Adaptation for habitats in Environmental Land Management Schemes

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Appendix to NE751

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Executive summary

This document has been produced to support the implementation of adaptation in the Environmental Land Management (ELM) Schemes.

It sets potential adaptation responses for habitats and should be used to help inform the choice of ELM options when considering how to respond to climate change.

The text has been extracted from the Natural England & RSPB Adaptation Manual (NE 751) and updated to reflect the options currently available under ELM.

Guidance is provided on the full range of potential adaptation interventions for different habitats. Which of those interventions will be most appropriate will be dependent on individual sites and farming practice.

The recommendations should be applied through the selection and use of the relevant ELMs options.

The adaptation actions listed are intended to be a guide only and will need to be adapted to reflect local circumstances. Implementation should be delivered through adherence to the prescriptions of any options chosen.

Reference

Natural England and RSPB, 2019. Climate Change Adaptation Manual - Evidence to support nature conservation in a changing climate, 2nd Edition. Natural England, York, UK. https://publications.naturalengland.org.uk/publication/5679197848862720

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Appropriate adaptation responses will differ across the country because the landscapes, woodland, what is expected of them, and the climatic pressures, differ. However, even within a single landscape, the critical factors may vary: changes in winter rainfall might be important for valley bottoms, whereas summer drought could be critical on adjacent south facing slopes.

Management of existing woodland is likely to focus on the reduction of non-climatic pressures such as pests and diseases, increasing the species and genetic diversity of new and existing woodland to reduce the impact of changes in the abundance of single species, and encouraging natural regeneration (i.e. evolutionary adaptation) by reducing grazing pressures from deer and thinning to create canopy gaps. However, in many cases acceptance and management of change will also be a key adaptive response to climate change.

Measures that aim to reduce the impact of drought and ensure the availability of water are likely to be increasingly important in different woodland types across the country.

For new woodland planting and, in some cases restocking, species and provenance selection will increasingly need to reflect projected future climatic conditions.

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

Existing woodland

- Reduce the impacts of other pressures, such as pests and diseases, pollutants, over-grazing and development. Reducing deer pressure, for example, allows more flowering and seed setting of ground flora such as primroses, so increasing the potential for populations to survive drought years.
- Undertake management interventions to encourage and protect regeneration.
- Assess future suitability of species present on the site using Ecological Site Classification; assess options for species diversification.
- Accept and encourage a greater mix of native trees and shrubs through active management, for example by accepting a greater component of oak in the canopy of ‘beech woods’.
- Increase the age structure and structural heterogeneity of woodland, for example by reducing coupe size and encouraging continuous cover forestry rather than large-scale clear felling.
- In woodland managed for timber, continuous cover forestry approaches may become more advantageous because they are thought to be more wind-firm, maintain a more even carbon storage, show lower soil carbon losses during harvesting, and promote recruitment by maintaining higher humidity levels (Kirby et al 2009).

- Consider blocking artificial drainage channels within woodland in areas predicted to experience increased drying out.
- Manage veteran trees to reduce the crown-to-root ratio, and improve protection for individual veteran trees.
- Undertake contingency planning for outbreaks of new pests or major new disturbance events such as wildfire.
- Critically assess the ecological role of near native species and consider accepting as a component of semi-natural woodland beyond their current native range, eg sycamore.
- Reflect management changes and potential changes in native tree composition in conservation objectives and guidance.
- Review objectives for woodland in relation to the wider suite of ecosystem services that woodlands provide. For example, outside designated sites and ancient woodland, changes in species composition, including the retention of non-native/exotic species, may be acceptable if the services that the woodland provides, such as urban cooling, visual amenity or recreational opportunities, remain intact.
- When determining the optimal management of sites, consider the requirements of key species such as woodland birds to ensure minimum patch size is retained.
- Take positive steps in all woodland situations to increase the proportion and diversity of decaying wood throughout sites. This will ensure both resilience of dependent species and the replenishment of woodland soils' organic content and hence the capacity for moisture retention and provision of other essential ecological functions needed by trees and other species.

New planting

- Assess options for species choice on the site using Ecological Site Classification (ESC) and an understanding of soil types present.
- On more free-draining soils in southern and eastern England, select more drought-tolerant species.
- In the southern and eastern parts of the country, and in locations prone to drought, use new planting to increase the patch size of small woods and reduce edge effects. This will help reduce water loss and also the effects of spray drift from adjacent farmland.
- Develop woodland and semi-natural habitat networks through planting new woodlands in targeted locations.
- Include a greater mix of species within new native woodland planting, including less commonly planted native species and, where ecologically appropriate and likely to benefit from projected climate change, near-native species from outside their current natural range should also be considered.
- Encourage a variety of species that can occupy the same functional space within the woodland ecosystem.
- Identify locations for planting where the direct impacts of climate change on the suitability of individual species may be less than in the surrounding region. These could include north-facing or more sheltered slopes and areas with more secure

water supply such as spring lines or low lying areas closer to the water table (though these may be valuable open features themselves).

- Consider the potential for tree planting to assist adaptation in other sectors, for example as shading for livestock, windbreaks, and flood alleviation.
- Consider higher density planting so that woodland can be economically managed in the future to maintain habitat condition and continue to adapt to progressive climate change.
- When establishing new woodland or restocking, consider the planting of more southerly provenances of native species where this is consistent with site objectives.
- Improve understanding of soil properties and heterogeneity across the site, including the requirements of individual species and how these may change as climate change progresses.
- Retain/encourage field layer (minimal use of herbicides and mowing regimes) in combination with the use of biodegradable mulch mats during establishment phase to minimise soil water loss and buffer soil temperature variation which make a significant contribution to losses.
- Consider promoting natural colonisation to generate new semi-natural woodland adjacent to existing woodland, allowing locally native species to develop resilience through natural processes.

2. Beech and yew woodland

As with other woodland habitats, there are likely to be changes in both the abundance of the habitat and the composition of species within it. In the south and east, reduced water availability will drive succession to other woodland types such as oak (especially English oak on heavier soils) or to scrub habitat, depending on soil depth, soil water holding capacity and the change in rainfall seasonality. Conversely, the vigour of beech in the north of its existing range will increase and it will become increasingly viable outside its current range.

The acceptance of change will therefore be a key response, with management to increase the resilience of beech woodland focusing on the reduction of non-climatic pressures and reducing the impact of drought.

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

- Reduce the impacts of other pressures, such as pests and diseases, pollutants, over-grazing and development pressures. Reducing deer grazing pressure, for example, allows more flowering and seed setting of ground flora, such as primroses, therefore increasing the potential for populations to survive drought years.
- In the southern and eastern parts of its range, and in locations prone to drought, increase the patch size of very small sites and ensure new planting is designed to

reduce edge effects by avoiding linear planting. This would help reduce water loss and spray drift from adjacent farmland.

- Consider soil type, aspect and topography carefully when evaluating woodland expansion options, including assessment using Ecological Site Classification, and use these features to maintain/enhance future suitability of the species.
- Where new planting is being considered, potential refugia need to be identified where the direct impacts of climate change may be less than in the surrounding region. These could include north facing or more sheltered slopes and areas with a more secure water supply (eg spring lines or low lying areas closer to the water table).
- Increase the age structure of high forest to reduce the susceptibility of beech populations to damage from droughts and storms.
- Accept a greater mix of native trees within the canopy of beech woods, including oak on non-calcareous soils, and smaller trees such as holly, whitebeam and birch.
- Where the climate is projected to become suitable, accept beech as component of semi-natural woodland in areas beyond its current native range.
- Take positive steps in all woodland situations to increase the proportion of decaying wood to ensure resilience of dependent species, the replenishment of soil organic content and the capacity for moisture retention.

3. Upland oak woodland

Actions that reduce the negative impacts of existing pressures such as pollution, over-grazing and neglect are likely to be the main adaptive response for most oak woodlands. The management of invasive species and monitoring and developing suitable management responses to pests and diseases will also be important for certain sites.

In areas likely to suffer from drought, there may be opportunities to identify potential refugia with consistent water supplies, such as at spring lines. Where these are found within existing woodland, they can be protected and managed. There may also be opportunities to plant new woodland in such areas where that is consistent with wider objectives.

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

- Where possible, reduce the impacts of other pressures, such as pests and diseases, pollutants and development pressures.
- Ensure sites are not overgrazed by livestock or deer, with grazing managed to ensure adequate woodland regeneration.
- Implement management such as rotational coppicing, where appropriate, to diversify the age structure and reduce shading. Reducing shading will help encourage natural regeneration. However, in drought-prone sites, maintaining greater canopy cover may be appropriate to reduce water loss and the impacts of drought on ground flora.

- Potential refugia, where the direct impacts of climate change may be less than in the surrounding area, can be identified. These could include north facing or more sheltered slopes and areas with more secure water supply, for example along spring lines or in low lying areas closer to the water table. Patterns of rainfall can also vary significantly in the uplands.
- In the southern and eastern parts of its range, and in locations prone to drought, new planting can be targeted in areas of high landscape heterogeneity, focusing on areas with resilient sources of ground water and on north-facing slopes less prone to drought. A broader mix of native trees within the canopy of ‘oak woods’, such as beech, rowan and birch, and within the shrub layer, can increase resilience. These potential changes in native tree composition should be reflected in site conservation objectives and guidance.
- Develop contingency plans for outbreaks of pests and diseases, or major new disturbance events such as fires.
- Take positive steps in all woodland situations to increase the proportion and diversity of decaying wood throughout sites so as to ensure both, resilience of dependent species, and the replenishment of woodland soils’ organic content and hence capacity for moisture retention and provision of other essential ecological functions needed by trees and other species.

