. Variation in geology, climate, location and exposure to wind and salt spray define the floral and faunal communities. Other key factors are the chemistry of the underlying rock, the water content and stability of the substrate and, on soft cliffs, the time elapsed since the last movement event. Plant communities in sheltered locations are more similar to those found inland, whereas those in exposed situations include more salt-tolerant species. Rock type is a significant factor defining the communities of cliffs and slopes (JNCC 2008).

The vertical faces and steep slopes of hard rock cliffs can be colonised by lichens and lower plants, but ledges and crevices support higher plant communities, some of which are unique to cliffs (Rodwell 2000). On hard rock cliffs, encrusting lichens are often the predominant vegetation at the lower levels in the wave splash zone, but other types can occur at other levels on cliffs. In extreme conditions, waves can lead to saline conditions on ledges or cliff tops, such that saltmarsh species can establish. In other areas, where cliffs occur adjacent to sand dunes on high energy coasts, windblown sand can accumulate on the cliff-slopes and tops (known as climbing and perched dunes), allowing dune species to colonise.

Where there is greatest exposure to the waves and winds, such as on the northern and south-western coasts, strictly maritime vegetation occurs. Here, species like rock samphire *Crithmum maritimum* and rock sea spurrey *Spergularia rupicola* occur. Where there are large colonies of cliff-nesting seabirds, their nesting ledges are enriched by guano and can support a particular community characterised by oraches *Atriplex spp.* and sea beet *Beta vulgaris spp. maritima*.

The vegetation of soft cliffs, which experience frequent slumping and landslips, forms in mosaics, and can include areas of recent slippage colonised by early successional communities as well as woodland on areas with prolonged (but not always permanent) stability (Hill *et al* 2002). Frequent slumping and slippages provide important nesting and feeding habitat for specialist invertebrates requiring soft substrates in open conditions. Seepages and springs associated with soft cliffs are also important invertebrate habitats (Whitehouse 2007).

Soft rock cliffs with no artificial coast protection are a rare resource in the British Isles and in Western Europe as a whole. It is estimated that only 256km of the English soft coast remains free of intervention. Soft rock cliffs often have shallow gradients which allow colonisation of vegetation and development of a wider range of habitats than on hard cliffs (Hill *et al* 2002). Species found here include a maritime form of red fescue *Festuca rubra*, thrift *Armeria maritima*, sea plantain *Plantago maritima*, buck's-horn plantain *P. coronopus* and sea carrot *Daucus carota spp gummifer.* Species of inland grasslands which also commonly occur in maritime grasslands include ribwort plantain *Plantago lanceolata*, bird's-foot trefoil *Lotus corniculatus*, and common restharrow *Ononis repens*, along with several species of grass.

Soft rock cliffs have long been known to support rare and notable invertebrates, particularly bees and wasps, beetles and flies. The ecological requirements of these species relate to the successional phases of cliff habitats, which are dependent on varying degrees of stability, and range from open bare ground to sheltered scrubby patches with nectar-rich plant species (Rees *et al* 2013).

