Character Area Climate Change Project NE115R

Responding to the impacts of climate change on the natural environment: The Cumbria High Fells

First published 31 March 2009

www.naturalengland.org.uk

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The Cumbria High Fells

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Keywords - Climate Change, Character Areas, biodiversity, landscape

Further information
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Summary

Introduction

Natural England is working to deliver a natural environment that is healthy, enjoyed by people and used in a sustainable manner. However, the natural environment is changing as a consequence of human activities, and one of the major challenges ahead is climate change.

Even the most optimistic predictions show us locked into at least 50 years of unstable climate. Changes in temperature, rainfall, sea levels, and the magnitude and frequency of extreme weather events will have a direct impact on the natural environment. Indirect impacts will also arise as society adapts to climate change. These impacts may create both opportunities and threats to the natural environment.

Natural England and its partners need to plan ahead to secure the future of the natural environment. One way in which we are doing this is through the Character Area Climate Change Project. The project aims to identify the local responses required to safeguard the natural environment and our enjoyment of it. In the pilot phase we are focussing on four of the 159 'Character Areas' in England, one of which is the Cumbria High Fells. The others are the Shropshire Hills, the Broads, and Dorset Downs and Cranbourne Chase.

This report provides the detailed findings from the pilot project. The summary leaflet is also available on our website at www.naturalengland.org.uk. It:

- identifies significant biodiversity, landscape, recreational and historic environment assets;
- assesses the potential risks climate change poses to these assets; and
- suggests practical actions that would make them more resilient to the impacts of climate change.

What we learn from the four pilot projects will be used to extend the approach across England as part of our aim to build a healthy and resilient natural environment for the future. Although the project is primarily concerned with the natural environment, it has also considered the impacts of climate change on other areas of Natural England's remit, including access and recreation, landscape, and the historic environment.

About the project

The objective of the Character Area Climate Change Project is to ensure that when decisions on the future of places like the Cumbria High Fells are made, proper account is taken of impacts on the natural world, as well as on communities and their livelihoods. It is not Natural England's role, or intention, to take such decisions, but to initiate debate on the impacts of climate change on the natural world, so that well informed decisions about its future can be taken.

Communities and their livelihoods are vital considerations in the development of any future strategy to respond to climate change. This report does not attempt to cover these issues, not because they are unimportant, but because our role is primarily in relation to the natural environment.

Ensuring a strong, healthy, diverse and inclusive society that lives within environmental limits is the key objective of sustainable development. Natural England seeks to contribute to this through its management of the natural environment. We recognise that environmental and social solutions need to proceed in tandem. Informed by this project, we will engage with communities, other organisations and Government to find approaches that deliver successful and long-term adaptation to climate change.

Taking action to respond to climate change will also depend on the cooperation of those who own and manage the land. We do not take that cooperation for granted and are aware that many measures would require appropriate incentives. At this stage we do not intend to pursue the mechanisms of change, but to explore with others potential responses which are feasible and acceptable in principle.

Significant natural assets

The Cumbria High Fells Character Area is the most mountainous landscape in England, containing its five highest summits and deepest lakes within a diverse landscape of varied geology. The rocks have been sculpted and shaped by the last glaciations into a landscape of U-shaped valleys, steep-sided mountains, corries and tarns. There are significant areas of semi-natural vegetation, especially above the fell wall, which support extensive sheep grazing. Improved pasture in the valley bottoms allows slightly more intensive farming. Farms are scattered between villages and small towns, and are dominated by vernacular buildings of local materials.

The Cumbria High Fells contain some of England's richest and most diverse areas of habitat. There are 110 Sites of Special Scientific Interest (SSSI) that cover about 18 per cent or 35,852 hectares (ha) of the High Fells area. The majority of the SSSI area (31,286 ha) is also designated as 'Special Areas of Conservation' (SAC) of European importance. A further 7,786 ha of habitat has been classified as County Wildlife Sites. Outside these extensive designated areas, Biodiversity Action Plan (BAP) habitats exist which have no formal designation.

The most significant biodiversity assets found in the Cumbria High Fells include:

- the Lake District High Fells SAC for heathlands, arctic and montane communities, and blanket bogs;
- Borrowdale Woodland Complex SAC, which has the most extensive block of western oak woods in Northern England;
- Bassenthwaite Lake and River Derwent SAC complex, which provides the best English example of a nutrient-poor lake and undisturbed river;
- internationally important assemblages of breeding birds;
- 153 protected species;
- montane rocky ledges (often damp and base-rich), that support sixteen nationally scarce plants and five nationally rare plants of Arctic-alpine flora at the UK southern limit of their distribution; and
- iconic species such as golden eagle, short-eared owl, osprey, freshwater crayfish, vendace, sea lamprey, otter, marsh fritillary butterfly, natterjack toad, great crested newt and freshwater pearl mussel.

The vegetation combines with the geology, topography, historical management and settlement pattern to create one of the most iconic cultural landscapes in the world.

The majority of the Character Area falls within the nationally designated Lake District National Park.

Significant landscape assets include:

- spectacular and rugged mountain scenery of open fells with an expansive character;
- radiating patterns of deep glaciated valleys with extensive lakes;
- farmland and sheltered valley landscapes at lower altitudes;
- traditional stone farm buildings and walls;
- extensive areas of ancient, semi-natural, broadleaved, mixed and conifer woodlands;
- lakeshore landscapes of managed grassland with occasional boathouses and dwellings;
- the historic environment, which includes a long history of slate and mineral extraction, still visible in today's landscape; and
- farms, villages and small towns dominated by vernacular buildings in local materials, with some Victorian and later tourist-related development.

The spectacular scenery and easy access have attracted people to the lakes in large numbers for well over a century. It provides a great place for many varied outdoor activities on the fells, down in the valleys, or on the lakes and rivers. The Cumbria High Fells is widely used for recreation and tourism and the Lake District National Park presently receives more than 12 million visitors a year.

Access and recreation assets include:

- large areas of open access land;
- extensive water-based recreation activities;
- woodland and lakeside walks with stunning views;
- sites for outdoor sports including fell walking, climbing and mountaineering;
- long distance footpaths and 2,458 km of public rights of way; and
- steep, rugged slopes and trails, popular with mountain bikers.

The most significant ecosystem services provided by the Cumbria High Fells, from which we all benefit, include:

- water supply – the catchments are used extensively to supply water to the North West region, supplying a quarter of the region's water from Thirlmere and Hawswater reservoirs alone;
- carbon storage – peat and carbon soils are particularly significant in the Cumbria High Fells where there is extensive blanket bog;
- flood protection – flood plains and upland catchments in the Cumbria High Fells provide natural protection from fluvial flooding;
- food, fibre and building materials – meat, fish, wool and wood;
- recreation, tourism and education; and
- climate regulation, especially through water and wetlands.

Likely impacts of climate change on the Cumbria High Fells

Evidence from the UK Climate Impacts Programme (2002) shows that the climate in the Cumbria High Fells over the coming century is likely to become warmer and wetter in winter and hotter and drier in summer. In addition, rainfall intensity will probably increase. Extreme events such as heat waves and storms are predicted to increase in frequency and severity.

Impacts due to temperature rise:

- The structure, species composition and dynamics of some habitats may alter due to seasonal changes.
- Some species may only survive if they can colonise and survive in different places.
- Upland areas will become refuges for species moving into them from lower levels.
- Montane habitats of the Cumbria High Fells are particularly susceptible to the impacts of climate change. Under warmer conditions, it is likely that a number of arctic-alpine species will be lost as they face increasing competition from other species in the same ecological niche.
- Climate change may increase the number of non-native and invasive species.
- The parts of the lakes supporting deep, cold water fish species such as the ice age relict the Arctic Char, will be 'squeezed' because of a rise in temperature and increasing oxygen depletion at depth.
- A consequence of an increase in temperature and a decrease in rainfall in summer may be an increase in the risk of peat and bracken fires.

Impacts due to winter and summer rainfall changes:

- An increase in winter rainfall may increase erosion, resulting in more nutrients being washed into lakes and rivers. This will interact with run-off from agriculture and erosion caused by walkers and cyclists on the fells.
- An increase in pests such as midges may affect outdoor activities and tourism.
- A decrease in summer rainfall may lead to a decrease in lake water levels through summer and autumn. This will impact on water resources.
- The ability of species and habitats to recover from repeated seasonal drought and flood events may be compromised.
- Summer drought could lead to a decrease in the water that is available for recreation. A decline in water quality (due to reduced dilution of pollutants) and an increase in algal blooms may also affect the recreational potential of the lakes during summer.
- Peat soils will be more easily lost through erosion due to drying out. Drying out of peat soils and blanket bog would release significant amounts of carbon dioxide to the atmosphere, exacerbating climate change.

Impacts due to increased storminess:

- Where semi-natural woodland is of a similar age structure, storm events may open up areas where young tree regeneration can take place.
- Ancient trees in parkland and wood pasture will be more susceptible to wind damage.

Other impacts:

- Air quality can be affected by climate change and there may be consequent impacts on biodiversity, for example nitrogen deposition on upland habitats.
- Drying out of peat soils may lead to the disturbance of buried archaeology.

Impacts on tourism, recreation and the landscape:

- Woodland based recreation is likely to increase in popularity as people seek shade in the hottest months.
- An increase in fire risk in the Cumbria High Fells may impact on tourism in terms of people's perceptions of safety and the need to close areas to manage fire risks.
- The 'hazardous season' could shift from winter to summer as heat becomes more of an issue than cold.
- There is likely to be an increase in footpath erosion rates due to increased intensity of rainfall and some path sections could become prone to sudden erosion events. However these effects may be countered to some degree by a reduced 'freeze-thaw action' in warmer winters.
- Higher winter temperatures will reduce the extent of ice and snow in the uplands, resulting in the loss of winter climbing and mountaineering opportunities.
- Increased visitor numbers may have negative impacts on wildlife and the landscape.
- While broad habitat types may persist (for example heathland and lakes) the characteristic species that make up those habitats may be different, subtly altering the appearance of the landscape.
- A more extreme cycle of wetting and drying may affect the foundations of walls and historic buildings, causing them to collapse. This in turn will affect the look of important vernacular buildings and walls within the landscape.

Indirect impacts
There will also be impacts caused by our responses to climate change, rather than by climate change itself. These include:

- An increase in the intensity of grassland management and, potentially, in the area of cultivation in the valley bottoms as a response to longer growing seasons. Coupled with demands for more or new crops, this may exacerbate pressures on land use and semi-natural habitats in the valley bottoms and lowland fringes.
- The timing of grazing and cutting and stocking levels will have to change in response to seasonal changes in grass production.
- A longer growing season may favour more commercial tree species and could provide more wood for coppicing, charcoal production and fuel. This has the potential to have both a positive and negative impact on the landscape depending on species and how it is planted.
- Renewable energy infrastructure could lead to conflicts with landscape, biodiversity and tourism interests and will be another pressure on land use within the area.

- Increasing pressure for food production on land use in valleys, in response to concerns about food security and population growth, may reduce the extent of floodplains, increasing flood-risks downstream.

It is important to remember that climate change will not be the only change over the coming century. Changes in farming systems, the economy, population patterns and cultural values will also affect the natural environment of the Cumbria High Fells. Indeed, climate change may have a greater impact on natural assets through changes in agriculture than through direct biophysical impacts. Changes in the types and varieties of crops, sowing dates, irrigation, pests, diseases and soil erosion are all likely. Our project does not try to assess these, although they will have significant implications for the area and any proposed adaptation measures.

Adaptation options

Responding to the impacts of climate change requires adaptation to prevent natural environmental assets and the social and economic benefits that they provide from being lost. The Cumbria High Fells is a large and complex area, with a varied topography and relatively rich mosaic of habitats. Consequently, it will be more resilient than many other areas in England to the impacts of climate change. However, its position as an upland refuge will mean that adaptive action will be critical.

The management of the fells over many years has been far from ideal for the ecosystems that occupy them. As a result, the majority of habitats are less resilient to climate change than they might have been. More recently, management and grazing levels in SSSIs have been more favourable. However, it will take a long time for these habitats, and for those surrounding them, to attain a good condition and therefore be more resilient to climate change.

Priorities for adaptation are outlined below. It should be noted that there may be policy, economic or other constraints to delivery of adaptation responses. Additionally, some of the actions identified may not have a delivery mechanism at present.

Managing the natural environment so it is more resilient to climate change

Areas such as the Cumbria High Fells will remain important for biodiversity as they have characteristics such as low soil nutrients that favour important habitats and species. To date, biodiversity action in the Cumbria High Fells has concentrated on trying to get sustainable grazing on upland SSSI habitats. This has been done through the excellent work of local land managers changing the grazing behaviour of their stock. This needs to be expanded into the extensive areas of other BAP habitats within the Cumbria High Fells.

Further adaptation actions include:

- Improving the condition of all existing upland habitats, and particularly high carbon ones like blanket bog.
- Ensuring that grazing regimes (intensity, seasonality, type of animal) are appropriate.
- Collecting long-term data sets and undertaking studies to assess environmental change. This information will be very important to inform adaptive management.
- Changing management policy to reflect the likelihood of compositional changes in species and communities.

- Using the spatial planning system to maintain adequate land for the natural environment.
- Removing conifers where they occur on ancient woodland sites and other habitats, particularly peat ones, and encouraging a return back to semi-natural habitat.
- Accepting the loss of certain species in montane habitats where the impacts of climate change may be more severe. However, not all arctic alpine species will be lost and there are many positive actions that can be taken to conserve these for the future.
- Improving the robustness of mountain areas, which will become refuges for species moving into them from the lowlands.
- Encouraging new native woodland expansion up the fell side for species to move up into.
- Expanding semi-natural habitats year on year to prevent a net loss of biodiversity.

Develop a high carbon landscape
The Cumbria High Fells has the potential to help mitigate climate change by locking carbon in soils and vegetation.

Upland land use needs to be managed to help to deliver climate change mitigation by protecting vulnerable soil carbon stores, and improving the ability of upland habitats (such as blanket bog, scrub and woodland) to sequester carbon dioxide.

The addition of native woodland into upland agri-environment agreements is one possible way to help create a high carbon landscape. A recent Higher Level Stewardship agreement involving the graziers and landlord on Mungrisdale Common is one example of how this might be achieved.

Reduce sources of harm not linked to climate
When the natural environment is under stress it is less able to cope with additional complications. Consequently, climate change may be the ‘tipping point’ that prevents habitats and landscapes from recovering from the combined effects of other pressures that have been operating over the last couple of decades.

Major sources of harm include pollution from agriculture, discharge from sewage treatment works and air pollution such as nitrogen deposition. Significant progress has been made with freshwater habitats, for example through work funded by United Utilities on sewage treatment and consequential river quality improvements. The Bassenthwaite Lake Restoration and Catchment Sensitive Farming Programmes have started to demonstrate that there are multiple benefits associated with whole system catchment management. Projects such as ‘Fix the Fells’ will be essential to continue to repair the most eroded footpaths and reduce run- off, and some upland grips (field drainage ditches) now need to be blocked up. This will often lead to the rapid recovery of sphagnum moss species.

Develop ecologically robust and varied landscapes
Variation is key; more diverse landscapes are more resilient and better able to adapt to changes. This may well mean choosing different management options on the fells and dales. For example:

- Expanding habitats through restoration and creation will be required to address multiple sources of pressure and help ensure that the landscape is more 'permeable' so that species can move through it.
- Increasing the variation within existing habitats through changes in management will increase their resilience to climate change.
- Promoting naturally functioning and healthy ecosystems that are more resilient and so better able to adapt to climate change.
- Accepting new species, such as heath fritillary butterfly and sycamore, and managing for them. These species will be moving in from their southern distribution and finding a suitable climate within Cumbria. At present many have been introduced into the area, but are often removed because they are considered 'non-native'.
- Expanding and linking habitats around existing high-quality sites can help to buffer the effects of climate change.
- Creating space to allow rivers to take their natural course will allow the development of more resilient wetland habitats.
- There will be multiple benefits from implementing the national 'Wetland Vision' within the Cumbria High Fells.
- Any adaptation work needs to incorporate and protect the historic and cultural landscape.
- Monitoring change and adapting management accordingly will be critical.

Recreation, tourism and economic adaptations
Recreation and tourism is very important for the economy of the area. The visitor experience can be further enhanced by the landscape and habitat improvements that will result from the climate change adaptation actions identified below:

- Extensive farming systems are more appropriate than intensive ones for delivering an adapted natural environment and for enhancing the visitor experience.
- A sustainable food economy that is less energy intensive and less reliant on fossil fuels, and where more food is produced and consumed locally, will be a critical part of adapting to and mitigating climate change.
- A local wood fuel economy would bring many more under managed woods back into active management, improving their landscape and biodiversity value and giving an economic return to woodland managers, while also helping to mitigate and adapt to climate change.
- Upland hydrology is very important for water resources. There are two major reservoirs in the Cumbria High Fells which serve Manchester, and good water management can help reduce flood risk for downstream settlements. In addressing impacts on water resources and water quality it will be necessary to manage river catchments in a more holistic manner within and beyond the Cumbria High Fells boundary. The ability of catchments to hold water can be increased by allowing the development of natural vegetation such as sphagnum-rich habitats and woodlands. Restoring the natural hydrology of catchments, including rivers and bogs, will be important in ensuring that water environments can adapt to climate change.
- Provision of shade for livestock within the hot summer months could be addressed through tree regeneration in the intake fields on deep bracken areas.

Adaptive management
Although the direction of climate change is clear, the detailed impacts and responses required are less so. Given this uncertainty, and to avoid the development of inappropriate solutions, a process called 'adaptive management' will need to be used. This involves modifying existing practices and carefully monitoring the results to ensure that the response is effective. It may involve making further modifications to management until the response is effective. Adaptive management will require:

- Monitoring and planning for future potential catastrophic events such as storms or pests and diseases that may occur as a result of, or be exacerbated by, climate change.
- Identifying research needs and commissioning appropriate studies to inform decision making about adaptation and increase the effectiveness of strategies when implemented.
- Collating long-term data sets and studies assessing environmental change.
- Adapting policies that reflect the change in the distribution of species and the make-up of habitats.

Next steps

This project on how climate change is likely to affect the natural environment of the Cumbria High Fells Character Area, and the adaptation responses required, is a significant first step but cannot be conclusive. It provides an indication of what may happen. However, the future impacts of climate change are still uncertain and are partly dependent on the amount of greenhouse gases that society releases and how much is released by natural feedback loops from the environment (one of our biggest unknowns).

When identifying adaptation actions, existing strategies, policies and initiatives need to be considered. Some actions defined as climate change adaptation are already occurring under a different name and it may be possible to modify existing programmes to provide a mechanism for delivering adaptation. An example of this is the planned incorporation of climate change adaptation into Natural England's Environmental Stewardship Scheme.

Natural England is now working on the following:

- An implementation plan, which may include a demonstration project. Natural England will work with local stakeholders, through the Lake District Partnership, to ensure that this builds upon and dovetails with other initiatives.
- An assessment of the contribution to climate change mitigation that an adapted Cumbria High Fells landscape will make.
- An economic assessment of adaptation measures in the Cumbria High Fells.
- Learning from the pilot process to assess likely climate change impacts and the required adaptation strategies for other Character Areas both regionally and nationally.

It is also clear that there is a lot we still do not know or understand and further work will be needed. Areas of research that we feel would be particularly useful in the short term are:

- A more detailed ecosystem services assessment for the Cumbria High Fells using a rapid assessment such as that used in the ‘Moors for the Future’ project.
- An assessment of the condition of blanket bog habitat in the Cumbria High Fells and the development of a restoration strategy to maximise carbon storage and capture.
- Investigating whether geology, trampling, grazing, climate or Victorian collections are the likely reason for the current distribution of arctic alpine flora, and how they might possibly survive under a substantially different management regime.

The future of the Cumbria High Fells depends on the actions we all take today to reduce our greenhouse gas emissions. This, combined with decisions we make about managing our landscapes to adapt to unavoidable climate change, will determine whether we continue to have a high-quality landscape that is cherished and respected by all.

Technical report

Contents

1. Introduction

Natural England is working to deliver a natural environment that is healthy, enjoyed by people and used in a sustainable manner. However, the natural environment is altering as a consequence of human activities; one of the most recent to be recognised is climate change.

The impacts of climate change on the natural environment are already being observed, with many species showing a tendency to move northwards or uphill. The potential effects on the natural environment are very serious. The IPCC (Intergovernmental Panel on Climate Change), in the 2007 summary for policymakers, indicated that, globally, 20 to 30 per cent of wildlife species are at increased risk of extinction with a 2.5°C rise in global temperature, rising to 40 to 70 per cent of species with a 3.5°C temperature rise. The IPCC also concluded that the majority of Europe's organisms and ecosystems are likely to experience difficulty in adapting to climate change. Part of the difficulty is due to pressures that wildlife is already experiencing from human activity, including the fragmentation of habitat, making it much more difficult for wildlife to move in response to the changing climate. For this reason, it is imperative that Natural England understands the nature of the threat to wildlife and landscapes, and identifies ways in which wildlife can be assisted to adapt. Without adaptation, there is a risk our landscapes will become less rich in wildlife, habitats.

The Character Area Climate Change Project has three main elements:

- identification of significant natural environmental assets;
- assessment of potential climate change impacts;
- development of potential adaptation responses.

The project has involved national experts and local staff with knowledge of The Cumbria High Fells Character Area.

Whilst the importance of the interaction between the natural environment and socio-economic factors is recognised, for example in relation to communities and agriculture, the report focuses on the impacts of climate change on the natural environment.

Mitigation of climate change is not included in this report; other projects are addressing this within Natural England and future work is planned on the contribution to mitigation of adaptation strategies within the Character Areas.

This report is structured as follows:

- Section 2: Background to The Cumbria High Fells Character Area - brief description which includes the important natural environmental assets.
- Section 3: Impacts – identification of direct and indirect climate change impacts based on bioclimatic data for the Cumbria High Fells.
- Section 4: Adaptation options – identification of strategic and detailed response strategies and assessment against 'good adaptation' principles.
- Appendix 1: Description of biodiversity assets in Cumbria High Fells Character Area.
- Appendix 2: Background and project methodology.

- Appendix 3: Note on indirect climate change and socio-economic impacts.
- Appendix 4 Main Tables.

1.1 Nature and status of the report

There are many issues to be considered in relation to future management decisions relating to The Cumbria High Fells. The communities which live there and their livelihoods, are vital considerations. This report does not attempt to cover these issues, not because they are unimportant, but because Natural England's role is primarily in relation to the natural environment.

In relation to adaptation responses, we are also conscious of the fact that those potential responses listed in the report would depend on the cooperation of those who own and manage the land. We do not in any way take that co-operation for granted and are clear that many measures would require appropriate incentives to be in place. The purpose of this report is not to pursue those mechanisms at this stage, but to initiate a debate on which potential responses to climate change might be feasible and acceptable in principle, subject to appropriate mechanisms being identified.

This report attempts to clarify only the potential impacts on the natural world and identify the options for responding to the possible climate change impacts. Our objective is to ensure that when decisions on the major strategic options are made, they take proper account of impacts on the natural world as well as taking account of impacts on infrastructure and communities etc. It is not Natural England's role, or intention, to take such decisions, but it is our role to initiate a debate on the impacts of climate change on the natural world so that those major strategic decisions are well informed.

1.2 Next steps

We recognise the sensitivity of these issues but with the impacts of climate change already being felt, we felt that now is the time to start the debate. As this report is about starting a debate in relation to the major strategic options, it does not contain any proposals – it considers the options in relation to their implications for the natural environment. Following the drafting of this report, Natural England will be working with regional partners to refine the detail and to seek consensus for particular small-scale adaptation actions within the Cumbria High Fells. In relation to adaptation, these require substantial debate to fully understand their implications for the environment and society of the Cumbria High Fells. Natural England, recognising the sensitivity of these issues, believes such discussions should be open and inclusive. Although others may lead that debate, this report, from the natural environment perspective, will be an initial contribution.

2. Background to Character Area

Box 2.1 Key features of the Cumbria High Fells Character Area

The most significant biodiversity assets found in the Cumbria High Fells include:

- Lake District High Fells SAC – including Standing water bodies, Wet and European Dry Heaths, Alpine and Boreal Heaths and Species Rich Grasslands, Juniper stands, Hydrophilous tall herb communities of the montane to alpine levels, Blanket bogs, Siliceous screes and Old sessile Oak woodlands.
- Borrowdale Woodland Complex SAC - the most extensive block of western Oak woods in northern England.
- Bassenthwaite Lake and River Derwent/Cocker SAC complex - designated for oligotrophic to mesotrophic standing waters, being one of the best examples of a nutrient-poor and undisturbed river system.
- Many northern species are at the southern limit of their distribution in the Cumbria High Fells.
- The highest mountain summits support some of the only remnants of montane moss and lichen heaths found in England.
- Montane rocky ledges (often damp and base-rich) supports sixteen nationally scarce plants and five nationally rare plants.
- The uplands of the Character Area support nationally important assemblages of breeding birds.
- Iconic species in the Character Area include; Golden Eagle, Short-eared Owl, Osprey, Freshwater crayfish, Vendance, Sea Lamprey, Otter, Marsh fritillary Butterfly, Natterjack Toad, Great Crested Newt and Freshwater pearl mussel.

The majority of the Character Area falls within the Lake District National Park and significant landscape assets include:

- Spectacular and rugged mountain scenery of open fells with an expansive character.
- Radiating pattern of deep glaciated valleys with extensive lakes.
- Farmland and sheltered valley landscapes at lower altitudes.
- Traditional stone farm buildings and walls.
- Extensive areas of ancient, semi-natural, broadleaved, mixed and conifer woodlands.
- Lakeshore landscapes of managed grassland with occasional boathouses and

dwellings.

- Long history of slate and mineral extraction, which is still visible in today's landscape.
- The majority of agriculture in the upland areas of Cumbria High Fells is hills sheep and some cattle grazing.

The Character Area is widely used for recreation and tourism and possesses a number of access and recreation assets including:

- All land above the fell wall designated as CROW open access land.
- Water based recreation activities.
- Extreme Outdoor sports such as climbing, canoeing and sailing.
- The Allerdale ramble, Coast to Coast and Cumbria Way long distance paths run through the Character Area. In total there are 2,458 Km of Public Rights of Way in the Character Area.
- Steep, rugged slopes are popular with mountain bikers but there are also sus-trans cycle routes in the Character Area.
- Shooting, hunting and fishing are important in the Cumbria High Fells.

The most significant ecosystem services provided by the Cumbria High Fells include:

- Water suuply to the North West region – a quarter of the regions water is supplied from Thirlmere and Hawswater reservoirs alone. Most of the Lakes area is also used to supply water including; Wet Sleddale reservoir, Ullswater, Windermere, Wastwater (for industry). Ennerdale, Crummock Water and Seathwaite Tarn.
- Flood plains and upland catchments in the Cumbria High Fells provide natural protection from fluvial flooding.
- The peat soil carbon soil is particularly significant in the Cumbria High Fells where there is extensive blanket bog.

Commercial forestry predominates at Whinlatter Forest around Bassenthwaite Lake, Ennerdale, Matterdale and at Thirlmere these areas are all within the River Derwent catchment and predominated by areas of conifer plantations.

2.1 Location

The Cumbria High Fells Character Area is located in the centre of Cumbria, forming the core of the Lake District National Park and surrounded by lower lying areas on all sides. The area is montane with ridges, steep scarps and glaciated valleys contrasting with dales containing lakes, rivers, woods and forests. Only 8.3 per cent of the area is

wooded, and it is largely unsettled with 99.7 per cent of the area being classed as countryside. Approximately 90 per cent of the Character Area is within the Lake District National Park and 18.8 per cent is designated as a Site of Special Scientific Interest (SSSI).

Figure 2.1 Cumbria High Fells Character Area boundary Location

2.2 Overall character

The Cumbria High Fells Character Area is the most mountainous landscape in England, containing its five highest summits and deepest lakes within a diverse landscape of varied geology. The rocks have been sculpted and shaped by the last glaciations into a landscape of U-shaped valleys, steep-sided mountains, corries and tarns. There are significant areas of semi-natural vegetation, especially above the fell wall where extensive sheep grazing is supported. Improved pasture in the valley bottoms allows slightly more intensive farming, with farms scattered between villages and small towns dominated by vernacular buildings of local materials. Consequently, the Cumbria High Fells have a diverse and rich natural environment.

Picture 2.1 – Glenderaterra Valley © Ian Crosher

2.3 Significant natural environmental assets

It is important to recognise the value of existing features in the Cumbria High Fells before assessing what the likely impacts of climate change will be. Existing features define the Cumbria High Fells and form the basis of most adaptation responses (see Section 4).

2.3.1 Biodiversity assets

Internationally important features

The majority of the SSSI area (31,286 Ha) is also Special Area of Conservation (SAC). The Lake District High Fells SAC is designated for its Standing Water bodies, Wet and European Dry Heaths, Alpine and Boreal Heaths and Siliceous grassland, Juniper stands, Hydrophilous tall herb communities of the montane to alpine levels, Blanket bogs, Siliceous screes and old sessile Oak woodlands. and covers 26,999 Ha of the Character Area.

Borrowdale Woodland Complex SAC has the most extensive block of western Oak woods in northern England and covers 667Ha of the Character Area (see Figure 2.2). It is designated for its old sessile oak woods with *Ilex* and *Blechnum*. It also supported siliceous rocky slopes with chasmophytic vegetation and bog woodland. A number of important bryophytes and lichens are associated with the western oakwood species.

Picture 2.2 – High Ladore Upland Oak woodland. © Ian Crosher

Bassenthwaite Lake and River Derwent SAC complex is designated for its oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*. Bassenthwaite Lake is a large lake with an extensive catchment area and consequently is subject to rapid through-flow of water and moderate nutrient status. The only two surviving populations of Vendace *Coregonus albula* are found in Bassenthwaite Lake and Derwent water. It also supports a number of European protected species including the marsh fritillary butterfly, sea lamprey, brook lamprey, river lamprey, Atlantic salmon, otter and floating water plantain.

Nationally important features

The variety of geology, climate and land use of the Character Area, together with its north-westerly location in Britain has led to the development of a rich tapestry of plant and animal communities which is unsurpassed elsewhere in England. Particularly significant to the development of the varied flora is that many northern species are at the southern limit of their distribution in the Cumbria High Fells. These are interspersed with many southern species at the northern limit of their distribution.

The highest mountain summits support some of the only remnants of montane moss and lichen heaths found in England (see box 2.2). Below these areas are cliffs, screes and rocky habitats. Where these are inaccessible to grazing sheep, they are some of the least modified habitats in the area. Montane rocky ledges (often damp and base-rich) support sixteen nationally scarce plants and five nationally rare plants. Montane areas also support nationally important invertebrate communities. Springs and flushes can emerge here and they support diverse arctic-alpine plant communities. Gills link the two zones above and below the treeline.

Picture 2.3 – Moss Campion, Artic Alpine © Robert Goodison

Box 2.2 The remnant Alpine flora

As the glaciers retreated and forest advanced up the hills the artic alpines were increasingly restricted to high levels. As early humans reduced the woodland cover, some species will have expanded but with the increasing number of domestic livestock artic alpine where restricted to the rockier areas. As deeper more acid soils developed further restrictions for these lime loving plants occurred. The Victorian plant hunters made a good record of the mountain flora but also depleted it further.

The key to botanical richness of the alpines is lime availability in the substrate, the lake district fells are predominantly composed of geology of acidic rocks deficient in calcium. This with the altitudinal limits of 600m does means the best sites are restricted to Helvellyn, Fairfield, High Street, Borrowdale fells, Skiddaw and Wastdale Screes ranges where calcareous rocks are more extensive, though patchy.

Ratcliffe (2002) questions the apparent preference of alpine plants to cold conditions found in north facing corries as misleading and the fact that many, such as roseroot and mossy saxifrage, will grow in lowland gardens. He speculates that many species now confined to these high levels were unable to find lower survival niches, at times of

maximum woodland extent, having since failed to descend. The present inability to reproduce by seed and just vegetatively for other will be the dominant factor in restricted distribution.

Source: Ratcliffe 2002

The lower slopes of the open fell support heather moors, acidic grasslands with areas of bracken and blanket bogs. These vegetation communities have been strongly influenced by grazing stock. High altitude woodland is scarce but valley and slope woodlands are more common especially in Borrowdale, Ennerdale, Longsleddale and north of Ambleside. Stands of juniper occur throughout the area.

The uplands of the Cumbria High Fells Character Area support nationally important assemblages of breeding birds including curlew, dotterel, dunlin, golden eagle, golden plover, hen harrier, lapwing, osprey, peregrine, red grouse, ring ouzel, sky-lark and spotted flycatcher. In addition, the UK BAP covers cuckoo, lesser red poll, linnet, reed bunting, tree pipet, twite, wood warbler and yellowhammer.

The lowland areas of the Cumbria High Fells support a range of grassland habitats including wet grassland, northern hay meadows and lowland limestone grassland. The lowlands are characterised by numerous farmsteads and pastoral fields, bounded by hedgerows.

The major lakes are dominant features in the landscape and there are 2,500 smaller tarns in Cumbria (see Figure 2.3). There are more than three major river systems in the Cumbria High Fells Character Area. The Derwent-Cocker River system provides the best English example of a nutrient-poor and undisturbed river. Lakes in the Cumbria High Fells Character Area support Arctic Char, a relic fish species from the last ice age. Arctic Char is one of the rarest fish species in Britain, found only in deep, cold, glacial lakes.

Picture 2.4 - Derwent Water © Cath Marsh

There are 110 SSSIs within or overlapping with the Cumbria High Fells Character Area. A large proportion of SSSIs within the Cumbria High Fells are currently in unfavourable condition (see Table 2.1).

