Natural England's climate change risk assessment and adaptation plan

www.naturalengland.org.uk

NATURAL ENGLAND

This report should be cited as:

Natural England. 2012. *Natural England's climate change risk assessment and adaptation plan*. Natural England General Publication, Number 318.

This report was prepared by S.J.DUFFIELD and N.A. MACGREGOR with contributions from H.P.Q. CRICK, I.E. CROSHER, B. LeBAS, T.R. MANSFIELD, M.D. MORECROFT, A.R. NEALE, R.C. PENNY, L.M. SPEAKMAN, S.D. TAYLOR & H. TOWERS.

Summary

Natural England's role is to conserve and enhance the natural environment for its intrinsic value, the wellbeing and enjoyment of people and the economic prosperity that it brings. The impact of climate change on the natural environment represents a critical and increasing challenge for us, and adaptation is essential.

The direct impact of climate change on the natural environment is already being observed. The resultant changes in species, habitats and ecosystems pose both threats and potential opportunities for Natural England's objectives. Indirect effects mediated through human responses to climate change, including adaptation in other sectors can also affect the natural environment in positive or negative ways. Appropriate management and conservation of the natural environment can make an important contribution to helping society adapt to a changing climate; for example river floodplains can be used to slow the flow of floodwater and trees can be planted to provide shade.

This report has been produced to meet requirements of the Climate Change Act (2008). It follows an interim report we produced in 2010 and presents our completed assessment of risks, under the present reporting round, and our plans to address them.

The risk assessment was based on our organisational objectives, as presented in our current corporate plan. Threats and opportunities were identified for each objective and potential responses identified and evaluated.

The risk assessment was initially carried out within the main management units ('Functions') reflecting the organisation's key responsibilities, complemented by additional place-specific vulnerability assessments at sub-national scales. Potential responses were then reviewed across the whole organisation to produce a coherent action plan.

We used the UKCP09 climate change scenarios to inform our assessment, but also took into account uncertainty in the environmental and human responses as well as in climate change projections. This meant that we used projections as indicators of broad trends and direction of travel rather than using specific scenarios.

The report highlights the key threats and opportunities that climate change poses to our objectives for our delivery at the national and sub-national level. We also considered the risks to our estate and how we operate. Appropriate responses to reduce the identified risks were determined, from which an integrated plan of actions was developed.

Our Adaptation Plan responds to the identified risks in a variety of ways: direct action by ourselves, working with others and providing evidence based advice to enable others to act, and focused advice and incentive schemes. The plan reflects the nature of the natural environment, the range of other interests and the limitations of the levers available to us.

Effective adaptation will require an adaptive management approach whereby plans are refined over time as the evidence base develops. This will require good monitoring of both climate change impacts and the effectiveness of our responses.

Our immediate actions will focus on building resilience of the natural environment to maintain our current species, habitats and landscapes. In parallel, we will also start to accommodate change which is inevitable or beneficial to meeting our objectives for the natural environment. For example we will develop ways of recognising the changing distributions of species in setting the objectives for protected sites.

In the longer term society is likely to have to confront more difficult questions about whether to accept or promote major change in ecosystems in order to maintain overall biodiversity and ecosystem

processes and services. We will start to develop the evidence base that will be needed to inform those judgements.

Contents

Annexes

1 Natural England and climate change

© Natural England / Simon Duffield

Our role

1.1 Natural England is a Non-Departmental Public Body, whose role is to conserve and enhance the natural environment for its intrinsic value, the wellbeing and enjoyment of people and the economic prosperity that it brings. Natural England was formally established on 1 October 2006 by the Natural Environment and Rural Communities (NERC) Act 2006.

1.2 Our purpose, as set out in the NERC Act, is 'to ensure that the natural environment is conserved, enhanced and managed for the benefit of present and future generations, thereby contributing to sustainable development'.

1.3 The Act states that this purpose includes:

- Promoting nature conservation and protecting biodiversity;
- Conserving and enhancing the landscape;
- Securing the provision and improvement of facilities for the study, understanding and enjoyment of the natural environment;
- Promoting access to the countryside, open spaces and encouraging open air recreation; and
- Contributing in other ways to social and economic wellbeing through management of the natural environment.

1.4 Our role is to support the government's wider strategic policies and fulfil aims and objectives agreed with the Department for Environment, Food and Rural Affairs (Defra). In doing this we work closely with Defra, its Arm's Length Bodies (including the Environment Agency, Forestry Commission and Marine Management Organisation) and a wide range of partners across government, civil society and the private sector.

The importance of climate change to our work

1.5 Climate change needs to be taken into consideration in all Natural England's work for two important reasons:

- First, the natural environment is vulnerable to climate change. We know that species are sensitive to changes in climate variables such as temperature and rainfall, and to extreme events such as droughts, storms and heatwaves. We are already seeing changes, in plants and animal species: particularly their geographic distributions and the timing of seasonal events (such as bird migration and appearance of leaves of trees in spring) (for example, Hickling and others, 2006; Crick 2004; Thackeray *et al*. 2010). Over time, this will lead to changes in ecological communities of plants and animals. There will also be changes to the physical environment, including as a result of storm surges and floodwater, sea level rise and intrusion of salt water into freshwater habitat. In combination, changes to the living and non-living natural environment are likely to cause changes to ecosystems, habitats and landscapes. This will in turn affect the way in which they are used and enjoyed by people. There are also likely to be indirect effects on the natural environment as a result of human action in response to climate change, for example, increased water abstraction to cope with water shortages, or increased use of biofuel as a mitigation strategy. This means that there are serious threats to the achievement of Natural England's objectives, although there are also some opportunities, for example, populations of rare heat-loving species may increase.
- Second, appropriate management and conservation of the natural environment can make an important contribution to helping society adapt to a changing climate, by providing a range of valuable services (Gill *et al*. 2007; Morecroft and Cowan 2010; Natural England 2009a). For example, trees provide shade and shelter for people, crops and livestock, and wildlife. They can reduce water runoff and erosion, help to maintain water quality, and provide an alternative and additional crop to increase farm income and hedge bets against climate risks. Wetlands and functioning river floodplains slow the flow of floodwater and increase infiltration into the soil, increasing recharge of groundwater. Conserving or recreating intertidal habitat such as salt marsh can provide defence against coastal flooding, absorbing the energy of waves and allowing space for 'storage' of high tides. Intertidal habitats also filter sediments and pollutants, and support shellfish and fish nurseries, helping make fish populations (and fishing industries that depend on them) more resilient to change. Environmental management can also play an important role in climate change mitigation, for example through protecting the large amount of carbon stored in peat soils. A high quality natural environment should therefore be seen as critical infrastructure, and it is important that we maintain its capacity to deliver the key services that underpin our prosperity and wellbeing.

1.6 Much of Natural England's work is about enabling the private sector and civil society to protect and enhance the natural environment. A wide range of ecosystem services are delivered by a healthy natural environment and we are committed to working with our partners and stakeholders, using a consultative approach, to ensure that the supply of services is secured and enhanced.

The Climate Change Act and Adaptation Reporting Power

1.7 The Climate Change Act (2008) contains an Adaptation Reporting Power. This gives Government the power to direct some organisations - those that have responsibility for critical infrastructure and services that people depend on every day - to report on how they have assessed the risks of climate change to their work, and what they are doing to address these risks. The Reporting

Power is the primary lever available to government to ensure that organisations are aware of and preparing for the risks from climate change, in order to ensure that services essential to the country are secure for the long term future.

1.8 In addition to the organisations that have been directed to report in this first round of the reporting power, a number of organisations have been invited, or have volunteered, to report. Natural England volunteered, because of the importance of climate change to our work, and the role we can play in tackling it.

1.9 This report describes the processes we have put in place to assess climate risks to our corporate objectives and to identify and implement appropriate responses. It outlines the most important risks we have identified, the range of possible responses and a series of actions that Natural England will undertake to reduce the threats and take advantage of those opportunities that climate change may offer. In addition the report also highlights areas where uncertainty exists around the potential impacts (direct and indirect) of climate change, and few possible responses.

1.10 Although the focus of this report is adaptation, we also note where actions also contribute to climate change mitigation by reducing green house gas emissions (such as preventing further deterioration of peatlands) or promote carbon sequestration (for example, through tree planting; conversion of arable land to permanent pasture; peatland restoration).

2 How climate change is approached within the organisation

© Natural England

Natural England's Strategic Direction

2.1 In Natural England's Strategic Direction 2008-2013 (Natural England, 2008) two high-level objectives have set the foundation for embedding adaptation to climate change within our work programmes:

"Our rich biodiversity thrives across the landscape, with ecosystems and habitat resilient to climate change"; and

"The natural environment is resilient in the face of climate change".

2.2 These were supported by a number of more specific five-year measures of success:

- National Parks and Areas of Outstanding Natural Beauty demonstrating an increasing level of exemplary management of our finest landscapes: including local character, cultural heritage, tranquillity, biodiversity in favourable condition, exemplary access management, resilience to climate change.
- Ecosystems are healthier, dynamic and delivering increased resilience and capacity to adapt to change.

- Sites of Special Scientific Interest are assessed for their resilience and ability to support healthy dynamic ecosystems that are able to adapt to change.
- Marine ecosystems and habitats have increased resilience and are more capable of adaptation.
- A network of Marine Protected Areas is identified, that contributes to increasing the health and resilience of marine ecosystems.
- A shared vision for adaptation of our landscapes in response to climate change.
- The major risks to the natural environment are understood and addressed by public bodies.
- Increased proportion of habitats and ecosystems in 'resilient condition'.
- Increased numbers of land managers actively managing more land for climate change adaptation and mitigation.

The state of the evidence base and how we are improving it

2.3 Climate change, and its interaction with the natural environment, is a complex topic, and although considerable progress has been made there is still a lot we don't fully understand (see Section 4 for evidence gaps).

2.4 It is vital that we continue to add to our knowledge about climate impacts on the environment and appropriate responses, and that we have the flexibility to develop and modify our conservation strategies in future, in light of new information.

2.5 We therefore have an ongoing programme of research into, and analysis and monitoring of, climate vulnerability, impacts and adaptation.

2.6 This includes long-term monitoring to track and provide interpretation of climate change impacts. Our research has led to a greater understanding of the factors that promote resilience to climate change and the opportunities and limitations of a resilience approach (as opposed to embracing change). We are developing a good understanding of the principles of climate change adaptation that is providing a solid basis on which to develop more specific methodology, helped by co-hosting a major external facing conference, Adapting Conservation to a Changing Climate in January 2011, held jointly with the British Ecological Society (Morecroft *et al*. 2011). We also have built up our knowledge of the key ecosystems and issues for maximising carbon storage by the natural environment (Natural England 2010; Alonso *et al*. 2011).

2.7 We have developed ways to assess the vulnerability of biodiversity and ecosystem services to climate change and have a variety of techniques available for different purposes which have been adopted by other organisations (for example, Areas of Outstanding Natural Beauty and National Parks).

Delivering adaptation for the natural environment and local communities

2.8 The organisation has a range of mechanisms available to us to develop appropriate responses to the threats and opportunities that climate change poses. These can be categorised under the headings of: regulation, incentives, practical action and advice.

- Regulation - issuing of licences to carry out activities in a way that protects the natural environment.
- Incentives - delivery of the government's Environmental Stewardship Schemes in England which offers around £400 million per annum as incentives to farmers to protect and enhance the environment and wildlife.
- Practical action - We directly manage two thirds of the National Nature Reserves in England.

- Advice - our statutory responsibility to give advice to government and to others in relation to any of our functions. We also provide advice, evidence and support to communities, NGOs, local authorities and other organisations, so they can take action for the natural environment.

2.9 In all of these activities we take the long-term view and support our decisions with reference to the latest science and evidence. Our responses to the risks that climate change poses are framed in light of this delivery framework.

2.10 We have begun to incorporate findings from adaptation research into our existing conservation delivery work, several aspects of which are already contributing to adaptation and have potential to make a much larger contribution.

2.11 For example, our work with land managers through the Higher Level Stewardship (HLS) scheme can help to conserve, restore, expand and buffer semi-natural habitats and make them more resilient to a changing climate, anticipating some of the recommendations of the Making Space for Nature review of habitat networks (Lawton *et al*. 2010). In some cases, we are using Environmental Stewardship directly to help species under threat from climate change. For example, we are working with Essex farmers using HLS funding to provide suitable new habitat for the Fisher's Estuarine Moth, a rare species dependent on a rare food plant in coastal transitional zones that is threatened by coastal erosion, storm surge and rising sea levels.

2.12 Our work on urban green infrastructure has the potential to help reduce the effect of heat waves, flooding and water shortage on human communities and wildlife all significant concerns in a changing climate.

2.13 With our partners (including the Environment Agency, Forestry Commission, Marine Management Organisation, National Parks, local authorities, non-government organisations and the private sector), we are also involved in a wide range of local initiatives across the country to help society become more prepared for a changing climate. Some examples examples include:

- Cheviot Futures, a partnership of agencies and organisations working with farmers and land managers in north Northumberland to promote simple and practical approaches to adaption;
- coastal realignment at Alkborough in the Humber Estuary, the UK's largest coastal realignment with an estimated annual flood protection benefit of over £400,000;
- recreating floodplains on the Long Eau river in Lincolnshire to alleviate flooding of houses and farmland downstream;
- working with the Moors for the Future partnership to restore peatland in the Peak District, which among other things has restored water quality for human consumption; and
- Sustainable Catchment Management Programme in Bowland and the Peak District, a partnership working to apply an integrated approach to catchment management on land owned by United Utilities. (See Natural England 2009a for more information about some of these).

Sustainable adaptation

2.14 Underpinning all of Natural England's work on adaptation is the understanding that adaptation must be consistent with the aims of sustainable development as required in the Climate Change Act (2008) (Morecroft and Cowan, 2010). Four principles have been proposed for sustainable adaptation (Macgregor & Cowan 2011). These are:

1) Adaptation should aim to maintain or enhance the environmental, social and economic benefits provided by a system, while accepting and accommodating inevitable changes to it. It is important for adaptation to be based on a clear set of objectives that frame the problem in terms of 'what are we adapting for?' (that is, focusing on the benefits we want to obtain).
2) Adaptation should not solve one problem while creating or worsening others. We should prioritise action that has multiple benefits and avoid creating negative effects for other people,

places and sectors. Many adaptation responses to address socioeconomic factors will have wider consequences for natural systems, and vice versa. Taking an ecosystems-based approach, and applying principles of sustainable development across sectors will be necessary to identify integrated, sustainable adaptation solutions.

3) Adaptation should seek to increase resilience to a wide range of future risks and address all aspects of vulnerability, rather than focusing solely on specific projected climate impacts. Actions must be taken in the face of uncertainty in relation to future climate changes, socioeconomic change, and the interaction between them. Therefore it is important to build resilience to cope with a range of plausible futures.
4) Approaches to adaptation must be flexible and not limit future action. Increasing the resilience of what we have is a good initial strategy but, in the longer term and under more extreme climate change, transformative approaches will increasingly be needed. New approaches to adaptation will need to be tested and monitored at the appropriate scale so we can learn from experience and revise our approaches accordingly.

2.15 Given the evolving evidence base an ‘adaptive management’ (Holling 1978) strategy is essential. This means taking a flexible approach and trying out new methods, with continual monitoring of results and adjustment of management practices if necessary. This can help to resolve the apparent dilemma of on the one hand needing to start adapting, but on the other needing to retain flexibility in the face of considerable uncertainty about the future. The starting point of an adaptive management approach should be to do things that i) would have benefits regardless of climate change (so called ‘no regret’ options); ii) would have multiple benefits for a range of objectives (‘win win’ options); and/or iii) would be likely to have significant adaptation benefits, be cheap to implement and easy to reverse (‘low regret’ options) (UK Climate Impacts Programme).

3 Our approach to climate risk assessment

© Nick Turner

Assessment of climate risks to our objectives

3.1 Natural England was restructured in April 2011 into a series of 'Functions', responsible either for delivering environmental outcomes or providing the necessary internal support for the organisation. Climate change is a cross-cutting issue and is addressed through the work of different Functions. Climate change adaptation and mitigation are coordinated across the organisation by a small number of climate change specialists, under the leadership of a 'Head of Profession', working with a group of expert staff termed a 'Community of Practice'.

3.2 Each of our Functions with responsibility for delivering environmental outcomes, assessed the risks, and any opportunities, that climate change presents to delivering their objectives. They then identified and considered possible responses, and agreed specific actions. They were supported in this process by specialist staff. The Functions that completed climate risk assessments were:

- Landscape and Biodiversity
- Marine
- Access and engagement
- Land management
- Sustainable land use

3.3 Coastal issues are an important and urgent concern that cut across all of the areas above, and so have been reviewed within each area.

3.4 Climate risk assessment across the work areas above has been undertaken in a coordinated way, to ensure that any gaps, synergies and conflicts have been identified and addressed. A steering group was established, made up of the staff coordinating each risk assessment, climate change specialists and head of profession, to review and discuss the emerging results of the risk assessment at each stage of the process. Information from the national Climate Change Risk Assessment sectoral analyses has been considered, to ensure that our approach is broadly consistent with it.

Climate change information used

3.5 We used information from the UK Climate Projections 09 (UKCP09) (Murphy *et al*. 2009; Lowe *et al*. 2009) to provide basic climate change scenarios. These projections are the most up-to-date evidence base on the UK's future climate. The projections indicate, among a range of other findings, that temperatures will increase across all areas of the UK, more so in summer than in winter and more in the south than the north (for example, summer mean temperature in southern England could be up to 4.2ºC warmer); that mean daily minimum temperatures will increase as well as the mean temperatures for the season; that although overall precipitation might not change to a great extent, winter precipitation could increase greatly in some areas (particularly the west of England, up to +33%) and summer precipitation decrease greatly (particularly in the south of England, down to -40%).

3.6 The UKCP09 scenarios contain very detailed information, enabling climate change to be considered across a range of emissions scenarios, geographic areas and probability levels. We used the main trends in the projections, focusing on median values, to provide an indication of the 'direction of travel' of climate change and a range of plausible scenarios we should prepare for. There is substantial uncertainty - not just in greenhouse emissions and climate projections but also in complex ecosystem responses and interactions with human behaviour such as changing agricultural practices. Our adaptation planning is not therefore predicated on a particular scenario. Climate change adaptation is an issue of risk management, rather than managing for particular situations.

Method

3.7 Each function used a standard method to assess climate risks and responses. The approach is consistent with other, published, frameworks for climate risk assessment (for example, Willows and Connell 2003). Since 2009, we have been developing, testing and refining risk assessment methodology through pilot studies.

3.8 The main steps of our method are summarised in Table 1 and explained briefly below. A more detailed description of methods is provided in Annex 1.

Table 1 Structure of Natural England's climate risk assessment method

1 - Identify objectives	2 - Establish decision making criteria	3 - Identify and assess threats and opportunities	4 - Identify and evaluate responses	5 - Implement actions and monitor
Step 1.1 Review and list current and possible future objectives	Step 2.1 Establish criteria for assessing and characterising risks and responses	Step 3.1 Screen objectives to identify those vulnerable to climate change	Step 4.1 Identify possible responses to threats and opportunities (adaptation)	Step 5.1 Agree specific priority actions that will be taken
		Step 3.2 Identify specific threats and opportunities	Step 4.2 Identify possible opportunities to reduce GHG emissions (mitigation) and broader ecosystem services gains	Step 5.2 Implement actions
		Step 3.3 Assess threats and opportunities (importance and proximity)	Step 4.3 Evaluate responses (sustainability; time and resources required)	Step 5.3 Monitor and review

Part 1 - Identify objectives

3.9 An essential first step in the process was to identify relevant Natural England objectives for each of our main work areas. These provide the reference point and scope for the subsequent steps in the assessment process.

3.10 We listed the key objectives for each work area, focusing at the strategic level; sufficient detail was provided to enable threats and opportunities to be identified.

Part 2 - Establish decision-making criteria for prioritising risks and responses

3.11 We used five variables to characterise and prioritise our risks and responses:

- The importance of a risk to delivery of our objectives.
- The proximity of a risk (the nearness of the point in time at which we estimate there is a reasonable chance our ability to deliver the objective would change under a business as usual scenario).
- The effort and resources required to respond.
- The time period required for an effective response, including both the time needed for Natural England to implement the response and the time required for the response to have an effect once implement.
- The likely positive and negative side-effects of a response on other objectives, as one measure of its sustainability (see the section on sustainable adaptation above for further aspects of sustainability that we are considering when identifying responses).

Part 3 - Identify and assess threats and opportunities

3.12 To focus our attention just on those objectives that are relevant for this risk assessment, we first screened objectives in each work area and identified which appeared potentially vulnerable to climate change related impacts (see Annex 2 for the results). These objectives were the focus of assessing risks. We also identified objectives that are not vulnerable to but are influenced by climate change. These are things that we can probably still achieve irrespective of how the climate changes, but that might need to be modified to take climate change into consideration.

These objectives were not relevant to identifying and assessing risks, but were relevant to identifying responses. This category of objectives often provided potential ways to help respond to risks to our vulnerable objectives. (To illustrate this distinction between 'vulnerable' and 'influenced' objectives: an objective to maintain Sites of Special Scientific Interest is potentially vulnerable, as climate change is likely to affect the natural environment in these sites. By contrast, an objective to give advice to land managers would not be vulnerable, as climate change will not prevent us from delivering advice, but the advice we provide would need to be modified to include information to help land managers adapt).

3.13 Having identified which objectives were vulnerable, we then identified specific threats, as well as opportunities, trying to consider the full chain of events linking an initial climatic change through to a consequence for our objectives.

3.14 We tried to identify both direct risks (resulting directly from climate change) and indirect risks (resulting from human action in response to climate change).

3.15 We then assessed the importance and proximity of each risk. From this, we determined an overall priority ranking of 'high', 'medium' or 'low'.

Part 4 - Identify and evaluate responses

3.16 We identified possible responses to manage threats and to make the most of opportunities. Two aspects were considered when identifying responses: the required action on the ground, and the action for Natural England to take (for example, action on the ground might be to increase woodland cover; action for Natural England might be to revise land management advice to encourage tree planting). Identifying responses included considering how delivery of those objectives identified as 'influenced' by climate change could make a contribution to addressing risks. We considered the levers available to Natural England to act, the potential barriers to action, and the other organisations with a role.

3.17 As well as identifying responses to address our risks, we considered how delivery of our objectives could make a greater contribution to reducing greenhouse gas emissions. Although not strictly necessary as part of a climate risk assessment it is important to integrate adaptation and mitigation as much as possible if sustainability is to be maximised. (We considered only action that Natural England could take to help reduce emissions in the sectors in which we play a role, such as land management. We did not look at actions to reduce emissions from our own work and estate, as Natural England already has a comprehensive plan in place to address this).

3.18 We considered the potential positive and negative side-effects of each of the possible responses identified. We then considered factors affecting the implementation of a successful response and estimated how much effort/resource would be required to implement each response, and the time required for a successful response to be put in place.

Part 5 - Implementation and monitoring

3.19 The final stage in the present process was to identify and agree a prioritised series of integrated actions to be taken across Natural England to address the most important risks and where possible exploit the potential opportunities.

3.20 We identified specific actions to be taken by each function, as well as more strategic actions to embed climate change into long term business planning, management of strategic risks, and development of future corporate plans and strategies.

3.21 Risk assessment and identification of actions are only the first part of good risk management: implementation and appropriate monitoring are clearly required. Actions will be implemented through delivery of our corporate plan, with the aim of embedding adaptation so it is considered as an integral part of all our environment decision-making.

3.22 We will monitor the effectiveness of our actions, and modify them if necessary, both through monitoring of progress to deliver our corporate plan, and through ongoing monitoring of environmental outcomes.

Sub-national climate vulnerability assessment

3.23 The consequences of climate change, their relative importance, and appropriate adaptation actions, will, in many cases, be specific to individual places and depend on local conditions, pressures and aspirations. Therefore, it is necessary for us not only to identify broad risks to our objectives at a national level, but to explore risks and possible adaptation responses at a finer spatial scale. This will help us to understand the relative importance and specific consequences of climate risks in different places. This can then guide our own conservation work and help local communities make decisions for the natural environment in their area.

3.24 In order to understand the risks to our objectives at the sub-national scale we have, in parallel with the organisation-level risk assessment, undertaken a range of projects to assess the vulnerability of the natural environment at both the National Character Area (NCA) and regional scales. There are 159 National Character Areas which are defined on the basis of their distinctive landscape characteristics, rather than administrative boundaries. This will help us to better understand the spatial aspects of climate-related risks to Natural England's objectives, and will also provide an additional check to make sure that the national assessment has covered all the major risks.

3.25 The studies followed a vulnerability assessment methodology that aimed to take a holistic view of the natural environment, using published literature and the expert judgement of both Natural England staff and local experts. In broad terms, the studies started by identifying the benefits provided by the landscape in each place (landscape character, ecosystem services and biodiversity), and the assets (for example, soils, fauna and flora, recreation infrastructure, historic environment and landscape features) that contribute to these benefits. They then considered how these important assets might be vulnerable to climate change, and the implications for the landscape character, ecosystem services and biodiversity of the area. Finally, they sought to identify and prioritise the possible adaptation actions that could be taken.

3.26 The first phase of studies was undertaken in 2008/9 and the results were published in 2009 (Natural England 2009b, 2009c, 2009d, 2009e). These were:

- Cumbria High Fells: a mountainous landscape with many lakes and peat soils in the Lake District area of north-west England.
- The Broads: a low lying wetland landscape with large areas of open water in eastern England.
- The Shropshire Hills: a hilly, farmed landscape bordering Wales, with fragmented heathland and diverse geology.
- Dorset Downs and Cranborne Chase: a rolling chalk landscape in south-west England characterised by calcareous grassland and chalk stream valleys.

3.27 A second phase of studies commenced in 2009. This second phase built on the lessons learnt in the pilot studies, and a revised methodology was developed. The results of these studies will be published in late 2011 or early 2012. They cover the following areas:

- Sherwood: an area of rolling countryside in the East Midlands with well established woodlands and a strong coal mining heritage.
- South East Northumberland Coastal Plain: a flat landscape with a coastline of sand dunes and rocky outcrops, scarred by a heavily industrial past.
- Humberhead Levels: a largely agricultural area with important wetlands and areas of lowland peat bog at the head of the Humber estuary.

- London - urban green space dominated by the influence of the river Thames.
- South Downs National Park: a chalk landscape of rolling arable fields and close-cropped grassland on the scarps, stretching from Eastbourne to Winchester in the south east of England.
- Lancashire and Amoundness Plain: a flat, predominantly drained coastal marsh landscape of mostly peat soils on the Irish Sea coast, which has seen significant coastal development of Victorian coastal resorts.
- Solway Basin a broad lowland coastal plain gently rising to the hills behind, with large expanses of intertidal mudflats backed by salt marsh.
- Morecambe Bay Limestones - a contrasting landscape of limestone hills interspersed with flat agriculturally-reclaimed flood plains, characterised by multiple estuaries and mudflats.