4. Upland mixed ash woodland

Ash dieback has the potential to significantly change the structure and composition of upland mixed ash woodland. Adaptation to climate change should be built into and aligned with responses to the disease.

Many actions that aim to improve the resilience of ash woodland, for instance actions to reduce non-climatic pressures such as pests and invasive species, and improving the structural heterogeneity and species diversity of woodland, will promote adaptation to climate change and improve the resilience of woodland.

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

- Reduce the impacts of non-climatic pressures through active management. These may include browsing damage from deer, sheep and other herbivores, pollution from agricultural spray drift, soil compaction and erosion, and the spread of invasive species such as Himalayan balsam *Impatiens glandulifera*.
- Avoid changes that impact on the hydrological functioning of the site.
- Allow natural woodland processes and/or woodland management to promote a diversity of age structure within woodlands. This may include retaining some undisturbed old growth stands, encouraging natural regeneration, allowing pockets of wind throw trees and deadwood, and creating a ‘graduated’ woodland edge (as opposed to a sharp boundary with neighbouring land uses).
- Promote through both natural regeneration and/or planting, a diversity of native tree species in the canopy, such as aspen, alder, rowan and small leaved lime. Take

opportunities to include species or provenances with a more southerly distribution; for example small leaved lime. Ecological Site Classification can be used to assess site suitability and indicative future impacts of climate change.

- Identify any resistance to *Chalara* in the ash population and take measures to protect these trees and allow them to regenerate naturally.
- Aim to maintain large, old trees and the quantity of dead wood.
- Retain sycamore if its presence is not impacting on other aspects of the native flora or fauna, or if it is supporting species otherwise endangered by ash dieback.
- Aim to buffer sites by extending the woodland edge and, where appropriate, taking opportunities for new woodland creation nearby.
- Identify potential refugia where the direct impacts of climate change may be less than in the surrounding area. These could include north facing slopes and areas with more secure water supply (eg near spring lines or low lying areas closer to the water table) and places with relatively high rainfall. These areas should be protected from other pressures where possible.
- Develop contingency plans to deal with outbreaks of pests such as emerald ash borer *Agrilus planipennis*, diseases and the increased risk of major new disturbance events such as wildfires.
- Take positive steps in all woodland situations to increase the proportion and diversity of decaying wood throughout sites so as to ensure both resilience of dependent species, and the replenishment of woodland soils’ organic content and hence capacity for moisture retention and provision of other essential ecological functions needed by trees and other species.

5. Wet woodland

Rainfall is likely to be the main cause of change in wet woodlands rather than temperature. At present, there is significant uncertainty in the climate projections for precipitation. Even if the current projections of drier summers and wetter winters prove to be accurate, the overall impact on wet woodlands is uncertain.

As with other woodland habitats, there are likely to be changes in both the abundance of the habitat and the composition of species within it. In certain sites reduced water availability will drive succession to drier woodland types such as beech and oak (especially English oak on heavier soils) or to scrub habitat, depending on soil depth, soil water holding capacity and the change in rainfall seasonality.

The management of water availability and levels will become increasingly important in catchments in the south and east of the country. The resilience of wet woodland may be increased by promoting structural and species diversity and the management of invasive species. New planting can reduce the vulnerability of existing sites though increasing patch size and providing a buffer to neighbouring land.

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

- Reduce the impacts of other pressures such as pests and diseases, pollutants, over-grazing and development pressure. Reducing deer pressure, for example, allows more natural regeneration.
- Remove sources of nutrient enrichment by increasing the area of extensively managed land around the wetland and implementing good practice throughout the site's catchment.
- Where water supply is critical for the interest feature, consider actions that enable water tables to be artificially maintained during the spring and summer, including the use of artificial structures.
- Actively manage woodland to ensure structural heterogeneity and different age classes among canopy trees, for example through rotational coppicing.
- Accept and encourage a greater mix of native trees and shrubs within the canopy and shrub layer.
- Monitor and address potentially harmful invasive native and non-native species. This might include the use of surveillance to detect the arrival of species at an early stage (while they can still be eradicated) and identifying potential sources of invasive species in the surrounding area.
- Promote wet woodland as potential new green infrastructure in new developments and as part of larger wetland creation schemes.
- Where new planting is being considered:
    - prioritise areas with more secure water supply (eg spring lines or low lying areas closer to the water table) as they may represent potential refugia from the direct impacts of climate change;
    - consider the proximity to sources of invasive species when identifying locations, and avoid sites that could connect invasive pathways to areas of conservation interest;
    - give priority to making existing sites larger and reducing edge effects;
    - promote resilience through planting a range of tree species; options can be assessed using Ecological Site Classification.
- Where possible, identify opportunities to restore or create wet woodland habitats as part of flood management schemes within river floodplains. Within wet woodland, the retention of in-stream woody debris can help to enhance flood alleviation.
- Take positive steps in all woodland situations to increase the proportion and diversity of decaying wood throughout sites so as to ensure both resilience of dependent species and the replenishment of woodland soils' organic content and hence capacity for moisture retention and provision of other essential ecological functions needed by trees and other species.

6. Wood pasture and parkland

The heavy influence of historic and current management on the structure, function and condition of wood pasture and parkland provides flexibility in designing appropriate adaptation and managing change. However, when making management decisions, consideration of the landscape and cultural value of the site will normally be necessary, particularly when dealing with historic parklands and other ‘designed’ landscapes.

An important value of veteran trees, which are often the main feature of both wood pasture and parkland habitats, is the ecological continuity in the dead and decaying wood they contain. Consequently, adaptation is likely to focus on actions that promote the longevity of existing mature and veteran trees and ensuring that new generations of appropriate species and genotypes are planted to replace trees as they are lost (and preferably before they are lost), thereby ensuring the continuing structural heterogeneity of sites. Management of younger trees to encourage the development of dead and decaying wood to fill the gap between veterans and younger trees will also be important.

Flexibility of grazing and the development of effective contingency plans to respond to increased climatic variation and an increase in extreme events will also be important adaptive actions.

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

- Where possible, reduce the impacts of other non-climatic pressures, such as pests and diseases, pollutants and development pressures. Adjust grazing levels according to environmental conditions to avoid over and under-grazing and compaction.
- Maintain pasture rather than arable land use under the trees to avoid adverse impacts on root systems.
- Protect mature and veteran trees from over and under-grazing.
- Ensure adequate regeneration and replanting to establish new generations of trees to replace individuals and species that are lost or likely to be lost under climate change. These new trees should be protected from grazing and competition, and should be managed to provide appropriate conditions for saproxylic invertebrates (ie decaying wood). Young trees may be protected from grazing and browsing by fallen branches and dead wood, giving an additional reason for retaining dead wood.
- Management of veteran trees to reduce the likelihood of catastrophic failure, for example by reducing the crown to reduce the sail effect in high winds and improving the protection for individual veteran trees. The benefits of undertaking crown works on veteran trees need to be weighed against the risks, and the guidance of a suitably qualified arboriculturalist can provide advice.
- Consider introducing or reinstating pollarding to semi-mature trees less vulnerable to storms and drought, to accelerate the development of veteran tree features and niches for specialist fungi and invertebrates, but consider the risk from crown works, as outlined above. Pollarding to reduce crown density can also help to reduce the possibility of catastrophic failure. The presence of ash dieback should be taken into account when management, pollarding or re-pollarding of ash trees is being considered.

- Ensure that standing and fallen deadwood is not cut up and is only moved if absolutely necessary, as it represents a key niche requirement for many specialist species.
- Trees blown over by storms may grow new stems if the roots are undamaged or the horizontal trunk remains connected to the root system, if left uncut and not 'tidied up' or removed from the site, where there are no safety concerns.
- Develop fire management plans, especially in wood pasture and parkland where the threat of fire is thought to be high, such as those with a bracken-rich or heather understorey. Introduce grazing animals, or other appropriate management, to reduce the amount of litter in sites with a lot of bracken.
- Develop contingency plans for outbreaks of new pests and diseases and other extreme events.
- When planting, understand soil type and heterogeneity across a site to better match species to planting location, including a consideration of the likely direction of climate change. Species choice is particularly challenging for future veteran trees, given the long planning horizon.
- Consider selecting more drought-tolerant species, or provenance from the southern parts of a species' range, when replanting. Where possible, select species whose decay fungi and mechanisms create similar conditions to existing species. For example, sweet chestnut grows faster than oak, but has similar heartwood and rots in a similar way, so some of the species associated with oak will find sweet chestnut a suitable alternative host.
- Consider planting non-native/exotic species (eg cedar, redwood), only where these are consistent with landscape character and designated/designed landscapes.
- New trees need to be established with sufficient space to grow with open crowns, if they are to provide habitat niches for those species dependent on the specific conditions in the trees, including many lichen species.
- Buffer and expand existing sites through planting or by encouraging natural regeneration of open grown trees.
- Encourage the establishment of veteran features in mature trees through veteranisation techniques.

7. Traditional orchards

The influence of historic and current management on the structure, function and condition of traditional orchards provides a high degree of flexibility in designing appropriate adaptation strategies and managing change. Continuing, or reintroducing, low input active management of traditional orchards is a key adaptive response. Increasing the species and structural diversity of orchards at a site and landscape-scale will also reduce vulnerability. Selection of the appropriate species and cultivars for the site will also play a role in future proofing orchards against climate change.