There are a number of National Nature Reserves (NNR) in the Character Area including Bassenthwaite Lake and Tarn Moss. Outside of these sites are extensive areas of Biodiversity Action Plan (BAP) Habitat (see Table A3.1 in Appendix 3). BAPs have been prepared for species including natterjack toad, great crested newt, marsh fritillary, vendace and juniper.

Table 2.1 SSSI condition in Cumbria High Fells Character Area (NE data - April 2008)

Main Habitat	Favourable	Unfavourable recovering	Unfavourable no change	Unfavourable declining	Grand Total
Acid grassland - upland	6.67		55.48		62.15
Bogs lowland	35.28		16.67	29.09	81.04
Bogs upland	1292.59	2836.67	139.97	916.01	5185.24
Broadleaved, mixed and yew woodland – lowland		23.34	1.66	6.58	31.58
Broadleaved, mixed and yew woodland – upland	468.55	539.84	757.05	104.01	1869.45
Dwarf shrub heath - upland	131.95	13610.72	319.67	600.61	14662.95
Earth heritage	1754.27		0.15	57.01	1811.43
Fen, marshland and swamp – lowland	150.32	214.7	21.67	22.27	408.96
Fen, marshland and swamp – upland	28.58	75.26			103.84
Inland rock	21.16	386.44		17.76	425.36
Littoral sediment	4.43	4.29			8.72
Montane habitats	9.69	1101.24	252.89		1363.82
Neutral grassland – lowland	3.47				3.47
Neutral grassland – upland	65.77	96.15	17.58	21.49	200.99
Rivers and streams	25.6		377.31		402.91
Standing open water and canals	436.51	98.02	2544.78	62.23	3141.54
Grand total	**4434.84**	**18986.67**	**4504.88**	**1837.06**	**29763.45**
Percentage Total	**14.9 %**	**63.8 %**	**15.1%**	**6.2%**	

This table highlights that only 14.9% of the SSSI's in the CA are in the best state to be able to cope with climate change impacts. A further 63.8% have the right management to become more resilient to climate change but will be recovering at different rates and states (upland habitats will be much slower to recover than many lower habitats).

Locally important features

Witihin the Character Area, 7,786 Ha of habitat has been classified as County Wildlife Sites. Areas of valley in-bye grasslands are mostly agriculturally improved and species poor but a few flower-rich hay meadows and wet pastures remain.

There are a number of iconic species which the Cumbria High Fells Character Area is known for. Theses may not be the most important species in terms of conservation interest (although they often are) but those which are popularly considered as representative of the area. Iconic species in the Cumbria High Fells include; Golden Eagle, Short-eared Owl, Osprey, Freshwater Crayfish, Vendance, Sea Lamprey, Otter, Marsh fritillary Butterfly, Natterjack Toad, Great Crested Newt and Freshwater Pearl Mussel.

Further information on the biodiversity assets of the Cumbria High Fells Character Area can be found in Appendix 1.

2.3.2 Landscape and geodiversity assets

The Cumbria High Fells Character Area possesses a range of upland and lowland landscapes and the majority of the Character Area falls within the Lake District National Park. The Lake District is currently being considered for World Heritage Status due to its iconic landscapes and natural beauty.

Picture 2.5 – Grange Bridge, Borrowdale

The landscape types and sub-types identified in the Landscape Character Assessment can be seen in Table 2.2 and Figure 2.8.

Table 2.2 Landscape types and sub-types in the Cumbria High Fells Character Area

Landscape type	Sub type
D – Lowland	D1 – Low farmland D2 – Rolling lowland
F - Rugged/craggy high fell	F1 – Upland tarns F2 – Upland forests F3 – Industrial landscapes
G – Rounded/angular high fell	G1 – Valley G2 – Forest
H – Broad upland dale	H1 – Dale with lake H2 – Dale with river floodplain H3 – Enclosed dale side H4 – Open dale side
I – Rolling upland limestone farmland	No sub-types
J – High fell edge	No sub-types
K – Low fell	K1 – Forest K2 – Parkland K3 – Farmland K4 – Moorland ridge
L – Low fell edge	No sub-types
M – Broad lowland valley	M1 – Valley floor with lake M2 – Valley floor with river floodplain M3 – Enclosed valley side M4 – Open valley side

The Cumbria High Fells is the rugged and montane part of the central and northern part of the Lake District. Significant features of the Character Area include:

- Spectacular and rugged mountain scenery of open fells with an expansive character and a mosaic of high craggy peaks and screes, heaths, mires, peatland, heather moorland, acid grassland, bracken and remote valleys with fast flowing streams and tarns.
- A radiating pattern of deep glaciated valleys with extensive lakes, reed beds, carr woodlands, meadows and other lakeshore vegetation, rivers and semi-improved and improved grazing land.
- Farmland and sheltered valley landscapes at lower altitudes with woodland, dry stone walls, hedgerows, copses, pollarded trees and scrub vegetation.
- Traditional stone farm buildings in vernacular styles with slated roofs, circular chimneys and occasionally spinning galleries.
- Extensive areas of ancient, semi-natural , broadleaved, mixed and conifer woodlands in Borrowdale, Buttermere, Ennerdale, Derwent Water, Duddon and the Thirlmere areas.
- Relatively formal lakeshore landscapes of managed grassland with occasional boathouses and dwellings, and broadleaved woodland and individual trees in a parkland setting.

There are many historical landscape features in the Cumbria High Fells Character Area. The archaeological record reflects several thousand years of settlement and industrial activity in the Upland Fells. The area west of Coniston, including the Old Man of Coniston and Wetherlam, has a long history of slate and mineral extraction, which is still visible in today's landscape. Archaeology includes a pre-Iron Age hillfort on Carrock Fell and evidence of prehistoric settlement and stone axe production. Old mineral workings at the head of the Blencathra valley contain a 16th Century track-way and have recently been designated a Scheduled Ancient Monument. Archaeological features can also be found in the Broad Upland Dale landscape; the cairnfields in the Ennerdale valley, the ancient stone art near Buttermere and evidence of Bronze Age settlements near Crummock all demonstrate the rich cultural history of the landscape. Archaeological remains are also prolific throughout the high fell edge, with many scheduled monuments including prehistoric funerary cairns, field systems, hut circles, stone circles and Roman forts.

The Cumbria High Fells Character Area is underlain by a range of geology. The high fells are underlain by the Borrowdale Volcanic Group of igneous rocks and Skiddaw Slates, containing various mineral and metal deposits. The rocks of the Borrowdale Volcanics and the Skiddaw Slates have been sculpted and shaped by the last glaciation into a landscape of U-shaped valleys, steep-sided mountains, corries and tarns. Surrounding this is a band of limestone at the edges of the Character Area. The Skiddaw Slates are easily weathered and this has resulted in the smooth profile of much of the rounded/angular high fell Landscape Character Type. The geology of the high fell edge is transitional, with six different types of underlying geology represented. To the north, the transition from Carboniferous Limestone through the Borrowdale Volcanic Group and into the Skiddaw Group is represented, whilst to the west, the transition from Sandstone to Borrowdale Volcanic Group and south east, the transition from Silurian Flags and Slates to Coniston Limestone is visible. The low fell edge is underlain by a range of different geology types including siltstones and sandstones.

Soils in the Cumbria High Fells Character Area are mainly classified as shallow, very acid, peaty soils over rock, freely draining acid loamy soils over rock and blanket bog.

2.3.3 Access and recreation assets

With all land above the fell wall designated as open access land, this is one of the most accessible and well served areas in the country for high quality public access, and consequently a very popular outdoor area. The Forestry Commission and the National Trust also own extensive areas of land open to public access.

Picture 2.6 – Walkers Cat Bells

Water based recreation activities are important in the Cumbria High Fells Character Area. The lakes and rivers attract many visitors and activities such as angling and boating are popular. There are also a number of footpaths which follow lakeshores. Extreme sports are becoming increasingly popular including white water canoeing, gill scrambling, rock climbing, caving and mine exploration and paragliding. The rugged terrain makes the area popular for multi-sport challenges and sporting events such as fell running mountain marathons.

Walking is a very popular activity in The Cumbria High Fells Character Area. The Allerdale ramble, Coast to Coast and Cumbria Way long distance paths run through the Character Area. In total there are 2,458 Km of Public Rights of Way in the Cumbria High Fells Character Area. The Lake District experiences high pressure from walkers' feet. In 1999 an upland path survey found that 145 were badly eroded and in need of urgent repair some being more than 20m wide (Lake District Access Management Group – path survey 2000). By 2008 more than fifty paths will have been repaired through Heritage lottery funding and the *Fix the Fells* project.

The Cumbria High Fells Character Area is also a popular area for cycling. The steep, rugged slopes are popular with mountain bikers but there are also sus-trans cycle routes in the Character Area. The C2C is a long distance cycle route which passes through the north of the Character Area and the national cycle network route 7 from Penrith to Carlisle crosses the Character Area.

The Cumbria High Fells Character Area is also used for motorsports. It is a popular for 4x4s and quadbiking.

Camping is an important activity in the Cumbria High Fells Character Area and there are a number of different types of campsites. Lakeside sites are popular, as is farm based camping but increasingly people are 'wildcamping',outside recognised campsites.

2.3.4 Ecosystem services assets

Human beings benefit from processes or structures within ecosystems that give rise to a range of goods and services called 'ecosystem services' (POST 2006). The Millennium Ecosystem Assessment grouped ecosystem services into four broad categories (UNEP 2006):

- Supporting services - such as nutrient cycling, oxygen production and soil formation. These underpin the provision of the other 'service' categories.
- Provisioning services - such as food, fibre, fuel and water.
- Regulating services - such as climate regulation, water purification and flood protection.
- Cultural services - such as education, recreation, and aesthetic value.

The majority of agriculture in the upland areas of Cumbria High Fells is hill sheep and some cattle grazing. Sheep farming is important to the economy of the Lake District. Approximately 90 per cent of Herdwick sheep farming takes place in the central and western dales of the Lake District. The lowlands support hay and silage meadows.

Picture 2.7 – Sheep grazing outside Keswick

Shooting, hunting and fishing are important in the Cumbria High Fells Character Area. There are important salmon and trout fisheries in the River Derwent.

A number of plantations of non-native trees are located throughout the Character Area. The Forestry Commission own a number of sites in the Character Area including Whinlatter Forest Park, Ennerdale and Matterdale.

The Cumbria High Fells catchments are used extensively for public water supply. Approximetly a quarter of the North West region's water demand is met from the waterbodies of the Cumbria High Fells. Thirlmere and Haweswater are major reservoirs with a network of smaller reservoirs including Wet Sleddale , Ullswater and Helton. Windermere supplies north Lancashire during periods of dry conditions and the Whitehaven water supply is fed from Ennerdale. Workington and Cockermouth source

their water from Crummock Water and Seathwaite Tarn supplying Barrow in Furness. There are also a number of Lakes that serve industry rather than potable supply; for example, Wastwater and Ennerdale serve Sellafield and Whitehaven industry.

The Cumbria High Fells Character Area is an attractive area for tourists, see Section 2.3.3. Many of the recreation and tourism assets also have value as an educational resource. There are a number of field study and visitor centres in the Cumbria High Fells Character Area. The natural beauty of the Character Area also gives it a strong sense of place and local distinction and the landscape has a spiritual quality for many people.

Flood plains in the Cumbria High Fells Character Area provide natural protection from fluvial flooding. Floodplains and wetland habitats also have a role to play in moderating water quality. The 'Wetland Vision' set out a vision for 50 years for our wetland habitats. It shows where new wetlands could be created and current wetlands restored. Implementation of this will help to adapt our wetland environments to climate change.

The natural environment provides an important climate regulation function. Carbon is stored in soils, particularly peat soils, and biomass. The UK uplands are estimated to store 5 billion tonnes of carbon (RSPB undated). The peat soil carbon soil is particularly significant in the Cumbria High Fells Character Area where there is extensive blanket bog. However, blanket bog is currently in poor condition in many parts of the Character Area, compromising its ability to store carbon in the long term. Improving the condition of UK peatlands is essential if we are to avoid releasing thousands of years' worth of stored carbon over the next few decades (RSPB undated).

2.3.5 All assets

An initial list of the more significant natural environmental assets has been compiled, see Table 2.3. Figures 2.4 to 2.6 illustrate the location of these assets within the Cumbria High Fells Character Area.

Table 2.3 Valued assets in the Cumbria High Fells Character Area

Type of asset	Assets
Biodiversity	Acid Grassland Ancient and/ or Species-rich Hedgerows Artic Alpines Blanket bog Coastal and Floodplain grazing marsh Fens – lake and flood plain fens Fern beds Juniper Lakes, Tarns & Meres Lowland calcareous grassland Lowland dry acid grassland Lowland raised bogs Montane grassland and heath Pond and ditch systems Purple moor grass and rush pasture Reedbed & reedbed birds Rivers and streams

Type of asset	Assets
	Swamps / fens Upland Calcareous Grassland Upland and lowland hay meadows Upland Heathland & birds (e.g. red grouse) Upland mixed ash Upland oak wood and birds (e.g. wood warbler) Upland Springs & Flushes Upland scrub Valley mires Wet woodland Wood pasture/ parkland and veteran trees Woodland, high fell and farmland birds
Access and Recreation	CROW open access land Cumbria Rights of Way Network Long distance footpaths Tourist / visitor attractions Lakes and rivers Forestry Commission and National l Trust land Cycle ways and mountain bike courses Camp sites Rugged upland landscape
Landscape	Lowland Rugged/craggy high fell Rounded/angular high fell Broad upland dale Rolling upland limestone farmland High fell edge Low fell Low fell edge Broad lowland valley Hedgerows Remains of mining industry Historic field patterns Archaeology Stone walls, farmsteads and barns
Ecosystem services	Provision of food and fibre – Farming, fishing and forestry Soils and geology Water resources – potable and non potable Recreation and tourism Cultural and spiritual values Educational resources Flood protection Water quality Climate regulation

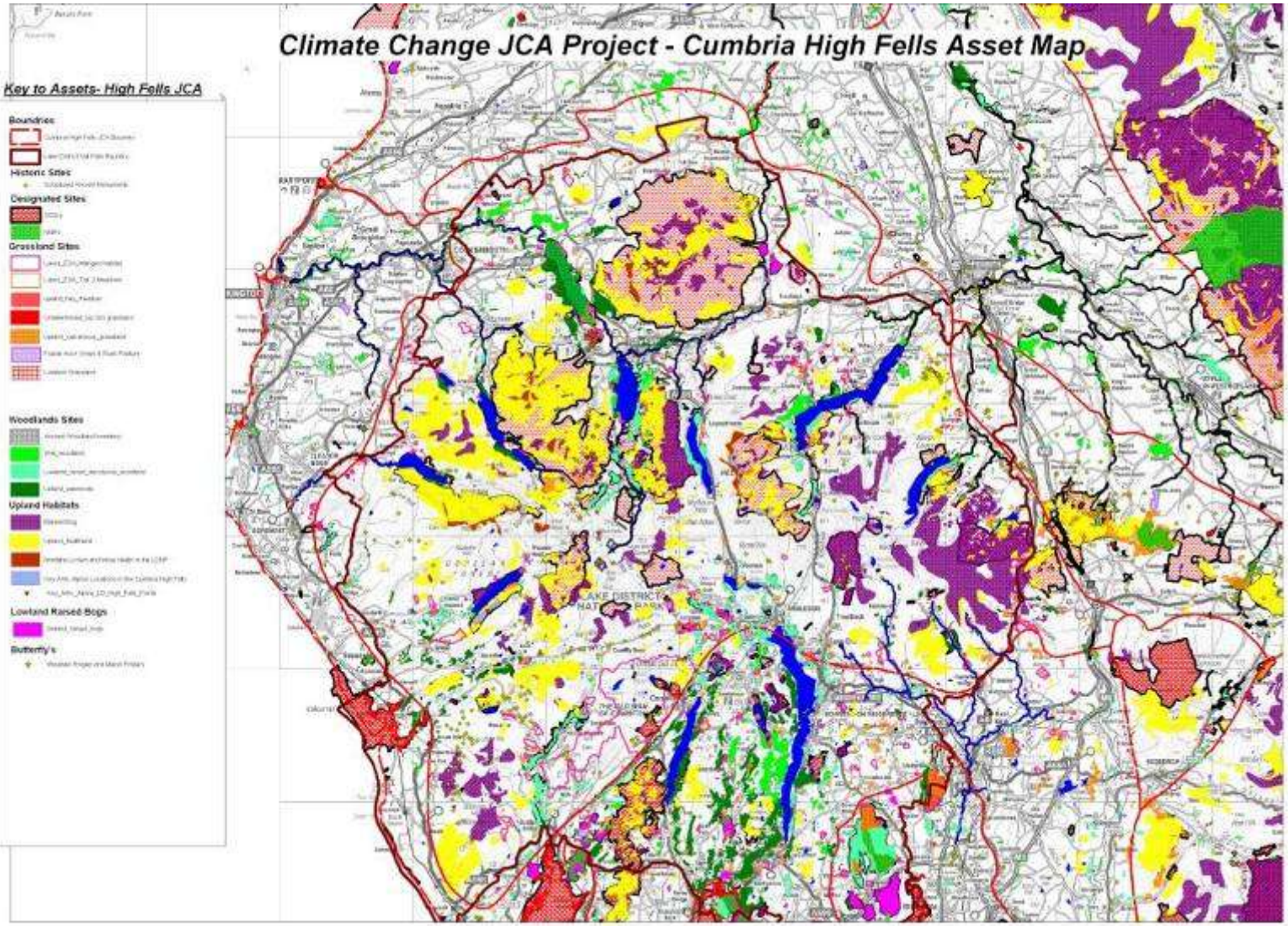

Figure 2.4 Significant biodiversity Assets in the Cumbria High Fells Character Area

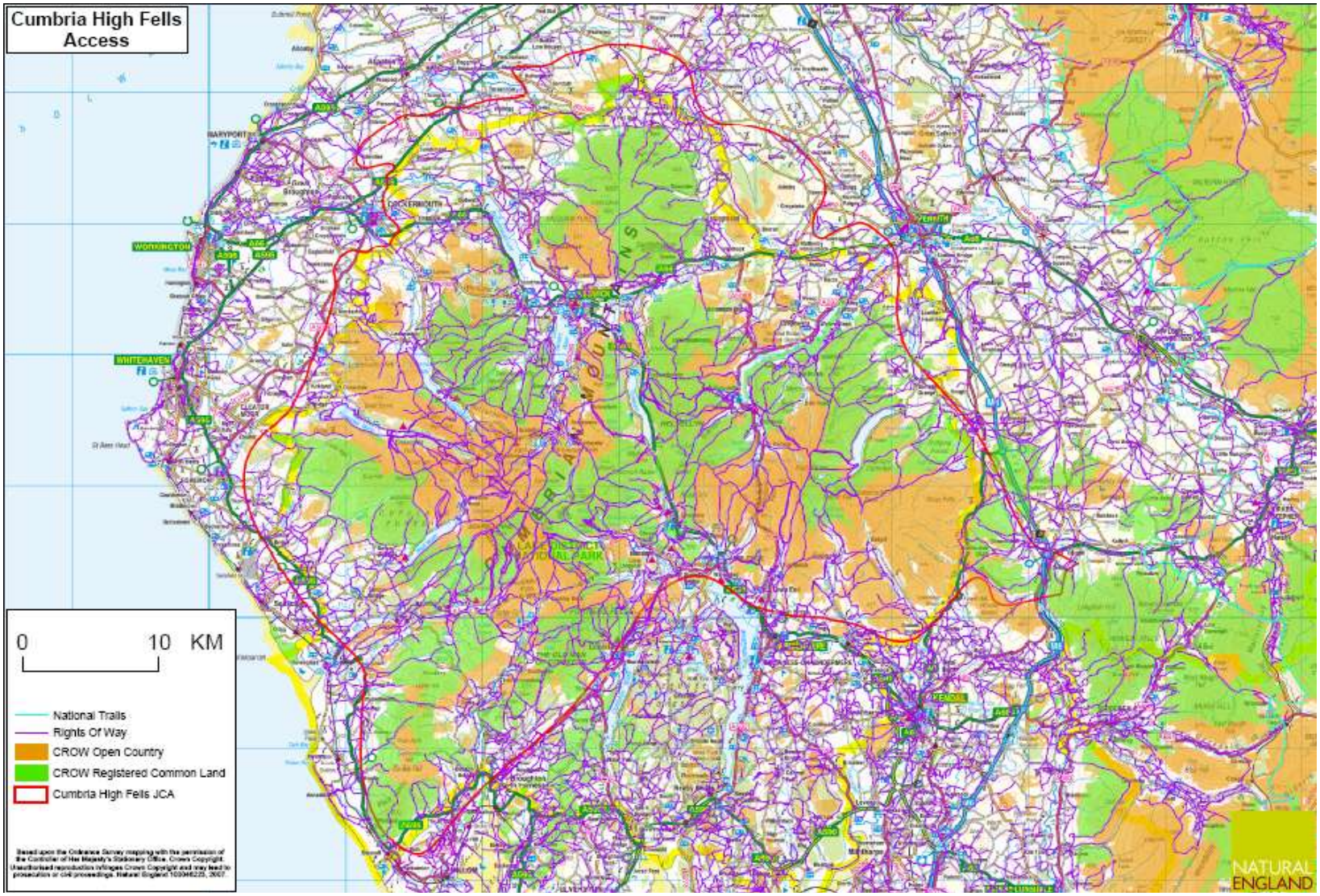

Figure 2.5 Significant access and recreation assets in the Cumbria High Fells Character Area

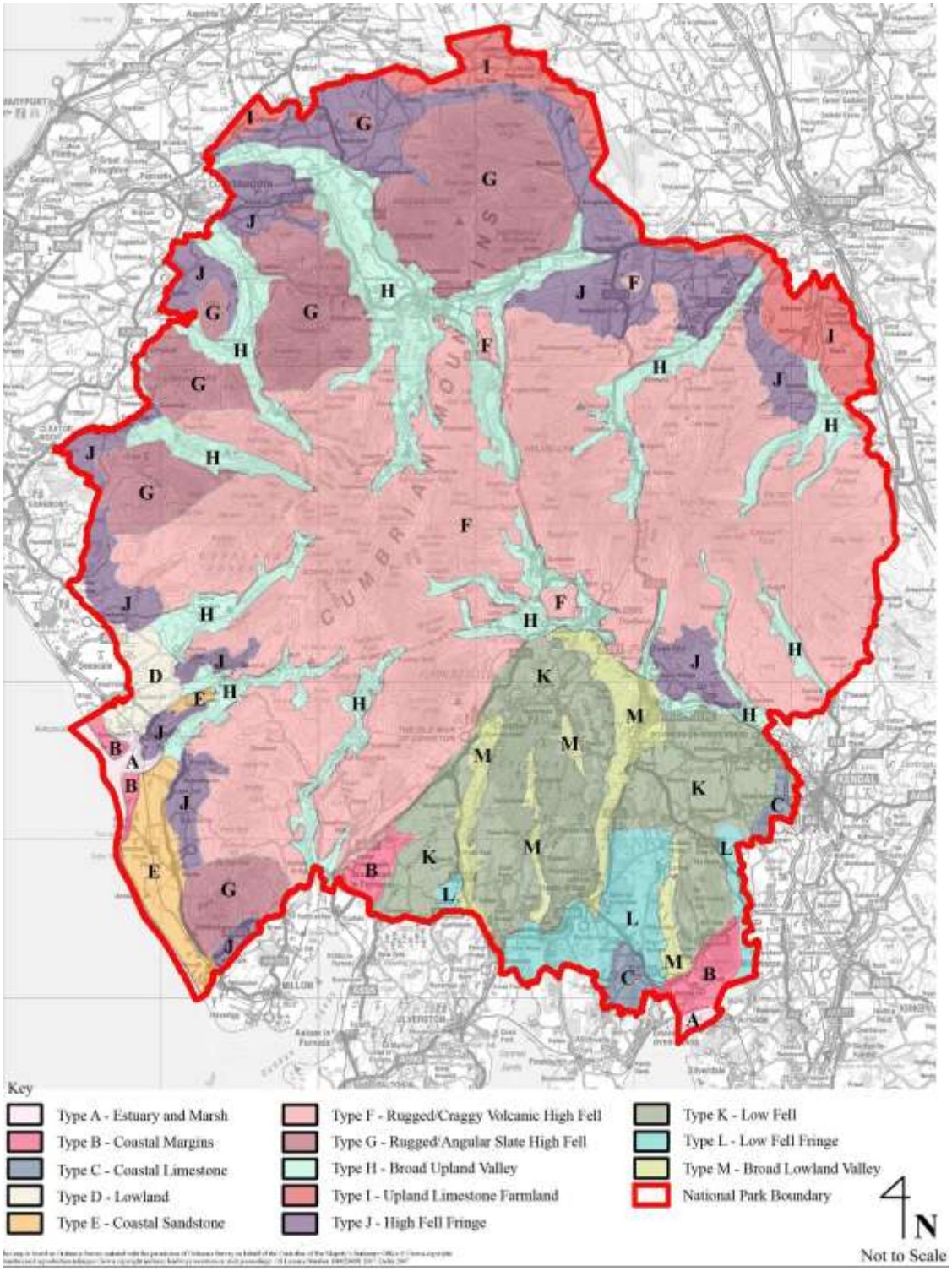

Figure 2.6 Landscape classification in the Cumbria High Fells Character Area

3. Impacts

Box 3.1 Key impacts of climate change on Cumbria High Fells Character Area

Impacts due to temperature rise:

- Change in species and communities composition due to seasonal temperature variations.
- Some species may only survive if they can colonise and survive in different places.
- Upland areas will become refuges for species moving into them from lower levels.
- Montane habitats of the Cumbria High Fells are particularly susceptible to the impacts of climate change. Under warmer conditions, it is likely that a number of arctic-alpine species will be lost as they lose suitable climate space and face increasing competition from other species as their ecological niche changes.
- Climate change may increase the number of non-native and invasive species.
- The parts of the lakes supporting deep, cold water fish species such as the ice age relict the Arctic Char, will be 'squeezed' due to a rise in temperature and increasing oxygen depletion at depth.
- A consequence of an increase in temperature and a decrease in rainfall in summer may be an increase in the risk of peat and bracken fires.

Impacts due to winter and summer rainfall changes:

- An increase in winter rainfall may increase erosion, resulting in more nutrients being washed into lakes and rivers. This will interact with run-off from agriculture and erosion caused by walkers and bikers on the fells.

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- Increase in pests such as midges which may affect outdoor activities and tourism.
- A decrease in summer rainfall may lead to a decrease in lake water levels in summer and autumn.
- The ability of species and habitats to recover from repeated seasonal drought and flood events may be compromised.
- Summer drought could lead to a decrease in water available for recreation. A decrease in water quality (due to reduced dilution of pollutants) and an increase in algal blooms may also affect the recreation potential of the lakes during summer.
- Reduced summer rainfall and more intense rainfall events will impact on water resources.
- Peat soils will be more easily lost through increased erosion due to drying out.

Drying out of peat soils and blanket bog would release significant amounts of carbon dioxide to the atmosphere, exacerbating climate change.

Impacts due to increased storminess:

- Where semi natural woodland is of a similar age structure, storm events may open up areas where young tree regeneration can take place.
- Ancient trees in parkland and wood pasture will be more susceptible to wind damage;

Other impacts

- Air quality can be impacted by climate change and there may be consequent impacts on biodiversity. e.g. nitrogen deposition on upland habitats.
- Changes in agricultural practices as a result of climate change may have a greater impact on biodiversity and landscape than direct biophysical impacts.
- Drying out of peat soils may lead to the disturbance of buried archaeology.
- There may be an increase in number of non-native and invasive species.

Tourism, recreation and landscape impacts

- Woodland based recreation is likely to increase in popularity as people seek shade in the hottest months.
- An increase in fire risk in the Cumbria High Fells may impact on tourism in terms of people's perceptions of safety and the need to close areas to access to manage fire risks;
- The 'hazardous' season could shift from winter to summer as heat becomes more of an issue than cold.
- There is likely to be an increase in footpath erosion rates due to increased intensity of rainfall and some path sections could become prone to sudden erosion events. However these effects may be countered to some degree because of a reduced 'freeze-thaw action' in warmer winters.
- The increase in winter temperatures will reduce the extent of ice and snow in the uplands, resulting in the loss of winter climbing and mountaineering opportunities.
- Increased visitor numbers may have negative impacts on wildlife and landscape.
- Whilst broad habitat types may persist (e.g. heathland, lakes) the characteristic species that make up that habitat may be different, subtly altering the appearance of the landscape.
- A more extreme cycle of wetting and drying may affect foundations, and walls and historic buildings may exceed their capacity to support the structure. This in turn will affect the look of the important vernacular buildings and walls within the

landscape.

Indirect impacts
(impacts caused by *our responses* to climate change, rather than by climate change itself)

An increase in the intensity of grassland management and, potentially, an increase in the area of cultivation in the valley bottoms, as a response to longer growing seasons and demands for more or new crops may exacerbate pressures on land use and semi-natural habitats in the valley bottoms and lowland fringes.

- The timing of grazing and cutting and stocking levels will have to change in response to seasonal changes in biomass production.

- A longer growing season may favour more commercial tree species and could provide timber for coppicing, charcoal production and woodfuel. This has the potential to have both a positive and negative impact on the landscape depending on species and how it is planted.

- The use of the natural environment for energy generation could lead to conflict with landscape, biodiversity and tourism interests and will be another pressure on land use within the area.

- Increasing pressure on land use in valleys as a result of food security, agricultural intensification and population growth may reduce the extent of floodplains, increasing flood-risk downstream.

3.1 Bioclimatic data

In anticipation of the next set of UKCIP scenarios of climate change for the UK, due to be published at the end of 2008, a report detailing observed climate for the UK for two 30 year periods 1961 – 1990 and 1971 – 2000 has been issued. This report presents detailed observed data on the climate variables to be included in the UKCIP08 scenarios (Jenkins *et al*. 2007). The observed climate between 1961 – 2000 for the Cumbria High Fells area can be seen in Table 3.1.

Between 1961 and 2000 some warming has been observed in the Cumbria High Fells Character Area. Warming is particularly marked in the summer and winter records with an annual average increase of 0.3 to 0.4°C. This is consistent with the UKCIP02 projections which forecast warmer summers and winters. The observed precipitation record shows less clear trend between the two thirty year periods although it appears that summers are becoming drier and winters wetter.

Table 3.1 Observed climate of the Cumbria High Fells area

Climate variable		**Observed climate 1961 - 1990**	**Observed climate 1971 - 2000**	**Change 1961-1990 to 1971-2000**
Temperature	Annual mean	4 - 10°C	4 - 10°C	0.2 – 0.3°C
	Spring mean	2 - 6°C	2 - 6°C	0.2 – 0.4°C

Climate variable		Observed climate 1961 - 1990	Observed climate 1971 - 2000	Change 1961-1990 to 1971-2000
	Summer mean	10 - 14°C	10 - 14°C	0.1 – 0.4°C
	Autumn mean	4 - 8°C	4 - 10°C	-0.1 to 0.1°C
	Winter mean	0 - 4°C	-2 - 4°C	0.3 – 0.5°C
Precipitation	Annual mean	1300 – 4550mm	1399 – 4650mm	-2 – 5%
	Spring mean	350 – 900mm	350 – 900mm	-5 to 5%
	Summer mean	260 – 800mm	350 – 800mm	-10 to 5%
	Autumn mean	350 – 1400mm	350 – 1450mm	-5 to 5%
	Winter mean	260 – 1300mm	350 – 1450mm	5 – 15%
Wind speed	Annual mean	No data	10 – 24kts	NA
	Spring mean	No data	7 – 24kts	NA
	Summer mean	No data	10 – 24 kts	NA
	Autumn mean	No data	10 – 24kts	NA
	Winter mean	No data	10 – 24kts	NA
Relative humidity	Annual mean	82 – 85%	82 – 85%	-0.6 to -0.3%
	Spring mean	79 – 82%	76 – 82%	-0.6 to -0.3%
	Summer mean	79 – 82 %	79 – 82%	-0.9 to -0.6 %
	Autumn mean	85 – 88%	82 – 88%	-0.9 to -0.3%
	Winter mean	85 – 88%	85 – 88%	-0.6 to -0.3%

Source Jenkins *et al*. 2007

The UKCIP02 scenarios project the impacts of climate change under a range of emissions scenarios for the UK (Hulme *et al.,* 2002). Scenarios for three different timeslices are presented, representing the average climate over 30 year periods centred on the 2020s, 2050s and 2080s. The climate changes projected to the 2020s are similar across all scenarios; this is because changes in the short term are dictated by past greenhouse gas emissions in recent decades. Climate changes beyond the next few decades depend on future emissions, but even the low emissions scenario represents an acceleration of climate change when compared to changes that have occurred in the 20th century The scenarios are based on a UK Met Office General

Circulation Model (GCM), coupled to a Regional Climate Model (RCM) which allows impacts to be projected on a local to regional scale.

The bioclimatic data used in this project is taken from the HADRM3 model, a regional climate model with a 50km^2 resolution, driven by different emissions scenarios; high and low emissions, based on the IPCC Special Report on Emissions Scenarios (SRES). The UKCIP02 high emissions scenario corresponds to the A1 SRES emissions scenario (see Appendix 3 for further explanation of socio-economic scenarios). Table 3.2 gives the bioclimatic data for the Cumbria High Fells Character Area.

Changes in mean temperature or total rainfall as presented in Table 3.2 are not the only changes we can expect. It is likely that there will also be change in extreme temperatures and rainfall events (e.g. an increase in heat waves and storms). It is important to note changes in extremes as they are likely to have a big impact on the natural environment.