3.28 The results of these studies were used in the risk assessment in two ways. First, they provided information that was used to inform both the identification of risks to different Natural England objectives, and possible action that could be taken in response. Second, they provide an initial partial picture of how climate risks to the natural environment (and therefore to our objectives) might vary geographically and across different ecosystem and landscape types. This highlighted that there are particular areas in the country where it appears likely that multiple risks to Natural England's objectives might co-occur and interact.

Assessing risks to our business and estate

3.29 As well as the work areas discussed above, that are specific to Natural England's statutory purpose, like all other organisations we have more general responsibilities to ensure we have suitable facilities for our work. This includes making sure they continue to deliver the most important elements of our work despite changing circumstances and potentially disruption, and can provide a safe working environment for our staff. Key requirements here include:

- Ensuring that our staff are safe, both in our offices and when travelling or out in the field;
- Maintaining suitable and properly-functioning buildings and other parts of our estate to be able to deliver our work;
- Being able to cope with disruption and continue to support critical areas of our work, and continue to deliver key services (including payments) to our customers; and
- Ensuring that our delivery partners and suppliers similarly act to ensure staff safety and continued delivery.

3.30 As part of a Defra-wide project, Natural England undertook a review of our estate to identify any emerging challenges that climate change posed. The review took the form of a site by site assessment of the potential impact that key climatic events would have on a selection of our offices.

4 Summary of risk analysis results

© Charlie Headley

4.1 The results of the detailed risk assessment carried out by each delivery Function are presented in Annex 3. Here we present an overview of the key risks for the organisation as a whole. The breadth and complexity of the issues identified reflects our broad responsibilities and the complexity of the natural environment.

Priority risks to Natural England's objectives

Threats to conservation and recovery of priority threatened species and habitats

- Species are unable to track changing climate space: Species tend to live within defined limits of temperature and precipitation; with climate change the geographical position of these limits will change such that Species Recovery and BAP Plan objectives become compromised, particularly for montane species.
- Increases in soil moisture deficits and episodic droughts: Priority habitats requiring certain levels of soil moisture may be subject to increasing levels of soil moisture deficit due to reductions in summer precipitation or episodic drought. The plant communities change with the loss of certain species and the gain of others, changing priority habitat quality and character.

- Changes in interspecies interactions: Changes in climate can affect the productivity and survival of species in addition to changing the timing of their annual cycles. As a result species may change interactions with other species through changes in competitiveness, predator-prey relationships, parasitism and disease. A key issue is the change in invasiveness of non-native species. These changes can compromise Species Recovery and BAP Plans, as well as the effectiveness of interventions made in the wider countryside and marine environments.
- Acidification in marine environments, resulting from high CO_2 concentrations in the atmosphere threatens sensitive species and may lead to change in community structure.
- Effects of hydrological extremes, particularly droughts on freshwater ecosystems can threaten species of conservation concern.
- Policy and market responses to the global effects of climate change, primarily around the sustainability, supply and cost of food and energy resulting in increased competition for space with other land uses.

Threats to the condition of protected sites (Sites of Special Scientific Interest, NNRs, MPAs)

- Tipping points in the interactions between climate and ecosystem responses may result in sudden loss of designated features. Tipping points may be crossed as a result of an extreme climatic event or series of events that push an ecosystem into an alternative stable state, for example an ecological 'regime shift' would be a storm surge and coastal flooding event that transformed a coastal reed bed habitat into a saltwater marsh. Understanding the proximity of tipping points is an important area of research.
- Gradual change will reduce our ability to maintain our current SSSI objectives as habitat and species features adjust from those given in the citation. In the future it may mean that our current designations fail to protect habitats and species because the guidelines/legislation which support them do not reflect the current and future changes expected in the environment.
- Interactions between different aspects of environmental change combine to degrade protected sites. Climate change will interact with all the other pressures on ecosystems, including land use change, air pollution and invasive species. These complex interactions are poorly understood and have the potential to reduce the capacity for designated features to adapt autonomously or to influence human adaptation interactions.

Threats to the conservation and enhancement of landscape character

- Climate change could lead to significant changes in landscape character (including its historic environment, geological and biodiversity components) and the potential loss of some valued landscape features. Unless we understand the dynamic nature of landscapes and the potential impacts of climate change, this will compromise our ability to advice on the conservation and enhancement of landscape character.
- Our statutory role in relation to conserving and enhancing the special qualities of protected landscapes may need to adapt as the special qualities for which National Parks and AONBs were originally designated change or are lost.

Threats to sustainable land and sea management

- Changes to rainfall patterns and intensity increases risks of soil erosion and diffuse pollution of fresh and coastal waters.
- Increased temperatures and acidification will affect fisheries and recreational use of the marine environment to the detriment of our objectives.
- Changes in agricultural and land use practice, in response to climate change (such as intensification, renewable energy), may lead to the unsustainable use and management of

land, soils and water, having a negative effect on our incentives schemes and advice programmes, making it harder for us to secure the protection of vital ecosystem services.

Threats to the protection of the natural environment through incentive schemes

- Increased incidence of more extreme weather events compromises the ability of land managers to meet agri-environment objectives whilst maintaining farming businesses. For example flooding damage to farm infrastructure and habitats managed under Environmental Stewardship.
- Warmer, drier summers and increased fire risk, threaten the ability of land management to provide effective management of priority habitats such as peatland.
- Changes to species abundance and distribution, and the composition of communities will make existing programme options and prescriptions less effective.
- Sea level rise affecting inter-tidal and coastal habitats, make existing scheme options and prescriptions unviable.

Threats associated with working with partners and local communities

- Potential human responses to climate change at national and international scales, including resistance to change, or desire to adapt in ways that damages the natural environment.
- Particular pressure on the coast where sea level rise and extreme events will increase coastal erosion, increasing the demand for hard defences.
- Increased demand for engineered flood solutions, and could lead to conflicting interests and questioning of Shoreline Management Plans and other spatial planning policies.

Threats to our delivery of planning and sustainable land use responsibilities

- Unsustainable abstraction of water due to summer drought in water stressed areas may have a negative effect on designated sites and BAP habitats and make it harder to secure new high quality conservation areas.
- Unsustainable responses, especially at the coast, which do not use an ecosystem approach are likely to have adverse impacts on BAP habitats or designated sites.

Threats to access and engagement work

- Increased erosion of access routes including National Trails which will lead to increased maintenance requirements.
- Increased risk of wildfire from hotter, drier summers on areas of statutory open access land, resulting in prolonged closures of areas of open country to the public.
- Increased coastal erosion and flooding will result in ‘rollback‘ of the new Coastal Trail and spreading room, but could restrict coastal access in some locations.

Potential opportunities

4.2 The risk analysis also identified a number of possible opportunities. The most important of these are as follows:

- Some priority species habitats might thrive under increasingly warmer and drier conditions, particularly those on drier heathland and grassland habitats.
- Some priority species and habitats may thrive through changes in interspecific interactions, for example increased competitive advantage.
- Opportunity to conserve rare and threatened species colonising new locations (these are likely to be those with southerly distributions).

- There is an opportunity to facilitate landscape change in ways that create valuable new landscapes that are more resilient to climate change and deliver improved benefits for society (sense of place, biodiversity and ecosystem services).
- Increased opportunities to engage with society to help people understand that landscapes are inherently dynamic and to identify the best ways to accommodate future changes.
- Opportunity to develop advice and incentives for land managers to support sustainable management of soils and water that underpins both ecosystem services and agricultural production.
- Opportunity to develop advice and support for farmers seeking to adapt their business in a sustainable way.
- It may be possible to increase the amount of farmland under environmental stewardship agreements.
- Climate change highlights the importance of a healthy natural environment and leads to a better understanding of ecosystem services by our partners and society. This means that measures to reduce current pressures on biodiversity, soil, water and the coast become higher priorities providing greater opportunity for Natural England to influence planning and agricultural land use and to deliver socio-economic adaptation and benefits and the development of better habitat networks and habitat creation, supporting a more joined approach.
- Opportunities for emissions mitigation through managing greenhouse gases and carbon stores within the natural environment will increase the quality of these natural assets and their capacity for climate change adaptation.
- Opportunity to secure improved management of woodlands and other habitats providing inputs for energy crops or Anaerobic Digestion to ensure that these mitigation initiatives are consistent with adaptation of the natural environment.
- Climate change has the potential to bring forward innovative, environmentally beneficial development and a balance of land use appropriate to local climate adaptation requirements and provides a strong impetus for the delivery of multi-functional green infrastructure.
- Greater interest in using natural environmental solutions to help communities adapt climate change. This may increase the provision of greenspace, street trees and water bodies increasing recreational opportunities.
- Increasing areas of land allocated for flood attenuation, particularly near settlements could lead to the availability of greenspace near to where people live.
- Increased awareness and interest in natural environment and in climate change impacts as a local, tangible issue may well make it easier to engage people with the natural environment and to take action, for example, through volunteering.

Commentary

4.3 Because of our statutory function to protect and enhance the natural environment, climate change-driven threats to the natural environment frequently translate to risks to the delivery of Natural England's objectives. The current risk assessment has identified the key areas where this occurs, but it does not attempt to replicate the broader national Climate Change Risk Assessment (CCRA), which covers a wide range of sectors, including the natural environment, in some detail and is expected to publish its findings early in 2012.

4.4 The direct effects of a changing climate on species, and their interactions, threaten the objectives of our landscape and biodiversity and marine functions to protect species and ecosystems. For example, achieving Species Recovery Plan objectives will become increasingly difficult, as a result of shifts in the ranges of species and habitats, habitat loss or damage, and changes to seasonal events. Climate change projections suggest that over the next 20-50 years the extent of direct changes will increase both in terms of their frequency and severity. As the detailed results set out in Annex 3 indicate, the direct effects of climate change on the natural environment could be complex - there are a large number of potential changes, which could interact in sometimes unpredictable ways.

4.5 Indirect threats mediated through the potential responses of government, society and individuals to current and future climate change locally, nationally and internationally could also have potentially harmful effects on the natural environment. Policy and market responses to global climate change impacts on food and energy security, supply and sustainability have been identified as priority risks to our landscape and biodiversity functions.

4.6 Many of the indirect threats would occur through greater competition for land and water, making it increasingly difficult to ensure sustainable land use and management and the protection of our designated sites through our advisory and statutory role. Our land management incentive schemes are also potentially threatened by similar drivers, for example the financial incentive that the schemes offer would become less attractive if global effects of climate change (and other long term drivers) lead to increases in commodity prices and a subsequent pressure for agricultural intensification.

4.7 Actions to promote mitigation and adaptation in other sectors have the potential to threaten sustainable land use and land management if consideration is not given to their effects on the natural environment and the suite of ecosystem services that it provides. For example:

- Abstraction of water to assist agriculture to adapt to drier conditions could reduce flows in rivers, or reduce the level of ground water to an extent where it has a negative impact on the natural environment.
- Increased demand for hard coastal defences to mitigate the impact of the increased frequency of storms and rising sea levels could threaten both the structure and function of coastal ecosystems, many of which are protected by both national and international designations.

4.8 Our climate change work with local experts in a range of National Character Areas in England has enabled us to do an initial exploration of how the risks that climate change poses to our interests might vary in different parts of the country. This analysis, though at this stage providing only a partial picture, has highlighted that there are some areas in which multiple risks appear likely to co-occur and interact. These include:

- Some coastal areas with soft coastlines such as dunes and coastal wetlands. Pressures could include a combination of rising water temperatures, sea level rise and saline intrusion (potentially causing some ecosystems to permanently change from freshwater/brackish to saline), erosion of coastlines, and potential ‘squeeze’ and subsequent loss of natural ecosystems against hard structures inland. This would have consequences for a range of species that rely on intertidal or coastal habitats (for example aquatic species in estuaries, and some nationally or internationally important colonies of seabirds), and for the recreation opportunities available for people. There could also be a reduction in the flood alleviation service provided by coastal wetlands. However, there could be opportunities to use managed realignment of the coast as a flood defence strategy that would provide a range of benefits for both people and wildlife. Examples of vulnerable coastal areas noted in our studies include some coastal stretches of the South East Northumberland Coastal Plain and Solway NCAs, the Broads, and estuarine wetlands in the east of the Humberhead Levels NCA near the upper end of the Humber estuary.
- Freshwater ecosystems such as rivers, lakes and wetlands. These are susceptible to the effects of potential reduction in water flows, rising water temperatures, increased runoff from agricultural areas during heavy rainfall, and possibly increased demand from agriculture for water during summer droughts. At other times of year there could be impacts on plant and animal species from floods and increased water flows, and from the management action that is taken by humans in response. (As noted above, in some coastal areas some of these impacts could be exacerbated by additional pressures from the seaward side.) This could have consequences for a range of species, both in the water bodies and in areas nearby that are affected by a reduction in available water, for the character of the areas, for the recreation

activities such as fishing and boating that can be provided, and for water quality. These areas were assessed as vulnerable in most of our studies.

- Upland and lowland peatlands, such as those in the Cumbria High Fells, the Humberhead Levels and small areas of the South East Northumberland Coastal Plain, are vulnerable to drying out, erosion and in some cases greater risk of fire, as a result of changes in seasonal precipitation. Consequences could include loss of biodiversity, significant increases in carbon dioxide emissions, and damage to important records of past archaeological and environmental change.
- Historic parklands and other woodland areas could also be affected by a range of impacts. Ancient trees, important both ecologically and for their cultural value, could be lost as a result of storms. Particularly in drier southern parts of the country, there could be changes and potentially loss of tree species as drought-intolerant species are affected by projected reductions in summer rainfall. There is also potential for a range of invasive pests of trees to become more numerous or widespread. Changes and damage to woodland and parkland would have consequences both for a range of species who live in, or potentially might need to move through, these areas. It could also dramatically affect the character of historic landscapes and the 'sense of place' that people gain from them (for example in the Sherwood NCA, where the image of Sherwood Forest has strong cultural significance), and affect the wide range of services that trees provide, including flood alleviation, filtration of runoff water, shading of water bodies. Such areas were noted as vulnerable in the South Downs, Dorset Downs and Cranbourne Chase, Shropshire Hills, South East Northumberland Coastal Plain and Sherwood NCAs.
- High upland areas, exemplified by the Cumbria High Fells NCA. As well as the potential impacts on upland peat bogs noted above, upland areas could suffer from changes in temperature and rainfall causing a change in species composition, with rare alpine species on the highest tops and northerly slopes being at risk of extinction. Water levels in lakes and rivers could fall, affecting not only the montane environment but potentially also the availability of water downstream. Important recreation infrastructure for people such as walking paths could be damaged by erosion.

4.9 This reinforces an emerging conclusion from the organisation-level risk assessment that wetland, montane and coastal systems appear particularly vulnerable in the short term. Together, these results suggest that climate risks will not be spread evenly across the country; there are likely to be 'hotspots' in which a number of important natural features, ecosystems and services are likely to be affected by multiple direct and indirect interacting threats. It might be necessary to focus particular attention on these and similarly vulnerable places.

4.10 Following the Climate Change Act reporting power guidelines, our analysis considered not just the threats that climate change poses to our objectives but also the potential opportunities that climate change might bring. Some species are doing well under climate change and are likely to continue to benefit, especially mobile species at the northern limit of their range. If these species are currently protected, or Biodiversity Action Plan species, such as the Adonis Blue, which is expanding its range northwards, meeting conservation objectives for these species could become easier. The potential for growing awareness of the benefits to both society and wildlife of green space and water management ('green and blue infrastructure') in urban areas, and a consequent increase in the creation of such areas, was also identified as a significant opportunity by several functions. However it is important to note that for all functions the number of potential opportunities was outweighed by the number of threats, although the balance was more even for our land use and land management functions.

4.11 We have based our assessment on the best available evidence. Nevertheless many of the threats and opportunities we have identified are based on expert opinion, and subject to considerable uncertainty.

4.12 A key area of uncertainty identified in our analysis is our knowledge of the ecology, systems and processes within the marine environment. Our knowledge of species, habitats and ecosystem function in the terrestrial environment is far from complete but the problem is particularly acute in

the marine environment. This is reflected in both the number and certainty of the threats identified in terrestrial systems, where our knowledge enables relatively specific risks to be determined. It is likely that there will be analogous threats in the marine environment, and there is therefore a particular need to expand our understanding of this environment.

4.13 The indirect nature of drivers caused by the human response to climate change places an additional layer of uncertainty on top of any uncertainty around climate change and its direct environmental impacts. Responses of government and broader society to climate change are difficult to predict. It is clear from our analysis that the nature of this response could produce a wide range of potential threats and opportunities, but at this stage it is difficult to evaluate their likelihood or importance. Natural England through the Monitoring Engagement in the Natural Environment (MENE) research programme has developed our understanding of current attitudes. What is uncertain is the response in the longer term when the local and global impacts of climate change become more apparent.

4.14 It is important to consider the full range of threats and opportunities, however uncertain, to build a picture of the future implications for our organisation. Our adaptation measures take account of uncertainty and adapting to uncertainty itself is an element of our approach. In the longer term understanding where there is uncertainty will help inform our evidence programme, to ensure that we focus on filling the gaps in our knowledge.

4.15 The spectrum of risks and the mapping of appropriate responses across the business has demonstrated the necessity of taking a coordinated approach to adaptation. For example, direct threats to the objectives of our landscape and biodiversity function are often most effectively addressed through the provision of advice and incentives delivered by our land use and land management functions. This is not unique to climate change and the organisation is familiar with this consequence of our organisational structure; it does however make cross-function coordination mechanisms particularly important.

4.16 A key area for a coordinated approach is on the coast where the cross cutting nature of potential threats and the desired responses is even more apparent as the interaction of the marine and terrestrial environment add an additional dynamic. This finding, although not surprising, has highlighted the need for the organisation to ensure that specific attention is given to coastal areas as the causes and required actions fall across three delivery functions.

4.17 As described previously, the spatial nature of the risks that climate change poses are in the process of being assessed, an analysis that will inform the guidance and advice provided in the National Character Area profiles that Natural England is producing. The early findings from this sub-national work demonstrate two clear benefits of the approach. The local nature of the assessment enables not only greater resolution of the potential threats and opportunities, but also the identification of geographically relevant responses, which in turn facilitates greater engagement with local communities and stakeholders.

4.18 Natural England directly manages a series of National Nature Reserves of which 95% by area are Sites of Special Scientific Interest (SSSIs). In addition to making up most of ‘the backbone of the wildlife protected area series in England’ (Lawton *et al*. 2010), these reserves also provide an excellent facility for research into and demonstration and communication of climate change adaptation. More than a third of NNRs are in coastal areas and, like much of the coast, suffer threats from increased erosion, coastal squeeze, habitat loss and saline intrusion, making the fulfilment of some of their current targets for biodiversity difficult or impossible in the long term. As well as ensuring that biodiversity and geodiversity targets are reviewed and adapted to reflect the changing conditions of reserves, consideration needs to be given to expanding the sites inland to compensate for areas lost, not least to ensure that public appreciation of and access to NNRs is not compromised.

4.19 In addition to the risks that climate change poses to our objectives for the natural environment, our estate and ability to operate will also be affected. The review of our building estate identified

specific issues that are informing our estates policy, and also will be incorporated into the objectives of our Sustainability Strategy that will be developed in 2012.

4.20 Finally, it is important to note that there will be limits to adaptation. Actions such as those described in this report can take us so far, but, if the causes of climate change are not addressed, the resilience of even the most robust system will eventually be exceeded. Whether through incremental change or the crossing of 'tipping points', the cost to the natural environment and to society will continue to increase. For example, according to recent studies, the risk of the UK floods in 2000 (which damaged nearly 10,000 properties, with insured losses estimated at £1.3 billion) was found to have roughly doubled as a result of human-induced emissions (Pall *et al*. 2011).

4.21 Our actions and those of our partners can make a difference to protecting and enhancing England's natural environment and the biodiversity it supports and we are committed to doing all we can. However, the more the climate changes, the harder it will be to reduce the adverse impacts. Adaptation, while essential, is no substitute for effective mitigation measures at a global scale. Although addressing the causes of climate change falls outside the remit of this risk analysis, it is a fundamental conclusion that needs to be recognised.

5 Natural England's adaptation plan

© Natural England / Simon Duffield

5.1 As highlighted previously, there is a close relationship between threats to the natural environment and to Natural England's objectives. To develop a prioritised action plan it was therefore important to identify the required change on the ground first, and then determine Natural England's capacity to achieve this change.

5.2 The ability of Natural England to achieve the desired outcome varied. In some cases Natural England, through the use of one or more of its delivery mechanisms, appeared likely to be able to achieve the required change through its own actions. Examples include reviewing our strategy for designating and protecting sites, and ensuring that adaptation is factored into the management objectives of National Nature Reserves.

5.3 In other cases it was clear that Natural England would need to work with others to achieve change. For example to improve the connectivity of the landscape in particularly vulnerable locations Natural England could target incentive schemes and advise on appropriate habitat creation and green infrastructure in responses to planning requests. However the change itself would only occur through the work of local land owners and local planning authorities.

5.4 In some areas, the ability of Natural England to achieve the desired change is severely limited. In some cases this is because of limits to our remit, for example our limited responsibilities in the marine environment; in others the result of an inability to influence the driver posing the threat, for example increasing global commodity prices. In these cases our action is focused on ensuring

the provision of up to date advice based on strong evidence so others are able to make informed decisions.

5.5 As described in Section 2, Natural England will adopt an adaptive management approach that will ensure that measures are regularly reviewed and lessons learnt for future work. Regular monitoring and flexible adaptive management, including testing and learning from new approaches, will be crucial for ensuring appropriate local management interventions in a changing environment. Monitoring schemes should include reference areas that can be used to guide our judgement in comparable areas elsewhere.

5.6 We need to improve our understanding of what features and attributes improve the natural environment's resilience and capacity to adapt to climate change and provide necessary services to society. We also need to improve our knowledge about how these features can most effectively be maintained or enhanced, and how we should measure success in managing a changing environment. We will need to acknowledge that the natural environment will change, as it has in the past, and that an important role for us is to provide appropriate management to give it the 'space to adapt' on its own - this could mean accepting new species, ecosystems and landscapes. The challenge will be to accommodate inevitable changes while ensuring that we make every possible effort to conserve the biodiversity, ecosystem services and landscapes we value and the important benefits the natural environment provides to people. We must not allow change to be an excuse for compromising conservation.

5.7 In the longer term, there are serious challenges that need to be considered. It appears likely that we will need to review and modify some aspects of our approach to conservation, to ensure that it has the flexibility to accommodate and respond to likely changes to the natural environment that we cannot prevent. This will be necessary not just to cope with threats but also to take advantage of opportunities.

5.8 In some cases the management of sites and landscapes may continue in a similar way, although the species they support may change. In other cases, different parts of the country might need to be managed quite differently from each other and from the way they are managed now. There might be difficult decisions to make, but there are precedents for accommodating even major changes. For example, at Porlock in Somerset we worked with partners to review unsustainable beach management practices at a coastal Site of Special Scientific Interest where a storm had breached the coastal ridge and changed a previously freshwater/terrestrial site to a saline system. The Site of Special Scientific Interest was successfully re-notified on the basis of the quite different, but equally valuable, new ecosystem and geomorphological processes that had been created.

5.9 These are long term questions that we are starting to explore. They will have to be considered carefully, on the basis of the evidence base that we and others are building, and decisions made in close collaboration with partners and local communities.

5.10 In addressing climate change, it will be important that we take an ecosystem approach, and consider the full range of ecosystem services a healthy natural environment provides to people, and the complex interactions between climate change and the provision of these services. There will be two aspects to this:

- First, there will be services we could need more of in the future, to help us cope with the effects of climate change, as mentioned in the first section of this report. These include coastal protection, prevention of flooding and low flow of water during periods of drought, and regulation of local climate as by the shading effects of trees and woodlands.
- Second, the provision of some services could be compromised by climate change and we need to manage ecosystems to reduce such impacts. For example, timber production could be affected by the negative effects of climate change on some tree species requiring more diverse tree planting, whilst reduced water supply would be compromised by climate-induced drought, which can be addressed by increasing water stored in wetlands and more generally in ground water stores.

5.11 To address these challenges, effective partnerships will be needed. In some cases Natural England has a leading role as a result of our statutory purpose (for example, in the case of recreation access to the natural environment) or through providing agri-environment schemes. In other cases other bodies (such as the Environment Agency in the case of flooding, or the Forestry Commission in the case of timber production) have the leading role. In all cases, however, broad delivery partnerships will be needed to safeguard and enhance environmental benefits, involving government agencies, local authorities, non-government organisations, land managers and local community groups.

5.12 The following sections outline specific actions that Natural England will take, to address the high priority threats, and take advantage of opportunities identified by our analysis.

5.13 Embedding responses to the risks that climate change poses to Natural England will be undertaken at several levels to ensure full consideration at the strategic through to operational level.

5.14 As noted above, many of the responses identified require a joint effort, and our partners and stakeholders are essential to the successful delivery of our plan.

Strategic actions

5.15 Embedding climate change into business delivery and thinking:

- At the highest level, the priority risks identified within the report will be considered against other risks identified within our Strategic Risk Register. The Strategic Risk Register contains the high level corporate risks and are reviewed regularly by the Executive Director's and the Board and formally approved by the Board. The risk registers are living documents audited by the Audit and Risk Committee.
- Natural England is developing a Strategic Context document, which will focus on long term (20 years plus) environmental outcomes while also setting out more detailed planning on what we, as an organisation, can contribute over the next five years. Climate change in general and the key findings of the risk analysis specifically will be included both within the key themes and delivery priorities set out in this document, enabling us to set out any common approaches, language or definitions that we wish to use to help inform common understanding.
- Natural England will review annually progress in implementing the actions identified in this adaptation plan.
- A Head of Profession for climate change provides leadership and coordination across the organisation, supported by a small group of staff with climate change expertise who form a 'Community of Practice. This group will help oversee the review process.

Developing a common level of understanding of climate change issues among Natural England staff

- We are developing a series of formal standards for all our work and these will include standards for climate change adaptation.
- A bespoke web-based training course has been developed that covers an introduction to climate science, as well as including modules on adaptation, mitigation and communicating climate change. It has been tailored to the needs of Natural England staff and will be available to all our staff.

Landscape and biodiversity

What we will do/are doing now

- Updating profiles and 'statements of environmental opportunity' for each of England's 159 National Character Areas to include the threats and opportunities presented by climate change.
- Revising our issues papers to ensure that sound and up to date advice is embedded in all our responses to strategic plans that take account of climate change, for example National Park and AONB Management Plans.
- Continue to build and develop our evidence base on landscape change and ongoing monitoring of protected sites, key habitats and biodiversity. This includes our long term monitoring project through the environmental change biodiversity network and partnerships with national and more local citizen science-based monitoring programmes (for example, British Trust for Ornithology and Local Record Centres).
- We will continue to work with partners to review landscape scale approaches to conservation and adaptation across Britain to draw conclusions about the best way to deliver this in the future.
- Work with Defra and partners to revise conservation objectives for SSSIs and input to new SSSI guidance that will take into account climate change issues.
- Implementing our Notification Strategy which includes a boundary and feature review of all SSSIs ensuring that climate change adaptation is considered.
- We will publish the seven remaining National Character Area Climate Change Vulnerability Studies.