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

- Ensure continued extensive management of orchards, with little or no agrochemical input, and using grazing rather than machinery to manage the understorey.
- Adjust grazing levels according to environmental conditions to avoid under and over-grazing and compaction.
- Minimise soil erosion by grassing-down alleyways. Alleyways are a feature of bush orchards rather than traditional orchards, which have permanent grass swards.
- Increase the age structure and variety of species within orchards through management and replanting.
- Consider selecting more drought-tolerant species, or provenance from the southern part of a species' range when replanting. This may not always be possible, for example if no cider varieties are able to be grown, then the cider industry would have to import fruit and therefore have no reason to conserve orchards.
- Select varieties with lower dormancy requirements. Many late-flowering, late-maturing varieties, especially cider apples, require greater cold vernalisation than early flowering varieties. This may conflict with the genetic conservation of rare, localised varieties.
- Ensure that all planting material complies with the EU plant passport scheme, which includes a requirement for freedom from fire blight.
- Establish windbreaks for shelter prior to planting trees and use strong tree support systems on exposed sites.
- Manage mature trees to reduce the threat of wind rock and wind throw. For example, encourage sustainable mistletoe harvesting from trees exposed to high winds.
- Plan for changes in the availability and demand for water by, for example, increasing on-farm water storage capacity or installing a trickle irrigation system.
- Ensure the continued presence of decaying wood within live trees by prolonging the life of old trees. Retain dead wood, both on the trees and where it falls.
- Develop contingency plans for outbreaks of new pests and diseases and other extreme events.
- Ensure regular monitoring of pests and diseases and adhere to best practice in integrated pest management.
- Consider the use of natural products and biocontrol agents for mildew control, and select resistant varieties in new planting.

8. Hedgerows

The current definition of hedgerows includes recently planted and species poor hedges, as well as species rich and ancient types. This, and the regional differences in species composition and management practices, means that appropriate adaptation actions are likely to vary according to hedge type and location.

In the majority of cases, reducing the impact of adjacent land uses through effective buffering will remain a key response, as will some form of management to prevent hedges developing into lines of trees (although lines of trees may have benefits in some circumstances, including providing shade in a warmer climate and acting as windbreak).

When planting, restocking or filling gaps in hedges, consideration should be given to using a diverse range of species, particularly those that are adapted to a wide range of climatic conditions. Accepting and encouraging changes in the composition and structure of hedges will increasingly become a necessary element of ensuring that hedges remain resilient to climate change. Change will need to be undertaken within the context of local landscape character, with gradual rather than transformational change promoted.

Hedgerows may provide opportunities for some species to disperse across the landscape, increasing the potential to colonise newly suitable locations, both locally and nationally. It should not however be assumed that all, or even most, characteristic woodland species will use or spread along hedgerows – for example, ancient woodland indicator plant species colonise new sites very slowly and the microclimate of a hedge is typically lighter and more prone to fluctuations in temperature than the interior of a woodland.

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

- The most important response to climate change is likely to be effective buffering against the impact of adjacent land uses, through for example the use of grass, uncultivated or low intensity margins, and fencing off livestock. This will become increasingly important whether or not there is an intensification of adjacent land use, as trees stressed by climatic factors such as drought or water-logging are more susceptible to other pressures.
- Regeneration of hedgerow trees and shrubs can be promoted through the management of grazing mammals and vigorous weed species, to promote a greater range of age classes.
- Maintenance of a diverse range of hedgerow structures through appropriate management, ranging from hedgerows that grade from tall scrub, with plentiful side shoots and foliage in the summer, to well-developed shrubs and tall sward grassland with herbs. Aim for a gradual gradation between the two habitats; the wider and more varied the structure the better.
- When establishing new hedges, aim to provide links to the existing hedgerow network and patches of semi-natural habitat in order to promote the movement of species through the landscape.
- When planting or restocking, aim to diversify the range of species and select species and provenances adapted to a wider range of climatic conditions. Where hedgerows contain tree species susceptible to climate change, consider restocking with more resilient species to establish the next generation of hedgerow trees.

9. Arable field margins

Maintaining or expanding the area of land available for margins is likely to be the most effective adaptation response, although this would need to be considered within the wider context and the best use of resources. The potential expansion of arable cropping into some areas of the west and north could assist this, but changes to global food supply, national food security issues and other pressures on land could make less land available overall for conservation.

The protection of margins from chemical inputs from adjacent cropped areas will remain a key measure to ensure their ongoing resilience to climate change.

Microclimates may vary considerably and lower temperatures resulting from shading, eg by hedges or slopes, could help to maintain some species in situ.

Field margins are likely to play a role in allowing some species to move within a landscape and find new locations locally or as part of a larger-scale change in distributions. There are some caveats to this, in that some species have limited mobility, and field margin habitats will not be suitable for others. However, as we move towards a more connected landscape-scale view of agri-environment and other land use interventions, we are likely to see more specific and tailored use of field margin habitat to facilitate suitable mobilisation corridors.

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

- Maintain or expand the area of land available for arable field margins.
- Ensure that margins are protected from agricultural inputs to adjacent crops.
- Where possible, locate margins in a range of locations to provide variety of aspect, soil type and shading.
- Maximise the diversity of margins to provide a range of habitats and to assist in the movement of species through the landscape.
- Select the most appropriate management options for specific objectives. For example, uncropped cultivated margins have been demonstrated to be the most suitable option for arable plants, exhibiting the widest diversity of annuals, perennials, grasses, forbs (non-woody broad-leaved plants other than grass), and spring and autumn germinating species (Still and Byfield, 2007), while tailored sown mixes deliver the greatest benefit for farmland birds.
- In planted margins, tailoring the diversity of flowering species to ensure the continued provision of pollen and nectar throughout the extended season.
- In planted margins, include species and cultivars that are able to tolerate and flower under hotter, drier summers.

10. Rivers and streams

Measures needed to help rivers and stream adapt to climate change are largely the same as those required to restore their health and integrity generally, through attention to natural ecosystem function. A summary of key measures is provided below – further information on restoring natural river ecosystem function is provided in Mainstone et al (2016). There is also the potential to lower water temperatures by providing shade from bankside vegetation and further is available from the Keeping Rivers Cool project (Woodland Trust 2016).

In the catchment

The main priority for adaptation within river catchments will usually be to promote land uses and land management practices that maximise natural rainfall retention within the catchment. This will help to reduce run-off energy and associated diffuse pollution. Allowing more water to be stored within the catchment will also help to reduce the extremes of peak flows and low flows. Other priorities will be slowing the spread of invasive species, and increasing the availability of cooler water by providing riparian shade.

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

- Improve the natural infiltration of catchment soils and percolation to groundwater by restoring soil organic matter levels and avoiding soil compaction and capping.
- Create semi-natural vegetation such as woodland and grassland along critical run-off pathways to slow surface water run-off and aid infiltration of water into the soil.
- Restore natural function of headwater streams, including ephemeral and permanently flowing sections – the health of these streams is vital to the health of the river network and the resilience of catchments to climate change.
- Make sure that crops are appropriate to the erosion sensitivity of the land in order to minimise erosion and siltation of water courses.
- Minimise nutrient (nitrogen and phosphorus) applications to crops to the minimum necessary for healthy growth, based on methods with high uptake efficiencies.
- Use low-nutrient livestock feeds with high efficiencies of nutrient uptake.
- Block drainage where possible and consistent with local agricultural land management objectives.

In the river corridor and floodplain

Maintaining and restoring natural river processes constitute the most ecologically effective climate change adaptation measures for river ecosystems (Kernan et al 2012). Natural river processes provide the most characteristic and self-sustaining mosaic of river biotopes (Mainstone et al 2016), and provide the best environmental conditions for characteristic species to survive in a changing climate. The restoration of natural river features also has important wider benefits for flood risk management and landscape character.

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

- Manage water demand, impoundment and abstraction to minimise impacts on the natural flow regime of rivers.
- Make use of high rainfall periods to store water (eg using small-scale winter storage reservoirs for agricultural irrigation) in order to minimise direct river abstraction during low-flow periods.

- Where consistent with managing flood risk to people and property, free river channels from constraints to natural movement and self-recovery of natural morphology and hydrology. This may involve the removal of weirs, flood banks and hard bank protection.
- Assist natural recovery of rivers by minimising maintenance of the river channel by dredging, weed clearance and the removal of woody debris. Large woody debris, in particular, is a critical part of river ecosystems that is often absent from English rivers.
- Where assisted natural recovery is not possible, actively restore river channels, banks and riparian areas, to create a more natural mosaic of characteristic biotopes. This may involve measures such as bed-raising, bank re-profiling, and riparian tree planting.
- As far as possible, avoid creating new constraints to natural river processes, including weirs, hard bank protection, flood banks and flow modifications (eg inter-basin transfers).
- Plan land use and management with river movement in mind. Develop long-term plans for managing the river channel within an ‘erodible corridor’, using set-back tree planting where necessary to constrain movement beyond this.
- Allocate greater areas of floodplain land to flood naturally, to minimise the build-up of peak flows to downstream urban areas.
- Plan biodiversity management in the floodplain with natural riverine processes and river restoration in mind. Develop a long-term vision for semi-natural habitat mosaics that takes account of river dynamics, and modify site designations and conservation objectives accordingly.
- In treeless river reaches, optimise riparian tree cover to provide patchy light and shade. This provides the best mosaic of biotopes, an ample supply of woody debris and leaf litter, and provides buffering against rising water temperatures, shading the water and lowering temperature on sunny days. The Keeping Rivers Cool project (2016) has published guidance on improving the level of shading to help keep rivers cool.
- Where possible, restore natural biological connectivity within the river network and between the river channel and floodplain by removing artificial barriers (in-channel structures and flood banks). Where applicable, the removal of barriers needs to be set against the risk of speeding up the spread of invasive non-native species. This is particularly key in situations where there are native crayfish upstream. Generally, weirs only provide short-term protection against non-native spread, and so this would not normally be considered a long-term constraint to weir removal. Natural in-river barriers (typically waterfalls) play a role in the development of certain types of biological community (eg fishless headwaters) and should not be removed.
- Where removal of weirs is not possible, minimise their impact on channel morphology/ hydraulics and the free movement of species. This may involve reducing the height of the weir and/or providing bypass routes for as many species as possible, including weak swimmers (such as shad *Alosa* spp) where appropriate.
- Where needed, species under threat from shifts in climate space may be targeted for assisted migration, working in line with guidelines for species translocations.