Table 3.2 Bioclimatic variables for Cumbria High Fells Character Area

Climatic Variable	Annual ave. value for Cumbria High Fells					
	2020s		2050s		2080s	
	High	Low	High	Low	High	Low
Change in absolute maximum temperature	1.21 ºC	1.02 ºC	2.90 ºC	1.82 ºC	5.01 ºC	2.58 ºC
Change in absolute minimum temperature	0.71 ºC	0.60 ºC	1.70 ºC	1.07 ºC	2.94 ºC	1.52 ºC
Change in minimum temperature expected over 20 years	0.93 ºC	0.78 ºC	2.24 ºC	1.41 ºC	3.89 ºC	2.00 ºC
*Change in growing degree days >5ºC	241	201	629	373	1175	552
Change in mean temperature of the coldest month	No data	0.57 ºC	1.63 ºC	1.03 ºC	2.83 ºC	1.46 ºC
Change in mean temperature of the warmest month	No data	0.80 ºC	2.29 ºC	1.44 ºC	4.16 ºC	2.04 ºC
Change in total potential evapotranspiration	No data	15.1%	44.3%	27.4%	80.2%	39.4%
Percentage change in moisture availability	-15.8%	-13.4%	-39.5%	-24.3%	-71.8%	-35.1%
Change in total precipitation	-1.1%	-0.9%	-2.6%	-1.6%	-4.5%	-2.3%

*Growing degree days are the cumulative total of degrees above 5ºC over the year.

3.2 Type of impacts

Climate change will not be the only pressure on natural environments in the future and other impacts will be felt through socio-economic change. The Cumbria High Fells is a farmed landscape and the farming system has developed within the environmental limitations of the land. Consequently changes in agricultural practices are likely to have a significant impact on species, habitats and landscapes. Changes in agriculture could be driven by climate change, such as crop switching to more drought tolerant plants or conversion of grazing land to arable. These would be classified as indirect impacts of climate change on the Character Area. However, shifts in agriculture may occur regardless of climate change e.g. fluctuations in crop prices or shifts in consumer demand for certain products. Such changes would be classified as socio-economic impacts. These changes, whether climate induced or not, would significantly impact on the lowland environment of the Cumbria High Fells Character Area. In reality direct, in-direct and socio-economic impacts are closely related. This project focuses mainly on the direct biophysical impacts of climate change on the assets identified in Section 2. Where significant indirect impacts have been identified (such as those related to agricultural change in the face of climate change) these have been documented.

The future will be different and we cannot predict what it will be like. Socio-economic scenarios provide internally consistent descriptions of potential futures, based on variations in governance (local to international) and social values (individualism or communism). The impacts of climate change will be mediated by the socio-economic scenario that prevails at the time; changes in attitudes and behaviour towards the natural environment and conservation will alter the nature of the impacts.

Whilst it is important to bear in mind that the future will be different, in order to identify impacts in this project, an assumption that the socio-economic scenario that prevails in future will be broadly similar to that which we currently experience has been made. In identifying climate change impacts, only one emissions scenario (high) for the 2080s has been used to indicate a direction of travel. The full range of bioclimatic data presented in Table 3.1 has not been used. This project has not adopted a formal scenario based approach, nor does it provide an integrated assessment as these are very complex. However, adaptation strategies will be tested against socio-economic futures to determine how robust they are to different scenarios. For further information about socio-economic scenarios, see Appendix 3.

3.3 Impacts on significant natural environmental assets in the Cumbria High Fells Character Area

The UKCIP02 climate change projections, the bioclimatic data given in Table 3.2 and expert judgement was used to inform the identification of impacts on the existing significant natural environmental assets identified in the Cumbria High Fells Character Area in Chapter 2. Whilst there is some uncertainty over the exact nature of climate change, the impacts identified in this report are based on the best available science and expert judgement.

One of the most important factors in determining habitat resilience to climate change is the condition of the habitat. A habitat that is in good health, with strong and vibrant growth should be able to adapt and cope with the changes more effectively. The drive of Natural England has been to get at least favourable management status in 95% of SSSIs by 2010. It has to be accepted though that many habitats in the uplands are not

in good condition and will need a sustained effort to get them in the best condition possible. This will be especially important for the habitats outside of the SSSI's which are suspected to be in a poorer condition.

Picture 3.1 - Derwent water

Table A4.1 in Appendix 4 identifies the climatic changes pertinent to the significant environmental assets and the likely impacts which are discussed further below.

3.3.1 Impacts on biodiversity

Direct impacts

The main biophysical impact of climate change is likely to be a change in species and communities that make up a habitat. Results from the Monarch study (Walmsley *et al.* 2007) indicate that certain species will gain suitable climatic space in the north and west whilst losing it in the south of England. Climate change may mean that some species may only survive if they can colonise and survive in different places**.** Changes in climate will alter the competitive balance between species thus changing where individual species can colonise and survive (see Box 3.2). However, climate is not the only factor determining colonisation; the means of dispersal, competition and presence of suitable habitat will all determine if species move.

Compositional changes are likely in a number of the key asset habitats in the Cumbria High Fells (assuming climate is currently the limiting factor rather than other pressures such as land use) including:

- loss of montane species (e.g. arctic and alpine vegetation, montane breeding birds and butterflies);

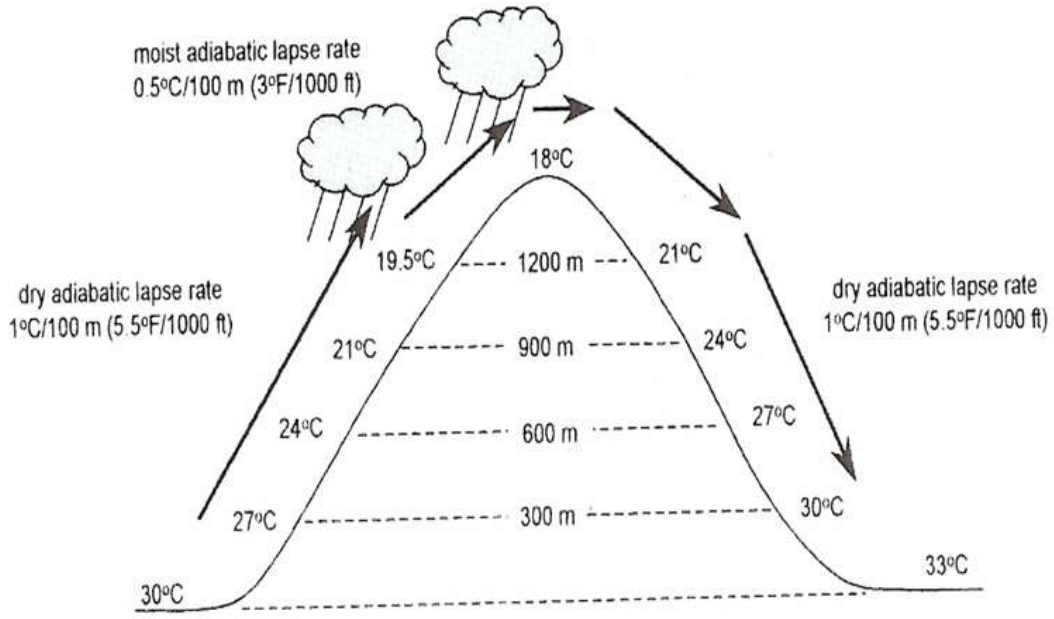
- loss of cold water fish from deep lakes and replacement with introduced species such as roach;
- loss of invertebrate species from headwater streams (e.g. stoneflys);
- loss of sphagnum and increase in heather in blanket bogs;
- decline in abundance of upland birds but increase in abundance of lowland heath birds;
- increase in drought tolerant ephemerals and re-colonisation by annuals with a persistent seed bank in lowland calcareous grassland habitat;
- change in woodland ground flora composition;
- change in upland oak woodland bryophyte layers and composition due to hotter dryer summers;
- reduction in range of upland butterfly species (e.g. Northern Brown Argus, Scotch Argus and the Mountain Ringlet).

The habitats adapted to the cold and wet microclimates within the mountains will be susceptible to a warming climate with different rainfall patterns. The varied topography does mean that localised movement across valleys and up the fell side will be possible for species as long as suitable sites are available to colonise. As such it is likely that these upland areas will become refuges for species moving into them from lower levels. For example, hay meadows currently found at lower elevations in the Cumbria High Fells Character Area may move upwards. However, upland areas will only become refuges for lowland species if the intervening land management is favourable; it is thus essential that habitats are robust and well connected, with a landscape that is permeable to species movement. There may also be physical constraints to movement such as soils and topography.

Box 3.2 Change in suitable climate space

As air rises, the pressure it experiences decreases and it expands. As it expands, energy is released and consequently the temperature of the air falls. As a rule of thumb, for every 100m air rises, its temperature drops by 1ºC; this is the dry adiabatic lapse rate. As a result of increasing temperatures at ground level, species will move upwards, if they are able, in order to find the temperature to which they are adapted. There is already observational evidence of this effect occurring; Hickling et al. (2006) report that a wide variety of vertebrate and invertebrate species have moved northwards and uphill in Britain over approximately 25 years. This phenomenon is more pronounced in the Alps with certain species observed to be moving 23.9m upwards per decade (Parolo and Rossi, 2007). In addition to moving upwards, species will move across valleys to north facing slopes as the temperature on south facing slopes exceeds that which they can tolerate. There is also evidence of species moving in response to topographic influence on micro-climate; Davies et al. (2006) report the changing slope and aspect preferences of silver-spotted skipper in response to climate change.

Figure 3.2 Adiabatic lapse rate



Source: Hopkins, from Bonan 2002

The montane habitats of the Cumbria High Fells are particularly susceptible to the impacts of climate change, being the surviving remnants of the last glacial period. Montane habitats in England are small in extent and fragmented in nature, hence the habitat present in the Cumbria High Fells is particularly significant. Montane areas support a number of arctic-alpine species at their southern most extremity of their range, both in the Cumbria High Fells and in the Welsh mountains (see Figure 3.2). The habitat is maintained by cold temperature and wind at high altitude.

Under warmer conditions, it is likely that a number of arctic-alpine species will be lost as they lose suitable climate space and face increasing competition from other species as their ecological niche changes. It is expected that stiff sedge will show a

decline in distribution and the mountain ringlet faces butterfly local extinction in the Cumbria High Fells. It is likely that small fragments of montane grassland and heath habitats will remain but they will be restricted to smaller patches on north facing slopes without adaptation to current management. Presently, the main limiting factor is sheep grazing of arctic alpines and trampling of montane heaths on flat summit ridges and peaks. These are socio-economic impacts not directly associated with climate change but could be exacerbated by increases in visitor numbers as temperatures warm.

Picture 3.2 – Montane Heath, Red Pike © Ian Crosher

However, it is possible that montane species will not be as greatly impacted by climate change as others in the Character Area. There is an argument that the great diversity of the high altitude habitats at a small spatial scale means there are potentially many niches for montane species to occupy. This diversity may increase the robustness of montane habitats to the impacts of climate change.

As some species are likely to lose climate space, others will gain it. It is likely that in the Cumbria High Fells, the areas potentially inhabited by lowland species will expand. Under a warming climate dragonflies which need hot weather to emerge from nymph to adult will do well; the Ruddy Darter and the hairy dragonfly have arrived in Cumbria since 2001. To identify which species may move into the Character Area it may be useful to look at neighbouring areas, particularly those south of Cumbria High Fells. For example, the heath fritillary butterfly, currently not resident in Cumbria, may well colonise in the Character Area as the climate space becomes favourable (Flora of the Fells 2008).

Not all the species gaining climate space are welcome; climate change may increase the number of non-native and invasive species. However, climate change may not be the only factor responsible for the greater presence of invasive species; visitor movements can introduce non-native and invasives to an area and the planting of

exotic species in gardens can be another source. Examples of non-native and invasive species that may be influenced by climate change in the Cumbria High Fells include:

- water plants such as pygmy weed in wetland habitats;
- Himalayan balsam as flooded winter rivers leave greater sediment and clear more space, with reduced flows in summer leaving more bare soil for colonisation;
- signal crayfish;
- Japanese Knotweed.

Picture 3.3 – Himalayan Balsam © John Martin

Freshwater systems are particularly susceptible to colonisation by new species. For example, it is likely that introduced roach which, in the past, has been restricted to a small number of areas through unsuitable climate conditions, will expand its range into the Arctic Char ecological niche. Impoverished habitats such as those on the fells will also be more susceptible to colonisation by new species but also new pests and diseases which may arrive as the climate changes.

Changes in temperature will have phenological effects which are also likely to affect community composition. For example; it is expected that temperature changes may cause certain hay meadow species to flower or set seed earlier in season. Phenological changes are already being observed in the UK; earlier arrival of birds and butterflies in the spring have been recorded (Sparks *et al.* 2001) and tree leaf appearance in Surrey has been found to be 10 days earlier in the 1990s than the 1980s (Sparks *et al.* 2001). Another example of such change is the arrival of migrant birds in the UK; on average, compared with 2001, migrant birds arrived 5.3 days earlier and resident birds bred 8.7 days earlier. Insects were first recorded 23.1 day ahead of normal(Woodland Trust, 2008).

Changes in phenology are another cause of compositional change as changes in the relative timing of events has consequences for other species in the community. An example from the Cumbria High Fells Character Area is upland birds such as the Red

Grouse and Ring Ouzel. The breeding period for these birds varies in response to temperature and there is a risk that under climate change, the bird breeding season will be out of phase with the invertebrate breeding season. Wetter winters may also be affecting a parasite which affects Red Grouse. Another example is flowering of woodland ground flora which must flower before trees come into leaf in order to take advantage of the increased light availability. If leaf appearance is earlier, then many of these temperature-sensitive bulb species may become starved of light and will not flower. There may also be increasing competition from species such as garlic mustard and cow parsley which will benefit from a warmer environment.

An increase in temperature and growing degree days will lengthen the growing season. This may be beneficial to some species which can adapt to a longer growing season, e.g. oak, but detrimental to those which can not, e.g. ash. Differences in the ability of woodland species to adapt to a longer growing season will be another cause of community composition change. Overall, it is likely that an increase in the length of the growing season will be beneficial for trees.

Temperature change will also have a direct impact on freshwater habitats, a significant natural asset of the Cumbria High Fells Character Area. As air temperatures increase, so too will surface water temperatures. An indirect consequence of higher water temperatures is a decrease in the amount of dissolved oxygen in water. Cold upland stream support many stonefly species which as they warm up are likely to get squeezed up the hill. This impact will be particularly significant in deep lakes. The part of the lakes supporting deep, cold water fish species, such as the ice age relict the Arctic Char, will be 'squeezed' due to this rise in temperature and increasing oxygen depletion at depth. A reduction in cold water fish numbers is already being seen in the lakes of the Cumbria High Fells Character Area; numbers of Vendace in Bassenthwaite Lake have declined.

Picture 3.4 - small waterbodies such as Tewet Tarn © Ian Crosher

An increase in temperature may also increase the frequency and duration of toxic algal blooms, reducing the water quality of lakes. This may also have an impact on the attractiveness of the area to visitors.

As well as temperature changes, climate change will alter rainfall patterns which will impact on freshwater habitats. Climate change may increase the rate of physical processes such as erosion in the Cumbria High Fells Character Area. An increase in winter rainfall may increase erosion in winter, resulting in more nutrients being washed into lakes and rivers. This will exacerbate nutrient loading form other sources including agriculture. An increase in erosion will also increase the sediment load of lakes and rivers, impacting on freshwater plants. Outflow from disused mines may also contribute to sediment loads during periods of high rainfall.

A decrease in summer rainfall may lead to a decrease in lake water levels. This is particularly significant for shallow lakes and tarns where exposure of littoral communities and erosion of marginal features may reduce the amount and quality of habitat available for freshwater species. In addition, a decrease in lake levels increases susceptibility to nutrient enrichment as the amount of water available for dilution and flushing of nutrients is reduced. A decrease in water quality will have a significant impact on the ability of the lakes to support freshwater species.

The combined impacts of climate change in freshwater systems may be more detrimental to biodiversity than individual changes. For example the combined effect of an increase in water temperature, increased sediment loading, lower water levels in summer and increase algal growth will impact on salmonid fish species. However, microcosm studies have suggested that warming is not the only driver of change in lake ecosystems; nutrient loading and the presence of predatory fish are potentially more important drivers of lake function than temperature (McKee *et al*., 2002a; McKee *et al*., 2002b; Moss *et al*., 2003). Whilst nutrient loading may be increased as a direct result of climate change through increased erosion rates, more significant sources are likely to be agriculture and tourism (see ‘indirect impacts’ below).

In addition to water bodies, the Cumbria High Fells has a range of wetland habitats associated with lakes and rivers, all of which could be detrimentally affected by changes in rainfall. The predicted reduction in summer water levels in reed beds and purple moor grass and rush pasture is likely to lead to a reduction in associated species. More frequent droughts would severely affect wet woodland, veteran trees and the moss flora of many of the woodlands found in the Cumbria High Fells Character Area. This in turn would lead to a reduction in associated species and a loss of landscape character. This is likely to be a significant impact for the Cumbria High Fells as scattered trees are an important component of the landscape.

However, wetland habitats may also be damaged by an increase in flooding in winter due to more rainfall and more storm events. Prolonged inundation of purple moor grass and rush pasture could cause a shift towards true fen or swap communities. Birds associated with reed beds and ground nesting birds are increasingly vulnerable to flooding. An increase in winter rainfall may also be detrimental to blanket bog peat wash out, especially which is currently in an unfavourable condition due to overgrazing and gripping.

Flash floods can damage vegetation and cause soil erosion. An increase in the frequency of intense storm events may reduce the ability of habitats to recover.

Greater variation between seasons may put pressure on habitats and the ability of species and habitats to recover from repeated seasonal drought and flood events may be compromised.

An increase in the frequency and intensity of storms may impact on the significant natural environmental assets of the Character Area. Woodlands and isolated trees are at particular risk of high winds associated with storms (see Figure 3.3) but although loss of isolated trees is significant, damage to woodlands from high winds is not necessarily a biodiversity problem and can actually be beneficial in creating greater heterogeneity. Where semi natural woodland is of a similar age structure, these storm events may open up areas where young tree regeneration will take place. However, there are uncertainties over predictions of future storminess. The UKCIP02 scenarios suggest that storm tracks may move south although the confidence ascribed to this is low.

Picture 3.5 – Oak trees, Brotherswater

A consequence of an increase in temperature and a decrease in rainfall in summer may be an increase in the risk of heathland and bracken fires in the Cumbria High Fells Character Area. Currently fire risk in the Character Area is low and burning is not currently used as a management practice. However, the impacts of fires on biodiversity are not necessarily all negative**.** The timing of fire is important: spring or winter fires tend to flash across the surface (assuming the ground is wet) and vegetation regeneration is usually quite rapid. In some instances where fires are quite small and occur in areas where scrub reduction is desired they can turn out by chance to be beneficial. Deep seated summer fires are more serious as they damage seeds and roots and regeneration is much slower.

Air quality can be impacted by climate change and there may be consequent impacts on biodiversity. Concentrations of low level ozone are predicted to increase as temperatures warm. Ozone pollution can affect biodiversity; beech and birch are sensitive to ozone and studies of ozone effects on grassland communities have reported changes in community composition (Morrissey *et al*. 2007). Other habitats, such as wetlands, heaths, montane and inland rock habitats are poorly studied although there is some evidence that montane habitats and bogs are sensitive to ozone (Morrissey *et al.* 2007).

Indirect impacts

In addition to direct effects of climate change, the biodiversity of the Cumbria High Fells Character Area will be impacted by indirect impacts of climate change on other sectors that interact with biodiversity. The key sectors in the Cumbria High Fells Character Area are agriculture and recreation. Changes in agricultural practices as a result of climate change may have a greater impact on biodiversity than direct biophysical impacts.

The upland farming system has always been restricted by the amount of good valley land available. This pressure has lead to the reclamation of much of the lower lying land from the natural meandering river. An increase in the area of cultivation in the valley bottoms as a response to longer growing seasons and the cultivation of new crops may exacerbate the pressure on land and semi-natural habitats in the valleys and lowlands. Grazing changes will also be required in response to changing patterns of vegetation growth. It is likely that winter growth will increase as temperatures warm, drought in summer may restrict growth, leading to an increase in grazing in winter.

However, agriculture is important in maintaining the existing significant environmental assets as currently defined in Section 2. A reduction in agricultural activity could have negative effects for some of the valued semi-natural habitats and landscape features in the Character Area through the abandonment of hard to manage habitats or features such as purple moorgrass and rush pasture or walls.

Agriculture also affects the permeability of the landscape, allowing migration of species along habitat networks. Creation and extension of biodiversity-friendly networks will be constrained by the presence of intensive agricultural land uses impermeable to species. These indirect impacts of climate change will be mediated by the prevailing socio-economic scenario in the future (see Appendix 3) and the state of agricultural economics is hard to predict. The future of agriculture in the Cumbria High Fells Character Area is also intrinsically linked to the policy and economics of continued grazing in the uplands.

In addition to agriculture, recreation is a significant driver of change in the Cumbria High Fells Character Area. The potential impacts of an increase in tourism and recreation on biodiversity in the Cumbria High Fells are identified in Section 3.3.2. Montane plants are particularly susceptible to trampling by visitors and freshwater habitats are at risk from an increase in water based recreation. The increase in tourism in the shoulder season (spring and autumn) in response to warmer temperatures may have a negative impact on ground nesting birds.

3.3.2 Impacts on access and recreation

Direct Impacts

Whilst the greatest impact on access and recreation assets may be due to an increase in visitor numbers (an indirect impact of climate change) there are a number of direct impacts of climate change on recreation assets. Some of the most significant recreational assets in the Cumbria High Fells Character Area are the lakes. Lakes attract many visitors to the area and are extensively used for water-based recreation. There may be an opportunity to develop lake tourism further as people seek shade and cooling. Activities such as swimming may become more popular as water temperatures increase as people head to the Lakes to cool off.

Summer drought will lead to decreasing lake levels and a reduction in water available for recreation in rivers. There is likely to be increased pressure on lakes for water-based activities at the time when water levels will be at their lowest, resulting in over-crowding and detrimental impacts on lake and river ecology. A decrease in water quality (due to reduced dilution of pollutants) and an increase in algal blooms may also affect the recreation potential of the lakes during summer. As well as being unsightly, blue-green algae can have negative effects on human health. Both impacts pose a health and safety risk and may reduce the overall attractiveness of the Character Area to tourists and visitors.

A further consequence of warmer temperatures in water environments is an increase in pests such as midges. This could reduce the attractiveness of the area to visitors. Possibly more serious is the potential for the re-introduction of vector borne diseases such as malaria. The Health Protection Agency (HPA) has mapped malaria suitability under recent climate and a range of future climate scenarios illustrating the number of months introduced mosquitoes could persist in the UK. Under the 2080s medium-high emissions scenario, the risk of malaria transmission is predicted to increase in North West England (HPA 2008).

The recreational potential of the lakes may also be reduced by climate change in winter. Increases in winter rainfall and more frequent storm events may result in flooding which would also reduce the recreational opportunity provided by the lakes. Footpaths and campsites at the edge of lakes may also be susceptible to flooding. However, flooding is likely to be a localised impact that will occur outside the peak visitor season. Flooding is therefore, unlikely to have a significant effect on the access and recreation potential of the Cumbria High Fells Character Area.

The most significant impact of increased winter and summer rainfall intensity is likely to be an increase in channeling and gullying on footpaths and other rights of way, leading to more rapid erosion. Frost heave in winter loosens soil and de-compacts paths, which are then easily washed away. This impact is predicted to lessen with the reduction in frosts. (Loxham & Davis, 1996)

Picture 3.6 – Footpath on Blencathra © Ian Crosher

Woodland based recreation is likely to increase in popularity as people seek shade in the hottest months and there will be an opportunity to develop visitor facilities at woodland sites. However, climate change may pose health and safety risks in woodland areas; woodlands susceptible to wind-blow from storms may become hazardous due to falling branches. In addition, tick-borne diseases such as Lyme disease may become more prevalent in woodland areas as warmer temperatures allow rapid development between tick stages (HPA 2008). However, there is no simple correlation between temperature and incidence of Lyme disease, other factors such as agricultural and wildlife management practices and increased exposure may be responsible for an increase in cases (HPA 2008). Increased use of woodland may have consequences for biodiversity, for example to deer.

An increase in fire risk in the Cumbria High Fells Character Area may impact on tourism, potentially leading, in extreme cases, to the closure of rights of way and visitor attractions to prevent accidental starting of fires by visitors. Should a fire occur, there is the potential for severe damage by fire to recreation assets such as historic sites and valued landscapes. Following several weeks of unusually warm, dry weather in summer 2007, a fire began on the eastern slopes of Barrow Fell, near Keswick. It burned unchecked for five days and devastated more than 100 hectares (Flora of the Fells 2008).

Hotter, drier summers may also lead to more incidences of heatstroke and other heat related illnesses. Currently, winter is seen as the high risk season for recreation. Under conditions of climate change, the hazardous season could shift to the summer and more people may need to be rescued due to heat stroke and heat exhaustion.

Some activities currently offered by the Cumbria High Fells Character Area may no longer be viable as climate changes. It is likely that the increase in winter temperatures will reduce the extent of ice and snow in the uplands of the Character

Area, resulting in the loss of winter climbing as a recreational activity. If winter climbing were to continue in a warming climate, the damage to crag flora would be significant.

Indirect impacts

The indirect impacts of climate change on recreation assets in the Cumbria High Fells Character Area are due to an assumed increase in visitor numbers as a response to an increase in temperature. Visitor numbers may also increase as UK-based holidays become more popular due to "carbon pricing" which may make too expensive or where temperature rises have made the local climate too uncomfortable. Whilst this assumption may be valid under the current socio-economic scenario, this may not be the case under alternative scenarios where people have different attitudes towards the environment and nature conservation has different objectives. The assumption that visitor numbers would increase has been made in this report and in Table A4.1 in Appendix 4.

A rise in temperature and the consequent rise in visitor numbers can be seen as an opportunity or a threat for the Character Area. In terms of recreation and enjoyment of the natural environment, climate change may present an opportunity. Currently, the amount of winter tourism in the Cumbria High Fells is lower than spring or summer; the impact of climate change may be to extend the tourist season as the autumn and spring months become popular. It is anticipated that the greatest increase in visitor numbers will be in the shoulder months. In the Cumbria High Fells there are likely to be particular opportunities for woodland and water based activities and water side locations as people seek cooler, shadier places in the warmer months

Picture 3.7 – Cyclist Langdale

However, an increase in visitor numbers may have negative impacts on wildlife and landscape and the opportunity must be carefully managed to prevent it becoming a threat. A number of potential negative impacts of an increase in visitor numbers can be identified including:

- Even greater congestion at 'honeypot' sites or on popular rights of way leading to a reduction in visitor experience and wilderness quality.

- Increase in litter, noise and pollution.
- Increased use of water bodies and navigable waterways causing congestion and increased erosion of banks.
- Greater pressure on water resources and sewage treatment works.
- Increased demand for visitor infrastructure e.g. accommodation and resources.
- Congestion on transport infrastructure e.g. roads, car parks, trains.
- Footpath erosion leading to increased run-off and sedimentation of rivers and lakes.
- Increased disturbance to sensitive wildlife.

An increase in visitor numbers in the Character Area may reduce the wilderness quality associated with the Cumbria High Fells Character Area. An alteration in people's perception of the Character Area may make it less attractive to tourists and visitors.

3.3.3 Impacts on landscape, historic environment and geodiversity

Direct impacts

Section 2.2 identifies the significant landscape, historic environment and geodiversity assets present in the Cumbria High Fells Character Area and Tables A4.1 and A4.1b describes the likely impacts. Changes in the elements and patterns that shape landscape character have an impact on the overall quality of the countryside (CQC, undated). Climate change will directly impact on the landscape of the Cumbria High Fells. Whilst broad habitat types may persist (e.g. woodland, heathland) the characteristic species that make up that habitat may be different, thus altering the appearance of the landscape. Whilst individual changes may be small, the cumulative effect on the landscape may be much larger. Where they are able to, habitats are expected to move upwards in response to climate change. The result will be an alteration in the appearance of the landscape with an increase in lowland features. Upland landscapes will be squeezed into smaller areas on the highest slopes, thus reducing the upland character of the Cumbria High Fells.

The smaller tarns and freshwater streams may be particularly at risk of drought and low water levels in summer. This is likely to be a significant impact for the Cumbria High Fells as the lakes and tarns are important components of the landscape.

Upland landscapes may also be impacted by climate change as some of the blanket bog and arctic alpine species that persist now may not survive drier, warmer conditions and may be lost from the landscape. Blanket bog which is already in poor condition will be particularly susceptible to drying out.

Picture 3.8 – Exposed Peat, Matterdale Common © Ian Crosher

The impacts of climate change on the landscape of the Cumbria High Fells Character Area are likely to be significant in the valleys. The combined impact of drought stress in summer and an increase in the severity of storms may lead to the loss of trees from lowland landscapes in the Character Area. Mature and parkland trees will be particularly susceptible to drought. Lowland trees are an important feature in the Cumbria High Fells as they 'frame' Lakeland views.

In addition to changes to existing assets, new features may become more prominent within the landscape. Bracken and scrub are likely to grow faster under climate change and, without management, will dominate the landscape more than they do at present**.** An increase in scrub would however, be beneficial to species movement as scrub is a permeable habitat and will be an important component of an adapted landscape. However, an increase in bracken and scrub is likely to be detrimental to the historical environment, particularly archaeology and historical field markings.

Warmer, wetter conditions are likely to accelerate physical processes such as weathering and erosion. This is likely to impact on the landscape of the Cumbria High Fells Character Area, particularly in the lowlands where the underlying geology is softer and in valleys containing river systems.

Climate change will also impact on the historical environment. Drying out of peat soils may also lead to the disturbance of buried archaeology. Some of the historic features of the Cumbria High Fells landscape are traditional dry stone walls and structures associated with the mining industry. These features are likely to be affected by subsidence caused by the drying out and cracking of soils during periods of drought or slumping in wetter winters or by an increase in the risk of flooding. The repeated cycle of wetting and drying may affect the foundations of historic buildings and may exceed their capacity to support the structure. Although the historic environment resource may be affected by direct climate change factors, the indirect factors leading to

inappropriate changes in land management and agricultural practices continue to be the most significant threat.

The Cumbria High Fells Character Area exhibits a number of characteristics of robustness to climate change (see Box 4.4). Whilst the extent of permeable habitat networks is not great (see Figure 4.1 below), the Character Area benefits from significant topographic variation; the Character Area possess extensive high open upland areas of semi natural vegetation as well as more gently sloping lowland areas. There are many land cover types within the Character Area; Table A4.1 lists twenty-eight different habitat types. The range of habitats also leads to a range of vegetation types. The Cumbria High Fells Character Area is thus potentially more robust to climate change than many other areas of England, although the lack of networks and habitats in poor condition could constrain its ability to adapt.

Indirect impacts

It is likely that the indirect impacts of climate change on agriculture could have a greater impact on the landscape of the Cumbria High Fells Character Area than any direct impacts. Changes in agricultural production in response to climate change will alter the appearance and character of the landscape. For example, re-intensification of agriculture in the lowlands due to improved growing conditions and new viable crops may result in loss of woodland and grassland habitats. Vegetation growth is likely to increase with warmer temperatures leading to changes in grazing regimes.

Box 3.3 Resilience and robustness to climate change

When evaluating the impacts of climate change on landscapes, the terms robust and resilient are potentially useful. However, there are subtle differences between the terms. Resilience is defined in the climate change literature as '*the ability of a system to recover from the effect of an extreme load that may have caused harm*' (UKCIP 2003) whilst robustness is defined as '*the ability of a system to continue to perform satisfactorily under load'* (UKCIP 2003). In terms of climate change and the natural environment, a resilient landscape can be thought of as one that can recover following an extreme climate event (such as a storm or flood) although recovery may not be to the same condition as it was in prior to the event. Recovering from climate change will involve a shift in state; recovery to the status quo will not be sustainable in the long term.

A robust landscape can be thought of as one that continues to function under the stresses caused by prolonged changes in temperature and rainfall. In order to continue functioning a robust landscape must posses the ability to change in response to climate change e.g. species need to be able to move. A robust landscape is likely to possess extensive, permeable habitat networks and exhibit heterogeneity within and between habitats. Landscapes robust to climate change are likely to possess the following features (Hopkins *et al*. 2007):

- high permeability;
- variation in topography – slope, aspect and height;
- soil diversity;
- numerous land cover types;
- diverse and structurally varied vegetation;
- diverse water regimes.

Changes in the agricultural systems may result in the loss of characteristic enclosure patterns. Increasing field sizes and the removal of boundaries could reduce the length of hedgerow and stone walls could fall into disrepair. An increase in agricultural land use may also obscure historic field patterns and reduce access to archaeology.

Picture 3.9 – Upland heathland, Caldbeck Fells © Ian Crosher

Conversely, a de-intensification of agricultural activity may also negatively impact the landscape of the Character Area. The Cumbria High Fells has thin, poor soils and a harsh climate which make agriculture difficult. Due to this much of the land will only ever be suitable for raising livestock which often has a low market value, making the hill farming system fairly dependent on the environmental subsidies and schemes given by government for managing this high quality landscape

Habitat restoration as a response to climate change may alter the landscape of the Cumbria High Fells Character Area. However, at this point it is thought that the scale of change will not be great enough to significantly alter the landscape character and would mainly strengthen it.

Changes to the landscape of the Cumbria High Fells alter people's perception of the area. The Lake District is seen as an iconic landscape and changes such as loss of snow in winter could impact on cultural perceptions related to the natural environment, which may affect recreation and tourism.

3.3.4 Impacts on ecosystem services

Direct Impacts

Climate change will have a direct impact on the ecosystem services offered by the Cumbria High Fells Character Area (see Table A1.4). Reduced summer rainfall and more intense rainfall events will impact on the water resources available for water based recreation, potable water supply and habitats. Increased demand from these as a result of hotter, drier conditions will compound this issue, potentially resulting in a supply-demand deficit. This will impact on potable supply, recreation and biodiversity.