What we will do in the next five years

- We will look to roll out the South East biodiversity climate change vulnerability model, a GIS based tool assessing vulnerability of BAP habitats, to other sub-national areas.
- Work with partners to ensure that the new Nature Improvement Areas are developed to consider the implications of climate change on the natural environment.
- Developing a strategy for the designation of protected areas that integrate landscape and biodiversity issues which will consider the implications of climate change.
- Continue to provide thought leadership and to work closely with our partners in government, academia and conservation organisations to develop our evidence base and share research findings on climate change impacts and adaptation with respect to landscape and biodiversity and society's responses to these.
- Work with colleagues in Land Management function to assess how Environmental Stewardship can facilitate the adaptation of wider countryside biodiversity to climate change.
- Review of adaptation initiatives. Linked to a wider project on reviewing landscape scale conservation actions, we are collating and reviewing examples of practical adaptation work. We are also working on this topic with other conservation agencies across Europe under the auspices of the ENCA (Network of Heads of European Nature Conservation Agencies) Interest Group on Climate Change, which we lead.

Access and engagement

National Nature Reserves team

What we will do/are doing now

- As part of the developing 'NNR Plan', review the Reserve acquisition, disposal and approval policies to take into account climate change threats and opportunities.
- Apply revised acquisition strategies to most vulnerable habitats: coastal, peatland and other wetland sites.

- Working with colleagues and partners, identify gaps and agree priorities to build NNRs into a connected series of high quality sites.
- Following analysis plans to compensate for losses at threatened coastal NNRs to be drawn up, taking into account land with potential 'future natural' status, for example as in the Great Fen project.
- NNRs to increasingly play a key role in monitoring the effects climate change and responses to it (especially for high risk habitats and species). Natural England's Evidence Team and academic institutions to use the sites to undertake targeted research and monitoring as illustrated by Natural England's current initiative, the developing Long Term Monitoring Project using Reserves as collection sites for a wide range of environmental variables.
- Agree the principles, priorities and functions of NNRs being used as the donor and recipient sites for species translocations and introductions.
- Ensure that NNR management planning consistently takes climate change threats and opportunities into account as plans are reviewed in the next five years, using the incoming Conservation Management System application to insert relevant 'library projects' into management plans concerning habitat heterogeneity, species monitoring and other responses identified.
- Establish a strategy for the investment in the machinery and infrastructure necessary to manage NNRs in the face of changing climate, such as a systematic programme of cutting fire breaks on vulnerable heathland sites to mitigate the threat of increased wildfires.
- Promote the carbon capture/storage function of NNRs and through Reserve outreach operations, build support for related actions that the public can take such as reduced horticultural use of peat.
- Build public support for the natural environment by using NNRs to illustrate Natural England's responses to climate change.

People and Partnerships and Statutory Access teams

What we will do/are doing now

- Ensure that operation of the Coastal Access Scheme (including identification of route, spreading room, alternative routes and 'roll back') fully considers future sea level rise and coastal change scenarios and plans for these at early stage in the implementation of each stretch, working closely with local and national climate change experts to plan accurately for the future.
- Reassess the definition for 'exceptional' circumstances for wildfires on open access land, revise Relevant Authority Guidance (RAG) and advise that legislation may need to be amended.
- Factor in the likely increased costs due to climate change of managing some National Trails in the current review of the mechanism of supporting the organisations that manage National Trails to agree a new more sustainable management model.
- Provide advice to ensure that management of NNRs, National Trails, Local Nature Reserves, Country Parks and other greenspaces and access routes plans carefully for the direct and indirect impacts of climate change.
- Work across Natural England functions and with others to monitor the direct impacts of climate change on management of access infrastructure and greenspaces and changes in visitor patterns. Continue to monitor the impacts of climate change on human health and wellbeing as it links to Natural England's interests, continuing to provide evidence and advice on the benefits to society provided by the natural environment. Provide consistent evidence, advice and good practice examples to communities, greenspace and land managers, and developers on climate change adaptation and ecosystem services in a way which offers value-for-money and innovative solutions. There are particular opportunities to work across Natural England to demonstrate the ability of the natural world to deliver benefits and services to society, including highlighting the benefits of planning for multifunctional green

infrastructure. We will also work with others to help share with communities, clear messages on the changing climate and its impact on the natural environment in their locality, particularly in areas where the threats are most apparent.

- Ensure that the material in the planned new Natural England online toolkit (initially planned for communities, greenspace managers, planners and developers) fully considers the implications of climate change and provides relevant evidence, messages and specialist advice on climate change adaptation and mitigation for those audiences.
- Prepare for increased demand for volunteering and other opportunities for individuals and communities to take action for the natural environment, particularly on NNRs, National Trails, Local Nature Reserves and Country Parks.
- Continue the MENE attitudinal survey as a significant contribution to understanding human responses to climate change and bring together other research on human responses and behavioural changes (as well as research on the direct impacts of climate change) to better plan for future impacts on Access and Engagement's objectives. In addition, use this evidence to assess whether climate change will hinder our objectives to target new, diverse audiences to enjoy the natural environment.
- Increase knowledge and specialist skills in climate change within the Access & Engagement function.

What we will do in the next five years

- Develop a programme to address the perceived barriers or real threats to human health from enjoying the natural environment, particularly in hotter summers.
- Ensure that Natural England has a robust evidence base of the effects of climate change on the extent of the habitats covered by open access, in advance of any review of open access land.

Land management

What we will do now

- Promote the carbon sequestration benefits of existing Environmental Stewardship (ES) options.
- Work with partners to develop advice and information for advisers and land managers on climate change mitigation and adaptation through land management.
- Provide advice to Defra on the potential for use of Rural Development Programme for England (RDPE) 2014 to address climate change mitigation and adaptation.
- Ensure that any tree felling for habitat restoration within Environmental Stewardship is consistent with Forestry Commission guidelines to minimise negative impacts on climate change mitigation.
- Ensure that woodland and energy crop management within our schemes is consistent with biodiversity adaptation principles.

What we will do in the next five years

- We know that the natural environment will respond to climate change, but that these responses will be complex and interdependent. There is a real risk that whilst our land management interventions continue to deliver against output targets, they do not achieve favourable outcomes for the natural environment, if they are not informed by an improved understanding of adaptive management.
- We know also that farming will adapt to changing conditions and that these human responses will provide another layer to the direct impacts of climate change on our natural environment.

Therefore we will:

- Work with partners to identify the need for support to farmers adapting to climate change and then work to develop that support.
- Include an assessment of agricultural responses to climate change in future reviews of environmental land management programmes.
- Use the best available evidence on adaptation of the natural environment when designing and reviewing future environmental land management schemes and projects.
- Include climate change vulnerability assessments in future decisions on the allocation of our land management resources and the targeting of our interventions.
- Use incentive schemes to facilitate and encourage landscape-scale projects which serve to connect reserves such as NNRs.
- Consider the potential for long term management arrangements to secure long term carbon sequestration.
- Investigate the potential for coordinated land management actions to contribute to catchment based approaches to flood risk management.
- Identify the level of need for our land management schemes to encourage actions to mitigate the risk of wildfire in susceptible habitats.
- Identify the potential for linking support for management of habitats with the production of renewable energy, for example, linking ES woodland management options to the production of woodfuel.
- Address evidence gaps, for example the impact of ES on agricultural production; methane emissions in response to peatland restoration; vulnerability of coastal sites to sea level rise and increased storminess.
- Use long term reference sites to monitor habitat and species responses to climate change.

Sustainable land use

What we will do/are doing now

- Identify Natural England's role in the new planning system and prepare the necessary guidance and best practice materials for climate change adaptation in pre-application consultation for new developments. At the same time we will seek measures to improve casework management to permit more time to develop at pre-application stage where appropriate. Our aim is that by being involved in pre-submissions we hope to reduce casework volumes, as it will result in higher quality applications, with less requirement for lengthy consultations.
- Work on advisor toolkit programme to ensure that climate change issues and training products are available for advisors. We will also monitor our own responses to plans to ensure the consistency of our advice.
- Working through the planning system and with partners we will secure green infrastructure that enhances the delivery of ecosystem services and provides multi functional solutions to climate change adaptation and mitigation.
- We will work alongside our partners, including the Environment Agency, the Forestry Commission and local authorities (through the Natural Leaders Programme) to build up a portfolio of good practice examples of climate change adaptation and the contribution of multi-functional green infrastructure to ecosystem services.
- Natural England will develop and use the land use function's national biodiversity climate change vulnerability assessment to prioritise biodiversity climate change adaptation. Tools will be developed and provided to our partners that will inform the delivery of new priority habitat and Green Infrastructure, delivering ecosystem services through the planning system. These tools will be aligned with the priorities highlighted within the Lawton Review (Making Space for Nature) to assist our work in supporting local partnerships in setting integrated

landscape and biodiversity objectives and promote restoration of ecological networks at landscape scale. This will also form part of our Natural Leaders Programme.

- Natural England will translate actions form the Natural Environment White Paper into action relevant to climate change adaptation within the land use function, for example the biodiversity offsetting project, and work with Local Authorities on how this can contribute to climate change adaptation.
- Natural England will ensure that coastal climate change adaptation issues are fully covered in guidance, toolkit and training as well as within demonstration projects to give our staff resources to enable them to give appropriate advice to stakeholders and the wider public. We will also work closely with the Environment Agency on flood risk management.
- Ensure appropriate detail to support adaptation to climate change is included in Natural England's conservation objectives for sites, for example, details around species richness to maximise the effectiveness of our casework advice.

What we will do in the next five years

- We will identify a mechanism for checking that climate change policies are consistent across plans, by beginning a programme of auditing spatial plans to assess the breadth and consistency of environmental policies to draw out good practice and model policies.
- As part of our Natural Leaders Programme we will disseminate advice and good practice on climate change adaptation, coastal risk management and ecosystem services to Local Authorities. We will also seek to look at making this material available to local communities as a resource to support planning.
- We will include climate change adaptation as part of the suite of training products being developed for planners.
- We will set up customer panels for certain sectors to explore what can be done to encourage a greater desire by developers to take account of environmental considerations, including climate change adaptation at an earlier stage of plan development, and what tools would be required to support this.
- We will seek ways to engage with the coastal engineering industry and make better use of engagement with professional bodies such as the Construction Industry Research and Information Association (CIRIA) to develop guidance materials which incorporate climate change adaptation.

Marine

What we will do/are doing now

- Natural England will work with its partners to reduce other sources of harm besides climate change through marine planning, licensing and improved management practices and consistent use of environmental assessments. The Marine and Coastal Access Act 2009 gives public bodies the tools to do this. We also need to continue advice on sustainable coastal management which enables coastal change and adaptation. Together, these actions will help to give our marine wildlife the best possible chance to adapt to changing conditions.
- Natural England will help complete the Marine Protected Areas (MPA) network to develop an ecologically coherent network of MPAs and will provide advice to help ensure the MPA network is well managed.
- Natural England and the JNCC will provide advice on the recommendations of the 4 Regional Sea Projects on Marine Conservation Zones (MCZ) to Government.
- Natural England will work to secure the integration of Water Framework Directive and MPA objectives to ensure water quality issues does not affect those areas reaching favourable condition, and in particular ensure join-up around the management of estuaries.
- Natural England will continue to provide advice to the various UK Marine Monitoring Assessment Strategy groups involved in setting Marine Strategy Framework Directive

(MSFD) targets to encourage measures to effectively maintain and recover biodiversity through the achievement of Good Environmental Status.

- Natural England will maintain engagement with programmes such as the Marine Climate Change Impact Programme and contribute and encourage research on the effects of Climate Change on marine ecosystems and function.
- Natural England will feed into the Great Britain Invasive Non-Native Species working group to get a better understanding of the impacts of invasive species on the marine environment, and advise on plans and projects effected by them on best practise.
- Natural England will report on condition of marine elements of Sites of Special Scientific Interests (SSSIs), MCZs (when designated) and feed into reporting on marine SPAs and SACs to the EU.
- Natural England will work to ensure that marine monitoring programmes can detect change in ecosystems to inform our reports on the condition of coastal MPAs. We will continue our 6 year MPA monitoring programme, linked to the JNCC-led marine biodiversity, monitoring programme to provide evidence based advice on the future management of MPAs.

What we will do in the next five years

- Natural England will continue to provide advice on Marine Conservation Zones, including reference areas, at sufficient scale and distribution within the Marine Protected Areas network to be ecologically coherent, and sufficiently robust to withstand the challenges that climate change impacts will present.
- Through the Marine Conservation Zone Project, some reference areas for representative, rare and/or threatened habitats and species have been identified to provide this high level of protection within the network. If Government decides to designate these areas these will enable us to better detect the signature of climate change and human impacts in other areas, whilst also doubling up as a network of refugia.
- Natural England will seek to understand range shifts and the emergence of new species and put into place appropriate management measures.
- Natural England will support and contribute to climate change research to develop a sound evidence base to support decisions for the marine environment in the face of climate change.
- Natural England will look at cross-functional opportunities for developing knowledge on climate change and the marine environment, including working with geologist in Landscape and Biodiversity Function to consider the extent that the demise of the last Ice Age can be used as an analogue for the possible future response of the West Antarctic and Greenland Ice Sheets to global warming.
- In the longer term, Natural England will explore the development of ‘climate smart Marine Protected Areas’, which would include addressing, for example, optimising adaptation and mitigation options and effective management of the sites’ carbon footprints whilst ensuring biodiversity objectives are maintained in the long-term.

Business and estates

What we are doing now

- Our Chief Executive has established a Health and Safety Steering Group to oversee the development, introduction, improvement and maintenance of Natural England’s health and safety management arrangements. The function of the group is to keep Natural England’s overarching health and safety policy under review and advise the Board and Chief Executive of any changes needed to ensure it remains fit for purpose. Progress will be ensured by the production of an annual improvement plan in March each year for the Chief Executive’s approval, and oversee its delivery. Monitoring will be achieved through an annual report for Natural England’s Audit and Risk Committee each September.

What we will do over the next five years

- A Sustainability Strategy will be developed that will build on the Climate Change & Adaptation Risk Assessment, led by Defra, that included part of the Natural England estate. It will introduce a sustainability appraisal toolkit that will incorporate the evaluation of projects against future climate risks using a series of indicators to measure and monitor progress on adaptation.
- The Strategy will tackle a number of additional significant environmental aspects of our work, including our ICT carbon footprint, use of finite resources and the integration of renewable energy systems into our estate.

Developing our evidence base

5.16 A series of projects will be undertaken by as part of our evidence programme to address some of the important gaps in evidence identified in the preceding sections. Specialists in the Evidence and Analysis Function will provide the cross cutting evidence and analysis necessary to support and help focus actions in the different functions and fulfil a coordination role for climate change work. More specific evidence needs are picked up by actions of the individual functions.

What we are doing now

- Completing a research project on *resilience to climate change*. This project will define resilience, what it is and what makes ecosystems and landscapes resilient, evaluate theoretical concepts of resilience, clarify definitions, identify practical approaches and test them as far as we are able. It will provide a strong basis for other climate change evidence projects. The resilience of both valued features (including landscape, geodiversity, habitats and species) and the ecosystem services they support will be assessed and included. It will compare across marine, terrestrial, coastal and freshwaters. Although climate change is the focus for this work, this project will also consider the extent to which resilience to other pressures is similar to that for climate change.
- *Evaluating adaptation measures in response to climate change.* This will provide an over-arching framework for assessing the effectiveness of adaptation measures. It will draw directly on the integrated research projects on resilience to climate change and the landscape approach, and feed into the development of new agri-environment schemes.
- Natural England's *monitoring* activities are all now part of a single integrated programme. The aim of the programme is to deliver our priority monitoring requirements in the most efficient and integrated way possible. Monitoring of the condition of our suite of protected sites, environmental stewardship schemes will provide evidence of change to a range of habitats and species across the country, helping to improve our understanding of the rate and extent of change, and identify areas of vulnerability. A project on long-term monitoring based around establishing detailed monitoring at up to 40 of our National Nature Reserves will provide an understanding of the key drivers of change, including climate change.
- *Species Conservation Programme*: Natural England is currently undertaking a review of the conservation threat assessment of the s41 list of species of principal importance for conservation in England. This analysis will collate the known conservation threat assessment, identify the distribution of species and identify preferred conservation responses to BAP listing. This work will seek to ensure that species needs are adequately incorporated into habitat management, taking account of climate change.

What we will do over the next five years

- Our evaluation of adaptation measures is an ongoing priority and will continue.
- We will continue to monitor changes in the natural environment and assess the extent to which climate change is causing these changes. We will develop the capacity to monitor the effectiveness of our adaptation measures.
- Development of a climate change adaptation manual for conservation managers, summarising evidence and best practice advice. This will bring together expertise from across

the organisation, coordinated by Evidence and Analysis Function and steered by the Climate Change Community of Practice.

6 References

ALONSO, I., WESTON, K. & GREGG, R. 2011. Carbon storage by habitat. Review of the evidence of the impacts of management decisions and condition on carbon stores and sources. Natural England Research Report, June 2011.

CRICK, H.Q.P. 2004. The impacts of climate change on birds. *Ibis*, 146, 48-56.

GILL, S., HANDLEY, J., ENNOS, R. & PAULEIT, S. 2007. Adapting cities for climate change: the role of the green infrastructure. *Built Environment* 3: 115-133.

HICKLING R., ROY D.B., HILL J.K. ROX R. & THOMAS C.D. 2006. The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology* 12, 450-455.

HOLLING, C.S. (ed.) 1978. Adaptive environmental assessment and management. Wiley, New York.

HOPKINS J.J., ALLISON H.M., WALMSLEY C.A., GAYWOOD M., THURGATE G. 2007. Conserving biodiversity in a changing climate: guidance on building capacity to adapt. Defra, London.

LAWTON, J.H., BROTHERTON, P.N.M., BROWN, V.K., ELPHICK, C., FITTER, A.H., FORSHAW, J., HADDOW, R.W., HILBORNE, S., LEAFE, R.N., MACE, G.M., SOUTHGATE, M.P., SUTHERLAND, W.J., TEW, T.E., VARLEY, J., & WYNNE, G.R. 2010. Making Space for Nature: a review of England's wildlife sites and ecological network. Report to Defra.

LOWE, J. A., HOWARD, T. P., PARDAENS, A., TINKER, J., HOLT, J., WAKELIN, S., MILNE, G., LEAKE, J., WOLF, J., HORSBURGH, K., REEDER, T., JENKINS, G., RIDLEY, J., DYE, S. & BRADLEY, S. 2009. UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK.

MACGREGOR N.A. & COWAN C.E. 2011. Government action to promote sustainable adaptation by the agriculture and land management sector in England. In Ford J.D. and Berrang-Ford L. (eds) Climate change adaptation in developed nations: from theory to practice. Springer, Netherlands.

MORECROFT M.D. & COWAN C.E. 2010. Responding to climate change: an essential component of sustainable development in the 21st Century. *Local Economy*, 25: 1-6.

MORECROFT, M.D., DUFFIELD, S.J., MARGERISON, C. & WAYMAN, E. 2011. Adapting Conservation to a Changing Climate. Natural England Commissioned Reports, Number 081.

MURPHY, J.M., SEXTON, D.M.H., JENKINS, G.J., BOORMAN, P.M., BOOTH, B.B.B., BROWN, C.C., CLARK, R.T., COLLINS, M., HARRIS, G.R., KENDON, E.J., BETTS, R.A., BROWN, S.J., HOWARD, T. P., HUMPHREY, K. A., MCCARTHY, M. P., MCDONALD, R. E., STEPHENS, A., WALLACE, C., WARREN, R., WILBY, R. & WOOD, R. A. 2009. UK Climate Projections Science Report: Climate change projections. Met Office Hadley Centre, Exeter.

NATURAL ENGLAND. 2008. Strategic Direction 2008-2013. Natural England report NE92. Natural England. Sheffield.

NATURAL ENGLAND. 2009a. No charge? Valuing the natural environment. Natural England, Sheffield.

NATURAL ENGLAND. 2009b. Responding to the impacts of climate change on the natural environment: The Broads. Natural England Research Report NE114. Natural England, Sheffield.

NATURAL ENGLAND. 2009c. Responding to the impacts of climate change on the natural environment: The Cumbria High Fells. Natural England Research Report NE115. Natural England, Sheffield.

NATURAL ENGLAND. 2009d. Responding to the impacts of climate change on the natural environment: Dorset Downs and Cranborne Chase. Natural England Research Report NE116. Natural England, Sheffield.

NATURAL ENGLAND. 2009e. Climate change impact assessment and response strategy: Shropshire Hills character area. Natural England Research Report NE117. Natural England, Sheffield.

NATURAL ENGLAND. 2010. England's Peatlands: Carbon storage and Greenhouse gases. NE257.

PALL P, AINA T., STONE D.A., STOTT P.A., NOZAWA T., HILBERT A.G.J., LOHMANN D., ALLEN M.R. 2011. Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, doi:10.1038/nature09762.

THACKERAY, S.J., SPARKS, T.H., FREDERIKSEN, M., BURTHE, S., BACON, P.J., BELL, J.R., BOTHAM, M.S., BRERETON, T., BRIGHT, P.W., CARVALHO, L., CLUTTON-BROCK, T., DAWSON, A., EDWARDS, M., ELLIOT, J.M., HARRINGTON, R., JOHNS, D., JONES, I.D., JONES, J.T., LEECH, D.I., ROY, D.B., SCOTT, W.A., SMITH, M., SMITHERS, R.J., WINFIELD, I.J., WANLESS, S. 2010. Trophic level asynchrony in rates of phenological change for marine, freshwater and terrestrial environments. *Global Change Biology* 16, 3304-3313.

UK Climate Impacts Programme (n.d.) Identifying adaptation options. URL: **www.ukcip.org.uk/**. [Accessed January 2012].

WILLOWS R. & CONNELL R. (eds) 2003. Climate Adaptation: Risk, Uncertainty and Decision-Making. UK Climate Impacts Programme, Oxford.

Annex 1 Risk assessment methodology

This annex provides a detailed outline of the methodology we have followed to assess climate risks and identify appropriate actions to be taken in response. It expands on the brief summary given in section 3 of this report.

Our methodology is based on guidance by the UK Climate Impacts Programme, Defra and the Environment Agency (Willows and Connell 2003), and is quite closely aligned with the methodology being used by the Environment Agency in its own climate risk assessment work.

The main parts, and individual steps, in the methodology are summarised in Figure A. Although these are presented in a linear structure here for clarity, it is important to note that risk assessment is an iterative process, so at each point there is often a need to go back and re- evaluate or add information to previous steps before continuing. The whole process is in fact circular, as monitoring of the effectiveness of responses might in time lead to modification of the objectives on which the whole process is based.

Table A Structure of Natural England's climate risk assessment method

1 - Identify objectives	2 - Establish decision making criteria	3 - Identify and assess threats and opportunities	4 - Identify and evaluate responses	5 - Implement actions and monitor
Step 1.1 Review and list current and possible future objectives	Step 2.1 Establish criteria for assessing and characterising risks and responses	Step 3.1 Screen objectives to identify those vulnerable to climate change	Step 4.1 Identify possible responses to threats and opportunities (adaptation)	Step 5.1 Agree specific priority actions that will be taken
		Step 3.2 Identify specific threats and opportunities	Step 4.2 Identify possible opportunities to reduce GHG emissions (mitigation) and broader ecosystem services gains	Step 5.2 Implement actions
		Step 3.3 Assess threats and opportunities (importance and proximity)	Step 4.3 Evaluate responses (sustainability; time and resources required)	Step 5.3 Monitor and review

Part 1 - Identify objectives

Step 1.1 Review and list current and possible future objectives

Risks (whether climate-related or not), and adapting to them, make sense only in relation to defined objectives. Therefore, an essential first step in the process was to identify relevant Natural England **objectives** for each of our main work areas. These provide the reference point and scope for the subsequent steps in the assessment process.

Each of our work areas listed its main objectives. Because this risk assessment is focusing on strategic risks to Natural England, and because climate change requires long term planning, we tried to focus on current high level objectives that are likely to continue to be applicable into the foreseeable future.

Part 2 - Establish decision-making criteria

Step 2.1 Establish criteria for assessing and characterising risks and responses

We identified five important factors that would help to characterise and prioritise our risks and responses:

- The **importance** of a risk to delivery of our objectives. (Risks with major effects on our objectives will be higher priority than risks with only small effects).
- The **proximity** of a risk (the nearness of the point in time at which we estimate our ability to deliver the relevant objective would change under a business as usual scenario). (The closer in time a risk is, the more urgently we need to address it).
- The **effort and resources** required to respond. (The greater the effort required to address a risk, the more carefully we need to consider it).
- The **time** period required for an effective response (including both the time needed to implement a response, and the time for the response to have an effect). It is important to consider not just when a risk might start to affect us, but how long in advance we would need to prepare our response.
- The likely positive and negative **side-effects** of a response on other objectives, as one measure of its sustainability. We should prioritise responses that have multiple benefits, and avoid adaptation in one area that constrains adaptation in or otherwise negatively affects another area.

(The scales used to rate each of these variables are outlined below in steps 3.3 and 4.3).

Part 3 - Identify and assess threats and opportunities

Step 3.1 Screen objectives to identify those vulnerable to climate change

To focus our attention just on those objectives that are relevant for this risk assessment, we first screened objectives in each work area for their vulnerability to climate change and assigned each objective to one of three categories:

1) Objectives that are vulnerable, whose achievability is likely to be affected by climate change. For example, an objective to maintain Sites of Special Scientific Interest is potentially vulnerable, as climate change is likely to affect the natural environment in these sites. These objectives were the focus of assessing risks (in part 3 of the methodology).
2) Objectives that are not vulnerable to but are influenced by climate change. These are things that we can probably still achieve irrespective of how the climate changes, but that might need to be modified to take climate change into consideration. For example, climate change is unlikely to prevent us delivering advice to land managers, but the advice we provide will need to be modified to include information to help land managers adapt. This category of objectives often provide opportunities to help respond to risks to our vulnerable objectives, and for working with others to deliver wider benefits (for example, providing environmental solutions to help communities cope with the effects of climate change). These objectives were not relevant to identifying and assessing risks (part 3), but were relevant to identifying responses (part 4).
3) Objectives that are not vulnerable to climate change.

Step 3.2 Identify specific threats and opportunities

Having identified vulnerable objectives, we then identified specific threats and opportunities. To consider the full chain of events linking an initial climatic change to a consequence for our objectives, risks were described in terms of the:

- broad **cause** of the threat (primary climatic change); and

- the more specific **event** that would occur in the area of interest.

We considered not just direct risks (resulting directly from climate change) but also indirect risks (resulting from human action in response to climate change). Therefore where relevant the **human response** relating to the threat was characterised:

- The **effect** of the change whether it was direct or indirect; and finally
- The **consequence** for a particular Natural England objective.