- Manage pollutant loads from effluents to minimise impacts on natural nutrient status and to minimise concentrations of toxins.
- Plan the development of hydroelectric power schemes to avoid constraining the restoration of natural river processes, since the latter is the key climate change adaptation measure for river ecosystems. Development should be focused on existing impoundments that cannot be removed, and on in-line turbines that do not remove water from the river channel.

11. Standing open water

Action to promote adaptation within standing waters needs to take place at a range of scales both within the water bodies themselves and within their catchments. Reducing non-climatic sources of harm can help to increase resilience. This should include reducing nutrient and sediment loads, reducing water management pressures (eg abstraction, water diversion/ transfer) and controlling non-native species.

Establishing ecological networks and ensuring hydrological connectivity is maintained between naturally connected sites is important to allow species to migrate between sites in response to climate change. However, many standing waters are naturally isolated and artificially connecting such sites may have detrimental effects. These include the easier movement of non-native species and the movement of pollutants into previously unpolluted water bodies. The standing water ecological network can be enhanced by the creation of additional ponds, as they act as stepping stones between standing water sites. In contrast, it is much harder to create new lakes, although there may be some opportunities where minerals have been extracted.

Habitat heterogeneity is important to allow species to respond successfully to some of the difficulties associated with climate change. Examples of heterogeneity in standing waters include ponds at varying stages of succession and with varying depths and permanence of water, and lake shorelines with natural process of succession and patterns of species zonation.

While all standing water sites will be subject to the influences of climate change, those away from the coast may provide refugia for species which would otherwise be subject to saline intrusion. Coastal Habitat Management Plans (CHaMPs) will help identify where saline intrusion at freshwater sites is inevitable. In these situations, additional habitat creation inland should be considered. This is most practical for coastal ponds. If species of conservation concern with poor dispersal ability inhabit the at-risk sites, assisted migration will need to be considered. However, this needs to be incorporated into long term planning before saline intrusion occurs.

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

In the catchment

- Improve natural infiltration of catchment soils and percolation to groundwater, by restoring soil organic matter levels and avoiding soil compaction and capping.
- Create semi-natural vegetation such as woodland and grassland along critical run-off pathways to slow surface water run-off and aid infiltration of water into the soil.
- Make sure that any crops grown are appropriate to the erosion sensitivity of the land in order to minimise erosion and siltation of water courses.
- Restrict nutrient (nitrogen and phosphorus) applications to crops to the minimum necessary for healthy growth, based on methods with high uptake efficiencies.
- Use low-nutrient livestock feeds with high efficiencies of nutrient uptake.
- Use Coastal Habitat Management Plans (CHaMPs) to assess which sites are at risk from saline intrusion and whether habitat creation or assisted migration is required.
- Replace lost habitat and provide stepping stones to allow species to move through the environment where appropriate via the maintenance of the existing ponds and the creation of new ponds. The Wetland Vision (Hume, 2008) includes the aspiration to double the number of ponds in the next fifty years, and includes maps identifying areas suitable for pond creation.
- Lakes are a relatively fixed resource in England; their distribution being fixed by past glacial activity and other topographical features, but there may be some opportunity to create new lakes where minerals have been extracted.

The standing water body

- Manage pollutant loads from effluents to minimise impacts on the natural nutrient status and to minimise concentrations of toxins.
- Maintain or restore lake marginal habitat and emergent structure to provide areas protected from wave action.
- Maintain or restore the natural hydrological regime including action that reduces drainage of surrounding wetlands and allows natural water level fluctuations and flushing rates.
- Optimise shoreline tree cover to provide some areas of shade. While shading reduces plant growth in standing waters, an ample supply of woody debris and leaf litter is beneficial to some species, and buffers against rising water temperatures, and therefore a limited amount of shade is beneficial.
- Manage access and leisure activities to minimise impacts and increase resilience.
- Promote good biosecurity to slow the spread of invasive non-native species and minimise their chances of colonising the water body and control damaging species already present.

12. Lowland fens

Maintaining and enhancing the quality and quantity of water is likely to be the main objective of adaptation. There are various existing drivers that require action to improve availability of water and water quality, including the Water Framework Directive (WFD) and the Environment Agency's Restoring Sustainable Abstraction programme. It is critical that risks to fens from climate change and other pressures are considered in the context of these, and that actions to improve resilience as well as the current status are identified and included in relevant programmes and plans, particularly the WFD River Basin Management Plans, which are updated at five-year intervals, and the Water Companies' Asset Management Programme (AMP) associated with the five yearly price review.

The requirement for a flexible management regime of grazing and/or cutting that is able to adjust to seasonal variation in rainfall is also important.

Removing or reducing pressures on wetlands, including groundwater abstraction, drainage and nutrient enrichment will continue to be critical. As well as dealing with licensed activities such as abstraction, this may involve the designation of larger areas to protect land around wetlands, and improved management of soil and water within catchments.

Restoring natural hydrological processes on and around wetland sites is likely to improve the resilience of features. This may not always be feasible or appropriate, for example on sites that have been created and sustained wholly by human intervention, but in many circumstances it should be seriously considered. In the first instance, this will require an understanding of how the site functions hydrologically, and any existing pressures and modifications to the wetland. For example, many fen sites retain artificial drainage networks which have been perpetuated for no reason other than 'it's always been there'. Consideration should be given to removing this drainage unless it is critical to a very high value feature or infrastructure/property.

Climate change is likely to alter the successional processes of wetland communities and active management is likely to be required to maintain the various stages in their current form, if that is the desired option.

National strategic documents such as the England Wetland Vision can be used to help identify priority areas for restoration and creation of fenland habitat, as part of sustainable drainage and flood defence systems.

Lowland fen communities will change under climate change and the extent to which change is accepted and managed will need careful consideration in each location, taking account of the particular circumstances.

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

- Determine and characterise all aspects of the water regime, reference ecological and hydrological state, existing state, pressures and threats, and the feasibility of restoration options, to ensure that any interventions are carried out with full knowledge of the site’s value and function.

- Ensure appropriate management through cutting or grazing combined with scrub management where required, to ensure that habitats do not develop into scrub or woodland.
- Ensure management is sufficiently flexible to provide appropriate management under a range of growing conditions. For example, ensure sufficient land is available to provide alternative grazing in years when fen is flooded.
- As far as possible, restore the natural function of floodplains. For example, consider restoring the connectivity of the floodplain, and filling in drained springs.
- Evaluate the existing drainage within and around fen sites as part of an eco-hydrological characterisation and identify which drains should be filled in or blocked and those which may be necessary to maintain water levels within the site. This will depend on landscape context and historical management.
- Remove sources of nutrient enrichment by increasing the area of extensively managed land around the wetland, and implementing good practice throughout site catchment.
- Increase the heterogeneity of habitats on larger sites by varying management regimes to produce a mosaic of habitat types, including open, unshaded areas free from scrub encroachment or trees, through to more wooded areas.
- Monitor and address potentially harmful invasive native and non-native species. This might include the use of surveillance to detect the arrival of species at an early stage (while they can still be eradicated) and the identification of potential sources of invasive species in the surrounding area.
- Identify and protect sites and areas within sites where the water quality and quantity is likely to be assured in the future. Long-term strategic planning will be required to determine the rate of loss of sites adjacent to the coast, and to identify appropriate locations and mechanisms for compensating for that loss through habitat creation and restoration inland. Ensure though that saltwater/freshwater transitions are allowed to develop naturally, as these are currently very rare and lacking from many coastal areas.
- Locations for the restoration or creation of fen habitats should be identified at the planning stage of flood management schemes within river floodplains.

13. Reedbeds

Extensive reedbeds, as an early successional natural habitat, have been lost from most natural wetland ecosystems. Consequently, the largest and most biodiverse reedbeds are now largely found in modified, intensively managed sites. In these situations, water management and vegetation management are necessary to maintain conditions for the persistence of reed dominated vegetation, which in a natural system, as peat accumulated, would generally succeed to different wetland habitats, or would be maintained by dynamic riverine/coastal processes. The maintenance of a high water table is likely to be the main adaptation challenge. Management of the reed itself will need to be flexible in terms of timing and extent to respond to annual variations in ground conditions.

Reedbed has suffered widespread loss due to drainage, agricultural improvement and abandonment over the last century, and the remaining areas are often small and fragmented. Measures to increase their size, restore more natural hydrological regimes, and connect them to other wetlands will play an important role in increasing the resilience of remaining sites.

In addition, significant habitat creation and restoration will be required to replace sites lost to saline intrusion at the coast. Opportunities will arise for the restoration and creation of reedbed as part of sustainable drainage systems and flood defence schemes, although the value of these for the core ‘reedbed’ species may be limited, depending on size and quality.