Agriculture will be indirectly affected by climate change through reduced water resources but it also faces direct impacts. Traditional sheep farming is likely to be impacted by climate change. The timing of grazing and stocking levels in the uplands

will have to change in response to seasonal changes in biomass abundance. Tick-borne diseases may become more prevalent as the temperature rises with implications for the treatment and dipping of sheep. An increase in temperature will also affect the shearing regime. There may be animal welfare issues in summer and farmers may need to provide shade for their livestock.

Forestry in the Cumbria High Fells Character Area may benefit from climate change. A longer growing season may favour commercial forestry species and could provide timber for coppicing, charcoal production and wood fuel. However, wind-throw as a result of an increase in storm intensity may impact on commercial forestry. It is likely that new pests and diseases will be present in the Cumbria High Fells Character Area as a result of warmer conditions and this may directly impact on forestry and agriculture.

Fisheries will be directly impacted by climate change. The fish species supported by the lakes and tarns in the Character Area are likely to change as water temperature increases and dissolved oxygen levels decline. Stocks of traditional species may decline but may be replaced by newly viable species. There may also be seasonal changes in fish movements and spawning.

An increase in the rate of physical processes could impact on the soils and geology of the Character Area. There is a risk that soils will be more easily lost through increased erosion due to drying out of peat soils. An increase in the rate of fluvial processes could lead to river channel migration and consequent impacts on the landscape. Currently river channels are constrained in valley bottoms; in a more energetic system river courses are likely to alter their positions, usually in sudden events, putting settlements at risk of flooding. Some degree of natural flood protection is provided by floodplains in the valleys but more may be needed in the future. Increasing pressure on land use in valleys as a result of agricultural intensification and population growth may reduce the extent of floodplains and exacerbate this impact.

An increase in soil erosion and loss of biomass as a result of climate change may impact on the climate regulation function of ecosystems. Blanket bog is a significant store of carbon in the Cumbria High Fells Character Area. Drying out of peat soils and the blanket bog would release significant amounts of carbon dioxide to the atmosphere, exacerbating climate change. Carbon can also be released into streams in sediment forms, giving water a brown colour, increasing water treatment costs (RSPB undated).

Recreation and tourism will both be directly affected by climate change. The Cumbria High Fells Character Area may become more attractive as a tourist destination and visitor numbers are likely to increase, particularly during the shoulder seasons (spring and autumn). Recreation is also likely to increase in the Character Area under warmer, drier conditions. However, certain impacts of climate change may reduce the potential of the Character Area for recreation. The risk of fire, particularly on heathland areas, threatens to reduce the attractiveness of upland areas to visitors. Lower lake levels may limit the potential for water based recreation within the Character Area. An increase in midges and mosquitoes may also have a detrimental effect on the attractiveness of the Character Area to visitors, particularly affecting water based recreation.

Natural resources are increasingly being exploited for energy generation. An increase in sunshine hours in the Cumbria High Fells Character Area could increase the opportunity for solar energy generation. Exposed, upland sites are preferred for locating wind turbines and there could be opportunities to exploit this resource. In addition, a longer growing season may favour the growth of energy crops in the valleys and lowlands. There is an opportunity to produce wood fuel in the Character Area. Although much of the Character Area is unsuitable for short rotation coppice or miscanthus as the soil is unsuitable and would be damaging to landscape, there is potential for new long rotation coppice woodland and restoring existing coppice landscapes. The use of the natural environment for energy generation is likely to lead to conflict with landscape and biodiversity interests and will be another pressure on land use within the Character Area.

Indirect impacts

Indirect impacts of climate change will also be felt by ecosystem services. The recreational and tourism services offered by the Character Area are at risk of being negatively impacted by an increase in visitor numbers. As well as an increase in recreation and tourism, the use of the Character Area for outdoor educational purposes is likely to increase as conditions become warmer and drier. Trampling and footpath erosion are likely consequences of an increase in visitors. A further indirect impact of an increase in visitor numbers is increased pressure on water resources and infrastructure, exacerbating direct climate impacts (see above).

3.3.5 Socio-economic impacts

Climate change is not the only cause of change in the natural environment of the Cumbria High Fells. Agriculture and recreation changes will have a significant impact on the biodiversity, access and recreation and landscape and geodiversity assets of the area. Changes in these sectors are hard to predict as there is no certainty over which socio-economic scenario will prevail in the future (see Appendix 2). The Character Area project has not adopted a formal scenario based approach, nor does it provide an integrated assessment as these are highly complex. Instead, it is assumed that conventional development (mainly World Markets with aspects of other scenarios) will prevail. Table A3.5 in Appendix 3 provides some examples of socio-economic impacts, which could affect the species, habitats, landscapes and recreational function of the Cumbria High Fells Character Area. This is based on knowledge of socio-economic changes, informed by current trends and drivers (e.g. the Water Framework Directive; European and UK Climate Change Programmes) and the futures literature (e.g. Evans *et al*. 2004; LUC *et al*. 2006; OST, 2002; UKCIP, 2001).

Potential changes in the agricultural sector are likely to have significant impacts on the Character Area. Changes in crop markets will have a significant impact on land use within the Cumbria High Fells Character Area. For example, if the market for energy crops becomes favourable, farmers may switch from food production to energy crop production with resulting impacts on biodiversity and landscape. Alternatively, a rising population may increase the demand for food crops, likely resulting in re-intensification of agriculture in the Cumbria High Fells Character Area, particularly in the valleys. An increase in nutrient loading due to agricultural re-intensification would be a significant driver of change in freshwater environments and would lead to loss of species and habitats. Increases in grazing pressure would have negative impacts on a wide range of features. Grazing management (and associated nutrient inputs in the

lowlands) is by far the most significant factor affecting the state of the Lake District at present and is likely to be in the future.

One socio-economic change in the agricultural sector may be a shift in consumer demand towards more organic and local produce. This growth is already being seen and is likely to continue in future as people become more concerned with where their food comes from and how it is produced. An increase in organic farming could have benefits for biodiversity; a reduction in pesticide use may increase invertebrate populations which will have a beneficial impact on bird species. In addition, a reduction in the use of artificial fertilisers will have benefits for water quality and nutrient loading. An increase in demand for local, organic meat in the Cumbria High Fells may also be beneficial as it may help to ensure the persistence of grazing in the uplands.

Changes in the water industry such as an increase in water metering or the introduction of variable tariffs could also have benefits for the natural environment as it may help to alleviate the pressure exerted on water resources in the Cumbria High Fells Character Area. However, water efficiency savings could be exceeded by an increase in demand from a rising population within the Cumbria High Fells and especially in Liverpool and Manchester. An increase in sewage may increase nutrient loading in water bodies, exacerbating the impacts of climate change and agriculture.

Whilst climate change policy could drive an increase in energy generated from renewable sources such as wind and biomass, socio-economic changes could have a similar effect. An increasing oil price and concerns over security of energy supply may lead to an increase in renewable energy, putting pressure on the landscape of the Cumbria High Fells through installation of wind turbines or growth of energy crops. Exposed, upland sites are preferred for locating on-shore wind farms; hence the Cumbria High Fells Character Area could find itself under pressure from wind turbine development. There is already a problem with vertical communication structures on the landscape; wind turbines would exacerbate this and be detrimental to the landscape character as currently perceived.

As can be seen from the discussion above, climate change is not the only, or necessarily most important, driver of change in the Cumbria High Fells Character Area. The impacts of climate change are likely to exacerbate existing pressures in the Character Area. It is possible that the combined effects of climate change and other pressures will exceed the ability of the natural environment to adapt.

3.3.6 Policy implications

A change in species and community composition may have an indirect effect on the delivery of current conservation targets which include definitions of ‘favourable’ habitats. Under current, static definitions of ‘quality’, species and community compositional changes may make it more difficult to meet targets as climate changes. In addition, a potential increase in non-native and invasive species may threaten the delivery of conservation objectives.

4. Adaptation

Managing the natural environment so it is robust to climate change:

- In order for adaptation to be successful, the condition of all existing upland habitats, and particularly high carbon ones like blanket bog, must be improved.
- Grazing management is the key factor in controlling the current state of the fells and it will be necessary to ensure that grazing regimes (intensity, seasonality, type of animal) are appropriate.
- Investigate the future of artic alpine flora to determine if geology, trampling, grazing, climate or Victorian collection is the likely reason for present distribution and what potential future they could have under a substantially different grazing regime.
- Reverse some of the historic land improvements where this has proved to be detrimental to the environment and where supplementary benefits will also be achieved.
- Long term data sets and studies assessing environmental change will be very important to inform adaptive management.
- A common impact across all habitat types is the likelihood of species and community compositional changes, therefore current management and policy need to reflect this.
- Use the spatial planning system to maintain and expand adequate land for the natural environment.
- Remove conifers where they occur on ancient woodland sites and other habitats, particularly peat ones.
- Not all arctic alpine species will be lost and there are many positive actions that can be taken to conserve these for the future.
- Mountain areas will become refuges for species moving in to them from the lowlands, for this reason it is key that the natural environment within them is very resilient to climate change.
- New native woodland expansion needs to be encouraged up the fell side to allow species climate space to move up into.
- Expand semi natural habitats year on year so as not to suffer a net loss of biodiversity due to climate change. These should be directed where multiple benefits and ecosystem services are also delivered.

Develop carbon storage through a high carbon landscape:

- Upland land use needs to be managed to help to deliver climate change mitigation by protecting vulnerable soil carbon stores and improve the ability of upland habitat to sequester carbon dioxide.

Reduce sources of harm not linked to climate:

- For freshwater habitats, reducing nutrient enrichment from agriculture, pressure from recreation and low water availability due to abstraction will make them more robust.
- Continue to repair the most eroded footpaths through projects such as Fix the Fells.
- There are multiple benefits associated with whole system catchment management.
- An alien species policy and action is needed, where species that are detrimental are eliminated but new immigrants that have slotted comfortably into our ecosystems are accepted within our biodiversity and landscapes.

Develop ecologically resilient and varied landscapes:

- Expansion of habitats through restoration and creation will be required to address multiple sources of pressure.
- Increasing the variation within existing habitats through changes in management will increase their robustness to climate change.
- We need to accept New Species and manage for them e.g. Heath Fritillary butterfly, Sycamore. These species will be moving in from their southern distribution and finding a suitable climate within Cumbria. Many of these are presently widely introduced into the area, but are often removed because of being considered ‘non-native’.
- Naturally functioning and healthy ecosystems are more likely to be able to adapt to climate change.
- Habitats do not migrate as a result of climate change but will change their structure, species composition and dynamics within them. Some aspects of species and niche interactions will change as a result of climate change and others will not. E.g. Temperature will increase but light will stay the same, where these are limiting factors in the community composition they may change species interactions.
- Expansion and linking of habitats around existing high quality sites can help to buffer the effects of climate change.
- Make space for the natural development of rivers.
- There will be multiple benefits from implementing the national ‘Wetland Vision’

within the Cumbria High Fells.

- The landscape needs to be made more 'permeable' so that species can move through it.
- Any adaptation work needs to incorporate and protect our historic and cultural landscape.
- Monitoring change and adapting management accordingly will be critical

Recreation, tourism and economic adaptations:

- Recreation and tourism is very important for the economy of the area. The visitor experience can be further enhanced by the landscape and habitat improvements that will result from the climate change adaptation actions identified in this report.
- A sustainable food economy where food is sold to the local community and visitors will be a critical part of adapting to and mitigating for climate change.
- Indirect impacts on the natural environment could be the biggest threat to achieving an adapted Cumbria High Fells.
- Extensive farming systems are more appropriate than intensive ones for delivering an adapted natural environment and for enhancing the visitor experience.
- A local wood fuel economy would bring many more undermanned woods back into active management, improving their landscape and biodiversity value and giving an economic return to woodland managers, whilst also helping to mitigate and adapt to climate change.
- To address impacts on water resources and water quality it will be necessary to manage river catchments in a more holistic manner within and beyond the Cumbria High Fells boundary.
- Provision of shade for livestock within the hot summer months, through tree regeneration suggested to be provided in the intake fields on deep bracken areas.

Other adaptations and actions:

- Need to be aware and adapt to future potential catastrophic events, that may occur due to or be exacerbated by climate change such as the emergence of new pests and disease.
- Identifying research needs and commissioning appropriate studies can be seen as an early step towards building adaptive capacity that should increase the effectiveness of strategies when implemented.
- Policies will need to reflect the change in the distribution of species and the make-up of habitats. There is a need for further research and practical evidence to better inform decision making about adaptation.

Based on the impacts identified in Section 3, a list of adaptation responses for the Cumbria High Fells has been complied (see Table A4.2, Appendix 4). These have been informed by Hopkins *et al*. (2007), who present guidelines for conserving biodiversity in a changing climate (see Box 4.2).

The adaptation responses have been tested against more generic criteria of effectiveness (see Section 4.2).

When defining adaptation actions, existing schemes, strategies and levers should be considered. Some actions defined as climate change adaptation may already be occurring under a different name or it may be possible to modify an existing programme to provide a mechanism for delivering adaptation. Climate change adaptation needs to be 'mainstreamed' into existing Natural England plans and policies such as Higher Level Stewardship but also those of other organisations.

It should be recognised that there may be policy, economic or other constraints to delivery of some actions; these are identified in Table A3.2. Additionally, some of the actions identified may not have a delivery mechanism at present. At this stage, all potential adaptive actions are included despite known constraints.

Box 4.2 Guidelines for conserving biodiversity in a changing climate, Hopkins et al (2007)

1. Conserve existing biodiversity;
   1. Conserve protected areas and other high quality habitats;
   2. Conserve range and ecological variability of habitats and species;

2. Reduce sources of harm not linked to climate;

3. Develop ecologically resilient and varied landscapes:
   i. Conserve and enhance local variation within sites and habitats;
   ii. Make space for the natural development of rivers and coasts;

4. Establish ecological networks through habitat protection, restoration and creation;

5. Make sound decisions based on analysis:
   i. Thoroughly analyse causes of change;
   ii. Respond to changing conservation priorities;

6. Integrate adaptation and mitigation measures into conservation management, planning and practice.

4.1 Biodiversity responses

The Hopkins *et al.* (2007) principles for adapting biodiversity to climate change can be applied to the Cumbria High Fells.

4.1.1 Conserve existing biodiversity:

- **conserve protected areas and other high quality habitats;**
- **conserve range and ecological variability of habitats and species**.

Climate change is likely to have a significant impact on the Cumbria High Fells Character Area. The impacts of climate change will be felt most in habitats which are already degraded or in poor condition. The most important drive within the High Fells will be to improve the condition of existing habitats. This is particularly true of the fells management which over many years has been far from ideal for the natural ecosystems and as such, the majority of habitats are in poor or degraded condition. Over recent years management and grazing levels have been closer to what is required to ensure favourable condition in SSSIs but it will take a long time for these habitats and those BAP habitats not yet addressed to attain a condition that is robust to climate change.

Picture 4.1 – Juniper on Carrock Fell © Ian Crosher

Presently the Cumbria High Fells has a very high quality biodiversity resource but many habitats are degraded. Many of these degraded habitats are subject to agri-environment agreements through schemes such as the Environmentally Sensitive Agreement (ESA), but are often not in the appropriate tier. Currently agri-environmental agreements are not being used to their full potential in the Cumbria High Fells Character Area and there is a need to ensure habitats are covered by the most effective scheme.

The topography of the area and the varied geology gives rise to rich ecological variation within the character area. The nature of upland areas such as the Cumbria High Fells is constantly changing, with many different habitats and microclimates present. The loss of certain features such as upland woodlands and scrub and the nature of heavy grazing since the Second World War has reduced this level of

variation. With correct management this variation could be restored within management units and across the Lake District hills. An example of management would be the cultivation of arable plots in the upland valleys for on-farm feed; these could increase variability of the landscape for birds, but will need careful siting to prevent detrimental effects on other habitats.

Translocation of species at particular risk from the impacts of climate change may be necessary to ensure their survival. Schelly have already been translocated to Blea Water. Arctic-alpine flora has been identified as at particular risk from the impacts of climate change. One response may be to grow propagules of these plants and translocate them.

A number of management practices are suggested in Table A1.2 that aim to maintain and enhance current significant natural environmental assets in the Character Area through adaptive management. Adaptive management involves modifying existing management practices in the face of uncertainty, in this case due to climate change.

The adaptive management approach involves making a change to an existing management practice and monitoring the results to ensure the response is effective. As a result of monitoring, the management practice may need to be reviewed again. Examples of management strategies that lend themselves to adaptive management include reviewing and enforcing appropriate grazing levels on montane upland grassland and heath depending on vegetation response to climate change (see Figure 4.1). For further discussion of grazing options for the Cumbria High Fells see Box 4.2

Adaptive management has a number of advantages over more radical adaptation options. It is relatively inexpensive as it is already an ongoing process which needs modification rather than a step change in approach to management. It is also a flexible approach and that should be able to quickly respond to change, assuming the change is gradual rather than a series of large shifts. Adaptive management is useful in dealing with those impacts which are uncertain as the response can be altered on an iterative basis depending on the results.

Box 4.2 Strategic grazing options for the Cumbria High Fells

It is evident that at present, many of the habitats in the Cumbria High Fells are in an unfavourable state. One of the contributing factors to this is inappropriate grazing levels, stock and locations. However, in many locations some form of grazing is required to maintain habitats in their optimum condition. Getting grazing right is crucial to maintaining the condition of habitats and landscapes within the CA and increasing its robustness to climate change. Presented below are a number of strategic options for the future of grazing in the Cumbria High Fells. These grazing options are for discussion and would not be appropriate in all areas, but possible in one or two trial places. Different options will be suitable for different locations within the Character Area and as such should not necessarily be seen as discrete choices for the Cumbria High Fells.

Option 1 – No grazing in the Uplands

In order to ensure upland habitats are in the best condition possible then sources of undue pressure need to be removed. One way of doing this would be to remove all grazing from the uplands, allowing land above the fell wall to re-naturalise and the treeline to redevelop (although it will continue to rise up the mountain sides as temperatures rise). However, this is likely to affect in-bye fields as there is no upland farming system present, leading to potential land abandonment in the valleys. Intermediate habitats and heathlands may also suffer over the longer time period.

Option 2 – Native cattle roaming natural uplands

This option involves the removal of the current stock system of sheep and replacement with a number of native cattle breeds roaming the upland blocks (see Figure 4.1). This approach has been trialled in Ennerdale. This option has the advantage of not losing grazing altogether from the uplands but could facilitate the suppression of undesirable habitats and increase variation in important habitats. There may also be some economic benefits from cattle and an increased deer population.

Option 3 – Extensive mixed grazing system

Option 3 proposes a mixture of cattle and sheep grazing at appropriately low levels. This option would retain the upland farming system, and may therefore be more economically viable than options 1 and 2; it may also deliver a low carbon agricultural system. HOW?

Option 4 – Stock exclusion from certain habitats

This option would need to be more targeted but would concentrate on removal of sheep from habitats most at risk from climate change. For example montane heath and artic alpine areas which are very susceptible to grazing pressure could benefit from this approach. This option could also determine no grazing zones possibly around upland watercourses. This would allow larger areas of heather and moss to develop with scattered trees and scrub, increasing water retention in catchments.

4.1.2 Reduce sources of harm not linked to climate

Climate change may be the 'tipping point' that prevents the Character Area from recovering from the in-combination effects of all sources of pressure, particularly in the case of freshwater ecosystems. In addition, the legacy of past sources of pressure on the natural environment may restrict the ability of the Character Area to adapt to climate change. It is thus vitally important that efforts are made to address other sources of pressure in order that habitats are more robust to climate change.

Reducing sources of pressure other than climate change is particularly important for freshwater habitats as they are already susceptible to nutrient enrichment from agriculture and recreation and low water availability due to abstraction. Table A1.2 identifies a number of responses for freshwater habitats that aim to reverse the impacts of historical management including:

- Increasing the ability of catchments to retain water through upland planting or successional areas and the good condition of bog habitats.
- Restoring river channels to their natural course.
- Restoring connectivity between river channels and their floodplains.
- Reduce nutrient loading for pollution within and outside the Character Area.
- Prevent pollution into water through resource protection of defuse pollution and direct inputs through storm drain overflow.

Picture 4.2 – suppressed heather © Ian Crosher

Blanket bog is another habitat that has been damaged by past management that will be susceptible to the impacts for climate change (see Figure 4.2). In order for adaptation to be successful, the condition of existing blanket bog must be improved. Responses to improve the quality of existing habitat include:

- Reduction or complete removal of grazing on blanket bog.
- Encourage a diverse species composition and the re-colonisation of Sphagnum mosses.

- Grip and drain blocking (not extensive areas in Cumbria High Fells).
- Re-vegetating bare peat with peat forming species.

Indirect impacts of climate change on the Character Area will be felt through changes in agricultural practice and recreation. A number of adaptive management responses can be used to respond to changes in agriculture but the main tool for ensuring the maintenance of the natural environment in the face of agricultural change will be agri-environment schemes. A number of adaptive management responses identified in Table A1.2 can be delivered through environmental stewardship schemes.

In order that upland habitats are robust to climate change, all other sources of pressure must be removed. Allowing land above the fell wall to re-naturalise by reducing grazing and allowing larger areas of heather and moss to develop with scattered trees and scrub will increase the robustness of this landscape to climate change. In particularly sensitive areas, grazing stock may need to be excluded in order to reduce the damage caused by over-grazing. Habitats that would benefit form this approach include blanket bog, montane heath and artic alpine areas, as they are very susceptible to grazing pressure.

Recreation has also affected the biodiversity of the Cumbria High Fells. An increase in visitor numbers due to warmer temperatures will exacerbate impacts due to recreation. There may be particularly detrimental impacts on montane species from an increase in recreation due to trampling of sensitive plants. Education of visitors through interpretive signing may reduce this pressure but fencing may be required to prevent it entirely. However, erection of fences would have a negative impact on landscape. Another solution is to use more subtle path building techniques, as has been done in the Fix the Fells project. Changes to paths and positioning of rocks are used to direct where people walk, avoiding trampling sensitive plants.

Habitat restoration and creation will be required to address these multiple sources of pressure. In addition to responding to the direct impact of climate change, this will allow other issues such as habitat fragmentation due to agricultural intensification and recreation to be addressed. The greater the area of good quality habitat, the more robust the landscape will be to the impacts of climate change and other pressures.

4.1.3 Develop ecologically resilient and varied landscapes:

- **conserve and enhance local variation within sites and habitats;**
- **make space for the natural development of rivers and coasts**.

The degree of heterogeneity in the landscape of the Cumbria High Fells means that tailored adaptation strategies will be required in different areas. Increasing the heterogeneity of existing habitats will increase their robustness to climate change. Responses such as planting a mixture of woodland trees and increasing riparian shading through floodplain planting would be good examples of a method of increasing heterogeneity within habitats and networks.

Picture 4.3 – Blencathra from Tewet Tarn © Ian Crosher

At present the same grazing formulas are applied across all SSSI blocks in the Cumbria High Fells to achieve favourable condition. In order to adapt to changes in biomass productivity, grazing will need to be managed in different ways at different sites. For example, the timing and stocking level required to manage habitats on Helvellyn will be different from those required at Skiddaw and the Buttermere Fells. It may also be necessary to increase heterogeneity within blocks; this is complicated by the presumption against fencing in the Character Area for landscape reasons.

Increasing the diversity of riparian habitats has been identified as an important response to climate change in freshwater habitats. Increasing catchment heterogeneity through planting of wet woodland and development of fen and scrub on floodplains will improve the ability of freshwater systems to adapt to climate change.

A direct impact of warmer conditions is an increase in the prevalence of pests and diseases within the Character Area. A common response across all habitat types is the need to be aware of future potential catastrophic events that may occur due to or be exacerbated by climate change such as the emergence of new pests and diseases. This response requires ongoing monitoring of species and habitats at the same time as preparing contingency plans. It is important that lessons from previous events such as the storm of January 2005 in the north west and Dutch Elm disease are learnt and that past experience is used to inform the development of future management responses. We can also look to other locations with similar climates to that which England may experience in future to identify potential threats.

There is a need to establish different grazing systems in different areas to take account of habitat heterogeneity (see Box 4.2). For example, in some upland areas it would be beneficial to remove sheep grazing and replace it with a number of native cattle breeds. This technique has the advantage of not removing all grazing but allows

variation in habitats to be maintained. There are also likely to be some economic benefits from cattle and an increased deer population.

The Cumbria High Fells Character Area possesses some of the least disturbed rivers in England, but there are still many that are canalised. The holistic management of river catchments within and beyond the Character Area border will be important if freshwater ecosystems are to be resilient to climate change. Catchment management involves more than just re-naturalising the river course; floodplains can be re-instated and re-connected to the channel and upstream planting can reduce overland flow into channels. There are multiple benefits associated with catchment management: it can increase the diversity of the freshwater and terrestrial habitats; there are benefits for landscape; it reduces downstream flooding and reduces the amount of sediment currently being washed into the lakes.

4.1.4 Establish ecological networks through habitat protection, restoration and creation

The extent to which plants and animals can move in order to adapt to the effects of climate change will be an important factor in their continued persistence at specific locations (Catchpole 2007) thus increasing the area of suitable habitat is likely to aid the conservation of species. In order to maintain the same degree of biodiversity in the face of climate change, more habitat is required. It is therefore essential to extend the existing habitat network in the Cumbria High Fells Character Area and beyond (see Box 4.3).

To date, habitat network maps have been created for three of the habitats present within the Cumbria High Fells Character Area: woodlands, grasslands and heathlands (see Figure 4.3). Currently, the heathland and woodland networks are the most extensive in the Cumbria High Fells Character Area. There is a need to increase the extent of habitat networks within the Cumbria High Fells Character Area in order to increase robustness of the landscape to climate change. Habitat networks can be extended at the habitat scale through maintenance of existing high quality habitats, habitat restoration and re-creation.

A number of responses in Table A1.2 highlight the need for habitat restoration throughout all the habitat types in the Cumbria High Fells Character Area including:

- Increasing the diversity of riparian habitats through regeneration of woodland, scrub, fen through the de-canalisation of the river systems.
- Increasing the size of woods in intensive agricultural areas and linking sites together.
- Scrub expansion as a permeable species conduit and increase in the woodland network.
- Convert species poor acid grasslands to heather and bilberry shrubs on thin soils and woodland on deeper soils often where bracken dominates.
- Expand montane habitats in general, and on north facing slopes in particular by removal of grazing pressures, this helps remove other pressures not related to climate change.

It will be necessary to make decisions about the relative value and importance of habitats prior to large scale habitat creation. The woodland and heathland networks overlap in the Cumbria High Fells; therefore choices must be made regarding which

habitat to extend in which locations. Currently, there is not enough grassland habitat within the Cumbria High Fells Character Area to form a network but it does have the potential to contribute to either the woodland or heathland network. The decision may be influenced by looking at the amount of the habitat and the extent of the network in neighbouring Character Areas or by assessing the ecosystem service offered by the alternative habitats. The relative value and desirability of ecosystem services may be mediated by the prevailing socio-economic scenario.

Creation of ecological networks cannot prevent biodiversity loss due to climate change, it can only reduce it and there is a danger of spending resources re-creating habitats that will not be sustainable under a changed climate. Similarly, habitat re-creation targeted at specific species may not be an effective response if the species is likely to be lost as a result of climate change. An example is the alpine saxifrage which is unlikely to persist under climate change. However, for other arctic alpine species the outlook is not so bleak and habitat restoration may be a feasible response to climate change. There may be physical constraints to habitat restoration, e.g. a lack of suitable soil conditions on which to recreate lowland grassland.

Habitat networks can be affected by the land use surrounding the habitat. Both thick conifer plantations and intensive agricultural grasslands with few field boundaries can act as barriers to species moving through the landscape. The addition of scrub in the right location can make the landscape more permeable to species. Supplementing the woodland networks could be achieved through extension of current scrub areas or planting of completely new areas. However, landscape issues would need to be considered and managed.

In the Cumbria High Fells the woodland network can be expanded to connect the Borrowdale and Bassenthwaite areas with the Grasmere and Ullswater networks. The heathland network could be strengthened between the Skiddaw and Helvellyn ranges and the Skiddaw and Buttermere Fells.

Box 4.3 Habitat Networks

The England Habitat Network (EHN) illustrates the existing networks of woodland, grassland, heathland and mires and bogs present in England. A habitat network is made up of current statutory sites and sites listed on habitat inventories and surrounding land that is potentially permeable to the species present in the habitat of interest. Different types of land use, in-between patches of semi-natural habitat, will have different levels of permeability for different species (Catchpole 2007); the network joins up those sites which are separated by potentially permeable habitat or land use. To maintain the same degree of biodiversity in the face of climate change, more habitat is required.

With regard to the EHN there is a need to prioritise habitat creation action (highest priority action at the top):

- Subject to 'ground truthing', aim to maintain the existing mapped EHN for its value as an aggregated area of existing habitat patches.
- Consider extensions/additions to the habitat patches, including the expansion of pinch-points, within the EHN.
- Expanding existing habitat patches in networks outside the EHN.
- Expand small isolated patches in 'hostile' environments.

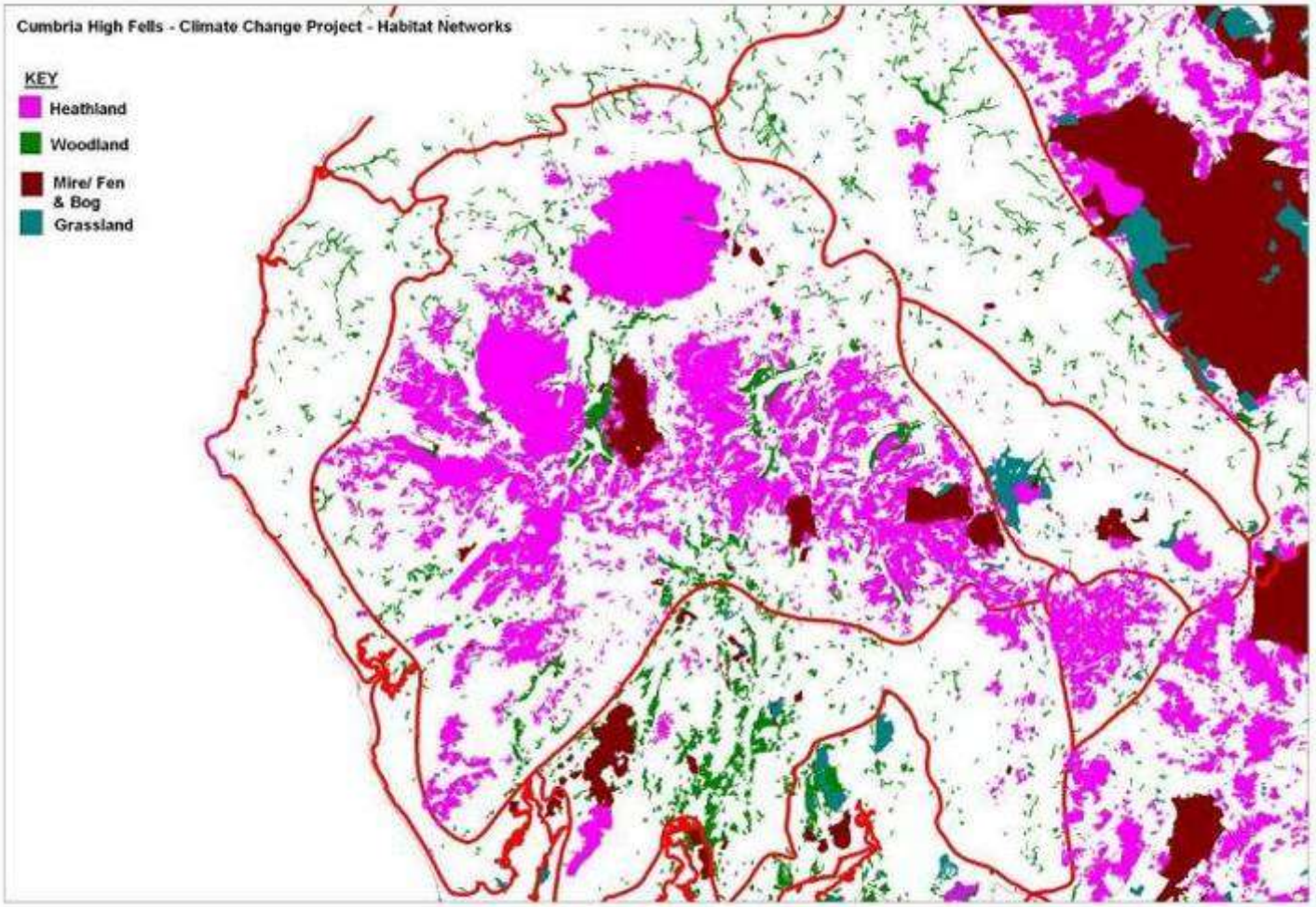


Figure 4.3 Habitat networks in the Cumbria High Fells Character Area

4.1.5 Make sound decisions based on analysis:

- **Thoroughly analyse causes of change.**
- **Respond to changing conservation priorities.**

The fifth guideline for adaptation states that sound decisions should be based on analysis. Identifying research needs and commissioning appropriate studies can be seen as an early step towards building adaptive capacity that should increase the effectiveness of strategies when implemented. Responding to the impacts of climate change may be hindered by incomplete information. For example, in order to respond to the impact on woodland of a decrease in summer rainfall, research into local hydrology is required. In addition, research is required to identify which montane species will be most impacted by changes in snow cover, drought and competition and how to manage these changes.

It is clear that there is a lot we still do not know or understand and further work will be needed. Areas of research that would be particularly useful in the short term in the Cumbria High Fells Character Area are:

- A more detailed ecosystem services assessment for the Cumbria High Fells – this could use a rapid assessment such as used for blanket bog in the 'Moors For The Future' project.
- An assessment of the condition of blanket bog habitat in the Cumbria High Fells and the development of a restoration strategy to maximise carbon storage and capture.
- Investigation of the future of artic alpine flora to determine if geology, trampling, grazing, climate or Victorian collection are the likely reason for present distribution and what potential future they could have under a substantially different grazing regime.
- Scrub habitats inventory and identification of juniper sites as these are key habitats in a permeable landscape, but current information is id poor.
- Investigation of the condition of all habitats within the Cumbria High Fells Character Area.
- Research is also required to identify which invertebrate species currently present in the Character Area will be impacted by climate change.