In steps 3.1 and 3.2 (screening objectives and identifying specific risks), the following check lists were provided as an initial prompt to help identify the primary climatic causes and second order events that might lead to risks and to think through the possible resulting chain of effects.

Possible **Causes**:

- Changes in rainfall patterns;
- Changes in temperature;
- Changes in rainfall intensity;
- Extreme weather events;
- Sea temperature rise;
- Sea Level Rise; and
- Global effects (climatic changes occurring elsewhere in the world).

Possible **Events**:

- Drought;
- Flooding;
- Increased soil moisture deficit;
- Water-logging of soils;
- Coastal flooding;
- High winds;
- Saline intrusion;
- Change in river discharge;
- Stratification of ocean waters;
- Sea temperature rise;
- River and lake temperature rise;
- Ocean acidification;
- Increased wave height; and
- Increased high tide levels.

Step 3.3 Assess threats and opportunities (importance and proximity)

We assessed the importance and proximity of risks using the following scales:

Table B

Importance rating	Description
Severe threat	Irrecoverable damage to major ecosystem structure or function occurs. One of Natural England's major strategic objectives (for example, 5 year measures of success) is impossible to deliver. Serious damage to the organisation's reputation.
Major threat	Major environmental damage; recovery potential uncertain; major reduction in ecosystem service provision, with uncertainty about recovery without major expense. There is a serious negative effect on Natural England's major strategic objectives, requiring major re-evaluation of work programming and diversion of funding streams to initiate restoration attempt.
Moderate threat	Important environmental damage; recovery likely only over the medium term; medium-term disruption of ecosystem service provision. There is a moderate effect on Natural England major strategic objectives, likely to result in delay in achieving them, or some diversion of funding to facilitate recovery.
Minor threat	Minor environmental damage that can be fairly easily reversed; or moderate damage that will quickly recover autonomously. Short-term disruption to small-scale ecosystem services, structure or function. Moderate effects on less important objectives within Natural England's corporate plan.
Negligible threat	Transient or limited impact on ecosystem services, structure or function. Negligible negative effect on achievement of NE objectives; no major objectives affected.
Minor opportunity	An opportunity which, if exploited, could slightly improve our ability to deliver small aspects of a current or future objective more easily or more cheaply. Climate change enhances an aspect of the natural environment that is currently a minor priority (or only a small part of a priority area) for Natural England.
Moderate opportunity	An opportunity which, if exploited, could enhance to some extent our ability to deliver a current or future objective more easily or more cheaply. Climate change enhances an aspect of the natural environment that is currently a medium priority for Natural England.
Major opportunity	An opportunity which, if exploited, could greatly enhance our ability to deliver a current or future objective more easily or more cheaply. Climate change significantly enhances an aspect of the natural environment that is currently a high priority for Natural England.

Table C

Proximity rating	Description
Now	Our ability to achieve the objective is already compromised, or enhanced by climate change.
Short term	There is a reasonable probability that our ability to achieve the objective will likely be compromised or enhanced by 2020.
Medium term	There is a reasonable probability that our ability to achieve the objective will be compromised or enhanced by 2050.
Long term	There is a reasonable probability that our ability to achieve the objective will be compromised or enhanced by 2080.
Very long term	There is a reasonable probability that our ability to achieve the objective will be compromised or enhanced after 2080.

The importance and proximity ratings were each scored from 1 to 5, ie an importance rating 'severe' scored 5, through to 'negligible' rating scored 1, and a proximity score of 'now' scored 5, through to 1 for a proximity rating of 'very long term'. From these scores a threat priority ranking was calculated using a simple additive score of importance + proximity, with threats being ranked as high (7-10), medium (3-6) and low (0-2).

We then rated how much **confidence** we have in our evaluation of importance and proximity, using the following scale:

- **low** - based on few, incomplete or inconclusive impact studies, or on expert judgement only;
- **medium** - based on expert interpretation of a number of (potentially conflicting) impact studies;
- **high** - based on impact studies that give a consistent picture but do not explore uncertainty fully; and
- **very high** - based on many impact studies that give a coherent picture and explore uncertainty fully.

Climate information used in part 3

In all the steps in part 3, and especially in 3.3 (assessing importance and priority of risks), UKCP09 projections were used. The UKCP09 median projections for rainfall, temperature and sea level rise under a medium emissions scenario were used as the primary 'direction of travel' of climate change over this century. More extreme scenarios (90% under high emissions) were considered to ensure that the full range of possible risks was explored.

Part 4 - Identify and evaluate responses

Step 4.1 Identify possible responses to threats and opportunities (adaptation)

We identified possible responses to all threats and opportunities. Two aspects were considered: **action on the ground**, and **action for Natural England** (for example, action on the ground might be to increase woodland; action for Natural England might be to revise land management advice to encourage tree planting). Identifying responses included considering how delivery of those objectives identified as 'influenced' by climate change could make a contribution to addressing risks.

Consideration was also given to the capacity of natural England to deliver the action on the ground (**NE's role**), which delivery mechanisms or **levers** would be required, and which **partners** could assist in the delivery of desired response.

Step 4.2 Identify possible opportunities to reduce greenhouse gas emissions (mitigation)

As well as identifying responses to address our risks, we considered how delivery of our objectives could make a greater contribution to reducing greenhouse gas emissions. This of course is mitigation, a separate issue from adaptation and not strictly necessary as part of a climate risk assessment. However, as sustainability is an important part of an adaptation response, we feel it is important to try to integrate adaptation and mitigation as much as possible. We considered the following sources of greenhouse gas emissions that are particularly relevant to Natural England's work:

- Loss of CO_2 from soils, especially peat soils, for example through degradation of peat bogs and fens.
- N_2O emissions from use of fertilisers and from animal waste in agriculture.
- Loss of CO_2 through degradation of intertidal habitat such as salt marsh.

When identifying responses, we considered the following broad categories of land/environmental management that can help to maintain carbon stores, sequester carbon or reduce emissions include:

- Reducing CO_2 emissions from land use through protection, restoration and/or creation of peat, fens, intertidal habitat, forests and preventing disturbance of soils.
- Reducing non-CO_2 emissions by improving efficiency of agricultural production.

We did not consider reducing the CO_2 emissions from our own work and travel, which is already being addressed through Natural England's sustainability targets.

Step 4.3 Evaluate responses (sustainability; time and resources required)

To further aid prioritisation of our adaptation efforts, we evaluated the possible responses we had identified.

Ideally, our responses to climate change should provide integrated solutions with multiple benefits - for example, help a range of aspects of the natural environment, and society as a whole, adapt while also reducing greenhouse gas emissions.

We considered the potential **positive and negative side effects** of each of the possible responses identified, using the following ecosystem service categories as a prompt.

- Flood and erosion regulation
- Carbon storage/sequestration
- Local climate regulation (shade, temperature regulation, storm shelter etc.)
- Water purification
- Water supply/storage
- Biodiversity
- Sustainable fuel production
- Food production
- Recreation and health benefits provided by the natural environment
- Cultural and 'sense of place' benefits provided by distinctive landscapes.

To identify truly sustainable solutions, we will also considered the impact of our responses on other sectors more broadly than covered by the list above.

Co-benefits were rated using the following scale:

Table D

Co-benefits rating	Description
Multiple benefits	Response would produce strong co-benefits for multiple ecosystem services.
Some co-benefits	Response would have benefits for at least one other environmental objective/ecosystem service.
Neutral	Response would have no significant benefits for other ecosystem services/environmental objectives.
Negative effects	Response might have potential significant conflicts with other objectives.

We then considered factors affecting the implementation of a successful response. We considered the levers available to Natural England to implement the response, and any potential challenges and barriers.

We estimated how much **effort/resource** would be required to implement each response, and the time required for a successful response to be put in place, using the following scales:

Table E

Effort & resource rating	Description
Minor	The response is a minor change to existing work. There are no major institutional barriers preventing implementation. We can implement the response using existing resources.
Moderate	The response is a reasonably significant change to existing work. There are some barriers in our way and/or some work (for example, research) to do to clarify exactly what needs to be done. We will need to re-allocate resources.
Substantial	The response is a major change to existing work, or a new piece of work. There are significant barriers that need to be overcome (for example, factors outside the organisation's control; gaps in current levers) and/or significant research projects required. We will need some additional external resources to adapt.
Major	The response is a major piece of new work. There are serious barriers to be overcome including factors outside the organisation's influence. We would need significant additional external resources to adapt.

Two aspects were considered with respect to time period, firstly the time for Natural England to respond, and to change the response if necessary.

Table F

Time/flexibility rating	Description
Rapid	Action could be taken or modified within two years.
Short term	Action could be taken or modified within five years.
Medium term	Action could be taken or modified within ten years.
Long term	Action would take longer than ten years.

Secondly, time for the response to start having an effect once fully implemented.

Table G

Lag time rating	Description
Immediate	Once implemented, the response would have an immediate effect.
Short delay	There would be a delay of a few years before the response had the desired effect.
Medium delay	There would be a delay of up to a decade before the response had the desired effect.
Long delay	There would be a delay of several decades before the response had the desired effect.
Very long delay	There would be a delay of well over 50 years before the response had the desired effect.

These values were combined to form an estimate of the **time to impact** of a response.

An indicator of the **priority** of each response was determined using the data collected in the above steps using the following technique.

Add score based on following :-

- Give each response a score of 5 if it addresses a high risk, 3 if a medium risk, 1 if a low risk.
- Add 1 if it addresses multiple risks of medium and above, or 3 if it addresses multiple high risks.
- Add 2 if it has very obvious multiple benefits (ie a high score in the mitigation/co-benefits fields).

Accordingly each response received a score out of 10.

The final part of the assessment was to record comments on any assumptions and areas of uncertainty in the methodology, with supporting evidence referenced.

Part 5 - Implement actions and monitor

Step 5.1 Agree specific priority actions that will be taken

Having assessed and prioritised our risks and responses a mapping exercise was undertaken. Each response was mapped across Natural England's different delivery functions. Within each function the response was mapped against the relevant mechanism of delivery.

Following this mapping exercise a set of proposed actions were drawn up for each function by the functional leads by coalescing similar responses where appropriate. The list of proposed actions was then considered and signed off by functional directors. The actions from the individual functions were then combined to form an integrated action plan that highlights actions that can be taken in the short term, and actions to be considered in the longer term. This integrated action plan was considered by the Evidence Group of Natural England and will inform the development of the corporate plan for future years.

Step 5.2 Implement actions

Actions will be implemented through delivery of our corporate plan, with the aim of embedding adaptation so it is considered alongside other environment decision-making in all our work.

Implementation will involve consultation with partners and stakeholders at both local and national level to develop specific actions.

Step 5.3 Monitor and review

The climate change Community of Practice will be responsible for ensuring monitoring of the Adaptation Plan. In practice this will be delivered through monitoring progress to deliver our corporate plan, and through ongoing monitoring of environmental change.

References

Willows R. & Connell R. (eds) 2003. Climate Adaptation: Risk, Uncertainty and Decision-Making. UK Climate Impacts Programme, Oxford.

Annex 2 Initial screening of function based objectives

To focus the detailed risk analysis on those aspects of our work that are vulnerable to climate change a screening exercise was undertaken on the full range of functional objectives.

Objectives in each work area were evaluated for their **vulnerability** to climate change and assigned to one of three categories: those objectives that are vulnerable (V), whose achievability is likely to be affected by climate change; objectives that are not vulnerable to but are influenced (I) by climate change and objectives that are not vulnerable (NV) to climate change.

The detailed risk analysis covered in Annex 2 focused on those objectives that were categorised as being vulnerable. However objectives determined as being influenced were also included as they frequently played an important role in terms of developing appropriate responses to the threats identified.

Table H Landscape & Biodiversity

Objective	Description	Vulnerability
LB 1	We increase the area of SSSIs in favourable condition whilst maintaining 95 percent area in favourable or recovering condition.	V
LB 2	We work with partners to improve the status of threatened species.	V
LB 2.1	Identify SSSI's that hold high risk species and review management to reduce their threat.	V
LB 2.2	To identify the habitat requirements of all UK BAP species relevant to UK BAP priority habitats. An analysis of the known habitat features required by each species and adjustment for regional variation.	V
LB 2.3	Agree species for research as main priority- projects are grouped into research, advice and delivery, and monitoring depending on the most significant aspect, but all are a combination of these activities.	I
LB 2.4	Species recovery programme - An integrated delivery framework to identify and address the needs of those species in most urgent need of attention so ensuring that we make the best use of all our delivery mechanisms. As well as our agri-environment and land management work, this includes a large number of direct action projects.	V
LB 3	We work with partners to increase the area and improve the quality of our priority habitat networks at the landscape scale.	V
LB 3.1	England Biodiversity Strategy which sets out how the quality of our environment on land and at sea will be improved over the next ten years. At the heart of the strategy is the drive to establish coherent ecological networks that benefit wildlife and people.	V
LB 3.2	Providing priority habitat information & baseline info to other functions.	NV
LB 3.3	Maintain or restore European (Habitats Directive) protected habitats (as in annex 1) and species (as in annex 2) at a favourable conservation status.	V

Table continued...

Objective	Description	Vulnerability
LB 3.4	Audit of existing condition standards through a project to replace Natural England's current in-house Common Standards Monitoring (CSM) of SSSIs and HLS Indicators of Success with one method called Integrated Site Assessments (ISA). The new approach aims to improve the efficiency of how we collect monitoring data as well as inform how we improve its storage, accessibility and use.	I
LB 3.5	Co-ordination the delivery of Integrated Biodiversity Delivery Areas (IBDA's) throughout England.	NV
LB 4	We support local partnerships in setting integrated landscape and biodiversity objectives for their area and promote restoration of ecological networks at landscape scale.	V
LB 4.1	Establish Local Nature Partnerships throughout England in recognition that diverse partnerships (individuals, businesses and organizations) delivering leadership at a local level will lead to more effective action to improve the Natural Environment.	I
LB 4.2	Establish Nature Improvement Areas which facilitate the step-change in delivery necessary to halt further biodiversity loss, which will be delivered through an integrated landscape-scale approach, delivering biodiversity gains, but also joining up with all other Natural Environment objectives.	I
LB 4.3	Update the National Character Areas (NCA) descriptions to develop more concise and overtly evidence based profiles. It will also include new Integrated Objectives to determine landscape quality and ecosystem services for each individual location.	V
LB 4.4	Deliver Natural England's statutory powers and duties in relation to protected landscapes. Further the management of and support protected landscapes through our advocacy, incentives, advisory and delivery activities.	V
LB 4.4b	Protection and enhancement of Geodiversity features.	V
LB 4.4c	Protection and enhancement of Historic Environment features.	V
LB 5	Contribute to an integrated surveillance and monitoring strategy so that interventions to deliver landscape and biodiversity objectives can be properly informed and outcomes monitored.	I
LB 6	Develop, agree and implement an integrated Landscape and Biodiversity Protected Area Designations Strategy that makes the necessary contribution to the Government response to the Lawton review.	I
LB 7	Develop and implement the External Funding Strategy, and establish a quantified baseline for leverage and 3 year growth targets for 2012/13 onwards.	NV
LB 8	Develop and implement a programme of Natura 2000 and SSSI designations that meets our statutory duties to review existing site networks and ensure they are fit for purpose.	I

Table I Access and Engagement function

Objective	Description	Vulnerability
AE1	We work with others to increase the opportunities for people to access and engage with the natural environment. (This includes Inspiring people to value and conserve the natural environment by: increasing the opportunities for new audiences to encounter nature closer to home; promoting projects engaging children and people from areas of multiple deprivation with the natural environment; increasing the number of people using 'nature's health service' and helping improve the quantity and quality of greenspace).	I
AE2	Submit Coastal Access Report for 30km of new Coastal Access rights in Weymouth to Secretary of State for approval; and start public consultation on 150km of new Coastal Access rights in the five lead areas. (This includes implementing a walking route around the open coast of England, together with associated spreading room en route. Advise government on new access rights and hand over management to Local Authorities in due course whilst retaining business-as-usual restrictions casework).	I
AE3	Deliver statutory access duties to open access land to agreed standards that maximise the amount of land available for public access, ensuring the least restrictive principle underpins all casework. (This includes delivering the restriction regime with respect to open access land. Review access land boundaries and code of conduct as required by Defra. Ensure public kept aware of access land).	I
AE4	97 percent of the Pennine Bridleway (Southern Section) completed by end March 2012 and new more sustainable management model for National Trails agreed. (This includes reviewing the mechanism of supporting the organisations that manage National Trails to agree a new more sustainable management model. Ensure public are aware of National Trails).	I
AE5	Influence the planning and design of new national, strategic and local initiatives to support access to and experience of the natural environment for as many and diverse a range of people as possible. (Influence the planning and design of new national, strategic and local initiatives to support access to and experience of the natural environment for as many and diverse a range of people as possible, providing evidence, tools and advice).	I
AE6	We confirm a vision and strategy for the management of Natural England’s National Nature Reserves. (Including ensuring NNRs contribute to the restoration and connecting of the natural environment, fully involving partners and civil society).	I
AE7	Ensure National Nature Reserves are managed as exemplar nature conservation sites. (Included are aims to: manage NNRs to ensure that a high percentage of SSSI features are in favourable condition; contribute to the England Biodiversity Strategy by maintaining and enhancing priority habitats and species; and, use NNRs to research and demonstrate nature conservation to underpin and support the development of Natural England's objectives).	V

Table continued...

Objective	Description	Vulnerability
AE8	Natural England's NNRs are providing increasing levels of public enjoyment, partnership working and involvement of local communities in the natural environment. (Including continuing to develop the public engagement opportunities offered by Natural England's NNRs, including physical access, volunteering, education and events).	I

Table J Land Management

Objective	Description	Vulnerability
LM1	We increase the percentage of agricultural land in Higher Level Stewardship.	I
LM1a	Increase the area of farmland under Environmental Stewardship agreements.	I
LM2	We secure more priority habitat under favourable management through agri-environment schemes.	I
LM3	Estates subject to IT exemption conditions are delivering environmental benefits.	I
LM4	Energy Crops Scheme land is contributing to UK renewable Energy targets.	V
LM5	Our RDPE advice is delivering improved resource protection.	I
LM5a	With the Environment Agency, support environmentally friendly farming practice through Catchment Sensitive Farming.	V
LM5b	Help develop a locally delivered catchment based approach under the Water Framework Directive objectives with the Environment Agency and Forestry Commission.	I
LM5c	Continue to support farmers and land owners with practical, tailored advice on the management of their land for environmental benefits.	I
LM6	Support Defra on the CAP reform negotiations, on MESME Project, on EWGS/ES merger and planning for post 2013 RDP delivery.	NV
LM7/12	Increase the extent of ES options that deliver biodiversity, climate change, historical, landscape and resource protection objectives.	V
LM7a	Increase Environmental Stewardship's contribution to ecological connectivity.	V
LM8	Carry out 'Integrated Site Assessments'.	I
LM9	Monitor and Evaluate Environmental Stewardship (inc R&D).	I
LM10	Reduce the Unit Cost of HLS Delivery.	NV
LM10a	Continue to reduce the cost of ES administration.	NV
LM11	Deliver the agreed Land Management contributions identified in the SSSI delivery plan.	I

Table K Sustainable Land Use

Objective	Description	Vulnerability
LU1	Secure new priority habitat and Green Infrastructure, delivering ecosystem services, through working with local partners. (KPI LU1 - We work with others to secure new priority habitat and Green Infrastructure, delivering ecosystem services through the planning system).	V
LU2	Enhance the quality of place, secure Biodiversity Action Plan habitat creation, high quality green infrastructure, new access, enhancements for Biodiversity Action Plan species, reinforce distinctive landscape character through our inputs to land, water and coastal use plans. (part of previous CCRA SLU objective).	V
LU3	Recognise and incorporate the value of ecosystem services to generate benefits for society and the economy by prioritising interventions and advising on the integration of the natural environment into new strategies and partnerships. (part of previous CCRA SLU objective).	V
LU4	With the Environment Agency, develop a 'single voice' approach with Local Planning Authorities and clearly align our advice. (KPI LU2 - Develop with local partners shared prospectuses for the natural environment in 50 key Local Planning Authorities).	I
LU5	Provide advice on the sustainable use of land, water and coast to communities and local government to support their planning decisions to protect and enhance local environments through the Natural Leaders programme; (land use corporate plan aim).	I
LU6	Help people realise long-term visions for the places they live, whilst acknowledging their short-term needs; (land use corporate plan aim).	I
LU7	Meet our targets for the number of casework responses delivered to agreed deadlines. (KPI LU3 - We will deliver a consistent, timely and high quality advisory service to local government, ensuring at least 95percent of our casework responses are delivered to the agreed deadlines).	NV
LU8	Ensure the environmental assets of land, water and coast are used in a way that recognises, protects and enhances the role of the natural environment in underpinning England's economic prosperity and well being, through provision of ecosystem services. (previous CCRA SLU objective - Sustainable land use contributing to natural environment objectives).	V
	Improving Freshwater Environment (new objectives)	
LU9	Secure water quality, air quality, water availability (flows and levels) to achieve conservation objectives for designated sites and wider priority habitats. By developing targets and objectives for air and water quality and water levels and flows; influencing planning mechanisms; implementing management plans (including freshwater non native spp management work); and responding to water and pollution casework.	V
LU10	Contribute to freshwater habitat creation and restoration. Through influencing statutory planning and the work of other agencies, as well as (with L&B) overseeing freshwater habitat targets under the EBS roadmap.	V

Table continued...

Objective	Description	Vulnerability
LU11	Improve the governance structure for water (and pollution) planning. Via influencing development of catchment based approach and join up between planning and funding mechanisms operating at catchment scale.	V
	Improving Coastal Environment (new objective)	
LU12	Recognise that the coast is best managed using solutions that work with coastal processes, enable coastal systems to function as freely as possible and ensure adaptation to both coastal and climate change.	V
	Energy	
LU13	Ensure that the EU and UK regulatory and policy framework for the energy, transport, agriculture and other sectors successfully integrate low carbon, low energy and renewable energy with a healthy natural environment - Provide advice on the setting of regional and local targets for renewable and low-carbon energy, ensuring they are based on robust capacity assessments that fully account for the sensitivities of the natural environment. (previous CCRA SLU objective).	V

Table L Marine

Objective	Description	Vulnerability
MN1	Substantial completion of the designation of a Marine Protected Area network in English territorial waters.	V
MN2	Deliver conservation advice to enable relevant authorities to implement MPA management measures.	V
MN3	Deliver an integrated monitoring programme so that all European Marine Sites will be subject to a risk based cycle of condition assessment by March 2012, and plans are in place for baseline monitoring of MCZs.	V
MN4	Work with the fishing industry and fisheries managers in an open and positive manner to protect and enhance the marine environment in English waters.	V
MN5	Promote sustainable use and management of the marine environment through engagement with government, industries, stakeholders and partners; and advise on the implementation of the Marine Strategy Framework Directive (MSFD).	V
MN6	Deliver an effectively planned, managed and monitored marine function that delivers its key targets on time, to agreed quality standards and within agreed resources; and secures efficiencies through joint working with partners across the Defra marine delivery landscape.	I

Annex 3 Detailed summary of risk analysis results

This annex presents a summary of the function-based risk assessment. For each Natural England function, a matrix of numbered threats is shown, assigning each threat a score of either high, medium or low priority according to its importance for Natural England objectives and its proximity in time. The threats are then summarised in text underneath the table, with the level of confidence in the assessment of importance and proximity shown in brackets. For presentation purposes similar threats to individual objectives have been combined. In these cases the worse case importance and proximity rating has been used, and the lowest confidence rating is highlighted. A similar matrix and list of opportunities is then presented.

Following the lists of threats and opportunities for each function, there is a short summary of the major areas of uncertainty that emerged during the analysis, followed by a commentary on the levers available to Natural England to address the risk, major potential barriers, and other organisations we would need to work with. There is then a summary of the priority responses that were deemed to be highest priority. Each of these is divided into two parts: first, the desired change that would help to address one or more risks, together with a list of the risks that would be addressed and an assessment of Natural England's ability to act in this area (scored as either low, medium or high); and second, one or more specific actions that Natural England could take to help to achieve the desired change, showing the ratings given for the level of resources required, the time to act and for the action to start to achieve the desired change, and possible co-benefits. Finally, the sources of information that were used in the identification and assessment of risks and responses are listed.

Landscape and Biodiversity

The Landscape and Biodiversity function brings together Natural England's expertise in landscape, seascape, the historic environment, biodiversity and geodiversity. It works with national and local partnerships to develop a shared purpose and set of integrated plans to deliver our statutory landscape and biodiversity outcomes.

The function works with Defra and other partners to improve the timeliness, coverage and consistency of the reporting of biodiversity outcomes; with local partnerships to take action for biodiversity and help catalyse local and community involvement;

Functional objectives threatened by climate change include work to: implement the agreements made at the Nagoya summit on the conservation & sustainable use of biodiversity; further improve the condition of the Sites of Special Scientific Interest and Natura 2000 networks to ensure that they include all of our most valuable nature conservation and earth heritage features; deliver the European Landscape Convention, UK Geodiversity Action Plan; and provide advice on the maintenance and enhancement of protected landscapes and employ landscape and ecosystem approaches working through National Character Areas, catchments and local authority boundaries.