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

- Seek opportunities to allow development of reedbed in its natural position through the restoration of large naturally-functioning wetland complexes.
- Ensure appropriate management through cutting or grazing, combined with scrub management where required, to ensure that habitats do not develop into scrub or woodland.
- Ensure management is sufficiently flexible to provide appropriate management under a range of growing and ground conditions.
- Manage ditch networks to increase their capacity to store high flows and flood water, and to maintain water table height in periods of low flows.
- Increase the heterogeneity of habitats on larger sites through varying management regimes to produce a range of age classes and areas of dead thatch.
- Make best use of available water (and acquire new sources of suitable water where practical) to enable water tables to be maintained during the spring and summer.
- Identify and protect areas within sites where the security of water supply will be assured in the future.
- Where long-term water availability is unlikely to be maintained, revise the objectives for the site and determine the most effective management options to facilitate change. For example, manage the site through cutting to facilitate the transition into a lowland fen-type habitat, or allow and encourage scrub development and/or undertake planting to move the site towards wet woodland, depending on local priorities and conditions.
- Seek opportunities to replace or create reedbed when flood management schemes within river floodplains are being designed. Significant reedbed creation will be required to replace sites lost near the coast.

14. Upland flushes, fens and swamps

The small size of many sites, sitting within a matrix of other habitats, means that minimising adverse impacts from the management of adjacent habitats will often be the most important adaptation response.

The majority of the high quality examples of the habitat occur in sites of relatively high naturalness, and are part of extensive areas of natural and semi-natural habitats.

The fragmented and isolated nature of these habitats reduces the chances of species moving between habitat patches and increases the risk to small blocks of habitat. Restoration of habitat to increase size and connectivity is therefore a priority.

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

- Remove pressures and encourage restoration of natural hydrological function, eg by drain blocking and re-naturalisation of stream and river systems.
- Manage grazing levels and timing to reduce the risk of over grazing, eutrophication and severe poaching.
- Where scrub encroachment becomes a problem, ensure appropriate management to prevent a loss of ground flora.
- The isolated nature of flushes means that the translocation of species from other sites may be a viable adaptation option where natural colonisation is unlikely.

15. Purple moor grass and rush pastures

Purple moor grass and rush pasture requires active management through grazing or cutting, and ensuring the appropriate level of grazing in the face of changing environmental conditions and the changing economics of agricultural production is likely to remain an important adaptive response on many sites.

Removing or reducing pressures on wetlands, including ground water abstraction, drainage and nutrient enrichment, is important to ensure the habitat is in the best possible state to adapt to any climate change impacts. As well as dealing with licensed activities such as abstraction, this will be facilitated by the designation or sympathetic management of larger areas to protect land around wetlands, and improved management of soil and water within catchments. Due the susceptibility of the habitat to changes in water levels, actions to ensure an adequate supply of water to sites will also be important.

In many areas, the remaining areas of purple moor grass and rush pasture sites are highly fragmented, and actions to increase ecological connectivity of remaining patches, by increasing their size and creating new habitat, will be needed to increase resilience.

Purple moor grass and rush pasture communities will alter under climate change, and the extent to which change is accepted and managed will need careful consideration in each location, taking account of the particular circumstances. Where loss of the habitat is anticipated as a result of increased summer flooding, for instance, encouraging the development of the habitat to reflect the new conditions (in the same wetland landscape if possible) should be factored into long-term planning.

There are various existing initiatives to improve the availability of water and water quality, including the Water Framework Directive (WFD) and the Environment Agency's Restoring Sustainable Abstraction programme. It is critical that any risks from climate change are considered in the context of these, and that actions to improve resilience, as well as current status, are identified and included in relevant programmes and plans, in particular, the WFD River Basin Management Plans, which are updated at five year intervals, and the Water Companies Asset Management Programme (AMP), associated with the five yearly price review.

The requirement for a flexible management regime of grazing and/or cutting that is able to adjust to seasonal variation in rainfall is also important.

Climate change interactions with nutrient enrichment from atmospheric deposition may accelerate negative change. Efforts to reduce nutrient enrichment from this source will continue to be necessary to maintain or restore favourable condition. Restoring natural hydrological processes on and around wetland sites is likely to improve the resilience of features. This may not always be appropriate, eg on sites that have been created and sustained wholly by human intervention, but in most circumstances it should be seriously considered. This, in the first instance, will involve being very clear about site function, existing pressures, and anthropogenic modifications to the wetland. For example, many sites retain artificial drainage networks which have been perpetuated for no reason other than because they have 'always been there'. Consideration should be given to removing these drainage functions unless they are critical to protecting very high value features, infrastructure or property.

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

- Establish an ecohydrological characterisation for the site that considers all aspects of the water regime, reference hydrological state, existing state, pressures and threats, and the feasibility of restoration options, to ensure that any interventions are carried out with full knowledge of the value and function of the site.
- Ensure appropriate management through extensive grazing combined, where required, with scrub management or cutting to ensure that habitats do not develop into rank grassland, scrub or woodland, or conversely, are over-grazed.
- Ensure management is sufficiently flexible to provide appropriate management under a range of growing conditions, for example by making sure alternative land is available for grazing in years when the land is flooded.
- Expand the resource through the restoration of semi-improved pasture and re-creation on improved grassland/arable land. Target this to ensure expansion and linkage of existing sites.

- Increase the heterogeneity of habitats on larger sites by varying the timing and range of management regimes to produce a range of vegetation structures and, where possible, a mosaic of habitat types.
- Locations for the restoration or creation of purple moor grass and rush pasture habitats should be identified at the planning stage of flood management schemes within river floodplains.

16. Blanket bog

A large proportion of blanket bogs are already degraded as a result of draining, burning (managed burning and wildfire), over grazing and atmospheric pollution. Many blanket bogs are now relatively dry and may already have lost the peat forming species such as Sphagnum mosses, which may have been replaced by other species such as heather and moor grass. In these cases, active restoration, including by grip-blocking and re-vegetation of bare peat, will be the most important adaptation measure. This is especially important as the resilience of bogs to environmental change has been shown to increase if Sphagnum cover can be maintained (Gallego- Sala & Prentice 2012).

Bogs are dependent on a reliable high water table, and in the longer term, as climate change progresses, actions that improve both the quantity and quality of water held on sites will become increasingly important.

The restoration of blanket bogs has multiple benefits. It increases the resilience of the habitat to climate change and improves the delivery of other ecosystem services such as carbon sequestration and drinking water provision. These systems therefore represent an ideal opportunity to involve stakeholders in planning work at a catchment scale.

In the longer term, it may become increasingly difficult to maintain active blanket bog in more climatically marginal areas. Habitat restoration and appropriate management to increase resilience remain a priority for designated sites, but may need to be reviewed in future.

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

- Adapt land management regimes, for example by avoiding burning and ensuring appropriate livestock and stocking regimes, to prevent further habitat degradation and encourage the restoration of ‘active’ blanket bog with peat forming processes.
- Re-vegetate areas of bare peat, using best practice restoration techniques and appropriate plant species mixes. Initially, this should help to prevent or reduce further peat loss, but in the longer term will help to restore ‘active’ blanket bog.
- Restore natural hydrological regimes through drain and gully blocking and re-profiling, using best practice techniques.
- In regions where climate change may have an especially marked effect on blanket bog processes, such as parts of the Peak District and the North York Moors, identify

areas likely to retain the hydrological regime required for bog development and ensure these are protected and are under optimal management.
- Identify areas where the hydrological regime is currently, or in the future may be, sufficiently impaired to prevent bog development, and determine the most appropriate alternative objectives. This might involve retaining a high water table for as long as possible to maintain ecosystem services such as carbon storage and water management.

17. Lowland raised bog

A large proportion of lowland raised bogs are degraded as a result of cutting, drainage, over grazing and atmospheric pollution. In all cases, this results in bogs ceasing to function as rain-fed systems, increasing their vulnerability to changes in ground water quantity and quality. In these cases, active restoration of the hydrology to reduce the reliance on ground water, through actions to improve the water retention of the site, will improve the resilience to both climatic and non-climatic drivers. Restoration activity is nearly always constrained by ingress of other land use. A fully functioning raised bog will need restoration out to the edge of the peat body or the installation of an appropriate hydrological barrier.

Bogs are dependent on a reliable high water table, and in the longer term, as climate change progresses, actions that increase the water table and water retention on sites will become increasingly important. The restoration of lowland raised bogs has multiple benefits. It increases the resilience of the habitat to climate change and improves the delivery of other ecosystem services, such as carbon sequestration and flood risk management.

In the longer term, it may become increasingly difficult to maintain active blanket bog in more climatically marginal areas in the south and east. However, habitat restoration and appropriate management to improve resilience should remain a priority, but should be kept under review.

Potential actions

- Cease peat cutting and ensure optimum management is in place to eliminate damage to bog surfaces by machinery or other means. Over-grazing by livestock can lead to poaching, compaction, surface contamination, and loss of grazing-sensitive plants. At the other extreme, a lack of grazing, coupled with drier conditions, on raised bogs usually favours widespread expansion of bracken, tall heather, birch and pine.
- Develop a full understanding of the hydrology and define the functional boundaries of the site.
- Restore natural hydrological regimes and high water tables through blocking or re-profiling drains to encourage the growth of *Sphagnum*. Where the surface is either

complex or very open and featureless, eg after peat milling, water may need to be penned, for example through extended pile or peat bunds.