4.1.6 Integrate adaptation and mitigation measures into conservation management, planning and practice

A common impact across all habitat types is the likelihood of species and community compositional changes and there is a need for policy to reflect this. Changing conservation objectives may require a radical shift in the current paradigms of conservation; non-native species may have to be favoured and the attitude towards alien and invasive species may have to change. Currently, species such as beech are seen as negative invaders which reduce the available space for more highly valued native species. However, if native species are no longer viable under conditions of climate change, attitudes towards non-natives may have to change. Is it possible that species currently considered of low conservation value in the UK, or invasives, may become so rare in their native habitat that the UK has a responsibility to conserve them.

Picture 4.4 – Ennerdale © Ian Crosher

Policy responses will also be necessary to reduce sources of pressure other than climate change. Environmental policy and regulation will be mediated by the prevailing socio-economic scenario; attitudes to the environment, energy generation and development will all be dependent on socio-economics.

When it comes to the restoration of habitats, actions may be required now that will take until 2050 to demonstrate benefits. Long term objectives should be defined and incorporated into present habitat management regimes as soon as possible.

4.2 Access and recreation responses

In addition to the indirect impacts caused by an increase in visitor numbers, a number of direct impacts of climate change on access and recreation in the Cumbria High Fells Character Area can be identified. An increase in summer heat related illnesses may be significant and the area should ensure that is has an up-to-date heat wave contingency plan. The provision of shade and drinking water at tourist attractions will be important. It will also be necessary to assess water quality in summer and there may need to be restrictions on water based recreation during periods of poor water quality.

An increase in fire risk could be caused directly by hotter drier summers but is also influenced by visitor behaviour. Whilst the baseline fire risk is low, the risk will increase as summers become warmer and drier. There is uncertainty over the best way to respond to an increased fire risk in areas frequented by visitors. There is an argument that excluding people from an area can reduce the risk of a fire occurring.

However, the counter argument is that by closing areas, fire is less likely to be detected if it does occur.

There are a number of potential strategies for responding to the risk posed to recreation by fire, mainly focusing on raising awareness and fire prevention including a tiered warning system. This will raise people's awareness of the level of fire risk and encourage them to adjust their behaviour accordingly. Natural England already uses a Fire Severity Index provided by the Met Office. This works on 10km square grids across England and Wales to facilitate restrictions on open access land. The possibility of extending this scheme to cover all land in Character Areas at risk of wildfires could be investigated. The success of this scheme will depend on public awareness that it exists and what measures to take at different levels of risk. Land managers may be able to learn lessons from other places which use a similar system including National Parks in Australia and the south of France. Knowledge about communicating risk may also be available from the Environment Agency's experience with its tiered flood warning system.

A tiered fire risk warning system on its own will not prevent fires: it is a response to an increased risk of severe fires. The majority of wildfires in this country are either started accidentally or maliciously by people or result from controlled burns getting out of control. Fire 'prevention' therefore, needs to take a two pronged approach; hazard management (e.g. vegetation management) and risk management (e.g. education, enforcement and access restrictions).

Whilst preventing fires occurring is the primary objective of a fire risk reduction strategy, limiting the damage caused by fire when it does occur is also important. It is important that the response to fire outbreaks is quick, appropriately equipped and co-ordinated. There is now an England Wildfire Forum which looks at this issue (members include the Fire Service, Forestry Commission and Natural England). There is existing good practice in this area including the Peak District National Park Fire Operations Group which co-ordinates a fire plan (includes communication protocols, lists of contacts and who has the key for locked moorland gates) which enables quick mobilisation of personnel and off road equipment including that belonging to private land owners and managers. Training is also run through the fire operations group, including working with helicopters.

The most significant impact of climate change on access and recreation is likely to be an increase in visitor numbers. This can be seen as an opportunity for recreation as more people will be able to enjoy the countryside. There is also an opportunity to generate more revenue which could be spent on protecting the natural environment. However, the opportunities may present risks to significant natural environmental assets if they are not managed correctly. The suggested responses to an increase in visitor numbers are thus aimed at reducing negative impacts and ensuring recreation and tourism can continue within the Character Area in a way that is sustainable.

A key part of any visitor management strategy must be an assessment of the likely increase in visitor numbers and identification of areas in the Character Area most at risk from the negative impacts of recreation. Currently, there are very few records of current and historic visitor numbers and types of visitors; systems for gathering this data should be established so that it can be used to predict increases and monitor change. There is a Destination Management Plan for Cumbria; this should be altered to take account the potential increase in visitors due to climate change. Better

coordination between organisations with an interest in recreation and tourism in the Cumbria High Fells such as Natural England, the Forestry Commission, the National Trust and the Cumbria Tourist Board will be required.

Modelling of visitor numbers and temperatures could also be undertaken to indicate the likely scale and timing of visitor number increases due to climate change. Once an indication of visitor numbers has been obtained, they can be theoretically allocated to visitor attractions based on previous experience, relying on the assumption that the factors attracting visitors remain constant over time (see Appendix 3). With this information, a risk assessment of those areas most at risk of disturbance to wildlife, footpath erosion, congestion, trampling etc can be made and adaptive management techniques deployed accordingly. This initial research is key to effective visitor management and allows a tailored approach to be undertaken at vulnerable sites.

It may be possible to spread the impact of an increase in visitor numbers across the Character Area. Burden sharing is a generic adaptation to climate change which can be applied to recreational assets in a natural environment. Currently, certain elements of the Cumbria High Fells are considered most desirable to visitors and there is a high demand for access and recreational services. As demand for recreation increases it is likely that these sites and routes will reach or exceed their carrying capacity. In response to this, it is suggested that alternative sites and routes are publicised in an attempt to spread demand throughout the less sensitive parts of the area. However, dispersal of visitors may create more problems than it solves, particularly in terms of biodiversity impact. It may be better to concentrate visitors at honeypot sites with existing visitor facilities. The need for quiet refuges for sensitive wildlife in montane areas will need to be maintained.

Picture 4.5 – Footpath work on Blencathra

Footpath erosion in the Cumbria High Fells Character Area is expected to worsen due to direct impacts of climate change and the increase in visitor numbers (McEvoy et al, 2006), see Box 4.4. The Fix the Fells project is already working to restore footpaths and prevent erosion through intelligent path design. Techniques include using obstacles such as boulders can be used to divert people around sensitive features or vegetation planting at the edge of paths to encourage people to stay on the path. Stabilising paths will retain soil, preventing it running off into streams. The project is currently due to run until 2011 but the increasing pressures on footpaths form the impacts of climate change may require the project to be extended in the long term.

It will be important to link any access and recreation responses with development in the urban areas closest to the Character Area. An advertising campaign based in these urban areas which serve as a gateway to the Cumbria High Fells for visitors, may help to disperse people more widely between attractions and draw their attention to more robust sites. Education to encourage behaviour change will be essential in managing an increase in visitor numbers. Another technique would be to provide and promote circular walks from urban areas, thus reducing the numbers of people in the more sensitive parts of the Cumbria High Fells and reducing the need to travel for recreation.

In order to avoid congestion, pollution and other negative impacts of an increase in vehicle movements within the Cumbria High Fells, it is felt that improvements to public transport facilities will be needed. Public transport initiatives within the Cumbria High Fells need to be integrated with other modes of transport, including the railways and roads serving gateway destinations to the Character Area. Presently the west coast mainline rarely stops at Oxenholmne (Kendal), Penrith and Carlisle and so restricts the use of this service to move around the CHF.

Box 4.4- Footpath Erosion

Footpath erosion is influenced by 3 factors: water (rainfall intensity), path gradient (slope) and recreational pressure (trampling) (Davis & Loxham, 1996). A small increase in visitor numbers can have a disproportionate affect on a steep path when rainfall is increasing under Climate change predictions.

Within the Bassenthwaite catchment (within the CHF) research suggests that 50% of upland paths are on gradients vulnerable to active erosion(McEvoy et al, 2006).
Climate change scenarios suggest an increase in average night-time temperatures of 1.5- 3^0C and a reduction in productive snow fall of between 40-90% by the 2080's. A freeze-thaw cycle is likely to set in which breaks down exposed rock through mechanical action. Frost heave on paths will further break up paths making them more easily eroded by heavy rain (McEvoy et al, 2006)..

Adaptive strategies

Correction of erosion damage through footpath repair or restoration is costly but early stage work before major damage can save significant money over the long term. Modification of walkers and mountain bike routes is also costly and difficult, as is the regular monitoring and management of footpaths by ' linesmen' to anticipate future damage(McEvoy et al, 2006).

4.3 Landscape, historical environment and geodiversity responses

Changes in the elements and patterns that shape landscape character have an impact on the overall quality of the countryside (CQC, 2007). Creating new areas of habitat or extending existing ones will have an impact on the landscape of the Character Area. Whilst habitat creation will be undertaken at the local landscape scale, the aggregate impact of habitat creation may change the appearance of the Character Area at the broad landscape scale. However, whilst there is uncertainty over exactly what will be created (as habitats will change due to climate change) it is unlikely that the habitats created will be radically different from those that exist currently.

The significance of the landscape impact can only be determined by understanding the context in which changes have occurred. The Countryside Quality Counts project (CQC, 2007) aims to provide a systematic assessment of how the countryside is changing. It assists in understanding where change is occurring and whether this change matters to people, in terms of the way it affects the landscape character as defined (as a baseline statement) in the Character Area descriptive profile (Countryside Agency, 1999).

Habitat creation and extension in the Cumbria High Fells Character Area will be necessary to adapt to the impacts of climate change. The CQC analysis supports the extension of woodland cover within the Character Area and as such, extension of the network should have a beneficial landscape impact. It may be necessary to adjust species in planting programmes according to the projected impacts of climate change as not all species are likely to thrive. An increase in heathland habitat would also be beneficial for the landscape of the Character Area and reduced stocking densities on open fells presents an opportunity for the regeneration and traditional management of heather moorland (CQC, undated).

In addition to extending the habitat networks, there are actions which could be taken to increase the robustness of the landscape to climate change. These actions are often targeted at specific assets rather than broader scale responses such as habitat creation or catchment management. It may be necessary to remove conifers in upland forests as part of wider habitat management or improvement works although there are many areas in the Cumbria High Fells where there will be potential to increase tree cover. Restricting the increase in conifer plantations in the uplands would be beneficial. Any new plantations must follow strict design guidance to minimise negative impacts upon landscape.

It will also be necessary to take action to protect trees below the fell wall. A programme of re-planting and pollarding of parkland trees affected by wind throw and summer drought may be required. However, when choosing species for re-planting, future climate conditions should be taken into account. This could be achieved through wetting up of the uplands, particularly blanket bog. This holistic approach to catchment management will have multiple benefits for biodiversity and landscape of the Cumbria High Fells Character Area.

Maintaining grazing is essential if the landscape of the Cumbria High Fells as currently valued is retained. Monitoring the impacts of climate change on pasture vegetation and grazing management patterns will be essential. Adaptive management can be used to ensure grazing responds to climate change. Cross-compliance and agri-environment incentives could be used to maintain and conserve

key landscape features associated with grazing. In addition, branding and marketing schemes to highlight locally produced food could be used to assist in maintaining required stock levels and types. It will also have a positive multiplier effect on the local economy (New Economics Foundation, Undated). This would be beneficial to the landscape of the Character Area and respond to some of the socio-economic changes identified in Section 3.

It is important to maintain a balance between enclosed and unenclosed grazing however; using fences to enclose areas may be detrimental to landscape if not appropriately sited below the break of slope. Alternative boundary markers such as hedgerows or woodland boundaries could be used and would have additional benefits for biodiversity.

It may be possible to re-instate old technologies for energy generation which would have benefits for the historic environment and other landscape assets. For example, water mills could be restored and used to provide a local source of energy. Similarly, wood can be promoted as a fuel, benefiting the landscape by retaining and managing trees.

Once an archaeological feature is gone, it is gone forever. This fact reinforces the need for a robust approach to the identification of key historic environment issues within Character Area response strategies, early liaison with relevant organisations and careful consideration of measures that may affect the historic environment resource. For many features of the historic environment, the only course of action is to record sites and features whilst they are still visible. A record should be made of all field patterns, structures and known archaeology. It may be possible to implement localised management for special cases but this will be determined on a site-by-site basis.

Picture 4.6 – Ulswater Valley

The significance and integrity of important historic assets can be threatened by poorly designed adaptation responses. An integrated approach is therefore required when assessing potential adaptation within this Character Area. For example:

- Planting of woodland – needs to take account of other environmental assets that may be damaged from such planting, including historic environment and geological features.
- Altering the number of grazing animals - can lead to poaching, erosion and scrub on archaeological remains.

However there are some responses which could have multiple benefits for biodiversity and the historic environment. Re-wetting of peat bogs will improve the condition of upland habitats but will also protect buried archaeology.

Increases in the rate of physical processes are likely to impact on geological assets. A similar programme of 'record-and-rescue', as suggested above for the historic environment, should be implemented for sites of geological interest.

4.4 Ecosystem Services responses

Climate change will impact on the ecosystem services offered by the Character Area and effective responses must be employed to protect them. Table A4.4 suggests potential responses to impacts on ecosystem services in the Cumbria High Fells. Many of the responses described under biodiversity, access and recreation and landscape responses will have multiple benefits in preserving ecosystem services and can therefore be described as win-win solutions.

In addressing impacts on water resources and water quality it will be necessary to manage catchments in a more holistic manner through a whole systems approach. By focusing on individual freshwater bodies there is a risk of missing the link to catchment management. In response to reduced water availability it would be beneficial to increase water storage capacity within catchments and to reduce the rate of overland flow. In the uplands it is important to increase water storage capacity by encouraging carpets of sphagnum, dwarf shrub and woodland habitats as opposed to grassland. Increased water storage in the valleys through river renaturalisation, can be achieved through planting of wet woodland on floodplains and reducing the area of bare ground. These measures will also have benefits for flood protection as water takes longer to reach the channel, thus avoiding high peak loadings. Habitat restoration and creation as a response to climate change impacts on biodiversity will be beneficial in enhancing water resources in the Character Area as it increases the vegetated area in the catchment. In addition, de-canalisation and a move towards allowing channels to respond in a natural way to rainfall events will decrease flood risk as water in meandering channel will have longer journey times.

Picture 4.7 – St Johns in The Vale © Ian Crosher

It may be necessary to increase water storage to take advantage of increased winter rainfall and respond to periods of low rainfall in summer. There are a number of dis-used reservoirs in the Character Area that could be re-instated such as Hayeswater. Farmers may need to increase their capacity for on-farm water storage. In addition, sensitive farming methods including leaving vegetated buffer strips around fields and not leaving fields bare will contribute to water resources and water quality. Catchment sensitive farming methods to protect soils will also have long term benefits for ecosystem services in the face of climate change.

Livestock will be impacted by climate change and farmers may have to adapt their practices. An increase in summer temperature may mean that farmers need to provide shade for their stock. Shade can be provided by trees which would have a beneficial impact on landscape. There may also be an impact on livestock feed crops and new species may become viable in future.

Climate change may provide an opportunity for forestry. Climate change is likely to improve the growing conditions for commercial tree species. When increasing the area of forestry in the Cumbria High Fells Character Area other environmental assets should be taken into consideration. Whilst there is scope within the Character Area to extend forestry, care must be taken to avoid disturbing sensitive habitats or the historic environment. Increasing tree cover will benefit soil retention, water quality and flood risk. There is an opportunity to link climate change adaptation to the Integrated Woodland Strategy.

Soils in the Cumbria High Fells are thin and susceptible to erosion. Sensitive farming methods including leaving vegetated buffer strips around fields and not leaving fields bare will improve soil retention but also have benefits for water quality. Maintaining appropriate stocking rates will also protect vulnerable soils. Catchment sensitive farming methods to protect soils will also have long term benefits for ecosystem services in the face of climate change.

Responses to an increase in tourism and recreation are addressed in Section 4.2. Climate change is likely to alter the nature of the Cumbria High Fells Character Area as a tourist attraction but it is likely to remain attractive to visitors. The pressures of tourism and recreation must be managed to prevent degradation of the service the Character Area provides. In addition to being a tourist attraction, the natural environment of the Cumbria High Fells is an educational resource. There is an opportunity to use the natural environment assets of the Character Area to educate people about the impacts of climate change and the need to take action.

The peat soils in the Cumbria High Fells store a significant amount of carbon. In order to improve the carbon store in the Character Area, action needs to be taken to improve the condition of blanket bog as described in Section 4.1.

4.5 Responses to other socio-economic impacts

Climate change is not the only driver of change in the natural environment; pressure also comes from socio-economic change. Table A4.5 in Appendix 4 sets out responses to socio-economic impacts.

Climate change may be the 'tipping point' that prevents habitats and landscapes from recovering from the in-combination effects of all sources of pressure. In addition, the legacy of past sources of pressure on the natural environment may restrict the ability of the area to adapt to climate change. It is thus vitally important that efforts are made to address other sources of pressure in order that habitats are more resilient to climate change. This is the Hopkins *et al*. (2007) second guiding principle for adaptation to climate change (see Box 4.2).

Potentially the biggest socio-economic impact in the Cumbria High Fells will be an increase in tourism and recreation. Increases in recreation are likely irrespective of climate change as the population of the North West increases and tourism is likely to increase as more people choose to holiday in the United Kingdom. Section 4.2 introduces the responses required to manage an increase in visitors.

As many of the socio-economic impacts will be felt through an increase in development pressure (for housing, transport, wind turbines etc) both within and adjacent in the catchment, the main response is to use the spatial planning system to maintain adequate land for the natural environment. It is also important that economic growth is within the environmental capacity for the area. It has already been identified that more habitat is needed in order for the natural environment to adapt but there will be competing pressures for land. Whilst there is no certainty over what the natural environment will look like under conditions of climate change, it is certain that more land will be required. The spatial planning and landscape designation systems must be used to ensure that land is available in future for the extension of networks.

It may be possible to exploit the energy generation potential of the Cumbria High Fells but care must be taken to avoid harming the significant environmental assets present. For example, erecting wind turbines on peat soils would be detrimental to the peat resource. Wood fuel may be the most sustainable source of renewable energy in the Character Area that will not have adverse impacts on landscape. There may be opportunities for farmers to implement small scale renewable energy installations using biogas.

4.6 Policy response

A common impact across all habitat types is the likelihood of species and community compositional changes and there is a need for policy to reflect this. Changing conservation objectives may require a radical shift in the current paradigms of conservation; non-native species may have to be favoured and the attitude towards alien and invasive species may have to change. Currently, species such as sycamore are seen as negative indicators which reduce the available space for more highly valued native species. However, if native species are less viable under conditions of climate change, attitudes towards non-natives may have to change. Is it possible that species currently considered of low conservation value in the United Kingdom, and worse, invasives, may become so rare in their native habitat that the United Kingdom has a responsibility to conserve them.

Potentially a more important and widespread case will be that the species/habitats currently considered characteristic of the Cumbria High Fells will change in abundance; the new assemblages will still be mainly native British species, but different. Conservation policy needs to change in response to changing habitats.

Picture 4.8 – Blencathra with Native Woodland

Responding to the impacts of climate change may be hindered by incomplete information. For example, in order to respond to the impact of a decrease in summer rainfall on wetland habitats, research into local hydrology is required. The fifth

Hopkins *et al*. (2007) guideline for adaptation states that sound decisions should be based on analysis. Identifying research needs and commissioning appropriate studies can be seen as an early step towards building adaptive capacity that should increase the effectiveness of strategies when implemented. Future research requirements were suggested in section 4.1.5.

Policy responses will also be necessary to reduce sources of pressure other than climate change. Whilst it is possible to recognise that policy change will be required, future policy can not be prescribed as it will be mediated by the prevailing socio-economic scenario; attitudes to the environment, energy generation and development will all be dependent on socio-economics.

4.7 Assessment of responses against 'good adaptation principles'

Adaptation measures need to be fit for purpose (UKCIP 2007b) although determining fitness is not a simple task as it is often only possible after the measure has been implemented and in place for some time. Also, the desired outcome of the adaptation action is often delayed, invisible or hidden in the implications of other introduced changes (UKCIP 2007b). There is a risk of producing a list of responses but with no guide as to which will be most effective at delivering the required adaptation. UKCIP (2007b) has published a set of guidelines to inform effective adaptation which can be used to assess responses to climate change (see Box 4.4). In addition, the Hopkins *et al*. (2007) guidelines (see Box 4.2) for conserving biodiversity in a changing climate provide a more tailored approach to adaptation in the natural environment. In addition to these criteria, adaptation options should be screened against socio-economic scenarios to ensure they are robust to different futures.

Box 4.4 UKCIP (2007) guidelines for effective adaptation

- work in partnership;
- provide a balanced approach to climate and non-climate risks;
- manage priority climate risks;
- address risks associated with today's climate variability and extremes;
- use adaptive management to cope with uncertainty;
- recognise the value of no/low regrets and win-win adaptation options;
- avoid actions that foreclose or limit future adaptation;
- avoid actions that conflict with mitigation objectives.

The first UKCIP principle suggests that good adaptation requires collaborative working with stakeholders. UKCIP (2007b) regard identifying and engaging relevant stakeholders as key to successful adaptation due to the knowledge and skills they bring to the process. The more comprehensive that knowledge and skills base is, the more likely adaptation is to be successful. Whilst there may be one organisation who is the primary owner of the action it is important to identify wider partners who will be

involved in the delivery of that action. Table A3.2 highlights the potential partners required to successfully deliver the specified adaptation action.

One of the frequently stated reasons for inaction on climate change adaptation action is uncertainty over the impacts. However, many decisions in business and politics are often taken in the face of uncertainty and are usually managed through a risk management approach. Adaptive management is an effective way of addressing uncertainty. Adaptive management involves implementing an action in a phased manner, initially addressing today's risks. The outcomes of implemented actions can be monitored and altered to take account of new information or increased understanding of vulnerabilities.

Addressing risks associated with today's climate variability and extremes can be seen as a starting point towards taking further action. Understanding the impacts of current weather and climate can also provide evidence of vulnerabilities within organisations which is necessary to guide future adaptation (UKCIP 2007b).

No-regrets options are adaptive measures that deliver net-benefits regardless of the extent of future climate change. Low-regrets options are measures which deliver benefits larger than the associated costs (UKCIP 2007b). Identifying no- and low-regrets options is important as both types of action are capable of delivering maximum return on investment with low associated risk. Win-win options are those which are effective at adapting to an identified climate risk but also deliver other socio-economic or environmental benefits.

It is important that actions taken today will not limit or prevent adaptation in the future. Delivering actions incrementally through adaptive management reduces the risk associated with being wrong. Adaptation is a process which will continually need to evolve and as such the viability of a particular response will need to be periodically reassessed (UKCIP 2007b).

It is also important that adaptation does not conflict with mitigation. Effective adaptation options are those which allow adaptation to the identified impacts of climate change without increasing greenhouse emissions.

In addition to these criteria, adaptation options should be screened against socio-economic scenarios to ensure they are robust to different futures. Table A4.3 in Appendix 4 provides an assessment of responses proposed to deal with the impacts of climate change on significant natural environmental assets.

From Table A1.3 a number of particularly effective response strategies can be identified. These responses are flexible, no or low regret and do not conflict with mitigation. In addition they offer opportunities for partnership working, deal with climate and non-climate risks and offer solutions for current climate risks. The particularly effective responses for wildlife in the Cumbria High Fells Character Area are:

- Maintain existing habitats through adaptive management.
- Change conservation objectives to reflect changing community composition.
- Increase ability of catchments to retain rainfall and reduce artificially enhanced surface run-off.
- Restoration of riparian shading by trees.

- Restoration of natural physical form and function of river channels and floodplains.
- Model increase in visitor numbers and identify areas most at risk of damage.
- Dispersal of visitors.

Picture 4.9 – Derwent Water with natural shoreline© Ian Crosher

Adaptive management

Although the direction of climate change is clear, the detailed impacts and the responses required are less so. Given this uncertainty, and to avoid the development of inappropriate solutions, a process called 'adaptive management' will need to be used. This involves modifying existing practices and carefully monitoring the results to ensure the response is effective and may involve making further modifications to management until the response is effective. Adaptive management will require:

- Awareness of and adaptation to potential future catastrophic events, that may occur due to or be exacerbated by climate change such as the emergence of new pests and disease.
- Identification of research needs and commissioning appropriate studies as an early step towards building adaptive capacity that should increase the effectiveness of strategies when implemented.
- Collation of long term data sets and studies assessing environmental change.
- Policies will need to reflect the change in the distribution of species and the make-up of habitats. There is a need for further research and practical evidence to better inform decision making about adaptation.

It should be noted that there may be policy, economic or other constraints to delivery of adaptation responses. Additionally, some of the actions identified may not have a delivery mechanism at present.

Next Steps

This report on how climate change is likely to affect the natural environment of the Cumbria High Fells Character Area and the adaptation responses that will be needed to lessen the impacts is but a small first step. It only provides an indication of what may happen as the future impacts of climate change are still dependent upon the amount of carbon dioxide that society releases and how much carbon dioxide is released by natural feedback loops from the natural environment (one of our biggest unknowns).

When identifying adaptation actions, existing policies, schemes, strategies and levers need to be considered. Some actions defined as climate change adaptation are already occurring under a different name and it may be possible to modify existing programmes to provide a mechanism for delivering adaptation. An example of this will be the future incorporation of climate change adaptation into Natural England's Environmental Stewardship Scheme.

Following production of this report, Natural England is now working on:

- An implementation plan, which may include a demonstration project. Natural England will work with local stakeholders, through the Lake District Partnership, to ensure that this builds upon and dovetails with other initiatives.
- An assessment of the contribution to climate change mitigation that an adapted Cumbria High Fells landscape will make.
- An economic assessment of adaptation measures in the Cumbria High Fells.
- Learning from the pilot process to assess likely climate change impacts and the required adaptation strategies for other Character Areas both regionally and nationally.

It is also clear that there is a lot we still do not know or understand and further work will be needed. Areas of research that we feel would be particularly useful in the short term are:

- A more detailed ecosystem services assessment for the Cumbria High Fells using a rapid assessment such as that used in the 'Moors for the Future' project.
- An assessment of the condition of blanket bog habitat in the Cumbria High Fells and the development of a restoration strategy to maximise carbon storage and capture.
- Investigation of the future of artic alpine flora to determine if geology, trampling, grazing, climate or Victorian collection are the likely reason for present distribution and what potential future they could have under a substantially different grazing regime.

The future of amazing places like the Cumbria High Fells depends upon the actions we all take today to reduce our greenhouse gas emissions. This combined with decisions we make about managing our landscapes to adapt to unavoidable climate change , will determine if we continue to have a high quality landscape that is cherished.

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Appendix 1 Description of biodiversity assets in Cumbria High Fells Character Area

Montane - above the tree-line

- **Montane heaths** are restricted to the harsh mountain summits and variously comprise mixtures of lichens, mosses and liverworts, heather, bilberry and mountain sedge. Restricted to moist oceanic areas, these habitats are only found on the western Atlantic seaboard in Europe.
- **Screes** are of shattered rock which are colonised by pioneer species and provide shelter for many sensitive plants. They are characteristically rich in ferns in Britain and the parsley fern beds of the Lake District base-poor screes are rare elsewhere in Europe. Where the rocks are rich in bases (e.g. calcium) the screes support a wider range of often rare ferns and flowering plants. Both base-rich and base-poor screes are listed in the EU Habitats and Species Directive.
- **Springs and flushes** occur where cold waters seep onto the surface and provide a habitat for moisture-loving plants. They consist of mixtures of small sedges, rushes, small herbs and bryophytes and often contain rare Arctic-Alpine species. The mineral content of the irrigating waters varies from place to place, and the most diverse flora and the greatest number of rare species are associated with base-rich (lime-rich) waters. Base-rich springs and flushes are also important for invertebrates including flies and snails.
- **Tall herb communities** are found on often damp mountain ledges out of the reach of grazing sheep. Where soils are more base-rich it includes plants that have found a niche in the valley-head hay meadows such as wood cranesbill and globeflower but greater woodrush, water avens and rose-root are also characteristic. This is a widespread but very local community in Europe and is listed in the EU Habitats Directive. Base-poor examples are slightly more common and can include greater wood-rush amongst bilberry and wavy hair-grass.
- **Montane grasslands** can again be base-rich or base-poor with the latter being the most extensive and species-poor and the former being species-rich but very restricted to some areas where the richer but softer rocks are exposed in gills and some rock ledges. The base-rich examples support much of the Lake Districts remnant Arctic- Alpine flora.

Sub-montane - below the tree-line and lowland

Heathland and grassland

- **Dwarf-shrub heaths** occur on acid soils and were formerly more extensive in the character area but have been much reduced, principally by over-grazing, but also other changes in agricultural practice and afforestation. They can occur on limestone rocks where these are covered by acidic drifts. Heather is most frequently the dominant plant, often with bilberry and bell heather. On waterlogged ground wet heath develops with cross-leaved heath as a characteristic species. These may occur on thin peats which represent a transition to blanket bogs.
- **Grass fell** is the most extensive habitat of the sub-montane fells, and occurs over limestones where the soils are derived from superficial acid deposits. Much

of it is derived from overgrazed dwarf-shrub heath. Bents and fescues pick out the better neutral/ deeper soils and mat-grass the poorer acid/ thinner soils. Although of limited specific importance for wildlife, in places it does support the rare mountain ringlet butterfly.

- **Bracken** originally a woodland fern, is now a common feature of open ground in the Cumbria High Fells and picks out deep dry soils. Its upper limit on the fell is determined by its sensitivity to frosts. The decline of cattle in the hills and the virtual cessation of the use of bracken as animal bedding may have led to some spread in recent years. It can provide important habitat for birds and butterflies and woodland plants can occur in its shade if no deep litter layer has formed.
- **Meadows** are a component of most farms in the Area but few species-rich hay meadows remain. Most have lost their botanical interest through agricultural improvement and conversion to silage. Those that do remain are characterised by their tall flowers and grasses which are allowed to grow up and set seed before being cut for hay. Their species composition varies according to whether they are situated in the harsh higher valleys or in the lowlands. Both types include grasses such as red fescue and Yorkshire fog and herbs including white clover, knapweed and meadow buttercup. However, greater burnet with pignut, lady's mantle and wood cranesbill are particularly associated with the valley head farms. These higher or "northern hay meadows" are rare internationally and are listed in the EC Habitats and Species Directive.
- **Roadside verges** have a similar tall herb component to meadows and they provide a refuge for meadow plants that have mostly been lost from adjacent fields because of agricultural improvement. The less intensive management of these habitats allows some late flowering species such as meadow cranesbill to occur which cannot survive in meadows that are cut earlier in the year.
- **Pastures** support plants that can flower and set seed within short, grazed swards. On base-rich (lime-rich) soils they are generally species-rich with bents and fescues, blue moor-grass, thyme, purging flax, rock rose, orchids and carline thistle variously occurring. Neutral types can be similarly rich but lack many of the lime-loving herbs. Base-poor (acidic or lime-poor) grasslands are more extensive in the area and tend to contain fewer species with sheep’s fescue, common bent, tormentil and heath bedstraw the most typical components. On hillsides that are predominantly of acid soils, neutral and even base-rich pockets can occur where the soil becomes thicker (e.g. towards the base of slopes), or where there is slight flushing of base-rich waters, and the vegetation varies accordingly.

Mires and swamps

- **Blanket bog** develops over large areas of level or gently sloping ground where deeper peats are able to accumulate in the wet climate of the hills. Typically dominated by deer-sedge and hare's-tail cotton-grass with heather and cross-leaved heath, a characteristic feature is an often high cover of bog moss. Britain's examples are of international importance as the habitat is very restricted worldwide
- **Lowland raised mires** are found in the Mungrisdale Valley. Only remnants of these habitats now remain but these are still some of the most extensive examples left in Britain, the rest having been lost to drainage, peat extraction and agricultural improvement. The areas that remain are all damaged to some extent, but habitat restoration is being carried out on many sites by ditch blocking and scrub removal on the drying surfaces. The surface of these deep peats hold a rich and rare wildlife resource and includes many types of bog moss, heather,

cross-leaved heath, cotton-grasses, bog asphodel, white beak-sedge and sundews. Lowland raised mires are listed in the EC Habitats and Species Directive.

- **Valley mires** as their name suggests, form in shallow valleys and are characterised by having a central watercourse which weaves its way through the mire vegetation. More common in the low rolling fells of the South Lakes. The plants associated with the watercourse often differ in type from those of the surrounding mire because of the dissolved minerals found in the stream. Typical plants of the mire include bog mosses and bog asphodel whilst the watercourse supports base-loving mosses, sedges and butterwort. Britain is thought to host a large proportion of the EC's resource of this habitat.
- **Swamps and fens** typically occur as narrow bands around the edges of the rivers, lakes and tarns, but more extensive stands of the reeds and many kinds of sedges do occur in sheltered bays and backwaters particularly on Bassenthwaite & Derwent water.
- **Springs and flushes** although not extensive, are some of the most diverse features of otherwise uniform areas of acidic grassland, particularly where they are flushed with base-rich waters. They are typically dominated by a variety of sedges, rushes, herbs, mosses and liverworts. Base-rich types can include bird’s-eye primrose, grass-of Parnassus and broad-leaved cotton-grass.
- Marshy grassland is a general term for vegetation on areas of permanently wet soils. This can be dominated by purple moor-grass, rushes, sedges or even when more species rich tall herbs such as meadowsweet. The species rich stands of **Purple Moor Grass and Rush Pasture (BAP Habitat)** are colourful in the summer with flowers such as marsh marigold, angelica, devil's-bit scabious, ragged robin, marsh bedstraw, marsh valerian, marsh hawksbeard and greater burnet.