Threats

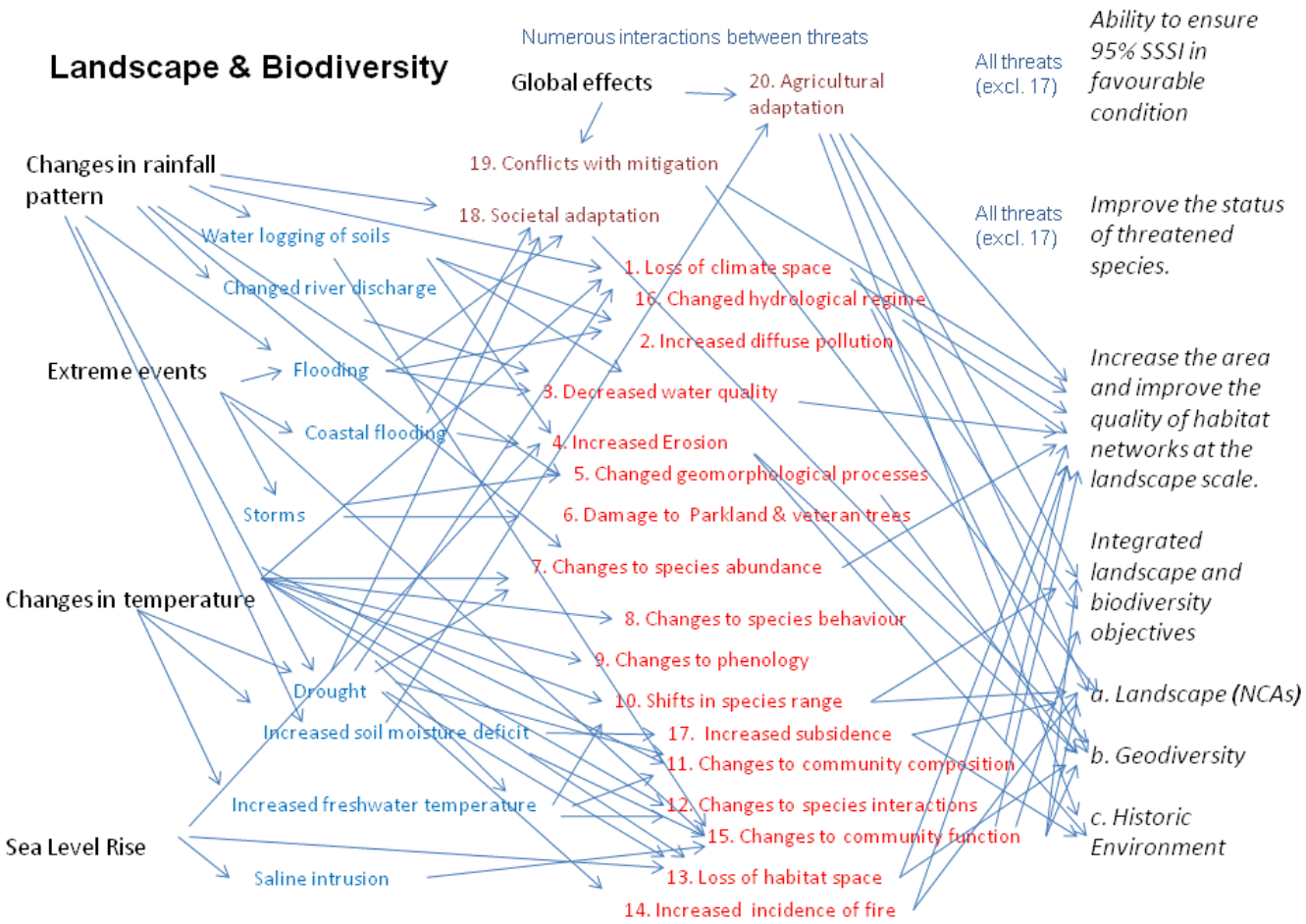

Figure A Threat analysis - Landscape and Biodiversity

Table M Matrix showing the priority of the different threats to Landscape & Biodiversity, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Severe**	(19)	(20)	15		
	Major	10	1,5,7,8,9,11,12, 13,14,16,	(18)		
	Moderate		3,4,6	17	2	
	Minor					
	Negligible					

(red = high; orange = medium; green = low). Indirect threats are indicated in brackets.

High priority threats

1) Loss of climate space (Medium[1]):

- Loss of suitable climate for montane species and those at the southern limit of their range (Berry *et al*. 2005; Britton *et al*., 2009; Franco *et al*. 2006; Mitchell *et al*. 2007; Trivedi *et al*. 2008; Walmsley *et al*. 2007).
- Loss of climate space for key woodland species, such as beech in the SE (Read *et al*., 2009).
- Potential loss of particular habitats including lowland heath, blanket bog and fen for example in the south of England (Clark *et al*. 2010; Mitchell *et al*. 2007).
- Potential loss of oceanic climate likely to affect bryophytes and ferns.
- Changes to river temperatures affecting invertebrate and fish species (Durance & Ormerod, 2007).

5) Changed geomorphological processes (Low/Medium):

- Storm events in combination with high tides and onshore winds will re-shape the coast including increasing coastal erosion and changing deposition patterns (Foresight 2004).
- Changes to river morphological and hydraulic characteristics (Whitehead *et al*. 2009).
- Changes in estuary morphology resulting in major changes to sediment types and productivity of inter-tidal habitats.
- Changes to geomorphological processes, resulting in hydrological and geochemical changes that will damage buried archaeology and sensitive palaeo-environmental remains (Howard *et al*. 2008), or notified features on active sites moving outside the site boundary.

7) Changes to species abundance (High):

- Changes in species abundance and habitat preferences (Morecroft *et al*., 2009; Thomas *et al*., 2008).
- Loss of key species from protected sites (Pearce-Higgins *et al*. 2011).

8) Change to species behaviour (High):

- Change in behaviour of species resulting in changes in niche requirements, for example, grassland butterflies moving to different microclimates.
- Changed patterns and timing of migration (Lehikoinen *et al*. 2004).

9) Changes to phenology (High):

- Changes to the timings of seasonal events (phenology), for example, tree budding and coming into leaf, eggs hatching, animals migrating, and a resulting loss of synchrony between species (Thackeray *et al*. 2010).
- Loss of synchrony between predators and prey (Winder & Schindler 2004; Pearce-Higgins 2010) or species they parasitise (Saino *et al*. 2009).
- Southern range contractions, colonisation northward and uphill (Warren *et al*., 2001; Hickling *et al*., 2006; Franco 2006; Morecroft *et al*. 2009, Pearce-Higgins *et al*. 2011) leading to potential loss of some species in parts of their previous range and expansion in others.
- A reduced ability to achieve our species recovery plan objectives or BAP species objectives through direct changes to their range or habitats (Pearce-Higgins *et al*. 2011).

---

[1] Terms in brackets relate to the level of confidence we have in our evaluation of importance and proximity

- Changes to valued landscape character, and the loss of original attributes for which sites were originally designated.

11) Changes to community composition (Medium):

- The composition of communities will change due to changes in the abundance and distribution of their component species (Morecroft & Paterson 2006; Devictor *et al*. 2008; Morecroft *et al*. 2009; Bain *et al*. 2011).
- Changes to biological communities leading to the development of new communities/habitat types resulting in a reduced ability to achieve habitat plan objectives (for example, for montane habitats) of the UK Biodiversity Action Plan (BAP) (Britton *et al*., 2009, Keith *et al*., 2009; Keith 2010).
- Changes to communities for which protected areas were designated and possible knock-on effects on species of conservation concern.
- Range expansions of both native and non-native species and resulting in different levels of competition, predation or disease.
- Generalists species favoured (through increased competitive advantage) over specialists - leading to a homogenisation of biodiversity (Olden *et al*. 2004; Britton *et al*., 2010).
- Changes in habitat types (for example, ancient oak woodlands in the north and west of England being regenerated by beech and loss of beech in the South and East) (Mitchell *et al*. 2007).
- Increased flooding and waterlogging during wetter winters leading to a shift in community composition in wetland and lowland habitats (Mitchell *et al*. 2007).
- Increase in temporary winter ponds replacing permanent ponds leading to significant change in community structure and function.
- Sea level rise and storms leading to flooding and over topping in coastal environments leading large swings in salinity and water levels. Leading to a reduced ability to achieve habitat and species objectives, in particular for freshwater coastal sites that will receive increased influence from brackish water or be converted to intertidal habitat (for example, The Broads).

12) Changes to species interactions (High):

- Range expansions of both native and non-native species and resulting in different levels of competition, predation or disease.
- Disaggregation of food-webs, for example, loss of fish prey populations for internationally important seabird colonies (Moss *et al*. 2005).
- Phenological mismatches (Saino *et al*. 2010).

13) Loss of habitat space (High):

- Loss to ecotones and habitats, in particular the transition between freshwater and saltmarsh, where such transitions are likely to be compromised further by coastal squeeze and where there is a lack of land suitable for managed coastal realignment (Lee 2001; Foresight 2004; DEFRA 2006).
- A reduced ability to achieve protected site, habitat and species objectives, in particular for freshwater coastal sites that will receive increased influence from brackish water or be converted to intertidal habitat (for example, The Broads).
- Impacts on coastal landscapes and historic sites on the coast (Murphy, Thackray & Wilson (2009).
- Insufficient water to support freshwater wetland & other habitats and species.

14) Increased incidence of fire (High):

- Increased fire risk of habitats such as heathland and moors (Mitchell *et al*. 2007).
- A reduced ability to achieve our statutory role in conserving and enhancing the natural beauty of landscapes with national designations, as these designations are currently stated, our targets for SSSIs and protected species.
- A reduced ability to achieve habitat plan objectives (for example, for heathland in a desired condition) under the auspices of the UK Biodiversity Action Plan.

15) Changes to ecosystem function (Medium):

- Increased risk of soil moisture deficiency and changes in soil microbial activity for many terrestrial habitats (for example, beech woodland) impacting on protected sites and landscape character (Mitchell *et al*. 2007).
- Changes in soil water (+/-), leading to loss of elements of soil biota reducing soil function leading to a loss of soil structure, and changes to nutrient cycling/fixing, and soil carbon storage.
- Potential changes to primary production and carbon cycling (Fay *et al*. 2008).
- Changes on the delivery of key ecosystem services such as pollination (Thomson 2010).
- Saline incursion into soils will alter their function, reduce opportunities for agriculture and change their potential for habitat restoration. This could lead to increased pressure to move current agricultural production on to other land to replace saline-affected soils, limiting habitat restoration potential or AE scheme uptake, or lead to loss of lower intensity and semi natural habitats to agriculture.
- Loss of carbon from increased drying of peatlands (Bain *et al*. 2011, Fenner & Freeman 2011).
- Work to monitor landscape change and to take an integrated landscape and ecosystem approach in each National Character Area will not ‘keep pace’ with the rate of possible changes.

16) Changed hydrological regime (High):

- Increased episodic events (flow rate, temperature) caused by extreme events, (Conlan *et al*. 2007).
- Decline in summer flows and increased winter flows (Arnell 2004; Mitchell *et al*. 2007).
- Insufficient water to support wetland and other habitats and species leading to a reduced ability to achieve our species recovery plan objectives for wetland/riverine species (including wetland birds) (Arnell & Reynard 2000).
- Increase in temporary winter ponds replacing permanent ponds.
- Increased stratification and loss of oxygen in freshwater systems, leading to eutrophication, algal blooms leading to a reduced ability to achieve habitat plan objectives for vulnerable rivers and lakes (Whitehead *et al*. 2009).
- Drainage issues for historic buildings, water table changes lead to acidification and destruction of palaeoenvironmental and archaeological remains.

19) Conflicts with mitigation (High):

- Impacts of some renewable energy initiatives on natural systems and biodiversity, for example, tidal barrages, wind turbines on peat or hydro electric dams (Drewitt & Langston 2006).
- Potential conflict between mitigation and adaptation through the creation of wind farms and large reservoirs (for HEP) in protected areas.

- Potential conflict between mitigation and adaptation through the creation of tidal barrages across the Seven, Mersey and other estuarine sites.
- Potential conflict between mitigation and adaptation through afforestation for carbon storage and wood fuel on habitats and sites.
- Potential conflict with bioenergy (Booth *et al*. 2010).
- Over-exploitation of Woodlands managed for production of timber and woodfuel.
- Increased provision of carbon sequestration through planting with fast growing locally inappropriate species such as eucalyptus. Leading to a loss of landscape character & biodiversity function in targeted areas.
- Negative impacts of renewable energy generation projects (for example, wind turbines, biofuels and hydroelectric) on landscape character and sense of place, and on important features and sites.

20) Agricultural adaptation (Medium):

- The introduction of new and different crops and techniques in response to changing climate within the UK (Foresight 2010, 2011).
- Many international and national climatic drivers of change including; the failure of international crops causing changes in agricultural policy and the economics of different crops (Schmidhuber & Tubiello 2007).
- Increased pressure on EU to increase agricultural and/or energy crop output (Schmidhuber & Tubiello 2007; Foresight 2011).
- Changes from pastoral to arable systems in West England due to warmer drier summers;
- Agriculture will require more irrigation to maintain present food production levels (Weatherhead & Knox 2009).
- Re-intensification due to longer growing seasons.
- Potential for farmers to respond to waterlogging and flooding with increased inputs of lime and fertiliser.
- Such changes have the potential to threaten many of our objectives through:
  - Increased pollution either from defuse agricultural sources or through other drivers like increased population or urbanisation (Dunn & Brown 2010).
  - Increased demand for water from agriculture leading to over abstraction from groundwater and rivers.
  - Deterioration (eventual loss) of traditional features including field boundaries, hedgerows and traditional farm buildings impacting on landscapes and historic features.
  - Walls and historic buildings increasingly uneconomic to maintain due to increased changed patterns of rainfall, storms and flooding are abandoned in favour of newer larger more robust agricultural structures negatively impacting the historic environment and landscape character.
  - Areas identified as containing opportunity for restoration of biodiversity used for higher intensity food production.
  - Increase in fragmentation of habitats (reduction in size) and species pathways so decreasing landscape permeability.

Medium priority threats

2) Increased diffuse pollution (Medium):

- Waterlogging leading to soil damage by machinery or livestock when wet, leading to compaction or poaching of soil, and increased runoff, carrying sediment and other pollutants into watercourses.
- Increased nutrient loading due to accelerated soil processes such as the mineralisation of organic matter (Bouraoui, Galbiati & Bidoglio 2002).

3) Decreased water quality (High):

- Lower flows reduce the dilution of nutrients and enhance the potential for toxic algal blooms and reduce dissolved oxygen levels (Whitehead *et al*. 2009).
- Increased nutrient loading of freshwater systems (Bouraoui, Galbiati & Bidoglio 2002; Whitehead *et al.* 2006).
- Increase flooding of ponds and run-off of fine sediment and nutrients into watercourses causing loss of water quality through pollution and eutrophication and siltation (Whitehead *et al*. 2009).
- Increased pollution either from defuse agricultural sources or through other drivers like increased population or urbanisation.

4) Increased erosion (High/Medium):

- Large proportion (around 30%) of English coast susceptible to erosion (Eurosion 2004).
- Projected increase in storm events in combination with high tides and onshore winds will re-shape the coast including increasing coastal erosion (Jones 2011).
- Added effects of erosion, particularly in water channels resulting in a decrease in water quality and a loss of marginal vegetation.
- Increased erosion and slope failure, leading to loss of nationally and internationally important historic and geodiversity features (Prosser *et al*. 2010).
- A reduced ability to achieve our statutory role in conserving and enhancing the natural beauty of landscapes, seascapes with national designations, as these designations are currently stated.

6) Damage to parkland and veteran trees (High):

- Damage to woodland, parkland and hedge habitats due to high winds (Della-Marta & Pinto 2009, Gardiner *et al*. 2010) which will lead to loss of veteran trees.

17) Increased subsidence (Medium):

- Increased shrink and swell of some clay-rich soils which may cause heave damage to historic buildings, walls, or other archaeological features.

18) Societal adaptation (Medium):

- ‘Coastal squeeze’ effect trapping habitats between the rising sea level and hard engineered sea defences (Doody 2004, Foresight 2004).
- Dynamic nature of coasts constrained by flood defences both current and future through the need to adapt to climate change impacts (the ability of natural habitats to provide sustainable flood defences not realised).
- Realignment of defences over freshwater or terrestrial habitats causing habitat loss.
- Changes to fishing practices to accommodate changing fish stocks.
- Increased demand for water in developed areas and for agriculture leading to over abstraction from groundwater and rivers in some areas that are potentially already under pressure.
- Semi-natural areas in floodplains 'sacrificed' to absorb flood waters.
- Potential damage to geological and geomorphological SSSIs as a result of engineering structures impacting on our SSSI targets.
- Action by other parties to prevent or repair damage from erosion, leading to loss of access to features of geological interest and potential damage to geological and geomorphological SSSIs as a result of engineering structures.

- Hotter drier summers with reduced holidaying abroad leading to greater demand for access to sensitive wildlife sites.

Opportunities

Table N Matrix showing the different opportunities for Landscape & Biodiversity, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Major**		(e)			
	Moderate			d,(f)		
	Minor		a,b,(g)	c		

(purple = high; blue = medium; yellow = low). Indirect opportunities are indicated in brackets.

High priority opportunities

e) Societal adaptation (Medium):

- The ability of natural habitats to provide sustainable climate change adaptation, for example, flood defences, recognised and adaptation action benefits both society and biodiversity.
- Increased awareness of the need for alternative approaches to flood risk management, providing opportunities to introduce a more sustainable system using more natural river banks and profiles, which could improve the protection of historic features and geodiversity and enhance biodiversity.
- Increased managed realignment for coastal areas providing an opportunity to meet Biodiversity Action Plan targets for coastal habitats (especially saline/brackish habitats) through managed realignment of coastlines, where appropriate, as a strategy for coping with sea level rise.
- Increased constructed wetlands in order to manage flooding.
- Increased interest from urban planners and businesses in the use of green infrastructure as an adaptation strategy leading to 'green and blue infrastructure' in urban areas. (for example, using vegetation and water for urban cooling) providing an opportunity to decrease fragmentation of semi-natural habitats adjacent to urban areas and increase urban biodiversity.
- Increased number of people using and valuing the English countryside.

Medium priority opportunities

a) Shifts in species range (Low):

- Potential for some taxonomic groups (for example, thermophilic invertebrates) to increase range and colonise new sites; this could result in an increased likelihood of reaching some Biodiversity Action Plan species targets (for example, Adonis blue, large blue, Dartford warbler) and could result in an increase in species richness for some habitats/geographical areas.
- An opportunity to accommodate change to improve the benefits provided by landscapes (their character, biodiversity and ecosystem services), for example by enabling new tree species and their associated plant and animal assemblages to establish.

b) Changes to community composition (Low):

- An increase in general richness of biodiversity driven by colonisation by mobile taxonomic groups.

c) Changed geomorphological processes (Low/Medium):

- New geodiversity features exposed leading to an enhanced ability to support conservation of geological SSSIs; potential enhancement of landscape character and local distinctiveness (Prosser *et al*. 2010).

d) Changed hydrological regime (High):

- Large scale changes to river flow and other processes, creating need for changed management and opportunity to restore natural processes.

f) Alignment with mitigation (Medium):

- Reintroduction of positive woodland management for the production of timber and wood fuel;
- Rewetting/water retention in peatland for carbon sequestration.
- Reduction in energy intensive agricultural practices in response to need for climate mitigation providing an opportunity to shift to more sympathetic soil management practices, leading to improved soil function and a decreased need for agrochemicals.

g) Agricultural adaptation (Low):

- Increased cost of fuel and carbon reducing area under intensive land management increasing the likelihood of meeting some Biodiversity Action Plan targets for habitats and species.

Areas of uncertainty

Topics that require further research to develop our approach include:

- **Effects of climate change on complex interaction between species**. In addition to the differing rates of change in phenology leading to mismatched timings within food chains, species have a wide range of interactions with competitors, parasites, diseases and predators that could be altered as a result of climate change and its affect on habitats. As some species distributions change more radically that others, novel combinations of species will occur with unknown consequences for interactions. Furthermore, there are likely to be local climates that have no analogy with any currently existing ones, potentially leading to the formation of novel ecological communities. Plant-soil interactions may also change, with consequences for nutrient relations.
- **Factors that promote functional connectivity and dispersal across landscape**. The highly fragmented nature of English habitats is widely recognised as a constraint on dispersal for many species and hence on their ability to colonise new sites. However the best methods to ameliorate this, is an area of uncertainty.
- **Non-native invasive species**. Most non-native species in Britain are not a threat and with climate change we may well have to accept and protect many species whose potential range is expanding into the UK, whilst retracting in other, more southerly areas. At the same time, however, non-native species may prove a threat as a result of their invasive nature or because they are pests and diseases. The identification of species that might pose a future risk as a result of climate change or as a result of encouraging habitat connectivity as an adaptation measure continues to be an area of active research.
- **Tipping points in the interactions between climate and ecosystem responses**. Tipping points may be crossed as a result of an extreme climatic event or series of events that push an ecosystem into an alternative stable state, for example an ecological ‘regime shift’ would be a storm surge and coastal flooding event that transformed a coastal reed bed habitat into a saltwater marsh. Understanding the proximity of tipping points is an important area of research.

- **Interactions between different aspects of environmental change**. Climate change will interact with all the other pressures on ecosystems, including land use change, air pollution and invasive species. These complex interactions are poorly understood and have the potential to reduce the capacity for the natural environment to adapt autonomously or to influence human adaptation interactions.
- How to enhance the adaptive capacity of species, habitats, ecosystems and ecosystem services to both gradual climate change and episodic but increasing frequency of extreme events.

Our ability to address the risks

Levers

- A key lever is through Environmental Stewardship agreements with land owners and providing advice on land use and management practices. Through targeted stewardship agreements and partnership working, we will build and strengthen ecological networks to link existing biodiversity-rich sites, following recommendations from the UK Biodiversity Partnership adaptation principles (Hopkins *et al*. 2007), England Biodiversity Strategy adaptation principles (Smithers *et al*. 2008) and Making Space for Nature (Lawton *et al* 2010).
- Provision advice on the designation and management of protected areas such as Sites of Special Scientific Interest, National Parks, and Areas of Outstanding Natural Beauty, Ramsar Sites and Special Areas for Conservation (SACs) including monitoring their impact and recommending new designations.
- Preparation and review of designated site citations and preparation of management approach.
- Support the preparation of management plans for Areas of Outstanding Natural beauty.

Barriers

- Staff time and resource, including availability of staff with sufficient knowledge and expertise working on delivery.
- May be difficult to get buy in from partners including land owners for measures to combat climate change threats, which many perceive are a long time in the future.
- Adaptation measures are often required in a different location to where the impact is experienced, for example, coastal erosion at one location may be due to sediment movement being restricted at a different location within the coastal cell.
- As change in our landscapes speeds up, delivery mechanisms and management options will need to be increasingly responsive to the adjusting natural environment.
- A key lever is agri-environmental schemes to deliver adaptation on the ground, however, the higher level scheme which provides more options which can be used to combat climate change threats, is often not targeted in areas where there are opportunities to develop an integrated approach which includes responding to climate change risk. Agreements are also usually only ten year agreements, and many measures will need to be in place significantly beyond this time frame, limiting our ability to plan long term.
- Our present system leases change but only for short periods of time - in many instances it would be far more cost effective to buy land to facilitate that change, leaving nature to take its course in a low intervention way.

Our partners and stakeholders

Delivery of the actions required to mitigate the threats and opportunities identified requires the coordinated action of Natural England's functions and a wide range of external organisations. A coordinated approach from Defra and its agencies such as the Environment Agency, Forestry Commission and Marine Management Organisation ensuring coordinated advice and guidance and joined up incentive schemes will be essential.

The authorities that run National Parks and Areas of Outstanding Natural Beauty will have a pivotal role in delivering actions within their protected areas, whilst NGOs such as the National Trust, Wildlife Trusts and the RSPB will play a considerable role within protected areas and in the wider countryside often coordinated through partnerships such as the Biodiversity Action Plan partnerships.

The JNCC, Universities and research councils will have an important role to play in the development and understanding of the evidence base. Whilst Local Record Centres supported by volunteers and the NGOs listed above will play an important role in monitoring change.

Summary of key responses to priority risks and opportunities

Desired change: an **improved understanding of how climate change is affecting the natural environment** in different parts of the country, to inform appropriate action targeted at the most urgent priorities.

- Risks addressed: most/all.
- Natural England's ability to influence this: high.

Action we could take: Further develop our **integrated surveillance and monitoring strategy**. This will include data from Integrated Site Assessments, data from local record offices and other partners, and our own monitoring work on change in the abiotic environment (geodiversity, historic environment and soils) and wider landscape change.

- Resources: Moderate.
- Time: Short term action, short delay to effect.

Desired change: a **national system of protected areas that takes climate change fully into consideration** and is not notified and managed as if the environment is static and unchanging.

- Risks addressed: 1, 5, 7, 10, 11, 12, 13, 16, a, b, c.
- Natural England's ability to influence this: high.

Action we could take: **Integrate climate change into our designation strategy for protected areas**. As part of our statutory duty to review existing designations, work with Defra and other partners to develop, agree and implement an integrated Landscape and Biodiversity Protected Area Designations Strategy, including our Natura 2000 and SSSI designations, which incorporates climate change considerations. This will:

- Reflect potential for changes in species and habitat composition in designated site citations, conservation objectives, condition assessment and guidance for habitat management to allow sites to continue to be important for biodiversity even if they don't contain the species for which they were originally designated.
- Continue to implement the SSSI Notification strategy, which includes a review of boundaries and features of all current SSSIs, making sure that climate change adaptation is also considered.

- Input into the new SSSI guidelines to ensure that changes to features are assessed and taken into consideration. This should include underpinning ecological processes whilst taking into account climate change impacts to increase resilience.

- Resources: Moderate.
- Time: short term action; short delay to effect.

Desired change: all **existing wildlife conservation areas are managed in a way that explicitly addresses climate change**, with appropriate awareness of vulnerability, conservation objectives, management actions and adaptive management. (The appropriate management will vary from site to site depending on the ecosystem and species in question, but should follow established principles for conservation biodiversity under climate change including, for example, increasing heterogeneity of land cover to increase available microhabitats and so increase the chances of species persisting in locally favourable microclimates and soil conditions, for example, including areas with northern slopes and wetter places within sites).

- Risks addressed: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, a, b.
- Natural England's ability to influence this: medium-high.

Action we could take: Developing and providing **detailed advice and guidelines to conservation managers** about possible adaptation actions for different ecosystems. This should bring together our knowledge on the impacts of climate change on the natural environment, including habitats, species, landscape, soils, geology and the historic environment together with suggested adaptive responses.

- Resources: Moderate.
- Time: rapid action; short delay to effect.
- Side-benefits (if implemented): Mitigation through carbon storage/sequestration in soil and vegetation; a wide range of other ecosystem services such as flood alleviation.

Action we could take: ensure that all sites Natural England directly manages (such as National Nature Reserves) are managed according to the best practice guidelines mentioned above. (See NNR section below.)

Desired change on ground: Ensuring habitat creation and restoration enhances **ecological networks**, which will promote movement of more mobile species, encouraging colonisation of new sites and reducing the risks associated with small isolated populations, while being aware of the risks posed by invasive non-native species.

- Risks addressed: 1, 7, 8, 10, 13, a, b.
- Natural England's ability to influence this: high.

Action we could take: Develop better **practical tools and methods for conservation managers to identify where ecological networks should be created or improved**, through increasing patch size, improving habitat quality and variability through the linking of sites. This could include providing spatial data of potential linkages between our larger SSSIs, identifying the key geology and soils types that allow good potential for landscape scale restoration and map out areas of landscape change where space for natural functioning process will need to occur over the longer term. It could also provide a mechanism to build on opportunities presented through the creation of Nature Improvement Areas and green infrastructure routes, as well as more innovative approaches to land use planning and agricultural environmental schemes.

- Resources: Moderate.

- Time: short term action; medium delay to effect.
- Side-benefits (if it leads to action on the ground): mitigation through soil carbon; flood alleviation through river conservation and urban green infrastructure; urban cooling through urban green infrastructure.

Action we could take: plan **Natural England's own ecosystem restoration and re-creation activities** in a way that contributes appropriately to the improvement of ecological networks; particularly through our land management and land use work and through conservation partnerships.

- Resources: Major.
- Time: medium term action; medium delay to effect.

Desired change on ground: **local communities and partners have access to the best available evidence about possible future environmental change** in their area, and about action that could be taken. This would help to enable communities to 'own' the landscape change in their area, and would help them to engage with the positive aspects of living in a naturally dynamic landscape.