- Where sites may have dried out and been colonised or planted with trees, remove up to 95% of native trees, and all invasive non-native species. After extraction, keep water levels raised to reduce re-colonisation, as evapotranspiration from trees and scrub will exacerbate drying effects.
- Review the hydrology of land surrounding the site to identify off-site drainage impacts, and also consider pressures such as abstraction, pollution and nutrient enrichment. Take action to reduce adverse impacts, for example through the creation of wetland to buffer the core area, or by diverting drains.
- Following restoration of the hydrology, re-vegetate areas of bare peat using best practice restoration techniques and appropriate plant species mixes. Initially, this should help to prevent or reduce further peat loss, but in the longer term will help to restore active peat formation.
- Identify areas where the hydrological regime is currently, or in the future may be, sufficiently impaired to prevent bog development, and determine the most appropriate alternative objectives. This might involve retaining a high water table for as long as possible to maintain ecosystem services such as carbon storage and water management.
- Use or develop a full understanding of the hydrology and extent of peat to determine whether the area of lowland raised bog could be expanded through habitat restoration or creation.

18. Lowland heathland

Heathland is threatened by many pressures that are not related to climate change, such as habitat loss and an associated increase in fragmentation and isolation, heavy access and recreation pressure, and lack of appropriate management. Increasing the resilience of the remaining areas of heathland by reducing these pressures is likely to be a key adaptive response in many cases. Tree cover in the right places can provide wildlife benefits and reduce fire risk as broadleaved species are less flammable than heathland vegetation. This needs to be balanced against the loss of heathland species, and tree cover should be kept below 15% to maintain favourable condition.

Different aspects of climate change will interact and have different impacts on the various components of heathland systems. Management of existing sites will need to be flexible, and be adjusted to reflect these changes.

In addition to actions on existing areas of heathland, adaptation will also benefit from targeted habitat restoration and creation to address historic habitat loss and to improve the resilience of heathland networks.

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

- Ensure optimal management through a combination of grazing and/or cutting to achieve a diverse vegetation structure.
- Adapt the intensity of management to changing growth characteristics of the heathland, for example by increasing grazing pressure or cutting cycles. More intensive management may be required to maintain condition.
- Ensure fire contingency plans are in place. These may include changes in the design and management of habitats to reduce fire risk, such as firebreaks, fire ponds and the closure of some areas at times of high fire risk.
- Ensure sufficient management capacity to be able to respond flexibly to changing conditions, such as a reduced window for winter management, and wetter conditions preventing winter operations.
- Consider maintaining broadleaved (not conifer) woodland in localised areas to provide a firebreak or a buffer next to urban areas.
- Within sites, identify areas that might act as potential refugia to climate change, such as areas with north facing slopes, complex micro-topography, robust hydrology and high species diversity, and ensure that these are under optimal management.
- Maintain structural diversity in the vegetation to provide a wide range of micro habitats and niches, including, where possible, bare ground, areas dominated by mosses and lichens, herbs, dwarf shrubs of diverse age classes, wet heath and mire, and scattered trees and shrubs.
- Ensure hydrological conditions are fully conserved, for example through blocking artificial drainage and reducing abstraction pressure.
- Increase the area of existing habitat and reduce the effects of fragmentation through targeted re-creation and restoration around existing patches, to increase the core area and reduce edge effects.

19. Upland heathland

Different aspects of climate change will interact and have different impacts on the various components of heathland systems. Management of existing sites will need to be flexible, and be adjusted to reflect these changes.

Heathland is threatened by many pressures that are not related to climate change, such as habitat loss and an associated increase in fragmentation and isolation, heavy access and recreation pressure, over grazing, and inappropriate or lack of management. Increasing the resilience of upland heath by reducing these pressures is likely to be a key adaptive response in many cases.

In addition to actions on existing areas of heathland, adaptation will also require targeted habitat restoration and creation to address historic habitat loss and to improve the resilience of heathland networks.

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

- Develop fire contingency plans across the whole upland habitat mosaic and ensure that the design and management of habitats reduces fire risk, such as by introducing firebreaks and fire ponds, and restricting access to some areas at times of high fire risk. Rewetting drier, degraded blanket bog and reducing heather cover will also help to reduce fire risk.
- Minimise erosion through the management of access and grazing .
- Consider allowing an increase in scrub and woodland cover within the upland mosaic to improve habitat heterogeneity, in order to provide potential refugia for sensitive plants and invertebrates.
- Within upland sites, identify areas that might act as potential refugia to climate change, such as areas with complex micro-topography, robust hydrology, and high species diversity, and ensure that these are managed accordingly.
- Maintain structural diversity within the vegetation to provide a wide range of micro habitats and niches, including, where possible, bare ground, areas dominated by mosses and lichens, low herbs, dwarf shrubs of diverse age classes, wet heath and mire, and scattered trees and shrubs.
- Consider the need to adjust designated site boundaries as habitats change (eg to create larger functional sites) and review the interest features for which the site is managed.
- Upland heath grades into various other habitat types along climatic gradients, particularly lowland heath with higher temperature, montane heath with lower temperature, and blanket bog in wetter conditions. Conservation objectives need to reflect these gradients, and build in an acceptance that there will change under a changing climate, and that the location for action to conserve particular species is likely to change.

20. Lowland dry acid grassland

The direct impacts of climate change may be less important than changes in land management, including the ongoing impacts of fragmentation and agricultural intensification, and the impact of atmospheric nitrogen deposition. Adaptation is therefore likely to focus on increasing the resilience of grassland by ensuring that other sources of harm are minimised. However, an adaptive approach is needed to deal with issues like changing seasonal patterns in growth and flowering.

Expanding the area of the habitat through targeted habitat restoration and creation will also be a key adaptive response, with the priority given to measures to increase the size, heterogeneity and connectivity of existing patches.

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

- Ensure best practice management of existing stands by maintaining suitable grazing regimes and avoiding over or under-grazing, or agrochemical and fertilizer inputs.
- Ensure remaining sites are protected and buffered from agricultural intensification.

- Increase the flexibility in site management to respond to the increased variance in seasonal growing conditions. For example, increase the capacity for changing the timing and intensity of grazing through the use of layback land or housing for animals when ground conditions prevent on-site grazing.
- Adjust grazing dates to align with longer term climate driven changes to flowering dates.
- Increase the area of dry acid grassland by restoring semi-improved grasslands and re-creating habitat on improved grassland and arable land to ensure the expansion and buffering of existing sites and improve the coherence of existing networks. Consideration should be given to increasing topographic and hydrological heterogeneity when identifying potential sites.
- Within sites, identify areas that might act as potential refugia from climate change, such as areas with north facing slopes, complex micro-topography, low nitrogen levels and high species diversity, and ensure that these are under optimal management.
- Permit the growth of scattered scrub, especially on drought prone sites, as this can provide a wider range of microclimates and soil conditions.
- Monitor and control the spread of potential native and non-native invasive species.
- Some changes in species complements on sites may be inevitable or even desirable (for example, an otherwise threatened species colonising a new site). Site objectives and management should be flexible enough to recognise this.

21. Lowland calcareous grassland

Lowland calcareous grassland has been shown to be relatively robust to the direct threats posed by climate change, at least in the short term, with other non-climate change drivers such as fragmentation, under or over-grazing and nutrient enrichment from atmospheric nitrogen deposition representing greater threats. In the medium term, climate change could alter the economics of grazing in relation to other land use. This may lead to a decline in the availability of grazing, an intensification of grazing systems, or pressure to convert land to arable production.

Adaptation should therefore focus on ensuring other sources of harm are reduced, to increase resilience. Priority should be given to measures to increase the size, heterogeneity and connectivity of existing patches of calcareous grassland, and these changes should be factored into long-term site management objectives.

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

- Ensure best practice management of existing stands through suitable grazing regimes (avoiding over or under grazing), and avoiding agrochemical and fertiliser inputs.
- Increase the area of existing habitat through targeted re-creation and restoration effort around existing patches. Consideration should be given to increasing topographic, soil and hydrological heterogeneity when identifying potential sites.

- Manage the grazing of sites flexibly in response to seasonal variations in vegetation growth.
- Accept changes to community composition where we can be sure that these are driven by climate change. For example, allow the transition from upright brome *Bromposis erecta* to heath false brome *Brachypodium pinnatum* on sites where this species appears to be increasing due to climatic factors. In northern calcareous grasslands, where *B. erecta* and *B. pinnatum* are absent or at very low frequency, consider early intervention to help prevent further ingress and potential dominance of these competitive grasses.
- A certain level of scrub can be beneficial, especially on sites that are prone to heat stress or drought, due to its shading effect potentially providing micro-refugia for a suite of invertebrates.
- Within sites, identify areas that might act as potential refugia from climate change, such as areas with north facing slopes, complex micro-topography, low nitrogen levels, and high species diversity, and ensure that these are under optimal management.

22. Lowland meadow

Lowland meadows are actively managed through grazing, cutting or a combination of the two. Increased flexibility in both the date and intensity of these management options in response to both long term changes and seasonal variability in growing conditions will become increasingly important for maintaining the biodiversity interest of these habitats.

For wet grasslands, ensuring an adequate supply, temporal variation and quality of water is a key adaptation objective. In the short term, this is likely to take the form of restoring and maintaining ditch networks, but over the longer term will require planning at the catchment level to restore the capacity of catchments to hold, retain and maintain flows under both wet and dry conditions.

Successful adaptation will require both site–based and catchment scale solutions to be considered. Some of the potential adaptation options for this habitat are outlined below.