Bempton Cliffs. © Natural England/Peter Wakely

Potential climate change impacts

Cause	Consequence	Potential impacts
Sea level rise	Greater levels of wave energy Altered coastal dynamics in long term	■ Increased marine erosion at cliff toes with higher sea levels and more frequent storms. With hard cliffs, rocky shore platforms may have more marine scour/wave attack at the cliff foot due to beach lowering, and may be lost with sea-level rise as they cannot accrete. ■ Headlands form natural hard points and may promote changes in the shape of intervening bays and beaches.
Increased storminess and more frequent extreme events	Greater levels of wave energy may reactivate landslides, and reduced time between storms could restrict the capacity for recovery	■ Loss of toe material at cliff foot, allowing landslides.
Increased annual average temperatures	Longer growing seasons and shorter winters	■ Warmer temperatures may favour invasive species e.g. Hottentot fig.
Hotter summers	Possible increase in visitor numbers	■ Changes in intensity of use of cliff top land may reduce the potential for colonisation of eroding slopes by semi-natural vegetation.
Drier summers	Clays and other friable substrates may dry and crack	■ Greater risk of erosion from collapses.
Increased winter rainfall	Increased rainfall may lead to higher groundwater levels, more water flowing over slope surfaces, and reduce the influence of salt spray	■ High levels of winter rainfall may promote greater risk of landslides, leading to more demands for coast protection. Old landslide complexes are likely to reactivate more rapidly than expected as groundwater pressure increases. ■ High winter rainfall combined with milder winter temperatures may extend the growing season and lead to increases in competitive plant species, particularly dominant grasses. ■ Less salt spray influence may change the balance of species on ledges and slopes.
Combination of causes		■ The balance of bare ground to successional vegetation may be altered on soft cliffs, with potential loss of mosaics important for scarce invertebrates.

Adaptation responses

Maritime cliff environments generally require limited management for nature conservation, and adaptation should focus on measures to work with the ongoing changes in cliff systems. Management plans should be developed with an understanding of the likely changes. Information about these may be available through a range of sources including Shoreline Management Plans (SMP), and tools that indicate erosion risk such as the Environment Agency's National Coastal Erosion Map. At all stages, coastal adaptation issues should be discussed with partners and stakeholders.

Where there are no existing erosion control measures, these should not be introduced, nor should drainage be installed on cliff slopes or cliff tops. The SMP policy will influence decisions on the maintenance or removal of any existing erosion control. Infrastructure, such as steps, cliff top fencing, paths etc. should be designed to be easily adapted, and its condition should be regularly reviewed. An understanding of the geological and geomorphological processes of the site in a wider context will be beneficial, as coastlines rarely function within individual ownership units.

Gannets at Bempton Cliffs, Yorkshire. © Natural England/ Andy Neale

An important aspect to consider is how the management of the cliff-top land will affect the cliff environment. Reversion to a semi-natural habitat type may be beneficial in the longer-term.

Generic guidance for considering adaptation of flood risk management infrastructure is provided in the **infrastructure report card** (Sayers and Dawson 2014).

Some of the potential adaptation options for this habitat are outlined below.

- Restore or maintain habitat in favourable condition and ensure that non-climatic pressures to maritime cliff and slopes (coastal defence works, quarrying, building construction, and recreational pressures etc.) are managed or reduced.
- Existing semi-natural habitats on cliff tops will be affected by erosion. This requires the development of strategies to re-create or expand these to account for future losses.
- Where intensive agricultural land is on the cliff top, a buffer area reverted to semi-natural habitat can promote greater resilience for cliff slope vegetation quality. Ideally, whole fields would benefit from reversion
- Develop information to support necessary adjustment of designated site boundaries and interest features as coasts evolve, allowing for between 30 to 50 years of change.
- Where features or buildings on the cliff top are within management control, ensure there is a clear plan for managing and recording historic or archaeological sites that may be at risk.
- Ensure that visitor management and recreation infrastructure planning takes account of coastal change and erosion risk, including using the 'roll-back' provision in the Coastal Access scheme to re-locate the England Coast Path route.
- Undertake more long-term or repeat studies on the impacts of increased rates of recession on cliff slope ecology.
- Monitor and control the spread of potential native and non-native invasive species.

Relevant Stewardship options

There are no specific options for cliffs. Grassland or heathland options may be suitable for cliff tops, but any issues of erosion leading to reduction in area during agreements must be agreed and addressed to ensure no loss of payments.

Further information and advice

Buglife **Soft Rock Cliff project**.

Natural England **Maritime Cliff and Slope Inventory** (NERR 003 2004/5).

MCCIP **Annual Report Card and Briefing Notes**.

Relevant case study examples

Natural England, **Coastal evolution in Suffolk: an evaluation of geomorphological and habitat change** ENRR647 (2006).

European Commission, **A guide to coastal erosion management practices in Europe: lessons learned** (2004).

Key evidence documents

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