- Risks addressed: 2, 3, 4, 5, 6, 11, 14, 15, 16, 18, 19, 20, e, c, f, g.
- Natural England's ability to influence this: high.

Action we could take: **Revise and update all England's National Character Area** profiles to take climate change into consideration. These would include the identification of opportunities for integrated action, based on information and analysis that reflects Natural England's interests, and will be made available as advisory tools to partners and local stakeholders, including local communities to help them set the context for their planning and decision-making.

- Resources: Minor.
- Time: rapid action; short delay to effect.
- Side-benefits: Potential for a range of ecosystem service benefits.

Desired change: **Make Protected Landscapes the most resilient areas** of the UK's Natural Environment to climate change - manage to increase the resilience further and develop a strategy to join some of them up.

- Risks addressed: 11, 14, 15, 16, 18, 19, 20, a, b, e.
- Natural England's ability to influence this: medium (need to work closely with AONBs and National Parks).

Action we could take: Develop improved **guidance and management practices for managing protected landscapes in a changing climate**. We need to ensure that any guidance and advice on conserving and enhancing protected landscapes reflect our understanding of the dynamic nature of all landscapes, the potential and actual impacts of climate change, and ways of ensuring that these places, as and when they change, continue to be highly valued by society as a whole.

- Resources: Substantial.
- Time: short term action; short delay to effect.
- Side-benefits: mitigation, flood alleviation, recreation opportunities.

Desired change: greater use of **large scale land management** that 'works with nature' to create areas in which ecological processes are re-established or facilitated, to allow large scale changes to our rivers, coasts and associated wetlands. This should provide benefits for wildlife, as well as flood alleviation benefits for human communities.

- Risks addressed: 4, 5, 11, 13, 15, 16, 18, a, b, d, e.
- Natural England's ability to influence this: medium.

Action we could take: build (with partners such as the EA) a **spatial evidence base** of the opportunities for such action, which can be used with partners to inform the location and management of future projects.

- Resources: Moderate.
- Time: short term action; medium delay to effect.
- Side-benefits: mitigation in coastal marsh, flood alleviation, recreation opportunities.

Action we could take: work with others, particularly organisations such as the Environment Agency, local authorities, NGOs and local communities to to consider how we can make space for the natural development of rivers and coasts in a way that helps both wildlife and people.

- Resources: Moderate.
- Time: short term action; medium delay to effect.
- Side-benefits: mitigation in coastal marsh, flood alleviation, recreation opportunities.

Desired change: **Biodiversity Action Plan targets and species recovery programmes retain their relevance** as climate change causes changes in species' distribution and shifts in ecosystems. Consideration is given to the role of additional mechanisms such as species translocation and ex-situ conservation.

- Threats addressed: 1, 6, 7, 8, 9, 10, 11, 12, 14, 14, 15, 16, 20, a, b.
- Natural England's ability to influence this: medium.

Action we could take: work with Defra and other partners in the England Biodiversity Strategy to regularly review the appropriateness of plans and targets.

- Resources: Moderate.
- Time: short term action; rapid effect.

Desired change: the full range of adaptation benefits provided by conservation areas are considered in land use planning decisions.

- Threats addressed: 18, 19, 20, e, f, g.
- Natural England's ability to influence this: medium.

Action we could take: see land use section.

Access and Engagement function - People and Partnerships, Statutory Access and National Nature Reserve Teams

Natural England's Access and Engagement Function has a variety of responsibilities that focus on helping people to enjoy, understand and appreciate our natural heritage. The Function embraces the organisation's statutory access duties, National Nature Reserves (including the direct delivery of nature conservation on those managed by Natural England) and the provision of advice regarding the quality of greenspace and the involvement of communities.

The work of the Function underpins Natural England's statutory purpose to protect, conserve and manage the natural environment for the benefit of present and future generations.

The Function is responsible for providing advice on matters specified in Natural England's general purpose which relates to: securing the provision and improvement of facilities for study; understanding and enjoyment of the natural environment; and promoting access to the countryside and open spaces and encouraging open-air recreation.

Natural England's aspiration and intention to increase the number and range of people who benefit from the natural environment is undiminished: we want people everywhere to experience and enjoy nature in their day-to-day lives because we know it contributes to their own wellbeing, which, in turn leads to more people valuing nature. We work with others to increase the opportunities for people to access and engage with the natural environment.

Our analysis considers our Team's work in two separate parts: objectives relating specifically to our work on National Nature Reserves; and objectives for statutory access and engaging people with the natural environment.

National Nature Reserves

We aim to manage our National Nature Reserves as exemplar nature conservation sites contributing significantly to public enjoyment and understanding of the natural environment and the provision of ecosystem services, and explore opportunities for civil society and local communities to become more involved.

The specific objectives to achieve this that are under threat from climate change are to: confirm a vision and strategy for the management of Natural England's National Nature Reserves; ensure that National Nature Reserves are managed as exemplar nature conservation sites; and, that Natural England's NNRs provide increasing levels of public enjoyment, partnership working and involvement of local communities in the natural environment.

Threats

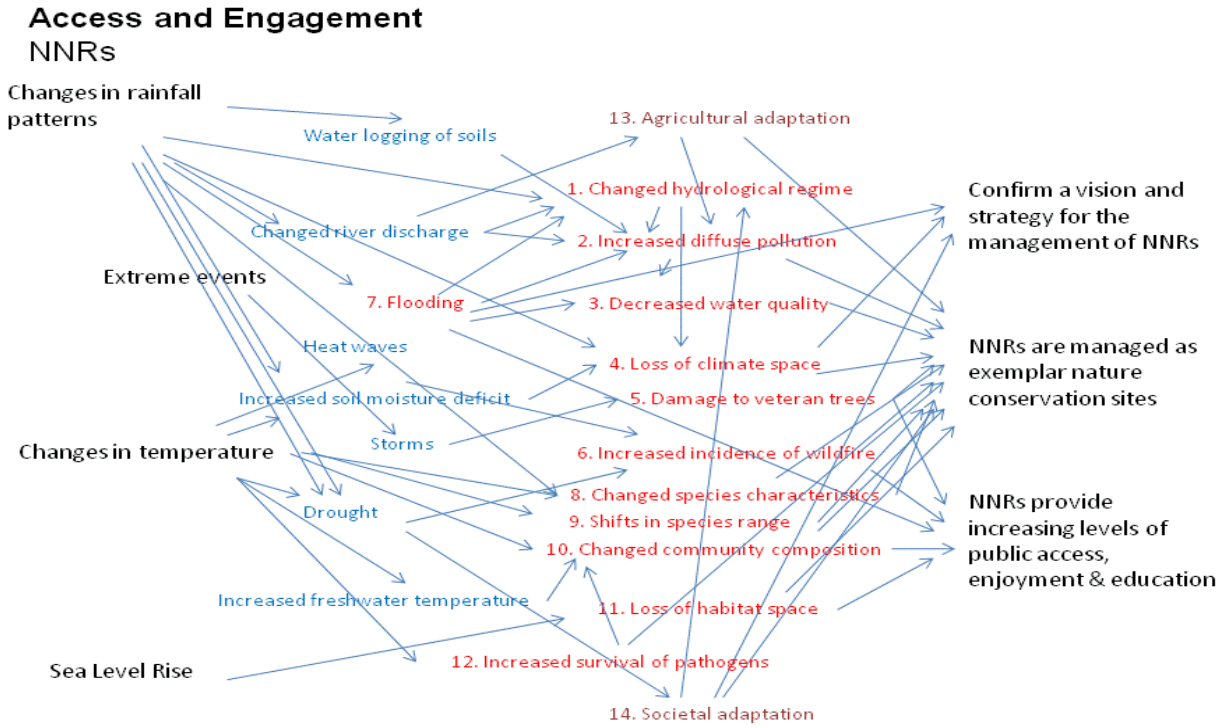

Figure B Threat Analysis - Access and Engagement: NNRs

Table O Matrix showing the priority of the different threats to National Nature Reserves team objectives, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Severe**					
	Major	6,8	9,10,11	7		
	Moderate	12	1	2,3,4,(13),(14)		
	Minor			5		
	Negligible					

(red = high; orange = medium; green = low). Indirect threats are indicated in brackets.

High priority threats

6) Increased incidence of wildfire (Medium):

- Drought and extreme high temperatures leading to increase incidence of wildfires in vulnerable habitats, especially heathland, lowland raised bog and blanket bog NNRs. Increasing resources required to manage sites to minimise impacts of wildfires (for example, fire breaks) and impact of those on landscape (Albertson *et al*. 2010).
- Restricted access on NNRs as a result of access land closures.

8) Changed species characteristics (High):

- Temperature driven change in behaviour of species resulting in changes in niche requirements (for example, grassland butterflies moving to different microclimates) (Davies *et*

al., 2006; Isaac *et al*. 2010) is increasing the complexity and costs of management to understand, create where necessary and maintain appropriate habitat niches on NNRs.

- Increased growth of some plant species, particularly invasive generalists leading to increased costs to maintain visibility of and access to NNR features, including geological features.

9) Shifts in species range (High):

- Shifts in species ranges (for example, southern range contractions, colonisation northward and uphill), leading to changes or potential loss of some species in parts of their previous range and expansion in others (Davies *et al.* 2006, Dockerty, Lovett & Watkinson 2003, Parmesan *et al*. 1999, Pearce-Higgins *et al*. 2011), could lead to an inability to meet current habitat and species objectives.

10) Changed community composition (High):

- Species compliments of NNRs changing: **a)** loss (or significant reduction) of key, often specialist species with effects on others in turn; tricky decisions on whether to put conservation effort into retaining species, or at least at what point to 'let them go'; **b)** new species colonising, or significant increase in species already present, often generalists (McKinney & Lockwood 1999, Olden *et al*. 2004), some of which may have adverse impacts on ecosystems. Both these effects could lead to an inability to meet current habitat and species objectives.
- Loss of specialists and increase in generalists leading (McKinney & Lockwood 1999, Olden *et al*. 2004) to a general reduction in what makes reserves special places for the public and therefore increasing the challenge of engaging the public.
- Increased stratification and loss of oxygen due to increased temperatures in freshwater habitats, leading to eutrophication and algal blooms (Durance & Ormerod 2007). NNRs with aquatic features affected as food webs may be interrupted with consequent species changes.

11) Loss of habitat space (High):

- Sea level rise and increased storms leading to a loss of coastal intertidal habitats, (Lee 2001) especially where there is a 'coastal squeeze' (Doody 2004) effect trapping habitats between the rising sea level and hard engineered sea defences, supra-littoral and adjacent terrestrial habitats (Foresight 2004).
- Fundamental changes to east coast NNRs with major losses of valuable habitats, species and geodiversity features. In many cases, no easy areas to retreat to due to abutting high value, improved agricultural land.
- Access to coastal NNRs significantly compromised. Cost of maintaining access features increased, including H&S considerations.
- Fundamental changes to affected NNRs with major losses of valuable habitats, species and geodiversity features, including the attributes for which the site was originally declared, with the implication that some sites should be de-declared.
- In many cases, no easy areas to retreat to due to abutting high value, improved agricultural land.

12) Increased survival of pathogens (Medium):

- Enhanced survival of pathogens due to milder winters leading to the spread of diseases onto NNRs such as *Phytophthora*, with consequent effects on susceptible species and ecosystems.

Medium priority threats

1) Changed hydrological regime (High):

- NNRs reliant on just surface water from rainfall will be especially vulnerable to change in hydrological regime due to changed rainfall patterns; sites with complex hydrological regimes less vulnerable (Winter 2000, Acreman *et al*. 2008).
- Loss or reduction in value of habitats and dependant species on wetland or aquatic NNRs could lead to an inability to meet current habitat and species objectives (Environment Agency 2008).
- NNRs in floodplains subject to loss of fine control of water levels, causing deterioration in habitat.

2) Increased diffuse pollution (Medium):

- Waterlogging resulting in damage to soils by machinery, livestock or access users when wet. Leading to compaction or poaching of soil, and increased runoff, carrying sediment and potentially pollutants into watercourses (DEFRA 2010).
- Increased nutrient loading of watercourses (Whitehead *et al*. 2009).

3) Decreased water quality (Medium):

- Flooding increasing the risk of eutrophication and/or pollution of semi-natural habitats (Whitehead *et al*. 2009; DEFRA 2010). Eutrophic or polluted floodwaters will adversely affect vegetation on NNRs and in turn invertebrates and other fauna.

4) Loss of climate space (Medium):

- Reduction in oceanic climate characteristics likely to affect bryophytes and ferns.
- Increased soil moisture deficit could lead to the loss or reduction of blanket bog and fen (Clark *et al*. 2010).
- Climate conditions exceed ecological niche for peat forming *Sphagnum* species and peat stops forming on major lowland raised bog and blanket bog restoration projects on NNRs (Clark *et al*. 2010, Lindsey 2010).
- Risk of significant reductions of key, often specialist, species on relevant NNRs could lead to an inability to meet current habitat and species objectives, or the loss of attributes for which the NNR was originally declared, leading to the prospect of de-declaration of sites.
- Increased risk of mortality of drought and heat sensitive species, for example, beech trees (Broadmeadow *et al*. 2005, Geßler *et al*. 2007).

5) Damage to veteran trees (Medium):

- Increased loss of veteran trees and damage to woodland, parkland and hedge habitats due to high winds in storm events (Della-Marta & Pinto 2009, Gardiner *et al*. 2010).
- Increasing tree safety management costs in honey pot zones on NNRs.

7) Increased incidence of flooding:

- Semi-natural areas in floodplains ‘sacrificed’ to absorb flood waters. Increase in area required for floodwater absorption, and consequent risk of eutrophication and/or pollution of semi-natural habitats. Will limit any expansion of NNRs on floodplains and connectivity between sites will be restricted by increased pressure on land use.
- Access areas and routes affected, and unavailable for longer periods of the year, restricting public access. Increased maintenance costs for certain NNRs and possible increase in visitor numbers and pressures on alternative NNRs during flood season.

13) Agricultural Adaptation (Medium):

- Increased inputs of lime and fertiliser as a response to waterlogging causing greater leaching of nutrients into groundwater and a decline in quality of ground water.

14) Societal Adaptation (Medium)

- In drought conditions increased competition for water between sectors. Leading to a reduction in available water to control site hydrology leading to negative impacts on habitats and species and restrictions on the expansion of existing wetland limiting connectivity between sites (Hume 2008, Spoor 2004).
- Increasing competition for land and other resources. Expansion of reserves and providing linkages becomes more expensive and politically challenging.
- 'Coastal squeeze' of coastal ecosystems between rising sea levels and hard coastal defences (Foresight 2004).

Opportunities

Table P Matrix showing the different opportunities for National Nature Reserves, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Major**	(e)	(g)			
	Moderate	a, (h)	b,(f)	c,d		
	Minor					

(purple = high; blue = medium; yellow = low). Indirect opportunities are indicated in brackets.

High priority opportunities

a) Shifts in species range (Low):

- Potential for some taxonomic groups (for example, thermophilic invertebrates) to increase range and colonise new sites this could result in an increased likelihood of reaching some Biodiversity Action Plan species targets (for example, Adonis blue, large blue, Dartford warbler) and could result in an increase in species richness for some habitats/geographical areas.
- An opportunity to accommodate change to improve the benefits provided by landscapes (their character, biodiversity and ecosystem services), for example by enabling new tree species and their associated plant and animal assemblages to establish.

e) Societal adaptation (Medium):

- Sea Level Rise and increased storminess is likely to increase the need for managed coastal realignment projects. Such projects could provide an opportunity for the creation of new or extended NNRs, or for linking up existing sites.

g) Agricultural adaptation (Low):

- Further intensification of English agriculture and greater pressure on land leading to increasingly value being placed in protected sites. NNRs better supported politically and by the public, and better resourced, facilitating the management, expansion and connection of sites.

- Saline incursion into soils will alter their function, reduce opportunities for agriculture and change their potential for habitat restoration.

h) Increased extent and complexity of climate change impacts (Low):

- Greater number of people environmentally aware.
- Evidence gaps in solving environmental problems become more apparent increasing the demand for solutions leads to greater support for research and monitoring activities. NNRs valued more highly for their research, monitoring and demonstration potential.

Medium priority opportunities

b) Changes to species abundance (Medium):

- Some specialist species undergo adaptive variations in response to environmental changes and become more generalist, for example, silver-spotted skipper becoming more generalist in its habitat requirements leading to population increases (Davies *et al*. 2006).

c) Changed hydrological regime (High):

- Quasi-natural, large scale changes to river flows and other aquatic processes benefiting biodiversity and geodiversity of NNRs in affected areas.

d) Increased incidence of flooding (High):

- Extreme events and changed rainfall events are likely to increase the demand for sustainable flood risk management increasing the onus on natural elements within river systems, again providing the opportunity for the creation of new or extended NNRs.

f) Alignment with mitigation (Medium):

- Semi-natural habitats play an increasingly significant role as carbon stores and sink increasing the value (perhaps including monetary) attached to NNRs acting as carbon stores.

Areas of uncertainty

The ecosystems represented on NNRs are invariably complex and responses to changing environmental variables are difficult to ascertain with a high degree of certainty. There are a great number of evidence gaps for habitats and species, including their rate of change.

NNRs contain a disproportionate number of rare and edge-of-range species, many of which are susceptible to climate change. In the case of diminishing populations of such species, there are no policies regarding when the conservation of a local population no longer justifies the resources required to maintain it.

Indirect impacts such as pollution from off-site sources or pressures from surrounding land use may be prevented or moderated by regulatory control; the degree of regulatory power may need to be enhanced if the pressures increase.

There are significant gaps in knowledge regarding the management of invasive species and diseases.

The management of damaged peatlands has improved significantly in the last decade but it is unclear whether there is sufficient knowledge and resources to address the enhanced threats caused by climate change.

Clearly, considerable uncertainty lies around the human-related responses to climate change and their consequent bearing on NNRs, such as the changes to agriculture and the values society places on the natural environment.

Our ability to address the risks

Currently, approximately two thirds of NNRs by area and number are managed directly by Natural England, often in close working partnerships with owners of the land. The remaining one third is managed by Approved Bodies: organisations such as the National Trust, RSPB and the Wildlife Trusts as well as some other environmental agencies, Local Authorities and a few commercial and private individuals.

- The majority of the on-site responses are deliverable by the organisations managing the Reserves, if resourcing is available.
- In some cases, resources are likely to be a limitation to the degree of management possible, for example in expanding Reserves, adapting access infrastructure or undertaking management of large hydrological units.
- NNRs will need significant inputs from specialist ecologists and academic institutions in order to understand the issues, develop the correct management, and to monitor the changes.
- For off-site responses, including the all-important issues of inter-site connectivity, Natural England will need to draw on its incentive schemes and regulatory powers (and call on others to use theirs).
- Natural England will require good relationships with stakeholders and strong societal support for the natural environment to achieve our objectives for NNRs.

Summary of key responses to priority risks and opportunities

Desired change: **facilitation of movement of species between reserves** by increasing reserve size and quality, maximising landscape permeability, creating 'stepping stones' and corridors; and assisting species movements where essential.

- Threats addressed: 1, 4, 6, 10, 11, [L&B: 1, 7, 8, 10, 11, 13, 16].
- Natural England's ability to influence this: low-high depending on the action required (other bodies managing NNRs also have a role; some actions would also be required outside reserves, requiring cooperation with a wider range of partners).

Action we could take: **Use and extend NNRs as stepping stones**.

- Resources: major.
- Time: medium term action; medium delay to effect.
- Additional benefits: Carbon sequestration through creation of wetlands and other semi-natural habitats; reduction in nitrous oxides for same areas.

Action we could take: Facilitate and **encourage large-scale projects** on land between reserves, to help to make the 'matrix' between them more permeable to species.

- Resources: major.
- Time: medium term action; medium delay to effect.
- Additional benefits: Carbon sequestration through conservation of agricultural soils.

Action we could take: **undertake translocations and introductions** to IUCN protocols.

- Resources: major.
- Time: medium term action; short delay to effect.

Desired change: creation of **new coastal conservation areas**, and extension of existing sites, to compensate for the projected loss of coastal reserves.

- Threats addressed: 10, 11, 14, [L&B: 1, 7, 8, 10, 11, 13, 16].
- Natural England's ability to influence this: medium.

Action we could take: **create new/extended nature reserves**.

- Resources: substantial.
- Time: medium term action; medium delay to effect.
- Additional benefits: Carbon sequestration through creation of wetlands, coastal marsh; Flood regulation; regulation of water quality; recreation provision.

Desired change: **reserves are buffered and protected** against detrimental effects arising on land surrounding the reserve.

- Threats addressed: 2, 3, 7, 13, 14.
- Natural England's ability to influence this: low (a large number of other organisations and individuals are involved, and in many cases the levers are not directly in Natural England's hands).

Action we could take: work with partners and local land managers and other businesses, and spatial planners, to **agree and establish appropriate buffer zones around reserves**. Agree and implement water use and other agricultural and industrial controls.

- Resources: major.
- Time: medium term action; short delay to effect.
- Additional benefits: Regulating service: response would help manage water quality, floods and pollution.

Desired change: all National Nature Reserves are appropriately managed, with **climate change explicitly considered in objectives and management actions**, which should be reviewed and revised on a regular basis.

- Threats addressed: 1, 4, 5, 6, 7, 8, 9, 10, 11, 12.
- Natural England's ability to influence this: medium (other bodies managing NNRs would need to be involved).

Action we could take: build **climate change adaptation into NNR management plans** and encourage managers to develop and adapt to new management techniques and invest in new equipment and infrastructure to deliver it. (Peatland NNRs in particular will require a focus on hydrological control through developing new techniques, increasing the extent of sites and creating buffer zones.)

- Resources: minor.
- Time: short term action; rapid effect.
- Additional benefits: Regulating service: response would help manage floods, water quality and wildfires on a small scale. Recreational benefits.

Desired change: wildlife conservation areas in England **fulfil their important potential role in the monitoring of the effects of climate change on the environment**, in the research into management techniques to mitigate and adapt to them, the demonstration of these techniques, and to help communicate the effects of climate change to the public. Reserves should also be used to promote and develop an adaptive management approach, including testing new management approaches.

- Risks addressed: a very large number of risks listed above in both the NNR and Landscape & Biodiversity sections.
- Natural England's ability to influence this: high.

Action we could take: **Increase the use National Nature Reserves for the monitoring, research** and public engagement roles listed above.

- Resources: minor.
- Time: rapid action; short delay to effect.
- Side-benefits: Recreational, cultural and scientific services.

Desired change: wildlife conservation areas in England are used to help **communicate the specific local effects of climate change to the public**.

- Risks addressed: raised awareness for the need to address a range of risks, particularly the indirect 'societal adaptation' risks.
- Natural England's ability to influence this: high.

Action we could take: Maximise the profile of NNRs as areas that **showcase and highlight some of the effects of climate change** and possible responses that can benefit both wildlife and people. Provide additional information to the public.

- Resources: minor.
- Time: rapid action; short delay to effect.
- Additional benefits: recreational, cultural and scientific services.

People and Partnerships and Statutory Access Team

We work with others to increase the opportunities for people to access and engage with the natural environment. This includes inspiring people to value and conserve the natural environment by: increasing the opportunities for new audiences to encounter nature closer to home; promoting projects engaging children and people from areas of multiple deprivation with the natural environment; showing the benefits of people using 'nature's health service' and helping improve the quantity and quality of greenspace.

Our objectives include delivery of statutory access duties to open access land that maximise the amount of land available for public access, ensuring the least restrictive principle underpins all casework, including the restriction regime with respect to open access land; facilitation and advice on new Coastal Access rights and work to extend the National Trail network and development of a new more sustainable management model.

We also influence the planning and design of new national, strategic and local initiatives to support access to and experience of the natural environment for as many and diverse a range of people as possible.

Threats

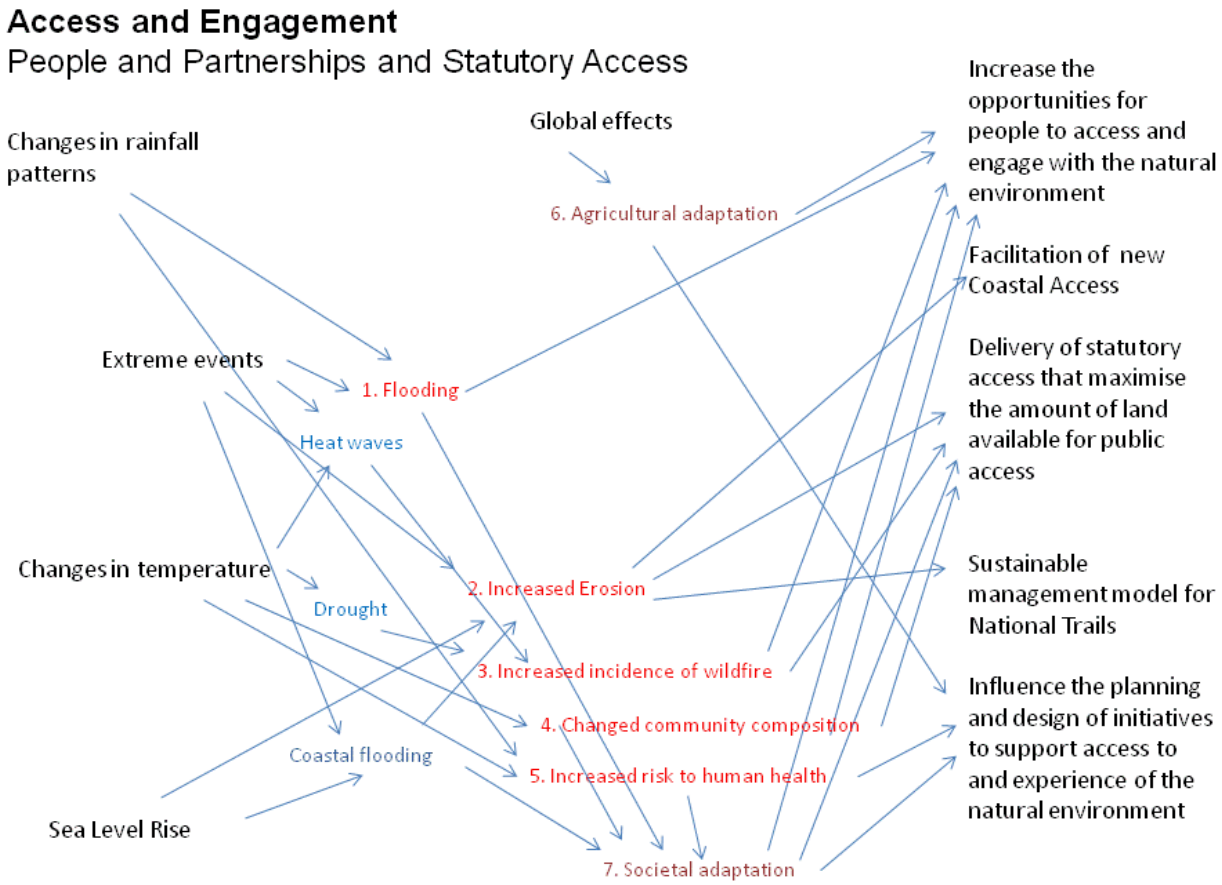

Figure C Threat Analysis - Access and Engagement: People and Partnerships and Statutory Access

Table Q Matrix showing the priority of the different threats to the People and Partnerships and Statutory Access Team objectives, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Severe**					
	Major		2			
	Moderate		1,3	(7)		
	Minor			4,5,(6)		
	Negligible					

(red = high; orange = medium; green = low). Indirect threats are indicated in brackets.