- Increase the flexibility of site management to respond to the increased variation in seasonal growing conditions. For example, vary the timing of the hay cut or the timing, duration and extent of aftermath grazing.
- Move cutting and grazing dates to align with climate driven changes to flowering dates.
- At the site level, take action to maintain or restore water level management, including actions to increase the water holding capacity of sites such as restoring ditch networks and reviewing the use of water management structures.
- Monitor and ensure the control of potential invasive species. Actions could include introducing biosecurity measures to minimise colonisation by invasive non-native species and increasing surveillance to identify the presence of any invasive non-native species before they become too widespread.

- Expand the area of lowland meadows by restoring semi-improved grasslands and re-creating lowland meadows on improved grassland and arable land. Where possible, action should be targeted at expanding and linking existing sites.
- Increase the structural heterogeneity of meadows in larger sites through varying the type and timing of management interventions.

23. Coastal floodplain and grazing marsh

Coastal grazing marsh is a habitat created by drainage and the creation of flood defences, as it occupies former intertidal zones. On-site adaptation of these coastal sites is therefore likely to involve the active management of flood defence and drainage systems, combined with off-site planning, including managed realignment, that will need to take into account the full suite of coastal habitats. Actions to promote adaptation should be integrated with the existing shoreline management planning process.

For inland floodplain grazing marsh, actions that ensure the continued supply of water and control over water levels are likely to be the primary objectives of adaptation.

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

- Take action to ensure non-climatic sources of harm are reduced, such as reducing the risk of pollution, minimising the adverse impacts of drainage and abstraction, and managing visitor numbers.
- Plan and take action to achieve desirable water levels on site. This might include measures to reduce water loss, providing additional storage for water abstracted from rivers in winter when flows are high, securing additional supplies of water, and increasing the ability to move water around on site.
- Minimise over and under-grazing through flexible management, for example by adjusting stocking density and the timing of grazing regimes in response to seasonal variations in growing conditions. This may require an increase in layback land – land use to graze livestock when they are not on the marsh.
- Expand the area of grazing marsh by re-introducing appropriate water level management on improved grassland and arable land. This should be targeted to ensure the expansion and linkage of existing sites and to promote functioning coastal floodplains (ie those that permit natural flooding regimes).
- Increase the structural heterogeneity of grazing marsh on larger sites by varying the type and timing of management interventions, including allowing areas of bare ground and isolated scrub.
- Monitor and ensure the control of potential invasive non-native species through effective biosecurity measures. Identify potential sources of invasive species in the surrounding area, and undertake active surveillance to detect the arrival of potentially invasive species at an early stage, while they can still be eradicated.
- Anticipate and develop approaches to managing the landward movement of grazing marshes by identifying potential sites for habitat creation.

- Ensure that managed realignment for flood defence or the conservation of intertidal habitat such as mud flats and salt marsh do not compromise the area or quality of coastal and fluvial grazing marsh.
- Adjust designated site boundaries and interest features as coasts evolve, with the aim of creating larger functional units.

24. Upland hay meadow

Adaptation is likely to focus on increasing the resilience of grassland by minimising other sources of harm. Management of sites will need to be flexible, and adjusted to reflect changing conditions and community composition.

Important components of upland hay meadows will inevitably lose climate space, so identifying and protecting potential climate change refugia will be important. Local climatic variations can be large in upland areas and vulnerabilities of sites may vary considerably within the same geographic area. Targeted habitat creation and restoration will also be important to ensuring the resilience of upland ecological networks.

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

- Adopt greater flexibility in the management of sites in response to increasing fluctuations in seasonal growing conditions. For example, recent evidence suggests that the impacts of grazing later into spring are more pronounced in warm (advanced) springs as plants are repeatedly arrested in their development through continual defoliation. While perennial species, including grasses, may tolerate periods of prolonged grazing into the growing season, annuals such as hay rattle *Rhinanthus minor* can suffer from high losses of germinating seedlings (Smith et al 2012). Over a number of years extending grazing into May resulted in reduced species diversity and a shift towards a more semi-improved grassland sward. Adaptive management may include varying the timing of the hay cut, bringing forward the date when grazing is stopped in order to grow hay, or changing the timing, duration and extent of aftermath grazing.
- Identify areas that might act as potential refugia to climate change, particularly areas with relatively cool and damp local climates, and ensure that these are properly protected and managed.
- Where possible, expand the area of upland hay meadows by restoring semi-improved grasslands and re-creating hay meadows on improved grassland and arable land. This should be targeted to ensure expansion and linkage of existing sites.
- Increase the structural heterogeneity of meadows in larger sites by varying the type and timing of management interventions.

25. Upland acid grassland

Changing phenology and a potentially greater seasonal variation in rainfall means that flexibility in moving stock and stocking density is likely to become more important to ensure good grassland management. This is true both for good agricultural practice and to maintain conservation interests, for example to maintain vegetation structure that supports animal populations.

Some changes in the composition of plant communities may well be inevitable, but are not likely to threaten conservation objectives as the habitat type supports few threatened plant species. They will however need to be recognised when management objectives are being set.

Ongoing efforts to restore the network of upland sites remain valuable. Increasing emphasis may be placed on improving the heterogeneity of sites within the network, and on including areas likely to be buffered from the impacts of climate change.

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

- Increase the flexibility in site management to respond to the increasing variance in seasonal growing conditions, particularly in the timing or duration of grazing.
- Identify areas that are likely to be buffered from the impacts of climate change and have the potential to be refugia, for example north facing slopes and areas with access to permanent sources of water, and ensure these areas are fully protected.
- Increase the structural heterogeneity of larger sites through varying the type and timing of management interventions.
- Build in changing community composition to designation criteria and site evaluation.
- Acid grassland occurs naturally as part of the mosaic of habitats found above the moorland wall, but grazing practices of the past 40 years in particular have seen the area of this habitat increase following the removal of heather by over-grazing. In some areas, the restoration of heather may be desirable for landscape or grouse management purposes. Where this is the case, the initial action will be to review the timing and extent of grazing. In some instances, further intervention will be required.
- An alternative to the restoration of heather on acid grassland sites would be to introduce or increase the area of trees, scrub and woodland. Gills and edges of water courses are the obvious places to commence this type of restoration, which could also be carried out in tandem with heather restoration. Proposals for increasing tree cover away from gills should include an assessment of likely impact upon other nature conservation interest, especially birds or habitats of international importance.

26. Montane habitats

The distribution and condition of many montane communities has been heavily influenced by over-grazing, trampling, Victorian plant collecting, and nitrogen-deposition. Reducing these pressures and allowing the habitat to recover may help to reduce their vulnerability to climate change, though there is a possibility that upland generalist species will grow more and out compete the rarities, leading to the development of acid grassland and upland heath.

Most of the arctic alpine flora is limited by competition, rather than an inability to tolerate higher temperatures, and it may be possible to exploit this. In cases of extreme rarity, direct, targeted management to remove or limit the growth of more competitive species is worth considering. It may also be possible to adjust grazing to ensure that sward height does not become too high and prevent scrub encroachment, although this is difficult in an extensively managed system.

Some species will suffer declines due to climate change (eg alpine saxifrage *Saxifraga nivalis*), but for others (eg purple saxifrage *Saxifraga oppositifolia* and mossy saxifrage *Saxifraga bryoides*), where non-climatic factors are more important, appropriate management can limit any decline. Monitoring and research is required to identify changes in community composition, species distribution and abundance and to determine the causes of any future change.

Microclimate variability can be very large in mountain areas, with large differences in temperature between north and south facing slopes, as well as with altitude. Cold air drainage can also create temperature inversions with lower than expected temperatures in localised pockets. Recognising such small scale refugia, ensuring their protection and prioritising the reduction of other pressures in these areas, may be the most effective element of adaptation in a local area.

While at the present time it would be premature to simply accept the loss of a species vulnerable to climate change in these habitats, it is important to take a view on the status of the species and communities across their whole range. This will allow decisions to be made that prioritise action where the need is greatest and the chances of success are highest.

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

- Ensure appropriate management through the control of grazing. Many of these habitats would naturally be controlled by climate and not grazing management, so shepherding and (where appropriate) fencing can be used to exclude livestock from sensitive areas. Changing climate may change the optimum stocking density required to maintain montane community composition (for example, grass growth will increase with longer growing seasons and higher temperatures), so flexibility is needed.

- Develop fire contingency plans across the whole upland habitat mosaic, to include adapting the design and management of habitats to reduce fire risk, and closing some areas at times of high risk.
- Minimise erosion through the management of access and grazing.
- Within individual upland units or sites, identify areas that might act as potential refugia from the impacts of climate change, such as areas with north facing slopes, complex micro-topography, robust hydrology, or high species diversity, and ensure that these are managed appropriately.
- Maintain the full diversity of montane habitats to provide a wide range of micro habitats and niches, including, where possible, bare rock and areas characterised by mosses and lichens, low herbs, dwarf shrubs of diverse age classes, wet heath and mire, and scattered trees and shrubs.
- Take the whole of the species range into account in deciding the priority attached to intensive conservation measures in a particular location.
- Translocation to establish new populations of species in climatically suitable locations which are likely to remain so in future might be considered. Although this would require a detailed study and would be dealt with on a case by case basis.
- When developing management plans, consider the wider mosaic of upland habitats and not just montane habitats in isolation.

27. Coastal sand dunes

Sand dunes are a component of dynamic coastal systems, and much of the emphasis on adaptation at the coast has been to maintain the natural coastal processes where possible; including through managed realignment. Under this approach, sand dunes will be lost in some places but develop in others. In the long-term this is likely to be the most important response. However, some on-site actions to increase the resilience and diversity of dune systems are also possible.