Woodland and scrub

- The **limestone woodlands** although rare in the Cumbria High Fells mostly comprise ash and hazel along with sessile oak, elm and shrubs. Many of these shrubs are found here close to or at the northern limit of their distribution in Britain. They can support a rich ground flora including daffodil, common violet, herb Paris and sweet woodruff.
- **Wet woodlands** of alder and sometimes ash occur with a rich flora of sedges and tall herbs; and small peaty basins with birch and purple moor-grass that are found here are uncommon elsewhere in Britain and are rare in the EC. The woodlands of the fells, particularly around Borrowdale are dominated by Atlantic Upland oak woods with some birch and they are of particular importance for their rich representation of Atlantic moss and liverwort communities which depends on the high rainfall and humidity of the area. The ground layer can be dominated by mosses with wavy-hair grass and bilberry. These forests are restricted to the British Isles in Europe, are of international importance and are listed in the EC Habitats and Species Directive. Parts of the Cumbria High Fells have been planted with non-native conifers and, in places; these can be of importance for uncommon or declining species such as the red squirrel.
- **Scrub** is an important habitat in the Natural Area and includes serial stages of developing woodlands with a variety of dominant species such as hawthorn, blackthorn, western and European gorse, limestone shrubs such as buckthorn, hazel and spindle and juniper. Juniper scrub is of international importance and is listed under the EC Habitats and Species Directive. Scrub is important for a

variety of breeding birds and in a mosaic with limestone and other grassland types it provides an important habitat for butterflies.

Lakes, tarns, rivers and streams

- **Open still waters** are synonymous with the Lake District. Many species of plant are found below the water's surface and these vary according to the minerals and nutrients that are present. Almost the full range of types of open water body that occur in Britain are found in the area. Pondweeds are the most important single group of plant but water milfoils, water lobelia, quillwort and shoreweed are also present. The fauna of the lakes and tarns is equally rich and includes rare fish such as vendace and schelly. Open water bodies that are poor in minerals and those which are lime rich are listed in the EC Habitats and Species Directive.
- **Rivers and streams** are more numerous in the Natural Area than anywhere else in England. The fast flowing waters are generally of very high quality, and support important populations of fish such as salmon and bullhead and of invertebrates, most notably the Atlantic freshwater crayfish which continues to thrive in the River Kent, and the freshwater mussel found in the River Ehen. The water crowfoot beds found in many of the lower sections of rivers are an internationally important habitat but predominantly outside the Character Area.
- **Gills** are familiar features of the Lake District fells and as they traverse both montane and sub-montane zones they frequently support a variety of habitats including tall herb and fern communities, Arctic-Alpine communities and woodland. Parts of gills are inaccessible to man and his grazing animals and so they can support near-natural plant and animal communities. Gills are especially important for mosses, liverworts and fern.

Appendix 2 Background and project methodology

There is little doubt that climate change is a reality and that it will pervade all areas of life. While there are impacts that are no longer avoidable, there is still time to develop adaptation techniques to cope with a changing climate, and mitigation strategies to limit further damage in the 21st century.

The Earth's climate is dynamic; the planet alternates between periods of glacial (cold) and interglacial (warm) conditions as part of its natural cycle (IPCC, 2001). While this is often altered by such events as large volcanic eruptions, the cycle is consistent. For the past 10,000 years the Earth has been in an interglacial period, which has provided a comfortable 15°C average surface temperature for mankind. However, there is substantial evidence that the impact of human activities has caused, and will continue to cause, a steady but significant increase in this average surface temperature.

The Earth is kept warm by certain gases in its atmosphere; gases such as water vapour, carbon dioxide (CO_2) and methane absorb outgoing radiation and re-emit it back to the Earth's surface. This has been described as the 'greenhouse effect', without which the Earth's surface would be approximately 33°C colder. Since the industrial revolution, mankind has consistently been adding to the greenhouse gases already in the atmosphere. Through burning of fossil fuels and changes in land use, the volume of greenhouse gases has increased from 270 parts per million volume (ppmv) in pre-industrial times to 379 ppmv in 2005 (IPCC, 2007). This far exceeds the natural range of the past 650,000 years (180 to 300 ppmv) as determined by ice cores (IPCC, 2007). This has caused an intensification of the greenhouse effect and a gradual warming of the Earth.

Addressing the challenges associated with climate change requires a 'two-pronged' approach; mitigation to limit the magnitude and rate of change and adaptation to deal with the residual impacts and opportunities. However, irrespective of the success of mitigation efforts, there will still be some degree of unavoidable climate change due to historic emissions of greenhouse gases (GHGs). Responding to the impacts of climate change requires adaptation. With respect to climate change, adaptation is thought of as 'an adjustment in natural or human systems to actual or expected climatic stimuli (variability, extremes and changes) or their effects, which moderates harm or exploits beneficial opportunities' (UKCIP 2007; 4). Adaptation requires effective measures directed at enhancing our capacity to adapt and at minimising, adjusting to and taking advantage of the consequences of climatic change.

The purpose of Natural England is to conserve, enhance and manage the natural environment for the benefit of current and future generations. In doing so, Natural England works towards the delivery of four strategic outcomes:

- A healthy natural environment: England's natural environment will be conserved and enhanced;
- Enjoyment of the natural environment: more people enjoying, understanding and acting to improve, the natural environment, more often;
- Sustainable use of the natural environment: the use and management of the natural environment is more sustainable; and

- A secure environmental future: decisions which collectively secure the future of the natural environment.

Dealing with the specifics of climate change, as opposed to the generalities, is very challenging but NE believe it important to start working towards comprehensive, geographically specific assessments of the possible impact of climate change on the heritage of wildlife, landscapes and our enjoyment of them. Such assessments would then allow us to start identifying responses which would reduce the adverse impacts identified. Character Areas have been chosen as there is systematic comprehensive coverage of England and they are at a manageable sub-regional scale. The four pilot Character Areas are the start of the journey. The pilots aim to translate the emerging principles of climate change adaptation into specific actions.

The 4 pilots were chosen to illustrate a range of projected climate impacts:

- Cumbria High Fells (montane impacts);
- Shropshire Hills (typical fragmented landscape);
- Dorset Downs and Cranborne Chase (drought);
- The Broads (wetland, sea level rise).

The purpose of the project is to create climate change response strategies for each of the selected Character Areas based on national and local expertise. In each Character Area an initial list of the more significant natural environmental assets has been complied; other valued assets may exist, but this exercise attempted to select some of the most important. Based on this list, Character Area specific impacts of climate change have been identified. Subsequently, Character Area specific response strategies have been complied that aim to practically adapt the habitats and landscapes in question to the identified impacts of climate change.

Project methodology

The basic methodology has been to:

1. Identify significant environmental assets in the Character Area;
2. Assess the projected nature of climate change by looking at biologically significant parameters such as precipitation;
3. Assess the impacts of the projected climate changes on the environmental assets;
4. Propose actions to minimise the adverse impacts.

The climate change responses are the result of dialogue between national experts and local staff within each Character Area. Figure A1 illustrates the method behind each Character Area report. Initially, national experts (in habitat types, species, landscape, access and recreation and geodiversity) were asked to fill in templates to identify the impacts of climate change on significant natural environmental assets.

The templates asked the National Experts to identify climate risks, as expressed by projected climate change. The nature of the effects generated by the risk were then identified; for example for arctic alpines the risk is an increase in temperature and the nature of the effect is that species are forced to higher altitude or north facing sites. The extent of the effect, both in terms of geographical variation and magnitude of change was then identified. The projected impacts column identified the biophysical

impact of the risk on the asset in question, so for arctic alpines the impact is that species move upwards or are lost. Following identification of impacts, the national experts were asked to suggest practical action that could be taken to adapt to climate change. Any key assumptions made in the impact assessment or useful references are listed in the final column. Table A2.1 shows a worked example of the process for arctic alpine flora.

Table A2.1 Worked example of national expert template

Valued asset	Risk	Nature of effects	Extent of effects	Projected impacts	Proposed responses	Key assumptions
Arctic alpine plants	Increasing temperature	Forces them to higher altitude/north facing slopes	Amount of temp increase from bioclimatic data	Retreat to higher altitude or loss	Improve condition of existing habitat to maintain as long as possible	

These master templates were then sent to the regional offices containing each of the chosen Character Areas. Regional staff were then asked to collate the assets pertinent to the Character Area in question and construct a Character Area specific version of the template. At this point regional staff reviewed the information provided by the national experts and updated it to reflect the specificities of their Character Area. One Character Area held an internal workshop to complete this part of the process.

Once a draft Character Area template had been assembled, national experts and regional staff met at a workshop to discuss and refine them further. The output of the workshops were annotated Character Area templates to reflect discussion held and a second template detailing practical response strategies for adapting to climate change. In addition, cross cutting issues such as landscape and ecosystem services were discussed at the workshops.

The outputs form the Character Area workshops form the basis of the climate change response reports. Around these templates, a narrative has been written which captures discussions held during and after the workshops.

The detail of any action – by who, when, cost, feasibility etc is not covered at this stage – that would be for subsequent implementation plans, which will involve working with regional partners.

The concept of connectivity, and how fragmented landscapes might be adapted to be more resilient in the face of climate change, has been the subject of a separate, specialist workshop with external bodies. This is a potentially important element in the response strategies.

Subsequently, after the pilot project, consideration will be given to:

- Assessing, broadly, the cost of the responses advocated;
- Assessing the contribution to locking up carbon (mitigation) which the response strategies would deliver;
- Rolling out the production of the response strategies to further Character Areas deemed to be at risk from climate change.

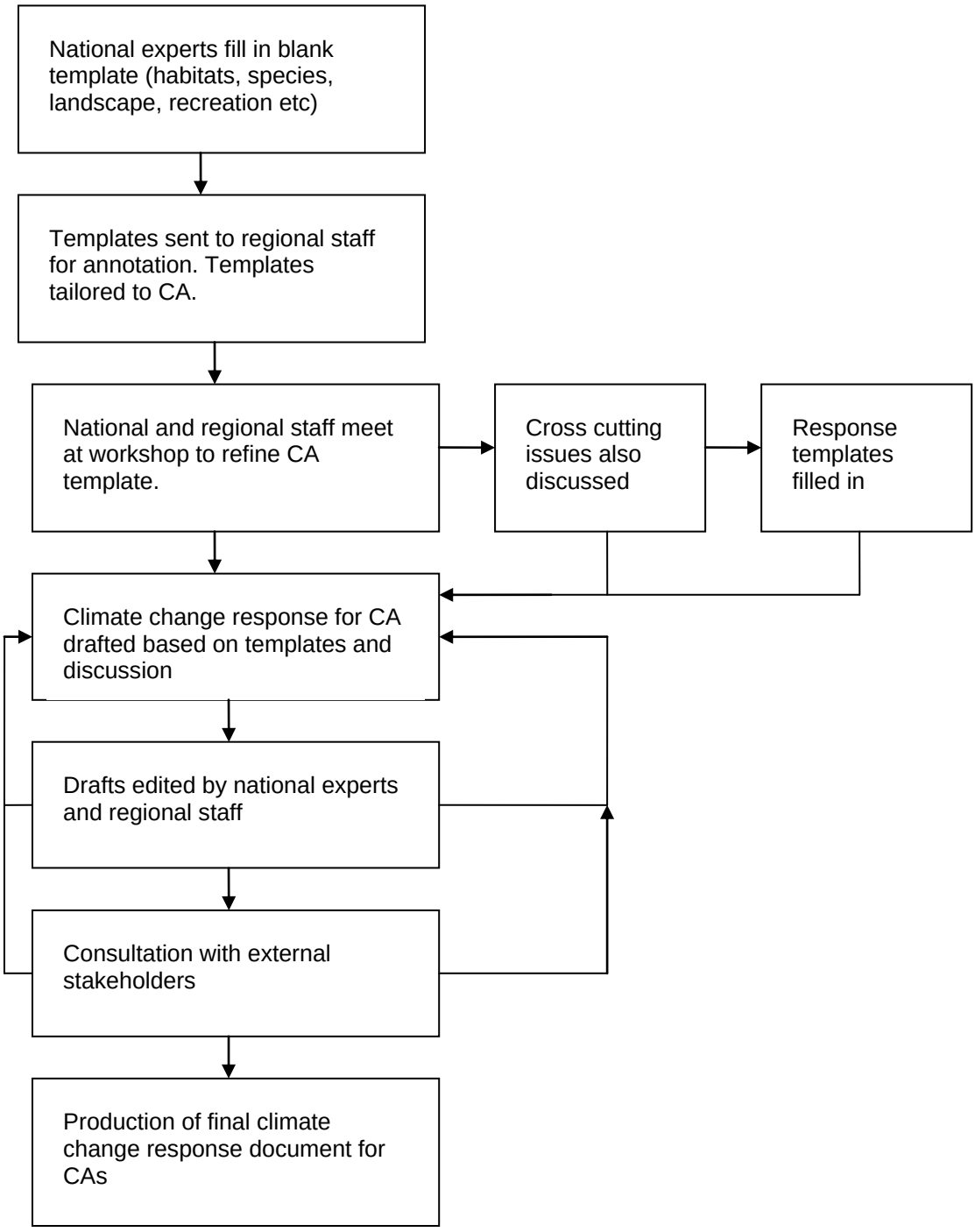


Figure A2.1 Flowchart showing project methodology

Appendix 3 Note on indirect climate change and socio-economic impacts

Socio-economic scenarios

Climate change will not be the only pressure on natural environments in the future. Other impacts will be felt through socio-economic change. Berkhout *et al*. (1999) identify five dimensions of socio-economic change:

1. Demography and settlement patterns;
2. The composition and rate of economic growth;
3. The rate and direction of technological change;
4. The nature of governance;
5. Social and political values.

Given the deep level of uncertainty, traditional forecasting techniques are inappropriate. Instead, *scenarios* of socio-economic change are developed. Scenarios can be defined as:

> "plausible, challenging and relevant sets of stories about how the future might unfold. They are generally developed to help decision-makers understand the wide range of possible futures, confront uncertainties and understand how decisions made now may play out in the future" (UNEP 2005)

Scenarios attempt to capture the dimensions of change described above; however, the last two dimensions are somewhat less tangible than the first three. The nature of governance concerns the degree to which governance is at a global or local scale. Governance can be international and strongly integrated or local and highly autonomous. Social and political values refer to the degree of individualism and consumerism that prevails, as opposed to communism and conservation. A continuum exists between the two extremes of each dimension and these can be used to form a matrix in which potential future socio-economic scenarios sit (see Figure A3.1). Other dimensions of change are then applied within this framework.

A number of socio-economic scenario sets have been constructed by a number of organisations for a range of purposes. Figure 1.1 includes socio-economic scenarios constructed by UKCIP (2001), for use alongside climate change impact and adaptation assessments, and the scenarios from the Millennium Ecosystem Assessment (MEA) (UNEP 2005). Both scenario sets consider the impacts on biodiversity, which are summarised in Table A3.1.

Table A3.1 Socio-economic scenarios related to biodiversity

Global Orchestration • Conservation sites maintained and slowly expanded but designed for access • *Large-scale farming, GM crops* • *Urban sprawl and demand for 'managed landscapes'*	**Techno-Garden** • High priority to protection • Pressures from growing demand • *Low input farming and sustainable landscape management* • *Tight planning controls* • *Control of industrial pollution*
Order-from-Strength • Policy not strong enough to restrict development pressures • Little public concern about biodiversity • *Intensified farming, larger farms* • *Environmental pollution*	**Adaptive-Mosaic** • Strenuous efforts to preserve wildlife • Access demands • *Extensive and more diverse agricultural* • *Development controls*

Adapted from UKCIP, 2001, with scenarios names from UNEP, 2005. Indirect socio-economic impacts i.e. socio-economic impacts on other sectors but with implications for biodiversity are shown *in italics*.

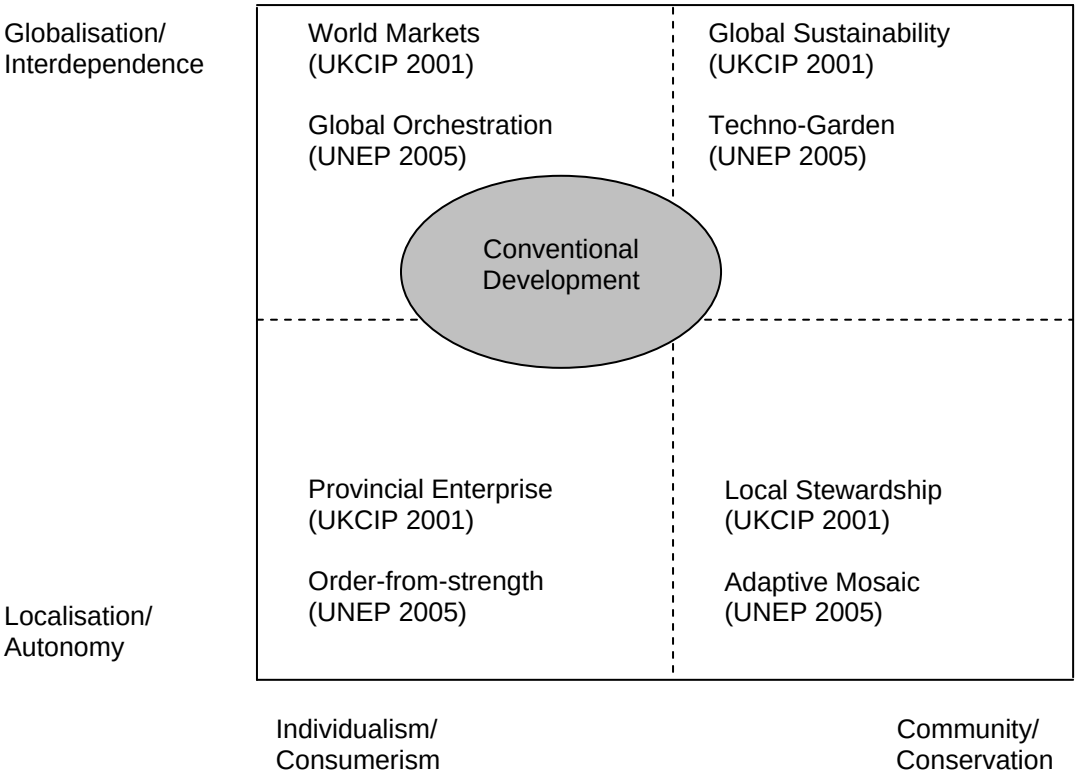
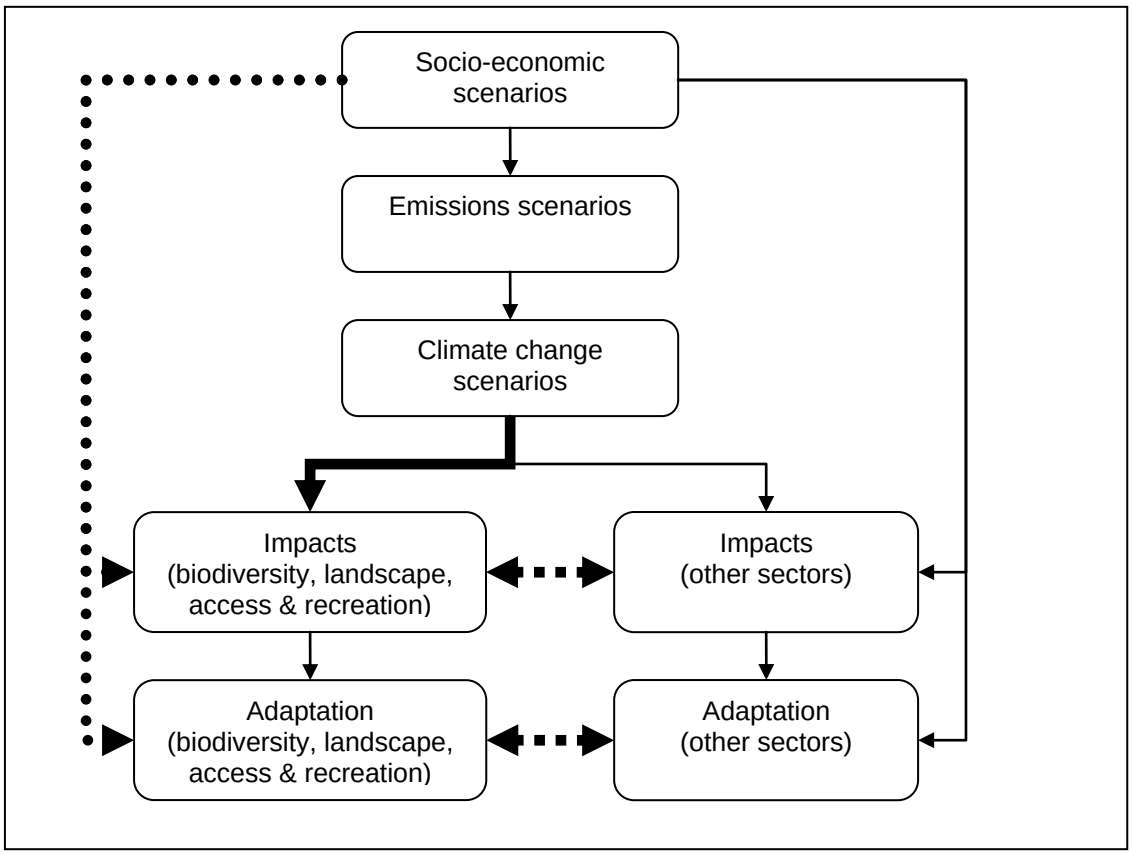


Figure A3.1 Socio-economic scenarios

Socio economic scenarios in climate change impact and adaptation assessment

We are increasingly used to working with climate change scenarios (such as those produced by UKCIP) to identify the direct and indirect impacts of climate change on assets of interest. These scenarios are informed by emissions scenarios (e.g. IPCC 2000) which are in turn driven by socio-economic scenarios (see Figure A3.2). Therefore the socio-economic scenarios not only directly and indirectly affect significant natural environmental assets; they also condition the climate change scenarios and resulting impacts. For this reason, socio-economic and climate

change scenarios are often linked e.g. World Markets with High Emissions, although alternative 'cross-over' scenarios can be employed.



Thick solid line = direct climate change impact on biodiversity etc; dashed line = indirect climate change and socio-economic impact on biodiversity etc; dotted line = socio-economic impact on biodiversity etc.

Figure A3.2 Role of socio-economic scenarios in climate change impact and adaptation assessment

Significance of socio-economic scenarios for the Character Area project

Climate change will directly affect valued assets in the Character Areas. The significance of the impacts of climate change will be mediated by the socio-economic scenario that prevails at the time; changes in attitudes and behaviour towards the natural environment and conservation will alter the nature of the impacts. For example, the priority attached to dealing with species loss will be dependent on what we perceive as 'valuable' in the natural environment.

In addition to direct impacts, climate change will also have an indirect impact through interaction of assets with other sectors. For example, many Character Areas are heavily influenced by agriculture. Changes in agriculture could be driven by climate change, such as crop switching to more drought tolerant plants or increasing intensification due to the failure of harvests in other parts of the world. These would be classified as indirect impacts of climate change on the Character Area. These indirect impacts will also be mediated by the prevailing socio-economic scenario at the time.

However, shifts in agriculture may occur regardless of climate change e.g. driven by fluctuations in crop prices or shifts in consumer demand for certain products. Such

changes would be classified as socio-economic impacts. These changes, whether climate induced or not, would significantly impact on the Character Areas.

Table A3.2 Examples of direct, in-direct and socio-economic impacts

Type of impact	Examples
Direct climate change impact	• Increased stress due to drought • Phenological changes • Carbon dioxide fertilisation effect
In-direct climate change impact	• Increased visitor numbers in Character Area (due to an increase in temperature) • Reduction in water available for habitats (due to an increase in potable water demand)
Socio-economic impact	• Increase in invertebrate and bird species due to a shift towards organic farming • Development pressure in Character Area due to population increase

In reality direct, indirect and socio-economic impacts are closely related. The Character Area project focuses on the direct biophysical impacts of climate change on the significant natural environmental assets of the Character Area (and is noting the downstream policy impacts where they arise). Where significant indirect impacts have been identified (such as those related to agricultural change in the face of climate change) these have been included and classified as indirect.

Table A3.3 Indirect impacts of climate change on significant natural environmental assets

Sector primarily impacted	Impact of climate change	How it might affect natural environment
Agriculture, horticulture and forestry	Crop switching to more drought resistant crops	Landscape change
	Re-intensification due to failure of harvests elsewhere	Landscape change, reduced access to the natural environment, increase in diffuse pollution, species compositional change, reduction of network size
	Increase in irrigation requirements	Reduction in water available for habitats
Flood management	Reduction in condition of existing defences and risk of subsidence	Potential for habitat creation
	Increased risk of breach and overtopping of defences	Increased risk of inundation of sites
Water resources	Increase in demand, reduction in supply	Reduction in water available for habitats
	Increased storage requirements	Potential for habitat creation
Buildings	Risk of subsidence	Increase in running costs of buildings
	Risk of overheating	
Transport	Subsidence	Reduced access to natural environment
	Damage to infrastructure	

Sector primarily impacted	Impact of climate change	How it might affect natural environment
Retail	Increased opportunity for outdoor retail	Increase in recreation potential
Leisure and tourism	Increase in visitor numbers	Increase in recreation opportunity Risk of overcrowding leading to loss of visitor experience, damage to footpaths, increased pressure on resources and infrastructure
Health	Increase in heat related illnesses	Reduced outdoor recreation in summer

The Character Area project has not adopted a formal scenario based approach, nor does it provide an integrated assessment as these are highly complex. Instead, it is assumed that conventional development (mainly World Markets with aspects of other scenarios) will prevail.

Table A3.4 provides some examples of socio-economic impacts, which could affect the species, habitats, landscapes and recreational function of the Character Areas. This is based on knowledge of socio-economic changes, informed by current trends and drivers (e.g. the Water Framework Directive; European and UK Climate Change Programmes) and the futures literature (e.g. Evans *et al*. 2004; LUC *et al*. 2006; OST, 2002; UKCIP, 2001).

Table A3.4 Socio-economic changes with potential to affect natural environment

Sector	Socio economic change	How it might affect natural environment
Agriculture, horticulture and forestry	Increase in demand for organic produce Changes in payments and subsidies	Increase in invertebrate and bird species Reduction in diffuse pollution Improve countryside stewardship Reduce monoculture
Flood management	Preference for ‘soft defences’ e.g. managed realignment Changes in flood defence budget (decrease) Changes in flood defences (increase)	Increase in inter-tidal and floodplain habitat creation potential Greater risk of inundation of valued assets – positive for some and negative for others Reduced risk of inundation of valued assets – positive for some and negative for others
Water resources	Increase in water metering Introduction of variable tariffs Increased pressure on water resources in growth areas due to population increase	Potential increase in water available for habitats as potable consumption reduces Potential decrease in water available for habitats in growth areas

Sector	Socio economic change	How it might affect natural environment
Energy	Increase in oil price resulting in switch to renewables Switch to nuclear energy	Negative landscape impact of wind turbines Risk of diffuse pollution, landscape impact
Buildings	Increase in new build rates to meet demand from population growth – urban expansion Demand for waterside locations	Pressure on land Diffuse pollution
Transport	Demand for new infrastructure – roads, railways, runways etc to meet growing demand	Habitat fragmentation, landscape impact. Positive impact on access to countryside
Manufacturing and industry	Shift of heavy industry to other parts of the world	Reduction in diffuse pollution, increase in sites available for habitat restoration and creation
Financial services	Demand for ethical investment increases	Increased financial support
Retail	Movement of retail out-of-town Increase in ethical shopping	Pressure on land Increased awareness of value of natural environment
Leisure and tourism	Increased demand for extreme sports Increased demand for eco-tourism	Increase in visitor numbers and demand for facilities and infrastructure Reverse some of the negative effects of previous tourism
Health	Increase in obesity	Increased potential to market the countryside as part of a healthy lifestyle
Defence	Terrorism	Heightened security measure required

Mitigation

Addressing the challenges associated with climate change requires a 'two-pronged' approach: mitigation to limit the magnitude and rate of change and adaptation to deal with the residual impacts and opportunities. In climate change literature, mitigation refers specifically to the reduction in greenhouse gas emissions (UKCIP 2003). Mitigation is often driven by policy e.g. the UK Climate Change Programme. In addition to direct and in-direct impacts of climate change, assets can be impacted by mitigation policy. Table A3.5 illustrates some potential impacts of mitigation policy on the significant natural environmental assets. Note that other mitigation actions e.g. individual, corporate or market-based may also affect assets, although they are likely to be of a similar type.

Table A3.5 Mitigation policy impacts on Natural England

Sector	Mitigation policy	How it might affect Natural England objectives
Agriculture, horticulture and forestry	Increase in biofuel production Increase carbon store in soils and biomass	Landscape change, increase in monoculture Habitat creation potential
Flood management	Support use of non-carbon intensive forms of flood defence	Habitat creation potential
Water resources	Reduce energy demand of water treatment	Diffuse pollution
Energy	Shift to renewable energy or nuclear	Landscape impact of wind turbines / new power stations
Transport	Renewable transport fuel Increase in public transport	Landscape change, increase in monoculture Shift in how people access recreational facilities, new infrastructure required
Manufacturing and industry	Burning of biofuels and CHP	Landscape change, increase in monoculture. Opportunity to capitalise on demand for waste organic products (e.g. wood chippings generated through reserve management)

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Appendix 4 Main Tables

Table A4.1 Impacts on valued assets of the Cumbria High Fells Character Area

Key
Indirect impacts are highlighted in italics
Policy impacts are underlined

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
1	**Reedbed**	Increased winter rainfall Increased intensity of rainfall Lower summer rainfall	Flooding Water level fluctuation	May be some impact on summer water levels in south and east as a result of lower summer rainfall. Less of an impact in the north west.	1a. Changes in hydrology and lake levels may lead to flooding in winter and drying out during summer	
2	**Deep lakes** >1ha (defined as greater than 3m depth)	Higher temperatures (summer and winter) Increased storminess and higher intensity rainfall Increased winter rainfall	Higher water temperatures Longer growing season Higher evapo-transpiration rates Increase in	Extent will depend heavily on interaction with other pressures in particular nutrient enrichment (including Nitrogen enrichment associated with atmospheric	2a. Increased rainfall volumes and intensity have the potential to increase erosion and hence nutrient/sediment loads. This may also have consequences for dissolved organic carbon levels and water transparency. 2b. Greater frequency and duration of (toxic) algal blooms. Shift in seasonal phytoplankton. 2c. Increased potential for invasive	Potential impacts on lake ecosystems are confounded by complex interactions between temperature increases and changes to hydrological regimes. Climate change impacts will interact with other pressures acting upon the freshwater resulting in more severe and unpredictable consequences. Cannot consider climate change impacts in isolation from sectors such as the water industry, inland navigation, fisheries

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
		Decreased summer rainfall	visitor numbers	deposition)	plants 2d. Recruitment possible for introduced fish species e.g. carp 2e. Loss of habitat for cold water fish species e.g. Char due to squeezing of suitable conditions in water column from rise in surface temperatures and longer periods of O_2 depletion at depth. 2f. Phosphorus release and fish kills 2g. Lower water availability - exposure of littoral communities and erosion of marginal features – including emergent plant communities and squeezing of area for these due to grazing of adjacent land 2h. Disruption of seasonal stratification patterns 2i. Decreased flushing/longer retention times (interaction with water quality pressures) - increased acidification risk 2j. Loss of fish spawning habitat 2k. Loss of connection with other freshwater habitat (rivers, ditch systems)	and flood defence. Microcosm studies have suggested that nutrient loads and the presence of predatory fish are more important drivers of shallow lake function than warming. In deep lakes key impacts are associated with changes to nutrient supply, retention time and thermal stratification. Potentially deep lakes may exhibit some degree of 'thermal inertia' and as such may be buffered against the extremes of climate change. However, deep low productivity lakes are susceptible to even slight increases in nutrient (important in this Character Area) and sediment loads. By looking individually at freshwaters there is a danger we miss the link to catchment management

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					2l. Increase in midges – potential loss of recreational value	
3	**Shallow lakes >1ha** (defined as less than 3m depth)	See above – deep lakes	See above – deep lakes	Not of great significance in Cumbria High Fells Character Area – only Bassenthwaite is shallow	See above – deep lakes	Many climate change impacts could act as forward switches. Climate change therefore has the potential to reduce our ability to manage for clear states even if other pressures diminish or remain constant. A key threshold is likely to be around 50ug/l total phosphorus – above this shallow lakes are likely to be very susceptible to forward switches.
4	**Ponds <1ha and ditch systems**. Cumbria High Fells Character Area is only place in England with corrie lakes	See above – deep lakes	See above – deep lakes	Extent will depend heavily on interaction with other pressures in particular nutrient enrichment.	See above – deep lakes 4a. Loss of brackish transition zone 4b. Flips between saline, brackish and freshwater states 4c. Ochre (iron precipitation) production	Major impacts are associated with drying out and increased susceptibility to nutrient enrichment. (Interestingly some ponds drying out could mediate nutrient enrichment/succession processes by allowing oxidation of accumulated organic material).
5	**Rivers and Streams**	Extreme rainfall conditions – increase in rainfall intensity Increase in winter rainfall	Changes in water temperature Drought Flooding	Effects likely across the whole of England	5a. Direct ecological consequences of increased water temp – loss of riverine species 5b. Flashier flow regimes that destabilise existing riverine sediments and river banks	This is based upon two key assumptions/underlying precepts: 1) other pressures may be of greater significance 2) interactions between climate change and other pressures are more important than direct climate change impacts.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
		Decrease in summer rainfall Changes in air temperatures	More intense land run-off rates Drier low–flow periods		5c. Downstream migration of perennial heads of streams and (where evident) winterbourne sections) - loss of riverine species 5d. Increased eutrophication and siltation effects 5e. Increased algal growths and standing crop 5f. Reduced spawning success of salmonid fish and other fish species using riverine gravels for spawning. 5g. Lower water levels, reduced dissolved oxygen levels, poorer flushing of contaminants, leading to loss of species most adapted to flowing water conditions. 5h. In headwater sections, ephemeral sections will become largely devoid of aquatic species, whilst perennial sections will become ephemeral – overall loss of riverine habitat. 5i. Loss of physical habitat complexity from any works to stabilize river channels and improve their flood conveyance capacity.	In CHF the majority of rivers and becks within enclosed land have been highly modified with reinforced banks fixing the river in one position and not allowing natural processes of erosion and deposition.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					5j. Introduced plant and fish species likely to benefit 5k. Societal pressure to increase abstraction rates during low-rainfall periods, and enhance traditional fluvial flood defences	
6	**Freshwater Wetland Birds**	Warmer winter temperatures Decrease in summer rainfall Increase in winter rainfall	Spring and summer drought Spring and summer flooding	Mainly south, east and central counties, especially on coast	6a. Food become unavailable, predation on eggs and young facilitated by drying, breeding assemblage declines/lost (Lapwing, Redshank, Snipe, ducks, reedbed birds) 6b. Increased summer storm intensity coupled with urbanisation of catchments puts floodwaters into freshwater wetlands rapidly causing nests to flood, chicks to drown and eventual loss of ground nesting birds 6c. SSSIs[1] and SPAs[2] move to unfavourable condition (if not already unfavourable) 6d. Failure to meet BAP[3] targets as loss of existing resource may outstrip pace of creation	Bittern, Marsh Harrier, Bearded Tit, Cettis' Warblers, Black-tailed Godwit, ducks, Geese and Swans, egrets (Not currently in CHF – but all breed/occur in Lancashire) Lapwing, Redshank, Snipe, Curlew and Osprey (populations currently very small in Cumbria High Fells) Impacts at UK scale imminent: current bias in avian biodiversity interest heavily skewed to small number of exceptionally important and also exceptionally vulnerable sites – these disproportionately important in terms of proportion of population held there or in terms of driving overall UK productivity

[1] Site of special scientific interest
[2] Special protection area

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
7	**Blanket Bog**	Reduced rainfall in summer Increase in storms - increase rainfall intensity Increase in winter rainfall Decrease in summer rainfall	Erosion of bare surfaces Wildfire Flash floods Drought	Impacts more severe on sites in poor condition (gripped, intensively burnt, overgrazed)	7a. Continuing loss of carbon from sites in poor condition 7b. Loss of historical record in the peat Increase in fire intensity and frequency 7c. Increase in bare peat 7d. Increased water colouration 7e. Impact on water table 7f. Increased plant growth - species competitiveness alters 7g. Community compositional changes – e.g. heather might out-compete sphagnum but heather might be lost through heather beetle (already observed on Armboth Fells)	We need to review available environmental modeling work on the quantitative and spatial effects of climate change predictions on river flow regimes (flood flows and low flows), aquifer recharge, and water temperatures. The work is disparate and not driven by concerns over ecological effects (but rather flood risk management and water resource management). Increased surface run-off is known to mean increased nutrient and fine sediment delivery. There is an issue as to how much the increased water volumes dilute and flush out these increased pollutant loads – depends on the retention rates within different rivers. Clearly standings waters such as lakes are much more retentive than most rivers.
8	**Upland Heathland** Priority HAP[4] type, Designated SSSI	Warmer summer and winter temperature Decrease in	Increase in fire risk Less CO_2 allocated to soil		8a. Negative for species depending on bare ground and open areas - probably not significant in Lakes 8b. Increased above ground biomass	The main papers dealing with impacts of climate change (drought and warming) on heathlands in the UK refer to an upland site in Wales, but they are the best info that exists.