High priority threats

2) Increased Erosion:

- Extreme events and changed rainfall patterns leading to increased erosion of National Trails and NNRs, open access and other access routes (Prosser *et al*. 2010, SNH, 2011).
- Increased numbers of people in some areas as they become more popular due to warmer summers, and/or closure of other sites due to adverse weather and flooding (McEvoy, D et al 2006).
- Storm events in combination with higher tides will re-shape the coast including increasing coastal erosion and changing deposition patterns (MCCIP 2010). Flooding, erosion or managed coastal realignment result in increased maintenance costs of repairs and realignments necessary for affected routes and reduced ability to provide opportunities for people to engage with and value the natural environment if there are insufficient resources to maintain access to an appropriate standard.

Medium priority threats

1) Increase in flooding:

- Localised flooding and associated increases in flood defences could reduce the availability of local greenspace and routes, and negative impact on the coherence of local rights of way networks. More greenspaces and access routes could be unavailable for longer periods of the year, restricting people's access (SNH, 2011, Gill. S, 2007).
- Networks and routes using increasingly flooded areas could be severed, damaged by flooding or less well maintained.
- Increase in area required for floodwater absorption.
- A reduced ability to provide opportunities for people to engage with and value the natural environment. Increased maintenance costs for greenspaces, routes and certain NNRs.
- Increase in visitor numbers and pressures on alternative sites during flood season.

3) Increased incidence of wildfires:

- Drought events increase the risk of wildfire on areas of statutory open access land, resulting in prolonged closure of areas of open country to the public (McMorrow, J et al, 2009). This leads to a reduced ability to provide opportunities for people to engage with and value the natural environment and requires more staff time spent on administering temporary restrictions.

4) Changes to community composition (affecting 'open access' status of land):

- Changes to composition of vegetation (see landscape & biodiversity threat 11) could mean that areas currently classified as open access might no longer meet the criteria, or vice versa. Natural England also has statutory duty to remap areas of open country, and changes to the landscape that were not noted could result in these maps being inaccurate.

5) Increased risk to human health:

- Significant increases in heat related mortality and morbidity (DoH and HPA, 2008), changing biodiversity – impacting on pathecenosis – increasing infectious disease risk. Summer air quality will be degraded by ground level ozone and VOCs aggravating respiratory conditions (DoH and HPA, 2008); extreme rainfall events are likely to increase the chemical and pathogen load of water courses and farmland exposure to pathogens. These risks would be exacerbated by going outdoors and into the natural environment. In these circumstances, people may be discouraged from going outdoors to avoid increased UV exposure, heat effects and diseases.
- Changing patterns of vector borne disease (Kuhn et al. 2005, Costello et al. 2009) which could also discourage people from visiting the natural environment (for example, malaria near wetlands).

6) Agricultural adaptation:

- Changes to agricultural systems and practices as farmers adapt to climate change (Foresight 2010, 2011). Leading to a reduced ability to provide opportunities for Educational Access visits, meaning fewer people are able to engage with and value the natural environment within an agricultural context. A reduced interest from farmers and landowners in providing new permissive or permanent access.

7) Societal Adaptation:

- Changes to climate in different parts of the country result in an increased appeal of certain areas of the country at certain times of the year (Coombes & Jones 2010) (Swanwick, C. 2009), posing a threat of overcrowding, potential disturbance to wildlife (for example, ground nesting birds) and damage to habitats and access routes.
- Hotter, drier summers may put increased pressure on certain areas which are already very popular in the summer (for example, the Cornish coast or the Lake District). Alternatively, the appeal of some currently popular areas may be reduced due to changes in landscape character or weather conditions, putting increasing pressure on other areas around the country which currently have limited access opportunities (Coombes & Jones 2010).
- A reduced ability to inspire people to use and value the natural environment as climate change alters landscape character and therefore what people perceive to be the 'special qualities' of those places, potentially resulting in negative perceptions of the landscape change (Swanwick, C. 2009). People demanding that change is resisted and slowing process of adaptive management.
- There is a risk that our current evidence on patterns of recreation in the natural environment will not 'keep pace' with changes to the environment and how people engage with it.

Opportunities

Table R Matrix showing the different opportunities to the People and Partnerships and Statutory Access Team objectives, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Major**	c	b			
	Moderate		a			
	Minor					

(purple = high; blue = medium; yellow = low). Indirect opportunities are indicated in brackets.

High priority opportunities

a) Opportunities for new recreational land (Medium):

- Increasing areas of land could be allocated for flood attenuation, with greater use of sustainable urban drainage systems (Gill. S et al. 2007). This land could be available for informal greenspace and access so Access to Natural Greenspace Standards (ANGSt) would be more likely to be achieved.

c) Opportunities to provide increased tourism and recreation opportunities (medium):

- Warmer drier summers, and changes to habitats and landscapes will result in an increased appeal of certain areas of the country at certain times of the year (Coombes & Jones 2010) (Swanwick, C. 2009). This will encourage more people to visit and use the outdoors and more people to holiday in England as opposed to abroad providing greater opportunities to increase the number of people inspired to engage with and take action for the natural environment.
- Opportunities to promote health benefits of taking part in outdoor recreation activities. Opportunity (though also a cost) to improve access infrastructure in places more frequently visited as a result of climate change, but wider leisure and tourism economic benefits to the local economy of these more popular locations.

b) Greater awareness of and engagement with the natural environment (low):

- Increasing global and local impacts of climate change could lead to greater recognition of the ability of the natural world to deliver benefits to society could support Govt's and NE's objectives to foster greater engagement with nature, more community involvement and increased use of greenspace with associated human health and wellbeing benefits (Natural England, 2011).
- Increased awareness and interest in the natural environment and in climate change impacts as a local, tangible issue leading to an increased demand and opportunity for community involvement to take action to protect and enhance the natural environment (for example, a likely increase in maintenance requirements of access routes provides engagement opportunities using ‘adopt a path’ type schemes, as recommended by the Humberhead Levels Study).
- Easier to engage people with the natural environment and to take action, easier to recruit volunteers and increased demand for volunteering opportunities, though this would demand more staff time to administer.
- Increasing opportunities to inspire people to use, value and conserve the natural environment by increasing the opportunities for new audiences to encounter nature and support National Nature Reserves, Local Sites, National Trails etc.

Areas of uncertainty

In the past, Natural England has highlighted a lack of data on human responses to climate change, however NE commissioned new ongoing research on attitudes as an addition to the Monitoring Engagement in the Natural Environment research programme (Natural England (2011), MENE, Attitudes to the natural environment 2009-10) which addresses some of the evidence gaps.

The following extracts summarise some of the findings:

'*In general, the English adult population regard the state of the natural environment as being in a fair condition or better, but some believe that it has degraded over the last ten years and most expect it to deteriorate over the next 50 years. However, most people expect changes over this period to be 'slight' and most expect the environmental scenarios to be 'fairly' rather than 'extremely' likely to occur*'.

'*Respondents were presented with a list of issues related to living in England today and then asked to identify their 'single main concern', along with any other issues of concern. In terms of issues related to the natural environment, climate change was selected by 38 per cent of respondents as one of the issues that concerned them. It is notable that this was a significantly higher percentage than obtained for any of the other issues relating to the natural environment. This was similar to the proportion of the population that selected the war in Afghanistan or the economic recession. Eight per cent selected climate change as the single issue of most concern to them*'.

The results also show that, '*levels of concern for a number of environmental issues such as climate change, carbon emissions and extinction of animals and plants was higher amongst those people who had visited the natural environment in the previous seven days*'.

Our ability to address the risks

Levers

Natural England has duties and powers to publish the Countryside Code, propose and consult on National Trails, implement a new coastal walking route around England's coast and to manage any restrictions and carry our periodic reviews of the existing conclusive maps of open country and registered common land.

In most areas of our access and engagement work (other than those where we have specific statutory duties), we are shifting from direct delivery to:

- proposing strategic direction and standards, and co-ordinating and sharing the evidence base (for example, MENE) that underpins them.
- working in partnership with stakeholders at an appropriate scale - usually some form of landscape scale - to support communities and integrate access and engagement with wider environmental, social and economic interests, including the business sector.

Our Strategic Standards will set out the principles of what our role is in engagement and access, and what it means. The gathering, collation and sharing of evidence and the development of proposed standards based on that evidence, will be important parts of our future delivery model. Priorities in this area are likely to include:

- monitoring the state of access facilities (including routes and spaces).
- monitoring their use by people (through a long-term commitment to MENE).
- demonstrating their economic value.
- collating and sharing good practice from around the country.

Production of advice with NE's Land Use Function on the climate change adaptation potential of multi-functional green and blue space is an important lever in promoting and encouraging use of green infrastructure and ecosystems approach to climate change.

The Access and Engagement function also leads for Natural England on the principles of working with local communities and civil society organisations. Providing advice and guidance, standards and good practice on the ways to engage communities, we also facilitate, support and encourage civil society partnerships. We increase opportunities for local community engagement to empower communities to make informed decisions and take practical action to deliver multiple benefits for people and nature.

Barriers

- Staff time and resource, including availability of staff with sufficient knowledge and expertise.
- It may be difficult to get buy in from partners including communities and land owners for measures to combat climate change threats, which many perceive are a long time in the future or not their responsibility.
- The difficulty in predicting attitudes, behaviour and human responses to climate change, either individually or collectively, and the comparative lack of current evidence to help make these predictions.

Our partners and stakeholders

We are working with partners and stakeholders - including NGOs, Defra and other bodies within the Defra network - to help develop a shared strategy and common language for engaging people with the natural environment, based on the concept of benefits to society from ecosystem services.

We work in partnership at an appropriate scale to engage communities and integrate access and engagement with wider environmental, social and economic interests. Natural England is committed to enabling and facilitating communities (of both locality and interest) to identify and meet their own priorities for safeguarding and improving access opportunities and the natural environment in their locality.

Delivery of the actions required to mitigate the threats and opportunities identified requires the coordinated action of Natural England's functions and a wide range of external organisations. Key stakeholders, such as communities, NGOs, farmers and developers also play a significant part in helping Natural England deliver its objectives with the challenges of climate change.

Summary of key responses to priority risks and opportunities

Desired change: operation of the **Coastal Access Scheme** (including identification of route, spreading room, alternative routes and 'roll back') **fully considers possible future sea level rise and coastal change** scenarios and plans for these at early stage in the implementation of each stretch.

- Risks addressed: 1, 2.
- Natural England's ability to influence this: medium.

Action we can take: We should work closely with local and national experts to **plan the delivery of the Coastal Access Scheme with climate change in mind**, and to engage with human communities at the coast to share information on the implications of climate change for their locality. The scheme is already designed to allow 'roll back' due to coastal erosion, but it might be necessary to identify further 'spreading room' if appropriate (for example, if managed realignment of coastlines is required to meet other objectives), or to identify alternative routes at the outset.

- Resources: Moderate.
- Time: short term action; short delay to effect.

Desired change: a system is in place to **restrict access by people, when necessary, to areas at high risk of wildfire**.

- Risks addressed: 3.
- Natural England's ability to influence this: medium.

Action we could take: The increased likelihood of wildfires on areas of open country should continue to be **managed through the restrictions process**, though as this was planned to be activated only in exceptional circumstances, it will need reassessing and the fire restrictions legislation placed on open access land and associated are likely to need to be reviewed. We will need to share our understanding of the effects of climate change with upland land managers, communities and interest groups.

- Resources: Minor.
- Time: short term action; immediate effect.

Desired change: maps of **open access land remain up to date and take into account changes** in vegetation cover as a result of climate change.

- Risks addressed: 4.
- Natural England's ability to influence this: high.

Action we could take: Ensure that any **review of maps of areas of open country takes changes in vegetation into consideration** in the revised methods. A robust evidence base will be needed of the effects of climate change on designated access land, and of the patterns in how people use the natural environment.

- Resources: Moderate.
- Time: short term action; medium delay to effect.

Desired change: An **improved evidence base** containing detailed information from across the country on changes to visitor patterns, number and timing of visits to different sites and areas, and attitudes to the natural environment. Appropriate monitoring mechanisms should also be in place to capture total or seasonal losses or gains in local greenspace, access routes and infrastructure (for example, from flooding).

- Risks addressed: 7, c.
- Natural England's ability to influence this: medium.

Action we could take: **develop and strengthen our collection and analysis of evidence** as above. Work with partners to ensure that we understand changing management costs and the impacts that changing patterns of visits to the natural environment have on local economies that are reliant on particular types of outdoor tourism and leisure. In the longer term, we might need to develop evidence on the real or perceived health barriers to people enjoying the natural environment under the changed conditions that are projected.

- Resources: Moderate.
- Time: medium term action; short delay to effect.

Desired change: Local communities, decision-makers, land managers, and developers have **access to information about the full range of benefits to human health and wellbeing that can be provided by the natural environment and outdoor recreation**; encouraging greater use of 'green infrastructure' and resultant cost-effective benefits to society.

- Risks addressed: a, b, c, 7, [threats in other functions, for example, land use].
- Natural England's ability to influence this: medium (other organisations also have a role in providing and communicating information).

Action we could take: We can work with partners to **develop consistent, locally-specific advice and examples of good practice**, highlighting the benefits of planning for multifunctional green infrastructure and the role of the environment in providing benefits to society.

- Resources: Moderate.
- Time: medium term action; short delay to effect.

Desired change: Increased interest in and appreciation of the natural environment and **awareness of the role nature-based solutions** have in adapting to climate change. Greater number of tangible and accessible opportunities to take action.

- Risks addressed: b.
- Natural England's ability to influence this: high.

Action we could take: provide **increased opportunities for people to experience and engage with the natural environment**, and to make a practical contribution to conservation. This could be done, for example, through providing increased volunteering opportunities and other activities on National Nature Reserves and other areas such as National Trails, Country Parks, Local Nature Reserves and other green spaces. In many cases this would need to be done with partner organisations.

- Resources: Minor (in addition to work in this area that is already being done).
- Time: short term action; short delay to effect.

Land Management

The Land Management function provides the ownership, accountability and expertise within Natural England for the delivery of sustainable land management. This is delivered through the targeted delivery of incentive payments to land managers to secure integrated environmental objectives and the provision of advice, directly and through others, to land managers and other bodies in support of their delivery of integrated environmental objectives.

Functional objectives threatened by climate change include targets for; the uptake of incentive schemes; the area of priority habitat within schemes and the contribution that schemes make to protected site management and to wider environmental benefits to biodiversity, landscape and the historic environment; how schemes are monitored and; ensuring that schemes, and advice work to improve resource protection and water quality.

Threats

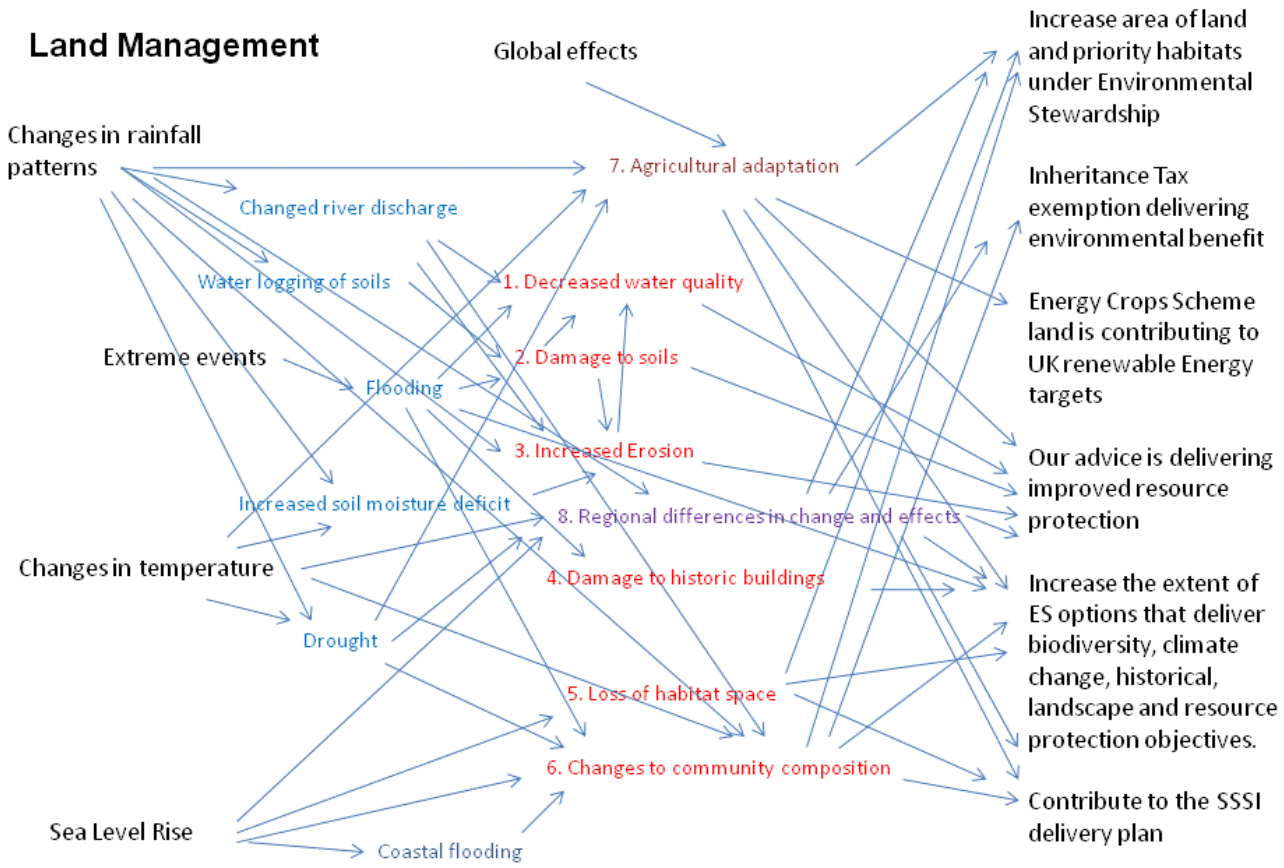

Figure D Threat Analysis - Land Management

Table S Matrix showing the priority of the different threats to Land Management, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Severe**					
	Major		6,(7)	5		
	Moderate	3		8		
	Minor	1,2	4			
	Negligible					

(red = high; orange = medium; green = low). Indirect threats are indicated in brackets.

High priority threats

3) Increased erosion (Medium):

- Increased coastal and riverine erosion (Prosser *et al*. 2010).
- Drier soils at increasing risk of erosion by wind.
- Peat soils vulnerable to increased drying (Bain *et al*. 2011, Fenner & Freeman 2011).
- Increased susceptibility to run-off.

6) Changes to community composition (Medium):

- Seawater intrusion to freshwater coastal priority habitats.
- Incremental change to the presence and abundance of key species in response to changes in temperature and rainfall (Morecroft *et al*. 2009; Bain *et al*. 2011).

Scheme advice and targets become irrelevant and out of date.

7) Agricultural adaptation (High) (Foresight 2010, 2011):

- Changing farming practices in response to climatic changes leading to decreased water water quality (Dunn & Brown 2010).
- Increasing area under production/intensity of production.
- Increased competition on land management - due to loss of productive capacity overseas or lower productivity potential of UK soils.

Scheme uptake, priority habitat, resource protection and wider contribution to environmental outcomes increasingly difficult to meet.

Medium priority threats

1) Decreased water quality (Medium):

- Increased likelihood of erosion and diffuse pollution due to heavy rainfall events, and/or increased soil moisture deficit severe drying, drought (Charlton *et al*. 2010).
- Intensification of agriculture leading to increased diffuse and acute pollution (Jeppesen *et al*. 2009; Dunn & Brown 2010).

Targets for resource protection and water quality increasingly hard to meet.

2) Damage to soils (Medium):

- Increased likelihood of damage to soils and water resources from waterlogging and flooding (DEFRA 2009).

Targets for resource protection increasingly hard to meet.

4) Damage to historic buildings (Medium):

- Historic building guttering and drainage unable to cope with increased rainfall intensity (English Heritage 2008).
- Coastal erosion threatening historic archaeological sites (Murphy, Thackray & Wilson (2009).

Incentive scheme objectives for historic environment increasingly hard to meet.

5) Loss of habitat space (Medium):

- Gradual loss of inter-tidal habitat due to sea level rise and increased incidence of storms (Lee 2001).
- Changed rainfall leading to reduced river flows and saline intrusion on floodplain coastal grazing marsh.

Loss of priority habitat within schemes and increasingly difficult to meet contribution to protected site objectives.

8) Regional differences in change and effects (Medium):

- Differential nature of climatic changes from one area to another, combined with differential vulnerability of environmental assets, means that our identification of priority or target areas may no longer be appropriate.

Opportunities

Table T Matrix showing the different opportunities for Land Management, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Major**	a	(c),(d)			
	Moderate	b				
	Minor					

(purple = high; blue = medium; yellow = low). Indirect opportunities are indicated in brackets.

High priority opportunities

a) Increased water stress (High):

- Increased soil moisture deficit due to increased temperatures and changed rainfall patterns resulting in loss productive capacity provide the opportunity to promote soil management, both as a carbon store and as a farming resource.
- Increased incidence of drought increasing the demand for actions that promote soil moisture retention and water storage.

b) Changes to community composition (Medium):

- Increased sea-level rise driven coastal flooding and/or saline intrusion resulting in changes to coastal habitats could provide increased opportunities to create new inter-tidal areas.

c) Alignment with mitigation (medium):

- Increased focus on protecting (Fenner & Freeman 2011) and restoring peat leading to an increased interest in the use of HLS to restore peat soils (Alonso, Weston & Gregg 2011).
- Increased focus on tree planting leading to an increased interest in use of HLS tree planting/woodland creation options (Nisbet *et al*. 2011).
- Increased demand for wood as fuel leading to a greater interest in woodland management resulting the restoration of derelict woodland (Forestry Commission 2011).
- Increased demand for biomass energy crops such as Miscanthus, short rotation coppice (SRC) SRC resulting in greater uptake of the Energy Crops Scheme.
- Increased awareness and market driven interest in mitigation through land management, leading to the need for appropriate advice for land managers on reducing emissions. Provides the opportunity to integrate mitigation advice with existing advice programmes.

d) Agricultural adaptation (High):

- Increased incidence and severity of climate change impacts resulting in greater interest in adaptation of land management, which in turn generates greater interest in use of ES to address climate change mitigation and adaptation.
- Opportunities to promote adaptation solutions that can benefit both farming and wildlife, such as planting of trees and use of temporary water bodies.

Areas of uncertainty

Areas of uncertainty in which further research and analysis are needed include:

- Uncertainties about the impact of climate change on habitats and species mean that we cannot be sure our land management programmes will provide the conditions required to support effective adaptation.
- Whilst increasing temperatures and atmospheric CO_2 concentrations may increase plant growth (both crops and wild plants), lower levels of soil water availability may limit plant growth (Met Office 2011). We shall need to understand these changes and their impact on land management to ensure that our programmes remain relevant to changing conditions and to ensure that we can continue to provide a valuable advice service to land managers.
- Existing evidence identifies how the agri-environment programmes reduce greenhouse gas emissions (Defra, 2008, Warner 2011). However, this can sometimes be associated with a loss of agricultural production (for instance where land is reverted from arable production to low input grassland). As the Foresight Report (2011) shows, food production will need to increase to feed a growing population, and this may be exacerbated if climate change makes farming more difficult in other countries from which we currently import food products. We shall need to better understand the impact of agri-environment management on production whilst developing support for protection of environmental features that underpin successful agricultural production.
- We cannot be certain now how individuals and societies will respond to future climate change and how this will impact on land management. Developments in agricultural policy and practice, forestry and energy production, both in the UK and overseas will all impact on the pressures affecting environmental land management in England.
- Peatland restoration by re-wetting drained soils protects carbon stored in the peat soil and helps provide the conditions for further carbon sequestration. However, it also leads, in the short term at least, to an increase in methane production. Whilst the evidence to date

suggests that the overall impact is in favour of peatland restoration, there are uncertainties about the significance of the methane issue. (Lindsay, 2010).

Our ability to adapt/mitigate the threats

Levers

- Our incentives programmes provide an opportunity to influence the actions of land managers over a wide area. Environmental Stewardship agreements currently cover nearly 70% of utilisable agricultural area in England. Higher Level Stewardship agreements provide scope for encouraging actions to help priority habitats adapt.
- Advice programmes such as Catchment Sensitive Farming encourage good management of soil and water resources.
- Our delivery of the Energy Crops Scheme includes an assessment of the environmental impact of energy crop production in any given location. This enables us to consider climate change adaptation when assessing these mitigation initiatives.

Barriers

- Our Environmental Land Management programmes, such as ES, are voluntary schemes: land managers are under no obligation to participate and, in the case of Entry Level Stewardship and Organic ELS, farmers are free to select the land management options to implement on their farms. This limits our ability to influence land management actions on the ground.
- Environmental Stewardship agreements operate in the short to medium term (5 years (Entry Level Stewardship) or 10 years (Higher Level Stewardship)). This is particularly significant when considering management for long term carbon sequestration or long term adaptation.
- The uncertainties in the evidence base (for example, in how species and habitats will respond to the interactions between different climatic changes), are complicating factors, but we shall need to manage this uncertainty in the development of future land management programmes.
- The first opportunity for significant changes to the agri-environment programmes is presented by the forthcoming CAP reform, but this will be subject to many drivers, of which our intention to address climate change is just one. The current economic climate makes it very unlikely that there will be increasing amounts of funding available to implement land management adaptations, yet our ES budgets are already under significant demand to address our existing environmental priorities for biodiversity, resource protection, access, landscape and the historic environment. We shall work constructively with Defra, partners and stakeholders, to make the case for land management programmes, increasingly focused on climate change adaptation and mitigation and sufficiently responsive to adapt as our understanding of the interplay between climatic changes, natural environment and land management increases.

Our partners and stakeholders

As the main lever of the function is our incentive schemes the success of our work to address climate change will depend on working with others.

As well as land managers who ultimately make the decision to join or not to join the schemes we will work with our Arms Length Body (ALB) partners, the Environment Agency (EA) and the Forestry Commission (FC) to ensure comprehensive and joined up advice on schemes and regulation. We will also work in close partnership with farming and land manager bodies such as the National Farmers Union and Country Land & Business Association to ensure the relevance of our advice to farmers and land managers. We shall also work with non-governmental organisations such as The Farming and Wildlife Advisory Group and the Wildlife Trusts to ensure that climate change adaptation measures for the natural environment are clearly understood and articulated.