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 are reduced.
- Manage recreational use to prevent excessive pressure on vegetation, by rotational exclusion of people, especially from fore-dunes and fixed dunes, and by retaining vegetation that can trap sand.
- Minimise large-scale surface sand erosion on fixed dunes through flexible management For example by adjusting stocking density and the timing of grazing in response to seasonal variation in growing conditions, while maintaining a proportion of bare sand.
- Manage dunes to maintain the full range of successional stages, avoiding a build-up of organic soil layers and the development of coarse grassland and scrub.
- Where possible ensure hydrological conditions are fully conserved to offset potential reductions in rainfall. Reduce abstraction pressures and ensure maximum

recharge of dune water tables by reducing the impacts of scrub, trees and coarse grassland.

- Develop management plans that respond to predicted changes across the whole coast and not individual sites in isolation.
- Anticipate and develop approaches to managing the landward movement of dune systems, which will require consideration of the impacts on adjacent agricultural land.
- Adopt a strategic approach to coastal planning and develop an understanding of the sediment budget, to ensure there is adequate space for dune systems to migrate, and that there is a continued supply of sediment.
- Adjust designated site boundaries and interest features as coasts evolve, with the aim of enlarging functional units.
- Plan for the relocation of human assets in flood or erosion risk areas. The future of dune golf courses will need to be specifically addressed.

28. Coastal saltmarsh

Although saltmarshes are sensitive to climate change, provided they have sufficient sediment supply and adaptation space they have considerable ability to adapt to changes in sea level. Being a component of dynamic coastal systems, adaptation is likely to focus on maintaining the natural coastal processes that provide the sediment to support saltmarsh. Ensuring that sufficient space is available for saltmarsh to develop naturally and migrate inland, and identifying sites for managed realignment to compensate for habitat lost will be key. It may also include the restoration of the coastal flood plain by removing or breaching artificial structures.

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

- Act to eliminate or reduce non-climate change associated erosion. For example that caused by altered drainage flows, contamination, removal of sediment by dredging, or wash from shipping.
- Manage recreational pressure to minimise erosion and damage to saltmarsh vegetation. Consider using sediment re-charge to reduce the rate of erosion of vulnerable areas of saltmarsh, where longshore drift of sediment has been disrupted by human activity (French & Burningham 2009).
- Minimise surface erosion through flexible management. For example, where grazing is appropriate to the site, adjust stocking density and the timing of grazing regimes in response to seasonal variations in growing conditions, and ensure that overgrazing does not reduce the potential for accreting sediment (taller vegetation tends to trap more sediment, Andresen et al 1990).
- Ensure that adaptation through the use of hard defences does not adversely affect coastal dynamics and increase the threat of coastal squeeze.
- Develop and implement management plans that respond to predicted changes along the whole coast, not individual sites in isolation.

- Anticipate and develop approaches to managing the landward movement of marshes by identifying and protecting priority sites for realignment projects.
- Ensure adequate space and promote policies that allow a continued supply of sediment (eg from eroding cliffs) for replenishing saltmarsh, through strategic coastal planning.
- Adjust the boundaries and interest features of protected sites as coasts evolve, and aim to enlarge functional units.

29. Saline Lagoons

Although coastal lagoons are highly sensitive to the impacts of climate change, naturally formed lagoons are ephemeral habitats that at least, in theory, have considerable ability to adapt provided there is space for adaptation with minimal human interference. However, saline lagoons do not exist in isolation but are part of the wider coastal system, which consists of a series of interconnected habitats including saltmarsh, coastal grazing marsh and estuaries, as well as smaller features such as shingle bars. In England, these dynamic habitat complexes have rarely escaped human influences, and coastal processes seldom operate in their fully natural state. The complex and dynamic processes between different coastal habitats also remain poorly understood (Mossman et al 2015).

Although there is a need for greater understanding about how coasts in England function in their entirety and the degree of naturalness that still remains within them (Beer and Joyce 2013), it is clear that adaptation responses for interconnected coastal habitats should consider the coast as a whole. It needs to be recognised that gains for some coastal habitats may mean the loss of others, but that there is also potential for the creation of new habitats to offset habitats that have been lost.

Three potential courses of action have been suggested as adaptation responses to climate change for coastal lagoons (Angus 2016):

1. Non-intervention, ie allowing processes to operate naturally. This option may mean that individual lagoons are formed, lost or relocated, or new and different coastal habitats are formed.
2. Manage the impacts of sea level rise by raising the height of the isolating barrier (if feasible and appropriate).
3. Translocation of vulnerable species to analogue sites. The success of this method is yet to be proven.

While option 1 is generally favoured, there is a risk that this could result in the local extinction of vulnerable lagoon species. Further research and monitoring is required for options 2 and 3 (Angus 2016).

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

- Act to eliminate or reduce non-climate change associated pressures on coastal lagoons, including erosion caused by altered drainage flows or removal of sediment, eutrophication, heavy metal and synthetic contaminant exposure, marine litter and recreational pressures.
- Restore or maintain habitat so that it is in the best possible condition and better able to withstand external pressures caused by climate change.
- Anticipate future changes and develop approaches to managing the land adjacent to the lagoon, including identifying and protecting landward habitat for the lagoon to retreat to naturally as sea level rises.
- Adjust the boundaries and interest features of protected sites as coasts evolve, and aim to enlarge functional units.
- Sediment recharge may be considered on vulnerable areas, for example where the isolating barrier of a lagoon is a shingle ridge. However, the impact of sediment recharge on other coastal habitats needs to be carefully considered before proceeding with this option.
- Develop and implement management plans that respond to predicted changes along the whole coast and not in individual sites in isolation. As a part of a wider coastal management scheme, a lagoon may need to be allowed to move naturally or even to be lost entirely and recreated elsewhere if appropriate.

30. Maritime cliffs and slopes

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.

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.

31. Coastal vegetated shingle

Coastal shingle environments generally require limited management for nature conservation, particularly near the sea. Adaptation should focus on measures that work with the ongoing changes in morphology of the coastal system. Management plans should be developed with understanding of the likely changes. Information about this may be available through a range of sources, including Shoreline Management Plans (SMP). Habitats behind shingle systems may be affected by future change, and plans should consider any habitat replacement needed in advance.

Where there are no existing erosion control measures these should not be introduced. Neither is it desirable for shingle beaches to be re-worked artificially after storm events. The SMP policy will influence decisions on the maintenance or removal of any existing flood risk management measures, but generally conservation sites should work towards a non-intervention policy. Avoid installing any infrastructure or ensure it can be easily adapted and its condition 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. Generic guidance for considering adaptation of flood risk management infrastructure is provided in the LWEC report card (Sayers and Dawson 2014) .

Visitor pressure should be managed to ensure existing sensitive areas of habitat are avoided, in order to maintain quality and promote natural recolonisation of vegetation.

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 on vegetated shingle areas (such as gravel extraction, coastal defence works, building construction, military use, agriculture, forestry and recreational pressures) are reduced.
- Develop management plans that take account of predicted changes within and beyond the site.
- Consider how activities on adjacent holdings may influence the capacity of the site to adapt, and ensure impacts are minimised. Use an understanding of shingle coastal processes to predict likely changes at a site level and adjust management accordingly. Avoid trying to maintain the current orientation of the beach ridge by artificial methods.
- Assess whether there is adequate space for shingle systems to migrate, and ensure sediment supplies into the site are not compromised.
- Adjust designated site boundaries and interest features as coasts evolve, with the aim of enlarging functional units.
- Together with owners, plan for the relocation of buildings or infrastructure within the site and behind or on shingle systems (as has been done for parts of the MOD ranges at Dungeness).
- Promote better management of shingle systems for flood risk management: avoid frequent artificial re-profiling and move towards wider beaches. This may need careful consideration where assets are present, but there are some good examples of adaptive management, including those contained in the IPENS Coastal Management Theme Plan (Natural England 2015).
- Plan for managing a potential increase in visitors, within a wider access strategy, for example by introducing zoning, better information, and wardening of rare species and breeding birds.
- Monitor the spread of potentially invasive species and plan for introducing control measures where necessary.

Alterations from Adaptation Manual

Deletions

Wetland

This will remain a challenge due to the low financial returns that management of these habitats provide.

Changed payment rate for relevant AES options means that this no longer applies

Purple moor grass and rush pastures

This will remain a challenge due to the low financial returns that management of these habitats provide.

Changed payment rate for relevant AES options means that this no longer applies

Lowland fens and reedbeds

This will remain a challenge due to the low financial returns that management of these habitats provide.

Changed payment rate for relevant AES options means that this no longer applies

Lowland peat

This will remain a challenge due to the low financial returns that management of these habitats provide.

Changed payment rate for relevant AES options means that this no longer applies

Edits

Lowland Heath

Ensure optimal management through a combination of grazing, cutting ~~and/or burning~~ to achieve a diverse vegetation structure.

Adapt the intensity of management to changing growth characteristics of the heathland, for example by increasing grazing pressure and ~~or burning~~/cutting cycles.

Reference to burning as a management tool has been removed due to the highly limited nature of when burning would be an appropriate management intervention

Upland Heath

Minimise erosion through the management of access, grazing ~~and burning~~.

Reference to burning as a management tool has been removed due to the highly limited nature of when burning would be an appropriate management intervention

References

Full reference list provided in

Natural England and RSPB, 2019. Climate Change Adaptation Manual - Evidence to support nature conservation in a changing climate, 2nd Edition. Natural England, York, UK. https://publications.naturalengland.org.uk/publication/5679197848862720