[3] Biodiversity Action Plan
[4] Habitat Action Plan

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	features, Annex 1 types under Habitats	summer rainfall	Longer growing season Drought		8c. Slight increased flowering 8d. Increased herbivory damage - increases in area damaged by heather beetle 8e. Positive warming feedback as more CO_2 is released 8f. Changes in soil chemistry. Possible impacts on soil fauna. Litter fall tended to decrease 8g. Water pollution - increased spring leaching of nitrate 8h. Spread of bracken 8i. Rhododendron spread	Refs below Variation in upland heathland in the CHF – including the oceanic types that are restricted to North-facing very humid slopes and would suffer under summer drought (might require trees to survive) – so summer droughting would lead to a reduction in oceanic and hyper-oceanic species.
9	**Fern beds** – U21 (Cryptogramma) and U19[5] (Thelypteris)	Reduced summer rainfall Warmer summer and winter temperature	Summer drought		9a. Decreased seedbank of *Calluna* 9b. Decreased growth and net primary productivity - lower plant replacement rate 9c. Loss of plant cover	

[5] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					9d. Positive warming feedback as more CO_2 is released 9e. Changes in soil chemistry. Possible impacts on soil fauna. Decreased litter fall	
10	Montane Grassland and Heath	Warmer winter / spring Increase in winter rainfall Decrease in summer rainfall summers Winter wind speeds may increase by 5% Extreme climatic events will increase – increase rainfall intensity	Longer growing seasons Increased competition from lowland species	Across all montane habitats in northern England, including the Cumbria High Fells Character Area. Many arctic-alpines do not occur within montane heath but are on crags/ledges	10a. Montane species will be lost due to competition from more “lowland” species moving up the hill. 10b. Montane plant species are likely to lose ‘climate space’ under current climate change scenarios. Gradual retreat of true arctic-alpine species through mixture of direct climatic effects and gradual replacement by faster growing species of grass but not on bare, rocky areas. 10c. Increased winter rainfall could affect alpines which thrive under winter snowcover but can’t stand damp. 10d. Small fragments of habitat and individual arctic-alpine species will become restricted to smaller pockets – i.e. the highest and shadiest ground (north-facing slopes). 10e. Predictions for the stiff sedge *Carex bigelowii* show a decline in distribution. Warmer temperatures may be damaging for the plant’s root growth	English montane habitats are relatively small in extent, rather fragmented in nature, and limited in terms of the species they contain. They are of significance because they represent examples of these communities near the southern-most extremity of their range in Britain – important in Cumbria High Fells. Montane areas support a number of arctic-alpine species which are nationally rare and scarce. A full list is contained in Uplands Management Handbook. Montane habitats are dominated by short vegetation cover maintained by harsh climate, especially cold temperatures and wind, at high altitude. Existing distribution of arctic alpines is very much a factor of grazing – they could expand significantly from existing distribution if we got the grazing low enough.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					but warmth could encourage fruit to grow larger, so improving reproductive success. 10f. The mountain ringlet *Erebia epiphron,* (only found in the Lake District within England) faces local extinction with climate change. 10g. Projected response of five 'montane' lichens shows climatic suitability in Britain is to decline compared between the present day and the 2050's.	Current distribution and condition of montane communities is restricted by over-grazing, trampling, Victorian collecting and probably nitrogen-deposition. Therefore they are in a vulnerable condition and susceptible to climate change – for many species and montane habitats there is still time to reverse this decline. We need to be careful not to write-off everything montane in face of climate change, for some species there is little hope (e.g. alpine saxifrage) but for others (e.g. purple saxifrage.; mossy saxifrage) there is lots we can do.
11	**Upland birds** Ring Ouzel Dunlin Curlew Raven Golden Eagle Peregrine Dotteral Red Grouse	Increase in temperature Decrease in summer rainfall	Decline in productivity of characteristic species Drought Changes in phenology Increase in competition from lowland species	Cumbria (Pennines and Lakeland) Pennines, N.York Moors Dartmoor, Exmoor, Bodmin, South Pennines, Shropshire, North York Moors	11a. Loss of suitable breeding habitat for montane breeders - montane zone lost, blanket bogs dry 11b. Decline in breeding success of Curlew, Golden Plover and Dunlin, possibly Ring Ouzel as food-rich wet areas dry; numbers decline - also due to habitat damage/fragmentation (although breeding success of these species is already minimal in the Lakes; not because of climate change) 11c. Mismatch between demand for invertebrate food (time of breeding varies in response to photoperiod) and food availability (varies in response to	

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					temperature) 11d. Potential for competition for nesting areas and food, with advantage going to new colonists quickly, especially as sward length increases in longer growing season 11e. Decline in upland bird abundance, increase in abundance of lowland heathland birds.	
12	**Upland hay meadows** (NVC MG3[6]) Priority HAP type Designated SSSI feature Annex 1 type under EU Habitats & Species Directive	Warmer winter/spring Decrease in summer rainfall	Longer growing seasons Species lose suitable climate space – increase competition from lowland species	Across the range of the community in northern England, including the Cumbria High Fells Character Area.	12a. SSSI condition will become "unfavourable".[needs explanation] 12b. Difficulty in meeting upland hay meadow HAP/BAP targets [needs explanation] 12c. Continuing unfavourable conservation status for Annex 1 Mountain Hay meadow habitat [needs explanation] *12d. Easier to make hay – good for traditional management.* 12e. Upland plant species may lose	Within the Cumbria High Fells, grasslands are highly fragmented (except for dull upland acid grassland) – the picture is different in Orton Fells and Morecambe Bay Limestone Character Areas. Some key areas – Shap, Lorton and Askham. Should we worry about the exact species compositions? The meadows will still be diverse, colourful, rich, good for curlew, insects. 95 per cent loss of species-rich hay meadows is due to agricultural management; minor changes due to

[6] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					climate space. Ultimately MG3[7] meadows could be converted to MG5[8] lowland meadows due to loss of uplands *12f. Sanguisorba officinalis,* a characteristic component of upland hay meadows is predicted to gain climate space. 12g. Plants that need low winter temperatures to prevent respiratory rundown of its carbohydrate and protein resources in the bulky rhizome likely to lose out	climate change. Sorting management is still the big challenge.
13	**Lowland hay meadows**	Increase in winter rainfall Decrease in summer rainfall Increased	Longer growing seasons Phenological changes	Across the range of the community but drought effects may be more pronounced in south east England	13a. SSSI condition will become "unfavourable". [explain] 13b. Difficulty in meeting lowland hay meadow HAP/BAP targets [explain] 13c. Continuing unfavourable	The component plant species of the various lowland meadow types mostly belong to the southern temperate, widespread temperate and temperate biogeographical elements. This suggests that the three lowland meadow NVC types might be relatively resilient to climate change scenarios,

[7] National Vegetation Classification reference
[8] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
		temperatures	Increased competition from drought tolerant species		conservation status for Annex 1 Lowland Hay meadow (MG4[9]) habitat [explain] 13d. Alter relative competitiveness of species - species composition change 13e. Increased spring temperatures (and legacy of wetter winters) may boost total biomass and favour competitive species 13f. Drier summers will favour stress tolerant (e.g. deep-rooted species) and ruderal species but retard competitors/stress-tolerant competitors	especially those related to temperature. MG5 is a component of the lower hill slopes (as a pasture) should be maintained and should survive under climate change.
14	**Lowland calcareous grassland** Priority HAP type synonymous with: NVC types	Increased winter rainfall Decreased summer rainfall Warmer winters Warmer	Drought Longer growing seasons Changes in succession Drought	Increased summer drought is likely to be a particular threat for those communities which already have a highly xeric character.	14a. Loss of/declining condition in parts of the SSSI/SAC series. 14b. Continuing unfavorable conservation status for Annex 1 habitat. 14c. Difficulty in meeting lowland dry acid grassland HAP/BAP targets.	Responses of chalk/limestone communities to climate change will be related to the life-history attributes of the dominant species. Sensitivity of the majority of perennial grasses to increasing incidence and intensity of summer drought resulting in possible substantial shift in community composition towards more annuality.

[9] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	CG1 – CG10[10] inclusive Designated SSSI features Annex 1 type under Habitats Directive	summers	Change in competition		14d. Increase in spring biomass and decline in summer biomass 14e. Possible losses/declines of perennials due to die back through droughting. 14f. Certain species will gain suitable climatic space in the North and West whilst losing it in the South. Likely declines in Artic montane associated with upland stands of CG9/10 and Boreal montane and Boreal temperate biogeographic elements of calcareous grasslands 14g. Change in relative competitiveness - increase and expansion of drought tolerant ephemerals and re-colonization by annuals with a persistent seed bank 14h. Delayed succession - gap formation in the sward will provide sites for colonisation of annuals, thereby enabling their persistence in the sward at the expense of perennials	Plants which have underground storage organs may show greater ability to survive droughts as may deep rooted species such as *Centaurea nigra*. In contrast shallow rooted species will be disadvantaged

[10] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					14i. Decline in abundance and diversity of associated fungi communities and specialist mosses 14j. Increased risk of wildfires resulting in damage to lower plant assemblages	
15	**Lowland dry acid grassland. Priority HAP type** (NVC U1, U3, U4[11]) Designated SSSI features. U1 is important in CHF	Decreased summer rainfall Increase in winter rainfall Increased temperatures	Summer drought Longer growing seasons Reduced frost heaving Increasing competition from drought tolerant species	Across the range of the habitat	15a. SSSI condition may become "unfavourable". 15b. Difficulty in meeting lowland dry acid grassland HAP/BAP targets 15c. Community change – favour annual species and southern temperate and Mediterranean continental elements in flora. Oceanic/sub-oceanic species may decline. 15d. Certain acid grassland species are predicted to lose climate space by 2080 namely *Koeleria macrantha* (U1), *Erica cinerea* (U3), *Filago lutescens* (U1), and *Agrostis curtisii* (U3). *15e. Erodium cicutarium* (U1) may lose climate space from some part of its current distribution but simultaneously	

[11] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					expand its range northwards. *15f. Silene otites* (U1) is predicted to gain climate space. 15g. Less summer forage available for livestock grazing	
16	**Other Species-rich grasslands**	Decrease in summer rainfall Increase in winter rainfall Increased temperatures	Drought Longer growing seasons	U5c/U4c in Cumbria High Fells	16a. Habitat could move up the valley/allotment slopes given the chance. 16b. U1 likely to increase in extent with increased summer parching	Need to think about upland calcareous grassland (for example Honister and Helvellyn) this can not move elsewhere (it only occurs on limestone-rich bands of rock). It's quite high altitude so getting it into good management would make a huge difference.
17	**Lowland raised bogs** (Only really at Mungrisedale within the CHF)	Decrease in summer rainfall Increase in winter rainfall	Summer deficit in water availability Drought Flooding	The residual risk to Wetland HAP targets is greatest for lowland raised bog in the less oceanic areas of the UK.	17a. Water deficit will compromise attempts at lowland raised bogs restoration. As ombrotrophic systems, bogs cannot be 'topped-up' with water from elsewhere if summer rainfall is deficient, so may be particularly vulnerable to climate change. 17b. Additionally, increased winter rainfall may increase the risk of bog burst, particularly on those already damaged bogs. This could be positive: if winter rain is held on the bog, it could reduce impacts of summer drought.	No further management intervention is possible to ameliorate summer rainfall deficits if the hydrology is already intact and the bog is in favourable management
18	**Valley Mires**	See lowland raised bogs	See lowland raised bogs	More important in South Cumbria	18a. Some larger/deeper areas might lock up significant amounts of carbon –	More surface water fed than lowland raised bogs so may be more resilient.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
				Low Fells Character Area.	loss of this will increase emissions	
19	**Swamps/ Fens**	Decrease in summer rainfall Increase in winter rainfall	Drought Increased surface flow in winter Flooding Variability in rainfall	Floodplain fens occur over a wide altitude range.	19a. Basin fens may suffer drying in summer (less so in Cumbria High Fells) 19b. Increased risk of polluted run-off with increased winter rainfall and extreme rainfall events. 19c. Boreal species may be lost from southerly sites 19d. Unpredictable inundation of floodplain fen. Increased silt loading when inundation occurs 19e. Change in rainfall pattern could have big impacts for spring-fed fens and flushes	Fluctuations in levels of water bodies greater – could have knock-on impacts for swamp and fen.
20	**Purple moor grass and rush pastures – Priority HAP type** synonymous	Reduced summer rainfall Increased winter rainfall Warmer winters	More severe summer drought episodes Longer growing seasons	M26, M23 and M25c important in Cumbria High Fells.	20a. Loss of/declining condition in parts of the SSSI/SAC series.[explain] 20b. Continuing unfavorable conservation status for Annex 1 habitat.[explain]	Responses of these *Molinia* and *Juncus* dominated communities to climate change will be related to the life-history attributes of the dominant species. Setting for lots of these communities are as lake margin wetlands e.g.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	with: NVC types M22- M26[12] inclusive Designated SSSI features Annex 1 type under Habitats Directive (M24 & M26)		Potential increase in spring biomass and decline in summer biomass		20c. Difficulty in meeting lowland dry acid grassland HAP/BAP targets [explain] 20d. Precise tolerances are not known but it can be speculated that there will be a loss of wetland interest and increased representation by 'dryland' species. 20e. Prolonged inundation may cause shift towards true fen or swamp communities. 20f. Potential declines and losses of Boreal montane (*Pinguicula vulgaris, Primula farinosa, Trollius europaeus)* and Boreal temperate (*Narthecium ossifragum, Potentilla erecta, Crepis paludos, Equisetum palustre Molinia caerulea*) biogeographic elements of fen meadows may be expected, particularly in M26 where these elements are better represented. 20g. Decline in abundance and diversity of associated mosses,	around Bassenthwaite Lake, Derwent Water, Ennerdale Water etc. Impacts of changed rainfall and/or greater lake fluctuations difficult to predict. Also difficult to distinguish this community (at the scale we are working) from fen/mire/reed swamp which also all occur in the same setting.

[12] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					particularly sphagnum component. 20h. Derelict stands will be prone to scrub invasion and woodland succession and a loss of species typical of fen meadows/rush pastures e.g. *Cirsium dissectum.*	
21	**Upland oak** Priority HAP type Designated feature on SSSIs. Annex 1 type Key part of treasured landscapes in Lake District .	Increased summer temperature Increase in winter rainfall Decrease in summer rainfall	Summer dry out Changed rainfall pattern – more variation	Type occurs largely in the north and west. Effects likely to be greatest on south-facing slopes and towards the margins of its climate suitability, e.g. on the upland fringe.	21a. Changes in ground flora composition, but probably no major losses of currently common species 21b. Tree species composition shift especially Beech increase. 21c. Bryophyte species loss very likely 21d. Some decline at margins of most bryophyte-rich types as modelled by *Dryopteris aemula,* W17 21e. Changes in canopy tree competitiveness (particularly with respect to beech, currently considered non-native through most of this type) 21f. Individual rare species may increase or decrease 21g. Shifts in the relative contributions of the sub-types of upland oak, e.g. W11 versus W17 with implications for reasons for designation as SSSI/ SAC	North Atlantic oceanic influence in Cumbria High Fells is best in England – not just the trees but also for bryophyte communities. The future of oak woods is higher on the fellside – like Keskadale Oaks need to recreate more upland woods – which is almost gone from the High Fells. We are currently "tinkering around the edges" of this issue. Need to change the scale of our delivery here. Woodland planting is likely to protect some oceanic species that would suffer in open ground in summer droughts. It would be helpful to reflect on the full range of species that would be affected by summer drought – i.e. those species that are of oceanic distribution (or hyperoceanic).

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					21h. Increased invasion of oakwoods by beech 21i. Changes in balance of woodland versus upland grass/moor under agricultural shifts	
22	**Upland mixed ash**. Priority HAP type Designated feature on SSSIs. Annex 1 type Restricted and not a dominant woodland type in the Character Area.	Increased summer temperature Increase in winter rainfall Decrease in summer rainfall	Summer drought Changed rainfall pattern	Habitat is predominantly in the north and west. Effects likely to be most pronounced on south-facing slopes and at the southern margins of the range, e.g. in South-west England.	22a. Changes in ground flora composition, but probably no major losses of currently common species 22b. Changes in canopy tree competitiveness (particularly with respect to sycamore and beech, currently considered non-native through most of this type) 22c. Species composition change – replacement by oak due to earlier bud-break in higher temperature out-competes ash. 22d. Individual rare species may increase or decrease 22e. Shifts in the relative contributions of the sub-types of upland ash, e.g. potential for expansion of the 'dry' (W8g[13]) forms down slope on hot sites;	Most of this woodland in the Cumbria High Fells is as "ash stripes" down wetter stream sides and flushed soils. The northern part of the Character Area goes back onto limestone – Ireby and Uldale might have significant examples Also Atlantic bryophytes are likely to be associated with this community as the upland oak woods. One of the types less likely to change significantly under climate change May be high risk if drier summers result in too much stress and a loss of habitat extent. Knock-on effects for ground flora under woodland.

[13] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					expansion of moist types (W8[14]) if rainfall increases humidity in ravines.	
23	**Wet woodland**. Priority BAP habitat Designated site feature on SSSIs Includes Annex 1 habitats	Summer temperature increase Increase in storms – intensity of rainfall	Higher intensity rainfall events Summer drought	Mainly a problem in the lowlands.	23a. Lower water tables in sites affected by increased abstraction 23b. Drying out of rainfall-dependent sites in summer 23c. Changes in ground flora communities 23d. Loss of condition of designated sites 23e. Failure to achieve Favourable Conservation Status on Annex 1 habitats 23f. Failure to meet HAP targets Potential opportunities for habitat creation on flood storage land. 23g. Possibly increased land for flood storage	Low risk and low impact in Cumbria High Fells – BUT greater lake fluctuation could have impact where wet woods on edge of Lakes etc.
24	**Juniper**	Increased winter rainfall Decreased		Key woodland/upland scrub asset and feature on	24a. Species affected by higher rainfall – won't regenerate in wet land.	More affected by land management changes than climate change e.g. increase in grazing pressure/rabbits/voles

[14] National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
		summer rainfall		Cumbria High Fells		Very wide distribution in western Europe, therefore good chance to remain in warmer summer scenario.
25	**Upland scrub (including willow scrub)**	Increased summer temperature Decreased summer rainfall	Drought	Very depleted resource. Major missing component of upland ecology.	25a. May lead to expansion due to climate change Could be potentially positive impacts of climate change .	Extent of impacts is driven by grazing.
26	**Wood-pasture and parkland + Veteran Trees** Priority HAP type, Designated SSSI feature, Various sites are also SACs Pollards and other mature trees.	Warmer summers Decrease in summer rainfall Increased storm intensity	Increased windiness or at least increased frequency of extreme storms Summer drought Increased flood frequency	Whole country potentially affected. High risk to nationally important designed parklands. Lake District is important for this. Glenamarn. Scales Wood. Martindale Forest. Pollards/veteran trees in Borrowdale. Patterdale.	26a. Increased rates of loss of existing veteran trees 26b. Loss of specialist associated species through loss of veteran tree habitat (primarily fungi, saproxylic invertebrates and lichens) . 26c. Loss of landscape quality through loss of old trees. 26d. Agricultural intensification leading to improvement/ ploughing of pasture element, clearance of scrub etc 26e. Increased loss of mature trees to wind blow	Main threat is assumed to be to the veteran tree population. However in addition changes in farming practice could affect both the sites and the landscapes in which they sit as an indirect consequence of climate change. Future veteran trees need recruiting population. High cultural and historic value Link to inostrates, rare bryophytes
27	**Woodland Birds**	Milder winters Increased		Throughout England	27a. Decline in productivity 27b. Spring migrants arrive earlier,	Pied Flycatcher/Redstart are hole nesters.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	Pied Flycatcher Redstart Woodpecker Tawny Owl	spring temperatures Increased windiness or at least increased frequency of extreme storms			breed earlier. Potential for mismatch with peak of prey availability 27c. Changes in the relative abundance of woodland species and communities 27d. Increased rates of loss of existing veteran trees leading to declining abundance of hole nesters 27e. Amount of grazing/windthrow determines ground flora composition and structure and bird community composition will vary accordingly.	Wood Warbler is a ground nester.
28	**Hedgerows are Priority BAP type (where 80% + cover of native woody species)**	Increase risk of storms Increased seasonal precipitation and increased annual variation Reduced cloud cover Increased CO_2 levels in atmosphere	Summer drought Increased flood frequency		28a. Potential increased mortality / die-back of hedgerow trees in vulnerable locations. 28b. Possible mortality of woody species exposed to prolonged flooding in growing season 28c. Increased mortality / die-back from damage to soil structure by agricultural operations in wet soil conditions 28d. May be localized loss of existing non-flood -tolerant woody species in flood-risk areas.	Assumed that impacts on soil and ditch levels will not be major but no information on likely hydrological effects on hedgerow species found (wetland specialists may have more information) Hedgerow trees may be vulnerable where soils are shallow, sandy or roots are damaged by compaction, ploughing, trampling or other disturbance, plus increased susceptibility to pests and diseases Increased growth may lead to increased management requirements to maintain dense shrub-sized hedgerows, a greater rate of change to

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					28e. Blow down of hedgerow trees especially those in vulnerable locations 28f. Increase in fruit ripening - greater wildlife populations can be supported 28g. Increased growth of woody species, effect on water use unclear	lines of trees, and increased shading of hedgerow herbaceous flora. Different wildlife occurs in different hedgerow structures but population level effects of change unknown.
29	**CROW open access Land**	Warmer summers Increased winter temperatures Increase winter rainfall Decreased summer rainfall	Increase in fire risk Increase in visitor numbers	Throughout Character Area but particularly in lowlands, particularly in southern areas and northern foci	29a. Increase in fire – damage to recreation assets 29b. Increase in erosion rates and surface flow leading to gullying 29c. Trampling	Increase in visitor numbers related to increase in temperatures – assumes current socio-economic scenario prevails
30	**Cumbria Rights of Way Network**	Warmer summers Increased winter temperatures Increase winter rainfall Decreased summer rainfall	Increase in visitor numbers	Throughout Character Area but particularly in lowlands, particularly in southern areas and northern foci. Linear features	30a. Trampling 30b. Over crowding 30c. Increase in erosion rates and surface flow leading to gullying	Increase in visitor numbers related to increase in temperatures – assumes current socio-economic scenario prevails
31	**Tourist /**	Warmer	Increased	Throughout	31a. Flooding of attractions	No national restrictions on mobility

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	visitor attractions	summers Increased winter temperatures Increase winter rainfall Decreased summer rainfall	flood risk Increased fire risk	Character Area but particularly in lowlands, particularly in southern areas and northern foci. Flash floods may be localised in time and space	31b. Fire damage 31c. Heat stress 31d. Over crowding of attractions and pressure on infrastructure	
32	**Lakes**	Warmer summers Warmer winters Drier summers Drier winters	Increase in visitor numbers Flooding Drought	Limited to waterbodies – widespread across Character Area	32a. Increased recreational use – increased pressure on declining resource 32b. Increased erosion and sedimentation 32c. Low water levels	
33	**Uplands and lowlands**	Warmer summers Increased winter temperatures Increase winter rainfall Decreased summer rainfall	Policy reduction in climate change gasses Increase in visitor numbers Flooding	Attractive rural areas Heathland & Moorland Problems particularly significant at holiday times on transport infrastructure.	33a. Potential reintroduction in vector borne diseases e.g. Tick borne diseases. Unlikely that most dangerous forms will establish 33b. Countryside seen as dangerous – potential reduction in demand for outdoor recreation. Summer becomes hazard season. 33c. Large areas of potential damage by fire & areas not available for	

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
			Drought Fire		recreation. 33d. Possible reduction in travel to more remote areas as cost increases leads to reduction in demand for major sites	

Table A4.1b – Impacts on landscape assets

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Gently rolling or undulating low-lying topography, dissected by meandering river valleys.	Very low	Minimal impact on geology and resulting landforms.	Widespread	Changes in erosion changing landforms.	Any impacts will be VERY long term and won't show in current timescales!
Pasture fields dominate land cover.	Low risk of direct impacts. Higher risk of indirect impacts due to land use changes in response to changed weather and socio-economic contexts.	Little direct impact on pastoral systems. Could be increased productivity of grasslands? Potential increase in arable production as climate changes	Widespread.	Increased productivity of pastoral systems? Increased cover of arable cropping? Slow change in characteristic tree and hedgerow species?	Change likely to be driven by "indirect" socio-economic responses rather than by direct impacts.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Combination of dispersed and nucleated settlements and scattered farmsteads.	Medium.	Increased pressure for settlement based upon "improved" climate	Widespread	Potential for settlement in-fill and expansion to accommodate additional demand.	Local climate may become "more attractive", encouraging further inward migration (potentially, ultimately from areas that have become less attractive because of climate changes)
Intensively farmed agricultural land below 100m OD	Low	Conditions likely to improve for intensive agriculture.	Valley bottoms.	Increased intensification?	Climatic and socio-economic conditions likely to improve for intensive agriculture in Cumbria High Fells.
Pasture land cover, with occasional patchy woodland and arable farmland.	Low	Conditions likely to improve for pastoral agriculture. Potential long term change in tree species composition.	Valley bottoms and lower slopes.	Intensification of the grassland systems	Climatic and socio-economic conditions likely to improve for intensive pastoral systems in Cumbria High Fells.
Large fields bounded by hedges or fences and/or hedgerow trees	Low	Slow change in species composition of hedges and hedgerow trees. Risk of removal of hedges/trees etc. as part of wider agricultural	Valley bottoms and lower slopes.	Minimal in landscape terms as long as hedges, hedgerow trees etc, remain in the landscape.	Climate change will lead to shifting "climate space" for currently characteristic shrub and tree species.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		intensification.			
Lowland agricultural landscape, dominated by undulating topography, with dissecting valleys.	Low	Topography will only change on VERY long timescale. Risk of agricultural intensification.	Widespread, but on fringes of Cumbria High Fells	Agricultural intensification in response to socio-economic factors. Grassland being turned into arable, loss of hedges, hedgerow trees etc.	Climatic and socio-economic conditions likely to improve for intensive agricultural systems in/around Cumbria High Fells.
Land cover - pasture and some woodland, scrub and other marginal land.	Medium	Agricultural intensification. Slow change in shrub and tree species composition.	Widespread, but on fringes of Cumbria High Fells	Grassland being converted to arable. Loss of woodland and marginal land	Climatic and socio-economic conditions likely to improve for intensive agricultural systems in/around Cumbria High Fells. Slow shift in “climate space” for tree and shrub species.
Hedgerow trees and hedgerows - variable field patterns relating to topography.	Medium	Agricultural intensification. Slow change in shrub and tree species composition.	Widespread, but on fringes of Cumbria High Fells	Loss of hedges, hedgerow trees, woodland etc.	Climatic and socio-economic conditions likely to improve for intensive agricultural systems in/around Cumbria High Fells. Slow shift in “climate space” for tree and shrub species.

Landscape Type F: Rugged/craggy High Fell

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Dome-shaped topography, with the highest point being Scafell Pike.	None	None	None	None	Geology will not be changed by climate change
From the highest point, ridges radiate out, with the landform gradually lowering towards the edges of the Lake District.	None	None	None	None	Geology will not be changed by climate change
Complex topographical patterns caused by glacial and fluvial erosion.	Low	VERY slow impacts upon topography due to changing patterns of fluvial and glacial erosion etc.	Widespread.	None on human timescales.	Impacts will be very slow and not noticeable on human timescales.
Land cover - bare rock, scree or low-growing vegetation. Low density grazing over much of the	Medium	Little change in geomorphological forces. Some potential change in extensive agricultural	Widespread.	Loss of vegetation cover if grazing intensifies. Increase in vegetation cover if grazing extensifies.	Indirect impacts caused by changes in upland agriculture will have greater effect than direct climate change impacts.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
area.		practices, sheep grazing densities etc.			
Scattered tarns and a complex network of becks.	Low	Little change expected in landscape aspects of tarns and becks.	Widespread	Greater seasonal variation in water levels/flows.	Changes in precipitation patterns are likely but little we can do about their local impacts at these altitudes.
Some areas of juniper and native oak woodland remain. Small areas of commercial conifers	Medium	Slow change in climate space for tree and shrub species. Risks from increased grazing pressure.	Localised – particularly around Borrowdale. Conifers particularly in the west.	Potential loss of characteristic species	The climate space of at least some characteristic species will shift through time.
Fell wall marks the edge of open land. Archaeological enclosures and field systems within upland areas.	Low	Change in agricultural patterns.	Widespread	Loss of characteristic enclosure patterns because of changes in agricultural systems. Though walls likely to be derelict rather than be removed.	Current enclosure patterns may become redundant in face of changing agricultural systems.
Settlement limited to isolated farms	Low	Potentially increased interest at living at higher (cooler) altitudes.	Localised.	Renovation of upland farmsteads.	Population shifts in response to changing climate.
Archaeological record reflects	Low	Potential loss of visibility	Scattered.	Archaeological sites/features less obvious within the landscape.	Loss of visibility likely to be worst impact. Sites/features assumed to

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
several thousand years of settlement and industrial activity in the Upland Fells.		because of increased vegetation cover?			remain present and intact.
Deep corrie lakes.	Low	Greater seasonal variation in precipitation patters.	Scattered. Somme Tarns, such as Easedale Tarn and Red Tarn	Greater seasonal fluctuation in levels, but given depth of these Tarns, may not be too great a problem	Changes in precipitation pattern is likely to lead to increased variation in water levels.
Other Tarns are shallower and have formed in upland basins.	High	Greater seasonal variation in precipitation patters.	Scattered. E.g. Eagle Tarn	Greater seasonal fluctuation in levels, which, given that these are shallow Tarns, may have substantial impact upon visual and aesthetic qualities, as well as associated biodiversity..	Changes in precipitation pattern is likely to lead to increased variation in water levels.
Scattered patches of 20th Century conifer plantations.	Low	Possible pressure to increase conifer planting as part of climate change response (renewable energy; structural timber; renewable resource etc.)	Scattered.	Risk of negative impacts upon landscape (and other environmental assets).	Regarded as negative feature in landscape (a “detractor”) and therefore removal beneficial. Assume that any increase in woodland/forestry planting as part of climate change response will be on “right species in right place” basis, therefore risk of negative impacts should be minimised.
Large and active slate quarry	Low	Assume no risk on basis of climate change.	The summit of Honister Pass.	None.	Assume climate change unlikely to affect slate quarry business.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		Wider socio-economic factors will have much greater impact.			
History of slate and mineral extraction	Low	Slow change in geomorphological processes will have long term impact on areas of bare rock.	Scattered. Area west of Coniston, including the Old Man of Coniston and Wetherlam	Slow change in nature of exposures.	Assume that rate of change will be very slow in comparison to human timespans.

Landscape Type G: Rounded/angular High Fell

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Skiddaw Slates are easily weathered - resulted in the smooth profile	Low	Increased weathering, but on very long timescales.	Widespread.	Increased erosion.	Timescales will be very long in comparison with human timespans.
Land cover - heather moorland and blanket bog. Some blocks of forestry including Whinlatter and Lamplugh Fell. Generally little deciduous	Medium	Change in vegetation cover in response to changing climate. Pressure for increased forestry as a response to	Widespread.	Risks to heather moorland from changes in grazing pressures, fire risks etc. Risks to blanket bog from changed precipitation patterns. Risk of increased cover of conifer forestry having negative impact upon character/value.	Socio-economic responses to climate change likely to drive greater indirect impacts than direct impacts.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
woodland.		climate change (renewable resource etc.)			
Majority of the Landscape Character Type is open moorland above the Fell Wall.	Low	Changes in agriculture leading to changes in enclosure pattern	Localised.	Spread of enclosure higher up valleys/ fellsides as farming intensifies land use.	Potential intensification of agriculture in response to more favourable climatic conditions and indirect socio-economic factors.
Occasional isolated buildings	Low	Long term increase in attractiveness of upland climate leading to increased pressure for settlement.	Scattered	Increased renovation/building of dwellings/expansion of farmsteads?	Possible migration of people to higher latitudes and altitudes as climate becomes more attractive
Blencathra valley contains improved fields, a farmstead and block of woodland	Medium	Increased agricultural intensification. Increased pressure for settlement Long term change in woodland species mix Increased woodland	Localised	Expansion of “improved” fields. Expansion of farmstead to create small “settlement”. Woodland species mix changing and potential expansion of woodland cover for food/fuel supply.	Productive agriculture moving up the hillside. Increased interest in settlement in upland areas. Increased interest in/market for woodfuel. Slow change in “climate space” for woodland tree species.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		planting for wood fuel			
Surfaced road running up the valley which provides access to the higher fells.	Medium	Easy access for increased commuter and/or recreational traffic.	Localised to road.	Could allow increased settlement and/or recreational pressure.	Potential increased interest in upland settlement and/or recreational opportunities.
Whinlatter forest - extensive upland area of Forestry Commission planted forest	Medium	Change in key forestry species? Increased demand for timber as renewable resource Increased demand for recreation in shady/cooler places such as forests	Localised.	Need to adapt species choice Potential expansion of forested area to increase supply of both timber and recreational opportunity. Potential increase in car-borne visitor traffic.	Slow change in climate space for key forestry species. Increased demand for home-grown timber as renewable resource. Increased recreational demand in uplands and/or in shade/cool.

Landscape Character Type H: Broad Upland Dale

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Broad U-shaped valleys, formed by glaciers cutting through underlying rock, during the last Ice Age	Very low	Very slow change in geomorphological processes.	Widespread	Very slow change in valley shape	Change in geomorphological processes will be VERY slow and not noticeable on human timescales.
Topography differs greatly - ranging from dramatic and steep valley sides with screes, sloping down towards a deep lake to valleys with gently rolling sides with a slow-moving river on the broad valley floor	Low	Slow change in geomorphological processes may affect scree slopes. Greater seasonal fluctuation in lake levels. Slow change in river form?	Widespread	Vegetating of scree slopes as growing conditions improve Changes in water environment.	Effects will be slow and largely outside cost-effective intervention.
Valley floors are either dominated by a lake or river; and pastoral farmland.	Medium	Greater seasonal fluctuation in lake levels. Slow change in	Valley floors	Changes in water environment. Return of some arable cultivation. Increased use of floodplain.	Increased variation of precipitation patterns. Improved climate for arable cultivation coupled with socio-economic factors driving increased profitability of upland

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		river form Intensification of farming systems. Potential increase in arable cultivation if not too wet Increased use of floodplain for flood management.			farming systems.
Valley sides are covered by mixture of pastoral farmland (in-bye land) and woodland. Steeper valley sides characterised by screes.	Low	Expansion of improved pasture up the fellsides. Slow change in species mix of woodlands.	Widespread	Change in balance between improved (in-bye) land and open/rough grazing. Change in species mix of woodlands. Potential for expansion of woodlands for wood fuel **OR** Potential loss of woodland as agriculture expands	
Isolated farms on valley sides, small nucleated and linear settlements	Medium	Increased settlement pressures	Widespread	Building and renovation of dwellings and associated infrastructure Change in local vernacular designs to become more “sustainable”	Increased interest in living in the more pleasant climate of upland areas

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
and large towns on valley floor					
Communications run along the valley sides or follow the edge of the valley floor.	Low	Possible pressure for road development if increased settlement and recreational use not based upon sustainable transport modes.	Widespread.	Increased road building, upgrading etc.	Increased interest in living /recreating in upland areas.
Predominantly flat landscape, dominated by lakes of	Medium	Increased variation of precipitation	Localised	Increased seasonal fluctuation of lake levels Increased potential for flooding	Increased variation in precipitation. Increased storminess.
Combination of habitats along the immediate lakeshore, including reeds, pasture and woodland giving a soft appearance	High	Seasonal variation in precipitation	Localised	Fluctuation lake levels affecting lakeshore habitats/lake setting.	Increased variation in precipitation. Increased storminess.
Footpaths follow lakeshore.	High	Seasonal variation in precipitation	Localised	Fluctuation lake levels affecting paths	Increased variation in precipitation. Increased storminess.
Valley floor dominated by	Medium	Seasonal variation in	Localised	Increased risk of flooding	Increased variation in precipitation.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
river floodplain		precipitation			Increased storminess.
Pasture fields generally run alongside the river. Occasional meadows and clumps of woodland adjacent to river course	Medium	Seasonal variation in precipitation Slow change in climate space for characteristic species.	Localised.	Increased risk of flooding. Risk of droughting/low flows in summer Loss of characteristic woodland species.	Increased seasonality of precipitation Change in climate space leads to change in habitat composition.
Scattered farmsteads within the valley bottom and pattern of stone walls at field boundaries.	Low	In-migration as local climate becomes relatively more attractive. Changes in agricultural practices.	Localised	Increased pressure for residential development. Neglect of field walls as function becomes obsolete.	Field walls may become obsolete if increase in animal “ranching” or shift to arable copping. Possible in-migration from less attractive climates
Patchwork of predominantly pastoral fields (“in-takes”), delineated by a series of stone walls, or in some cases hedgerows	Low	Change in climate for agriculture.	Localised.	Loss of characteristic hedgerow species. Intensification of grassland management	
Clumps of trees or woodland.	Medium	Change in climate space for characteristic	Localised.	Change in characteristic tree/woodland species.	

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		tree/woodland species.			

Landscape Character Type I: Rolling Upland Limestone Farmland

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Carboniferous Limestone geology	Medium	Increased seasonality of precipitation	Localised.	Risk of increased droughtiness in summer	Lower rainfall in summer.
Long views in places.	Medium	Indirect impacts of renewable energy developments.	Widespread	Visual impact of inappropriate developments such as wind turbines.	Potential threat from wind turbine development
Improved and semi-improved pastoral farmland. Occasional tree clumps. Parkland with plantations associated with the Lowther Estate	Medium	Changes in agricultural practices. Changes in climate space of characteristic hedgerow and tree species. Increased storminess affecting individual (parkland) trees Increased plantations to supply renewable	Various.	Further improvement of pastures. Arable conversion. Change in characteristic hedgerow and tree species. Damage to parkland landscapes. Increased plantation forestry affecting openness of landscape.	

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		energy and/or sustainable materials.			
Occasional small copses	Medium	Change in climate space of characteristic tree species.	Localised.	Change in characteristic tree species.	
Small villages and dispersed farmsteads. Several Halls and Estates.	Medium	In-migration as local climate becomes relatively more attractive.	Localised.	Increased residential development pressure.	In-migration as the climate in other areas becomes relatively less attractive.
Network of secondary roads	Low	In-migration	Localised.	Pressure for road improvement if local population increases.	

Landscape Character Type J: High Fell Edge

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Hills dissected by numerous streams and minor river valleys.	Low	Increased seasonality of precipitation.	Localised.	Localised flooding Increased erosion in storm events.	
Predominantly improved pasture and meadows with a pattern of stone walls giving way to hedges at lower levels.	Medium	Changes in agricultural practices. Change in climate space of characteristic hedgerow	Localised.	Further improvement of pastureland. Neglect of field walls. Change in characteristic hedgerow species.	

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		species.			
Small patches of woodland on steeper slopes and alongside streams and rivers, with numerous field boundary trees and tree clumps occurring around farms.	Medium	Change in climate space of characteristic tree and woodland species	Localised.	Slow change in characteristic tree and woodland species.	
Scattered farms and hamlets, served by minor roads located at the base of the slopes.	Low	In migration as climate becomes relatively more attractive.	Localised.	Increased pressure for residential development, road improvement etc.	

Landscape Character Type K: Low Fell

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Large areas of semi-natural and coniferous woodland.	Medium	Change in climate space of characteristic tree and woodland species	Widespread	Slow change in characteristic tree and woodland species.	
Diverse patchwork of rough grassland,	Medium	Changes in agricultural practices.	Localised to an in combination of Widespread	Slow change in characteristic of grassland, trees and woodland species.	

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
semi-improved pasture, small broadleaved and coniferous copses, rock outcrops, heathland, tarns and becks, small wetlands, mires and bracken.		Changes in climate space of characteristic hedgerow, tree species & wetland habitat. Increased drying out and flooding of water bodies		Fluctuation waterbody levels affecting wetland habitats/lake setting. Increase in bracken abundance and density, having high visual impact.	
Dispersed settlement pattern, served by a network of minor roads and tracks.	Low	In migration as climate becomes relatively more attractive.	Localised.	Increased pressure for residential development, road improvement etc.	
Dry stone walls, villages, hamlets, isolated farms and barns, built from local limestone and slate.	Low	Changes in agricultural practices, building use and local vernacular building. As mitigation measure are necessary	Localised	Increased pressure for residential & commercial development. Neglect of field walls as function becomes obsolete.	Field walls may become obsolete if increase in animal “ranching” or shift to arable copping. Extensification of farming means wall upkeep not possible Possible in-migration from less attractive climates
Expanses of dense semi-natural broadleaf; and coniferous woodland.	Medium	Change in climate space of characteristic tree and woodland species			

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Generally strong sense of enclosure.	Low	Changes in agricultural practices,	Localised	Neglect of field walls as function becomes obsolete.	
Rough grassland clearings.	Low	Loss of associated species	Localised		
Well-managed landscape with a parkland character of single mature native and ornamental trees amongst areas of managed grassland.	Medium	Increased storminess affecting individual (parkland) trees	Localised	Damage to parkland landscapes.	
Large country houses or halls and associated estate cottages form the main (often central) built elements.	Low	Change in nature of land use and viability of large estates	Localised but dominate at this scale	Could be both a positive or negative impact	
Generally manicured appearance, which contrasts with surrounding more types of landscape.	Low	Uptake of a more extensive farming system leads to the loss of this landscape character	Widespread in character types		Agriculture may intensify or become more extensive, so either increasing or decreasing this charractistic.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Dry stone walls, built from local limestone and slate.	Low	Changes in agricultural practices,	Localised	Neglect of field walls as function becomes obsolete.	
Landscape peppered with farmsteads and small vernacular hamlets.	Low	In migration as climate becomes relatively more attractive.	Localised.	Increased pressure for residential development, road improvement etc.	
Predominant land cover is grassland or moorland	Low	Change in agricultural patterns	Widespread.	Intensification of grassland management for grazing.	

Landscape Character Type L: Low Fell Edge

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Combination of rolling, undulating or plateau farmland.	None				
Stone walls at field boundaries.	Low	Change in agricultural patterns	Widespread.	Potential loss of walls – mainly through neglect.	Inertia will mean little change in wall patterns

Landscape Character Type M: Broad Lowland Valley

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
Broad U-shaped valleys, containing either a river or lake on the valley floor.	None.				
Mixed landcover of pastoral grazing land and woodland (predominantly broadleaved) adjacent to the rivers or lakes.	Medium	Agricultural intensification	Widespread.	Expansion and intensification of pasture land. Potential for some arable cropping. Expansion of woodland for woodfuel **OR** Loss of woodland to agricultural expansion. Change in characteristic tree species.	
Patches of parkland (exhibiting mature landscape structure) along dale sides.	Low	Increased storminess	Localised.	Loss of ancient trees	Basic pattern of the designed landscape not threatened, but storminess may cause some trees to fall.
Pattern of stone walls and hedgerows delineating field boundaries.	Low	Change in agricultural practices. Change in climate space for hedgerow	Localised	Potential loss of hedges through neglect, removal or species change.	Agricultural change in response to improved climate and favourable socio-economic factors. Walls unlikely to be removed, but could fall into disrepair.

Asset	Risk	Nature of risk effects	Extent of effects	Projected impacts	Key assumptions
		species.			
Wide, predominantly flat valley floor and floodplain.	Medium	Increased variability of precipitation.	Localised.	Flood risk	
Landscape is dominated by lake.	Medium.	Increased variability of precipitation.	Increased variability of precipitation.	Fluctuations in lake levels – loss of characteristic fringing habitats etc.	
Sloping landscape forming the lower valley sides.	None.				

Table A4.2 Responses to climate change impacts in the Cumbria High Fells CA

Key
Policy responses are underlined

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
Freshwater	1a 2g 2k 5b 5g 6b 7c	Increase ability of catchments to retain rainfall and reduce artificially enhanced surface run-off	High	Immediate	Medium	Very effective for a number of freshwater assets. Can be delivered through agri-environment scheme	Natural England Government (regulatory role) Forestry Commission Environment Agency Land use planners	Reliance on voluntary action – need regulation Character Area scale
	1a 2k 5b 5i 6b	Restoration of natural physical form of river valleys and function of river channels and floodplains	High	Immediate	Medium	Effective but requires more research and evidence base (particularly hydrology and geomorphology)	Environment Agency Land use planners Highways authorities	Public understanding Lack of advocacy Lack of evidence base
	2c 2d 5a 5h 6c 6d 7g	Reflect potential for changes in species composition, particularly with regards to natural invasives, in conservation objectives and condition assessment.	High	Immediate	Low	Will need to be flexible and requires monitoring	Natural England Defra EU	EU – Habitats Regulations
	2b 2i	Reduce pressures not associated with climate	High	Immediate	Potentially high -	Very effective if other pressures are reduced. Could	Natural Englnad Defra	Economics

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	5d 5k	change – nutrient loading form agriculture, tourism etc			polluter pays	be delivered through agri-environment schemes	Farmers	
	2k 5a	Restoration of riparian shading of upland streams by trees	High	Before 2020	Low	Effective – can be monitored through invertebrate populations	Natural Englnad Environment Agency Land use planners	
	2a 2c 4a	Increase diversity of riparian habitats – woodland, scrub, fen etc	High	Before 2020	Medium	Effective	Natural England Environment Agency Land use planners	Land use pressure Compensation
	21b 21d 21f 21h 21i 22d 26a 26b 26c 26d	Increase size of small woods/buffer woods in intensive agricultural areas	Medium	Before 2020	Medium	Will be effective in the longer term but will require monitoring of climate change impacts	Natural England Land use planners	Lag time – not visible Potential regrets Land use pressure Land owner attitudes
	21g 23e 23f	Reflect potential for changes in native tree composition in conservation objectives	Medium	Before 2020	Low	Very effective but will require monitoring to ensure effectiveness persists	Natural England	EU – Habitat Regulations
	21c 21f 21i 22d	Scrub expansion	High	Immediate	Medium	Effective if undertaken as part of a long term programme. Increases landscape	Natural England Landowners	Other conservation interests

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	24a 25a							
Lowlands	14e 14g 14h 14i 15d	Maintain existing grassland habitat	High	Ongoing	Low	Will be partially effective but will need to be used on conjunction with other measures	Natural England	
	14e 14g 14h 14i 15d	Expand grassland habitat	High	Immediate	High	Can be delivered through agri-environment scheme	Natural England Land owners Defra	Agricultural economics Recreation Physical characteristics – e.g. soils
	13a 13b 13c 14a 14b 14c 15a 15b	Reflect potential for changes in species composition in conservation objectives	Medium	Before 2020	Low	Very effective but will require monitoring to ensure effectiveness persists [no!]	Natural England	EU – Habitat Regulations
	21c 21f 21i 22d 24a 25a	Convert grassland to heather and bilberry shrubs or woodland	High	Immediate	High	Will increase landscape permeability for heathland and increase conservation interest (currently grassland)	Natural England	Other conservation interests – value judgement required
Uplands	7g 8i 12a	Changing conservation objectives to accept changes in species and community	High	Immediate	Low	Will need monitoring to determine effectiveness	Natural England	Political resistance

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	12b 12c	composition						
	10c	Research into which montane species will be impacted by changes in snow cover, drought, competition etc	High	Immediate	Low	Better information about montane species will assist in delivering effective management	Natural England Universities	Perception of montane species as doomed
	29c 30a	Reduce trampling of alpine plants - interpretive signs, education, fencing and path works	High	Immediate	Medium	Very effective if message communicated.	Natrual England Tourist board	Cost to visitor economy. Impact on landscape
	29c 30a	Reduce grazing and trampling on montane grassland and heath	High	Immediate	Medium	Pressure from grazing could be addressed through HLS	Natural England Defra Land owners	Anti-fencing policy. Conflict between biodiversity and landscape value - but it doesn't have to be done by fencing
	10a 10b 10d 11a 12e	Expand montane habitats on north facing slopes	Medium	Before 2020	High	Will be effective in conjunction with other measures	Natural England	Process of freeze-thaw difficult to recreate in warmer climate
	7a 7d 7f 7g	Grip blocking to get blanket bog back into favourable condition	High	Immediate	Low		Natural England	Increased recreation
	7b	Reduce burning intensity of	Medium	Before	Medium	Will be effective – low baseline	Natural England	Access

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	7e	planned burning – raise water table		2020		risk of wildfires		requirements
	7c	Revegetate bare peat with peat forming species and sphagnum	High	Immediate	Medium	Effectiveness will depend on ability of species to persist under climate change	Natural England Major land owners	Climate change
	8b 9c 12e 12f	Introduce appropriate grazing levels depending on vegetation response to climate change	Medium	Before 2020	Medium	Effectiveness uncertain – will depend on vegetation response and hydrology but well known response.	Natural England Land owners	Graziers may decrease over time
Access and recreation	29a 29b 29c 30a 30b 30c 31b 31d 32b	Regulation – zoning, closure of certain footpaths/areas, planning	Low	Before 2020	Low	Highly effective but should be used as last resort	Natural Englnad Local authorities Commoners National Trust	Perception of countryside and right to access. Political resistance.
	29a 29b 29c 30a 30b 30c 31b 31d 32b	Education – interpretive signs, visitor center	High	Immediate	Medium	Effective if sustained and aimed at correct market	Natutral England Local authorities National Turst	Resources Public resistance

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	32a	Innovation – e.g. solar powered boats	High	Immediate	High	Need to learn from failed ideas elsewhere.	Natural England Market suppliers Land managers	Lack of ideas Consumer uptake Planning and regulation
	29a 29b 29c 30a 30b 30c 31b 31d 32b	Management – fixing the damage done by visitors	High	Immediate	High	Effectiveness depends on resources	Natural England Local Authorities National Trust Land managers	Cost Public attitudes
Landscape	Na	Adoption of adaptive development planning and control policies	High	Immediate	Low	Effectiveness depends on resources		
	Na	Use of cross-compliance and agri-environment incentives to maintain/ conserve key landscape features	High	Ongoing	High	High if drastic changes occur	DEFRA Natural England	EU Policy
	Na	Promote woodfuel as renewable energy and as driver for retaining/managing trees and woodlands.	High	Ongoing	Low	Effective if sustained and aimed at correct market	Forestry Commission & Cumbria woodlands	
	Na	Organic/local branding and marketing schemes to maintain required stock levels	High	Ongoing	Low	Effective if sustained and aimed at correct market	Farming community & Organisations. Leader Plus	

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	Na	Record field patterns, archaeology etc. as historical document. Localised management for special cases.	Low	Before 2020	Low	Effective		
	Na	Removal of conifers in upland forests as part of wider habitat management / improvement works.	High	Before 2020	Medium	Effective	Forestry Commission, Natural England & LDNP	
	Na	Restrict increase in conifer plantations. Ensure any new conifer plantations follow strict design guidance to minimise negative impacts upon landscape.	High	Immediate		Effective	Forestry Commission, Natural England & LDNP	
	Na	Seek to retain a balance between enclosed and unenclosed grazing.	High	Monitor change and then act		Low depends if action tacken at appropriate time	LDNP	

Table A4.3 Assessment of responses against 'good adaptation principles'

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
Maintain existing habitats	Landowners, farmers	Deals with habitat fragmentation, protects from agricultural and development pressures	Response can be delivered through adaptive management	No regrets	Improves scope for future adaptation	Potential synergy with mitigation – increase carbon storage capacity	Future biodiversity will depend on the diversity we conserve today even if it is different. Value of habitats may change under different scenarios.
Extend existing sites	Landowners, NGOs, EA (for flood plain habitats)	Deals with habitat fragmentation, protects from agricultural and development pressures	Swap certainty for uncertainty – don't know exactly what habitats will thrive. Limited value in recreating habitats which will not be sustainable under climate change	Low regret – although possible regret if based on existing composition	Can improve scope for future adaptation if flexible over what habitats are created	Potential synergy with mitigation – increase carbon storage capacity	Value of habitats may change under different scenarios. May have a different emphasis between conservation and recreation.
Habitat re-creation or restoration	Landowners, NGOs, EA (for flood plain habitats)	Deals with habitat fragmentation, protects from agricultural and development	Swap certainty for uncertainty – don't know exactly what habitats will thrive. Limited	Potential for regret if habitat is re-created based on current composition	Can improve scope for future adaptation if flexible over what habitats are created	Potential synergy with mitigation – increase carbon storage capacity	Value of habitats may change under different scenarios. May have a different

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
		pressures	value in recreating habitats which will not be sustainable under climate change				emphasis between conservation and recreation.
Changing conservation objectives	No	Can be used to deal with invasives and non-native species	Must be flexible in response to uncertainty	Low regret	Must remain flexible in order to have no impacts on future adaptation	No interaction with mitigation	Attitude to conservation may be different. Value placed on habitats and species may be different. May be greater or lesser emphasis on recreation over conservation.
Manage grazing level – extensive grazing	Landowners, farmers, graziers	Can be used to deal with changes in agricultural economics – shift towards arable cultivation	Adaptive management therefore allows flexibility in the face of uncertainty	No regret	No impact on future adaptation – adaptive management therefore flexible / reversible	Increased stocking levels may increase methane emissions	Will be mediated by changes in agriculture sector
Flexible hay cutting date and timing/duration	Landowners, farmers		Adaptive management therefore allows	No regret	No impact on future adaptation –	No interaction with mitigation	Will be mediated by changes in

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
of aftermath grazing			flexibility in the face of uncertainty		adaptive management therefore flexible / reversible		agriculture sector
Be alert to potential new pests and diseases	Farmers, Forestry Commission, NGOs	Pests and diseases can arrive independently of climate change – e.g. through import of plants	Response robust to uncertainty – don't need to know what new pests and diseases are	No regret	Beneficial impact on future adaptation	No interaction with mitigation	Useful information regardless of socio-economic scenario
Crown works on existing trees where this helps improved the root:crown ratio	Reserve managers	Assists in control of succession and maintenance of biodiversity		Low regrets	No impact on future adaptation	Reduced biomass carbon store	Socio-economic scenarios unlikely to affect response
Replacement of trees with a mix of species	Land managers, NGOs	More resilient to pests and diseases	May not be robust as uncertainty over which species will thrive	Potential regret if species chosen not sustainable – requires research	No impact on future adaptation if flexible	Potential synergy with mitigation – increase carbon storage capacity	Value of species may change under different scenarios. Attitudes towards non-natives and invasives may change.
Promote beech on north facing sites	Farmers, Forestry Commission, land use planners	Does not address non-climate pressures	Uncertainty over the ability of Beech to persist – response is not adaptable in	Potential regret - Beech may die out regardless of efforts made now therefore	Long term land use change therefore may prevent other adaptive uses	Potential synergy with mitigation – increase carbon storage capacity	Value of species may change under different scenarios.

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
			the short term	would be a waste of resources			
Move wood pasture	Farmers, Forestry Commission, landscape	Does not address non-climate pressures	Uncertainty over persistence of wood pasture	Potential regret – value of wood pasture in landscape is due to historical context. Would not be possible to recreate this.		No interaction with mitigation	Value of species may change under different scenarios.
Increase ability of catchments to retain rainfall and reduce artificially enhanced surface run-off	EA Highways authorities Land use planners	Addresses run-off from development and agriculture		No regrets and win-win for many sectors. Reduces flood risk, increases soil moisture and water available for abstraction	No impact on future adaptation	Synergies with mitigation – collected water can be used for building cooling	
Aquifer protection (reduce abstraction)	EA Water companies	Addresses pressure from development and potable water demand	Level of abstraction can be varied to take account of uncertainty	No regrets and win-win. Improves water quality and biodiversity	No impact on future adaptation	Reduced emissions associated with pumping and transferring water	
Restoration of natural physical form and function of river channels and	EA Land owners Land use planners	Addresses pressure from development, reduces flood risk	By allowing systems to naturally respond to changes deals	Low regrets. Win-win – improvements in flood defence, water quality,	Benefits future adaptation as flood risk is lower	No conflicts with mitigation	Whilst our perceptions of biodiversity and landscape may change,

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
floodplains			with uncertainty	landscape			reduced flood risk will be seen as a benefit under all scenarios
Restoration of riparian shading by trees	EA Land use planners Forestry Commission	Improves landscape		Low regrets. Win-win – benefits for landscape	No impact on future adaptation	Potential synergy with mitigation – increase carbon storage capacity	Socio-economic scenarios unlikely to affect response
Control of nutrient inputs to rivers	EA Water companies Farmers	Addresses existing pressure from agriculture and recreation		No regrets	No impact on future adaptation	Potential conflict if more energy required to treat water to a higher standard. Potential synergy with preference for organic farming	Will be mediated by changes in agriculture sector
Dispersal of visitors	Highways authorities, local authorities, tourist board	Alleviates existing pressure on honeypots which will be exacerbated by a population increase	Robust to uncertainty over visitor levels	No regrets. Benefits for biodiversity.	No impact on future adaptation	No conflict with mitigation	Sensible regardless of socio-economic scenario. May see a decrease in visitor numbers.
Sustainable public transport provision	Public transport providers, local authorities	Alleviates congestion due to population increase	May not be viable under scenarios of lower visitor	No regrets	No impact on future adaptation	Benefits for mitigation	May not be viable under scenarios of lower visitor

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
			numbers				numbers
Model increase in visitor numbers and identify areas most at risk of damage	Tourist Board National Trust and other visitor attractions	Addresses damage done by increase in visitor numbers due to population increase	Use adaptive management once areas at risk identified	No regrets. Win-win – useful information for other bodies. Benefits for biodiversity.	Should benefit future adaptation – can tailor it to highest priority sites	No conflict with mitigation	Research should take differences into socio-economic scenarios into account
Potential temporary closure of footpaths	Highways authority	Addresses damage done by increase in visitor numbers due to population increase	Closures would be temporary therefore could be classed as adaptive management	Some regrets – constraining recreation opportunity, will nee dot re-create lost paths elsewhere. Benefits for biodiversity.	No impact on future adaptation	No conflict with mitigation	Use of footpaths will depend on attitudes to the environment and outdoor recreation
Education of visitors through advertising and interpretive signing	Tourist Board, Local Authorities	Can improve visitors appreciation of the natural environment	Robust to uncertainty – material presented can be adapted	No regrets	Might be beneficial if people are aware of need for adaptation	No conflicts with mitigation	Material presented can be tailored to prevailing socio-economic scenario
Link areas of open access land - form a recreation network	Highway authorities Land owners Interest groups	Addresses congestion due to population increase		Potential regrets include increase in area of habitat disturbed.		May lead to increase in vehicle emissions if more people drawn to the area	Use will depend on attitudes to the environment and outdoor recreation

Table A1.4 Impacts on ecosystem service and suggested responses

Indirect impacts highlighted in italics

Category	Ecosystem Service	Impact of Climate Change	Response	Key assumptions
Provisioning services	Water resources	Lower summer flows - less water available for agricultural abstraction, recreation and habitats Increased overland flow during high intensity events – less groundwater recharge	Catchment management – improving permeability of surfaces through planting, creation of wet woodland, SUDS etc Demand management Switch to more drought resistant plants On farm water storage	Increases in efficiency could limit problem of low water availability in summer
	Farming	Changes to livestock / crop viability New pests and diseases affects crops and livestock Summer drought – higher agricultural water demand	Crop / livestock switching Alter stocking rates Improvements in water management – on farm storage, reduced surface run-off, increase infiltration rates Be aware of new pests and diseases	
Cultural services	Recreation	More opportunities – increased visitor numbers *Risk of increase in congestion, footpath erosion, trampling* Risk of fire on heathland Decrease in water resources for recreation	Fire action plans Improve recreational infrastructure where appropriate Identify vulnerable areas	Assumes increase in visitor numbers with increase in temperature. Assumes conventional development prevails.

Category	Ecosystem Service	Impact of Climate Change	Response	Key assumptions
	Tourism	More visitors (esp. in shoulder months) *Increased risk of congestion, footpath erosion, trampling* *Greater pressure on resources – accommodation, transport infrastructure, water etc*	Fire action plans Improve recreational infrastructure where appropriate Identify vulnerable areas Education Infrastructure vs. protection (debate needed)	Assumes increase in visitor numbers with increase in temperature. Assumes conventional development prevails.
	Education	*Increased demand for field studies*	Change in curriculum	Assumes increase in visitor numbers with increase in temperature.
Supporting services	Soils	Quaternary deposits could be lost through erosion – important as they record the impact of recent past climate change on the landscape. Valuable in understanding long term trends and how the landscape has responded to climate change in the past. Contain archaeological evidence of human activity in the landscape	Improvement in soil and vegetation management Changes in agricultural practice Limiting visitor numbers in sensitive areas	
	Geology	*Access issues if widespread habitat creation in response to climate change* Change in fluvial processes	Ensure access to geological features	

Category	Ecosystem Service	Impact of Climate Change	Response	Key assumptions
Regulating services	Flood protection	Increase in flood risk – greater winter rainfall, more overland flow, more storm events *Impact on infrastructure – roads, rail, isolated communities etc*	Catchment management – improving permeability of surfaces through planting, creation of wet woodland, SUDS etc Habitat creation opportunity from flood defence works – flood storage areas, managed realignment Temporary closure / diversion of rights of way	
	Water quality	Diffuse pollution – less dilution due to lower flows *Increase in nutrient loading due to increase in visitor numbers and potential agricultural re-intensification.*	Vegetation and soil management to achieve potable water improvements Vegetation buffer strips around fields Reduce nutrient input to water bodies	

Table A4.5 Socio-economic impacts and responses in Cumbria High Fells Character Area

Sector	Socio economic changes	Impact on Cumbria High Fells Character Area	Response	Key assumptions
Agriculture, horticulture and forestry	Increase in demand for organic produce Changes in payments and subsidies	Increase in invertebrate and bird species due to reduction in pesticides used Reduction in diffuse pollution Improved countryside stewardship Reduce monoculture	Extension of the habitat network through habitat creation on arable field margins	Assumes conventional development. Demand for organic and local produce would be highest under Local Markets Is also assuming rather a lot from change to organics; some organic systems can be very intensive and not necessarily beneficial in all respects
Water resources	Increase in water metering Introduction of variable tariffs Increased pressure on water resources due to population increase/growth in recreation demand	Potential increase in water available for habitats and recreation as potable consumption reduces Potential decrease in water available for habitats and recreation	Wetland habitat creation and restoration Resist development in areas of water stress through the water resource and spatial planning system	Assumes water demand grows as population grows. Greater water efficiency may reduce per capita consumption.
Energy	Increase in oil price and concern over security of supply	Switch to renewable - negative landscape impact of wind turbines and biofuels	Resist inappropriate structures on the landscape through spatial planning system	Increase in oil price and concern over security of supply could lead to increase in nuclear power rather than renewables
Buildings	Increase in new build rates to meet demand from population growth and urban expansion	Pressure on land	Resist development in sensitive areas through spatial planning system	Assumes UK population will increase

Sector	Socio economic changes	Impact on Cumbria High Fells Character Area	Response	Key assumptions
Transport	Demand for new infrastructure – roads, railways, runways etc. to meet growing demand	Habitat fragmentation, landscape impact. Positive impact on access to countryside	Resist development in sensitive areas through spatial planning system Improve public transport access to Character Area – reduce demand for travel	Assumes conventional development and limited use of public transport.
Leisure and tourism	Increased demand for outdoor activities – walking, cycling, water sports Increased demand for eco-tourism	Increase in visitor numbers and demand for facilities and infrastructure Reverse some of the negative effects of previous tourism	Visitor dispersal Education	
Health	Increase in obesity	Increased potential to market the countryside as part of a healthy lifestyle – increase number of people enjoying the countryside	Market the countryside as part of a healthy lifestyle	Assumes conventional development – lifestyles may change to be less sedentary