In addition we will work with Defra to ensure that the schemes remain relevant and able to deliver the flexibility needed to help land owners and the natural environment adapt to climate change.

Summary of key responses to priority risks and opportunities

Desired change: **Restoration and conservation of upland and lowland peatlands**.

- Risks addressed: 2, 3, c, [L&B: 3, 4, 15, 16, 19, f].
- Natural England's ability to influence this: medium (through agri-environment schemes and working with National Parks and AONBs).

Action we could take: continue to use agri-environment programmes to **support peatland restoration**. At the same time, to protect peat soils as long term carbon stores we shall need to consider longer term management arrangements than the 10 year duration of Higher Level Scheme Environmental Stewardship agreements.

- Resources: Substantial.
- Time: short term action; medium delay to effect.
- Additional benefits: mitigation through carbon storage and sequestration; water purification and supply; flood alleviation in lowland areas; landscape.

Desired change on ground: Habitat creation and restoration to **enhance ecological networks and buffer high value sites**, to promote the movement of more mobile species, encouraging colonisation of new sites and reducing the risks associated with small isolated populations, while being aware of the risks posed by invasive non-native species.

- Risks addressed: 1, 7, 8, 10, 13, a, b [L&B: 7, 8, 10, 11, 12, 13],[A&E-NNR: 8, 9, 10, 11].
- Natural England's ability to influence this: high.

Action we could take: Targeting of Environmental Stewardship options that **secure appropriate management adjacent to priority sites**.

- Resources: Substantial.
- Time: medium term action, medium term delay to impact.
- Additional benefits: mitigation through carbon storage, improved landscape character.

Action we could take: Targeting of Environmental Stewardship options to **enhance ecological networks through habitat creation and restoration** in appropriate locations.

- Resources: Substantial.
- Time: medium term action, medium term delay to impact.
- Additional benefits:mitigation through carbon storage.

Desired change: protection **of soils from drying, wind erosion and loss of carbon** during projected dry conditions, and from water erosion during wet conditions. Appropriate management of water resources to avoid over-use during drought and runoff and diffuse pollution from agriculture during heavy rainfall.

- Risks addressed: 1, 2, 3, 7, 8, c, d, [L&B: 1, 3, 4, 15, 20], [Marine: 8].
- Natural England's ability to influence this: medium.

Action we could take: we need to **develop advice and incentives focused on the ecosystem services** provided by the natural environment and hence promote land management that supports both the natural environment and the environmental resources that underpin agricultural

production. For water, management and coordination will be needed across catchments, involving multiple land managers. We shall promote the value of agri-environment measures to support soil and water protection and management of ecosystem services in our advice to Defra on the development of future land management programmes.

- Resources: Moderate.
- Time: short term action; short delay to effect.
- Additional benefits: mitigation through maintenance of soil carbon; Reduced green house gas emissions from land under scheme options; improved water supply and quality.

Desired change: land management programmes such as **incentive schemes remain appropriate and relevant to local conditions**, and are informed by an understanding of both changes in the natural environment and likely agricultural responses.

- Risks addressed: 6, 7, 8, c, d, [L&B: 1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 20, a, b, d, f, g].
- Natural England's ability to influence this: high.

Action we could take: We shall ensure that future reviews of our land management **programmes are informed by an understanding of environmental change** and agricultural responses. As part of this, we need to improve our knowledge and understanding of the varying vulnerabilities of different areas and natural resources to climate change, and different pressures and opportunities that are present in different places, to ensure that we can focus our interventions most effectively.

- Resources: Minor.
- Time: short term action; rapid effect.
- Additional benefits: Reduced green house gas emissions from land under scheme options.

Action we could take: We will need to work with others to understand **farmers' information and support needs as they seek to adapt their businesses** to changing climatic conditions.

- Resources: Minor.
- Time: short term action; short delay for effect.
- Additional benefits: Greater uptake of appropriate scheme options; reduced green house gas emissions; mitigation through increases in soil carbon.

Desired change: Flood risk management **actions taken across catchments where flood risk is anticipated to increase**, including using soils and river floodplains to store floodwater and increase infiltration into groundwater.

- Risks addressed: 1, 2, 4, 7, a, d, [L&B: 1, 3, 4, 5, 16, 20, d, e],[Marine: 8].
- Natural England's ability to influence this: low.

Action we could take: We can increase the use of agri-environment targeting in **promoting coordinated action across vulnerable catchments and coastal zones**.

- Resources: Substantial.
- Time: short term action; medium delay to effect.

Desired change: **increased woodland and tree cover** in agricultural areas, in order to protect and expand woodland ecosystems and species they support and as a means for protecting soils and water in targeted locations.

- Risks addressed: 1, 2, 3, c, d [L&B:1, 2, 3, 4, 7, 9, 10, 12, 19, f].
- Natural England's ability to influence this: low (Forestry Commission has the major responsibility; also need to work with land managers and Defra).

Action we could take: Promote use of Environmental Stewardship **woodland creation and tree planting options**.

- Resources: Minor.
- Time: short term action; medium delay to effect.
- Additional benefits: mitigation through sequestration and storage of carbon in soils and vegetation and substitution of timber for GHG-intensive building materials or fossil fuels; water quality; alleviation of erosion and flooding.

Action we could take: Consider **alignment and integration of Environmental Stewardship and England Woodland Grant Scheme** in future Rural Development Programme for England. We need to ensure that our land management programmes contribute to wider initiatives such as those led by the Forestry Commission, to help implement these responses and hence to address threats to woodland habitats and to soil protection.

- Resources: Substantial.
- Time: short term action; medium delay to effect.
- Additional benefits: mitigation through sequestration and storage of carbon in soils and vegetation and substitution of timber for GHG-intensive building materials or fossil fuels; water quality; alleviation of erosion and flooding.

Land Use

The Land Use Function leads on the delivery of Natural England's work with the planning system.

We advise on the sustainable use of land and water to support communities and local government in their planning decisions to protect and enhance local environments. We also aim to secure new priority habitat and green infrastructure which deliver ecosystem services for both people and wildlife.

Threats

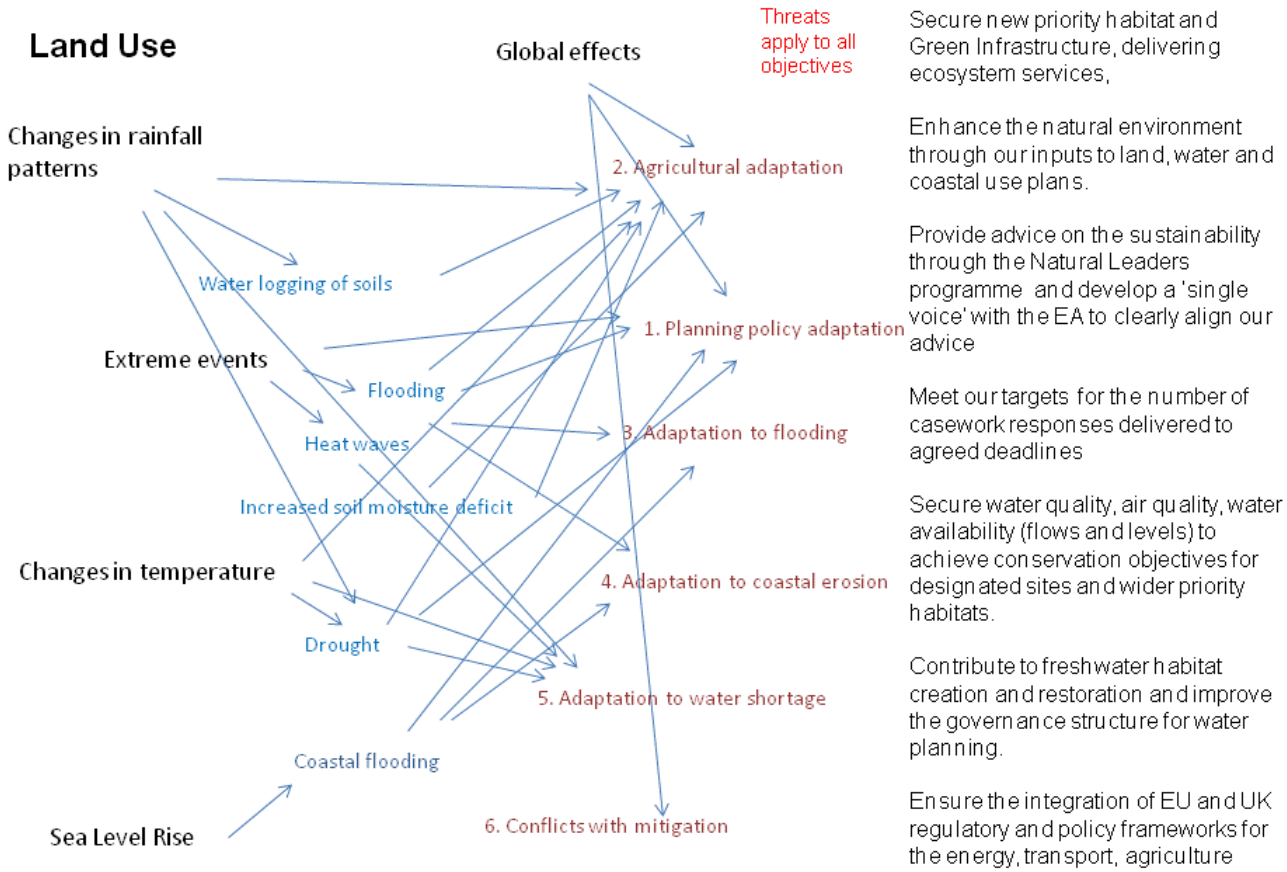

Figure E Threat Analysis - Land Use

Table U Matrix showing the priority of the different threats to Land Use, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Severe**					
	Major	(3),(6)	(2),(4),(5)			
	Moderate					
	Minor	(1)				
	Negligible					

(red = high; orange = medium; green = low). Indirect threats are indicated in brackets.

High priority threats

2) Agricultural adaptation (Medium):

- Land use change in response to climate-related issues, food security concerns, increased water supply from reservoirs and expanding markets for biofuels) (Foresight 2010, 2011).
- Changes to cropping patterns requiring increased abstraction (Environment Agency 2010, 2011).
- The potential for 'pollution swapping' (Stevens & Quinton 2008) in agricultural practices lead to air pollution effects on designated sites and BAP habitats.
- Unsustainable use of land (incl soil) and water lead to adverse effects on designated sites and BAP habitats.
- Reduced ability to successfully influence land and water use plans to achieve SSSI objectives, secure BAP habitat creation, benefits for BAP species, green infrastructure, new access, soil protection and landscape character benefits.

3) Adaptation to flooding (High):

- Greater demand for hard engineered solutions to flooding (Harries & Penning-Rowsell, 2011).
- Increasing number of applications with environmentally unsustainable climate change measures, such as major 'hard' flood defence schemes in response to riverine and coastal flooding and erosion.
- Demand for bigger engineered solutions in response to greater risk of coastal and flooding.

4) Adaptation to coastal erosion (High):

- On coastal soft cliffs, more demand for coast protection due to greater risk of coastal flooding landslips. Engineered solutions given more prominence, potential loss of sediment sources, decline in relations with LAs/communities threatened by change (Hosking & McInnes 2002).
- Hard defences seen as solution rather than working with natural coastal processes and making use of risk reduction from sedimentary systems. NE has less influence on securing sustainable coastal/estuary form (Foresight 2004, DCLG 2010).
- Coastal changes resisted at all levels of society, from individual to political, poor understanding of benefits of enabling change to build resilience. Limited adaptation responses available, Shoreline Management Plan policies disregarded (Jones 2011).

5) Adaptation to water shortage (Medium):

- Unsustainable abstraction of water in water-stressed areas as a result of summer drought, particularly in those areas such as the south east where water resources are already limited (Defra 2011).

6) Conflicts with mitigation (High):

- Impacts of some renewable energy initiatives on natural systems and biodiversity, for example, tidal barrages, wind turbines on peat or hydro-electric dams (Drewitt & Langston 2006).
- An increase in climate and energy-related casework overwhelming our capacity to provide specific advice on each case.
- Increasing applications for wind/hydro/biomass plants.
- Local Authorities focus solely on climate mitigation and management of climate hazards, to the detriment of other environmental concerns.
- Drive to reduce carbon reduces our opportunities to influence development design. Policies/schemes implemented that that tackle climate change but damage air quality (and

vice versa), for example, gas fired combined heat and power plants and biomass plants in the wrong places/large scale uptake (reduced CO_2 emissions but increased NOx and particulate emissions) lead to air pollution effects on designated sites and BAP habitats.

Medium priority threats

1) Planning policy responses (Medium):

- Changes in forward planning practice which prioritise certain geographical areas for development, for example a focus on areas of low flood risk. This constrains our ability to deliver environmental benefits to more limited geographical areas.
- Short-term solutions to immediate and locally specific land use issues.
- Multiple pressures of climate change lead to separate policy frameworks for environmental impacts leading to trade-offs. Conflicting policies reduce our ability to provide holistic and integrated responses at the individual scheme/plan level.
- Change in focus of planning system to prioritise climate change without a consistent approach to climate change adaptation and mitigation. Natural England loses influence with Spatial Planners. Risk of disassociation between climate change and eco-system services. Reduced ability to meet objectives to encourage use that protects and enhances the value of the natural environment in a strategic way.

Opportunities

Table V Matrix showing the different opportunities for Sustainable Land Use, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Major**	(a),(b)				
	Moderate					
	Minor					

(purple = high; blue = medium; yellow = low). Indirect opportunities are indicated in brackets.

High priority opportunities

a) Societal adaptation - opportunities for more 'green infrastructure' (High):

- Increased incidence and severity of climate change impacts, locally and globally leading to:
  - Greater recognition that by enhancing natural features such as wetlands and more generally soils, water resource adaptation can be improved in terms of quantity and quality, including defence from damaging flooding and reduced low water flows in rivers (Gill *et al*. 2007, Natural England 2009a).
  - Increasing focus on natural solutions and eco-system services to deliver socio-economic benefits. Greater focus on ecosystem service delivery should also provide a more holistic and joined up approach rather than the environment being treated as a series of separate silos (Natural England 2009a).
  - The incorporation of natural features of adaptive value into new built development, including built structures themselves (for example, urban green spaces and green roofs which reduce flood risk, and wooded areas which provide local direct cooling) (Natural England 2009b). Development which is adapted or resilient to climate change from the start - fewer implications for natural resources, for example, water.
  - NE engaging with more applications and casework with a climate change offers opportunities for better habitat networks and to link new habitat creation schemes with those for statutory habitat replacement in response to coastal sea level rise.

- Innovative community-led development responding to local climate change impacts facilitated through the planning system reforms.

- Climate change creates a strong impetus for the delivery of multi-functional green infrastructure (Natural England 2009b) to counter:
  - the effects of flooding, for example, providing multi-functional flood storage areas, green spaces that slow the flow of flood waters.
  - the effects of heat waves and heat island impacts, for example, shade and cooling provided by green spaces and green travel corridors (Gill *et al*. 2007).
  - the effects of drought, for example, retaining water in wetlands and drought tolerant planting and management practices.

- Better adapted and resilient Green Infrastructure providing ecosystem services (Natural England 2009b).
- Increased opportunities to engage with local planning authorities and developers to advise on the design of proposed development at an earlier stage, resulting in a better set of economic, social and environmental outcomes.
- Increasing focus on multi-modal transport solutions that incorporate climate change adaptation into local transport plans by, for example, including natural shading by vegetation and sustainable drainage, as well as increased use of cycling and walking routes (for example, Tameside Metropolitan Borough 2010).

b) Alignment with Mitigation (Low):

- Increase in the number of, and size of renewable energy generation projects providing opportunities to influence design and location through engagement with industry.
- Concerns about action on climate change mitigation combined with food, biofuel and water security and focuses attention on soils as a component of the natural environment leading to greater focus on soil in the planning process.

Areas of uncertainty

Due to the nature of the indirect threats and opportunities identified in the land use climate change risk assessment, ie they are behavioural and policy responses, there are areas of uncertainty beyond those associated with the uncertainty associated with the climate change projections. These include the following:

- Assumed changes in the focus of the planning system on climate change either in geographical location or increased focus on mitigation measures have low confidence levels due to a lack of current evidence that Local Authorities are becoming overly focused on climate change and is also strongly reliant on local forward planning decisions. Therefore implications likely to be highly variable depending on risk and location.
- There is uncertainty about the policy context, resource issues and infrastructure regarding the future changes in agricultural and energy practices that would affect sustainable land use. These are particularly around water supply and cropping capability.
- The expected increase in the number of applications with environmentally unsustainable climate change measures are likely to range from very small-scale and local, to large-scale and significant, so there are uncertainties about the locations and scale of these applications.
- The opportunities highlighted on the potential increase in innovative and environmentally beneficial development depends hugely on uptake of community-led development proposals.

There are a number of areas where further work could increase our understanding of the dynamics between indirect climate change impacts and sustainable land use. These include:

- Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment.
- Development of better assessments of medium to long term climate change impacts on ecosystem function (for example soil functions and effects of CO_2).
- Although pollution swapping is widely understood it has received relatively little research attention and receives little consideration in agri-environmental policy.
- The planning system in England is undergoing a major re-structuring with the proposed National Planning Policy Framework and supporting legislation with its emphasis on local plans, which is not due to be presented to Parliament until December 2011. Until the proposals and any supporting guidance have been published, it is uncertain how this might impact on Natural England's role in the planning system. Guidelines to assist what is a step-change in the way planning works in England will be needed and Natural England should be proactive in seeking to influence such guidance which is likely to be produced by others.

Our ability to address the risks

Below are some levers for and barriers to our ability to deliver the suggested on the ground responses listed above to the threats and opportunities highlighted by the land use climate change risk assessment.

Levers

- Natural England is a statutory consultee in the spatial planning process. Natural England's views carry significant weight if presented appropriately. The use of advice and guidance around climate change adaptation is likely to be high, so it will be important that this contains the latest thinking on climate change adaptation.
- Production of climate change training products for local planning authorities and developers on climate change adaptation and the role of multi-functional green and blue space is an important lever in promoting and encouraging use of green infrastructure and ecosystems approach to climate change.
- The Natural Leaders programme and partnerships Natural England continue to be part of, such as coastal groups, provide significant communication opportunities with our partners.

Barriers

- The uncertainty on the new planning system and Natural England's role within it needs to be clarified, before we can seek to identify how best to engage with customers of the system. This is also limiting our ability to develop joint approaches with other agencies including the Environment Agency and Forestry Commission.
- Commenting on large scale proposals and providing greater levels of up-front advice, particularly at the coast requires a range of expertise and skills, which may cause resource implications for Natural England. Better skilled, more efficient and confident advisers will to some extent reduce these pressures.
- The perceived cost of multi-functional green space as a climate change adaptation tool by some developers can be a major barrier to the enhancement of some schemes. Better communication of the existing evidence of the benefits of green infrastructure supported by case studies is an important tool to overcome these concerns.

Our partners and stakeholders

The delivery of sustainable land use actions to address climate change adaptation will require close working with our partners in order to maximise benefits and ensure success.

Local Authorities will be key partners for Natural England in delivering climate change adaptation through the planning system and the delivery of green and blue infrastructure that provides vital ecosystem services to society. Our Natural Leaders programme will ensure a joined up and comprehensive approach to partnership working with Local Authorities.

We will work closely with our Arms Length Body (ALB) partners, the Environment Agency (EA) and the Forestry Commission (FC) and to ensure comprehensive and joined up advice on planning issues and regulation, especially around spatial planning and water and coastal issues. Our 'Single Voice' approach will provide greater clarity on ALB responses on land use planning to Local Authorities.

We will also work in close partnership with Protected Landscapes and NGOs on sustainable land use climate change adaptation issues to ensure that climate change adaptation measures for the natural environment are clearly understood and articulated.

In addition we will work with Defra to ensure our work on climate change adaptation remains relevant and able to deliver the flexibility needed to help the natural environment adapt to climate change. This is particularly important at the coast.

Summary of key responses to priority risks and opportunities

Desired change: Land use planners and developers, and local communities, have information - based on the **best available evidence - on how to create 'green infrastructure' most effectively in different places and situations** that can contribute both to ecological networks and the conservation of biodiversity and ecosystems, and to increasing human health, prosperity and well-being, including providing adaptation benefits to human society and helping to mitigate climate change.

- Risks addressed: 3, 4, 5, a, b.
- Natural England's ability to influence this: medium-high.
- Additional benefits:
  - Well designed green infrastructure can deliver multiple benefits including direct climate regulation, flood risk reduction and a greater opportunity for wildlife to respond to climate change, but also recreational access and enjoyment of nature near to home, reducing the use of carbon-based transport.
  - Creation and restoration of a wide range of habitat types which enhance adaptation also can store carbon and/or emit fewer greenhouse gases.

Action we could take: Develop a **strong evidence base and use it to develop advice and best-practice examples** for the public and industry. This advice should be tailored as far as possible to local circumstances.

- Resources: Moderate.
- Time: rapid action; rapid effect.

Action we could take: **Include climate change as part of the training and resources for our advisers**, to help them identify opportunities for action that would have adaptation benefits.

- Resources: Moderate.
- Time: rapid action; immediate effect.

Action we could take: **Build effective partnerships** with industry through a shared understanding of the way in which the natural environment underpins our economy. Some sectors will be particularly important to work with. An example is our already increasing work with the water industry to secure water supplies that are of a higher quality and quantity.

- Resources: Substantial.
- Time: short term action; medium delay to effect.
- Additional benefits: Renewable energy applications directed to the most environmentally appropriate areas.

Action we could take: Produce **training materials for planners on climate change** adaptation and eco-system services benefits. This could be done in collaboration with the Royal Town Planning Institute.

- Resources: Moderate.
- Time: rapid action; immediate effect.

Desired change: **Local Planning Authorities recognise the role that the environment contributes to their social and economic aspirations** and take this into consideration in decisions.

- Risks addressed: all.
- Natural England's ability to influence this: medium.

Action we could take: as a statutory consultee we have a role in commenting on spatial plans, and can provide information on ecosystem -based solutions to climate change adaptation (for example, rethinking the role of floodplains and coastal change) in planning policies, to **ensure Local Planning Authorities take a sustainable view of climate change adaptation**.

- Resources: Minor.
- Time: rapid action; immediate effect.

Marine

Natural England's marine function works to ensure that our marine and coastal environment is better understood, valued and protected. We are responsible for advising Government and industry on marine conservation and seascape issues in England's territorial waters.

To achieve these goals the function has specific objectives covering; the substantial completion of the designation of a Marine Protected Area (MPA) network in English territorial waters and the delivery of conservation advice to enable relevant authorities to implement MPA management measures; the delivery of an integrated monitoring programme and plans are in place for baseline monitoring of Marine Conservation Zones (MCZ).

The function aims to work with the fishing industry and fisheries managers in an open and positive manner to protect and enhance the marine environment in English waters to promote sustainable use and management of the marine environment through engagement with government, industries, stakeholders and partners.

Threats

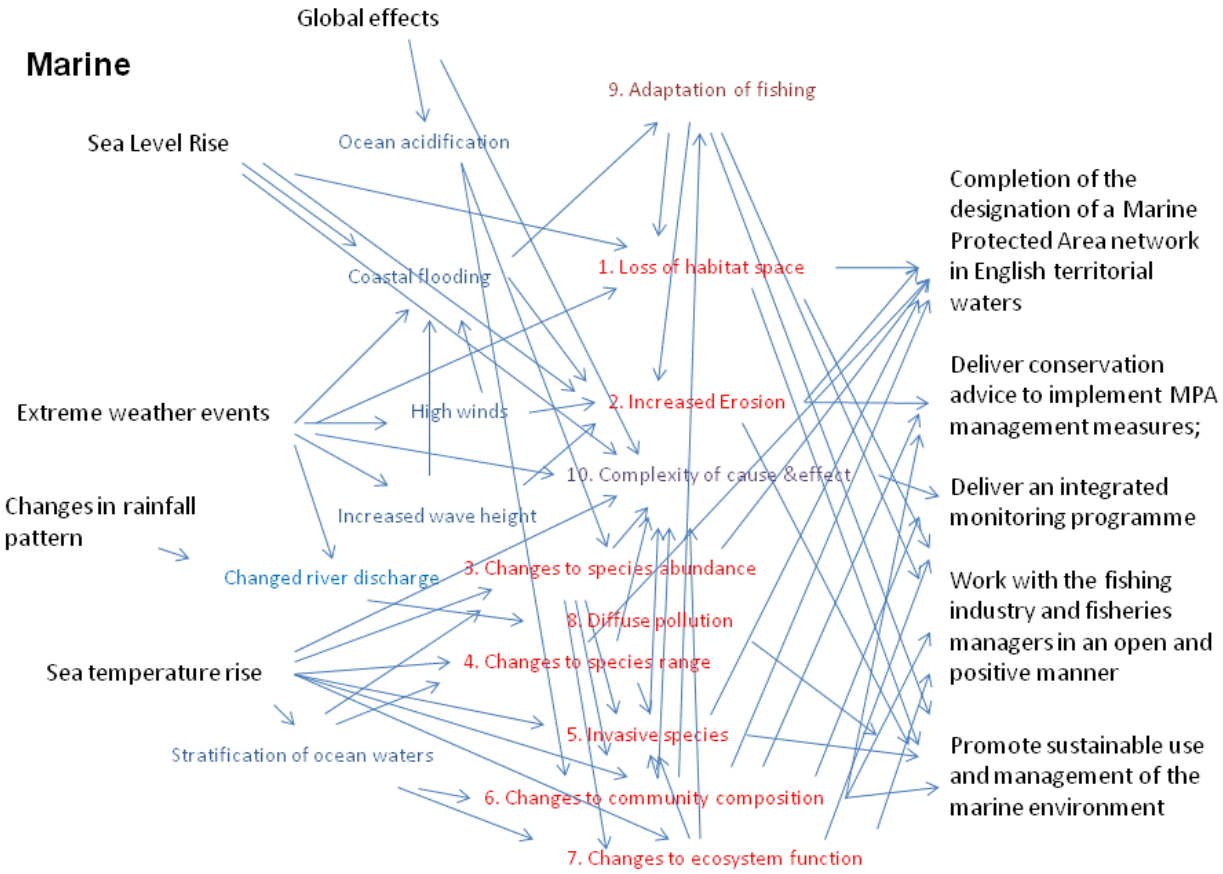

Figure F Threat Analysis - Marine

Table W Matrix showing the priority of the different threats to Marine objectives, according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Severe**					
	Major		1,2,(9)	3,4,8	6	
	Moderate		5,7			
	Minor		10			
	Negligible					

(red = high; orange = medium; green = low). Indirect threats are indicated in brackets.

High priority threats

1) Loss of habitat space (Low):

- Loss and damage of coastal habitats and species (Lee 2001) and change of remaining habitat and species in location.
- Changes in type and quality of coastal habitat, damage to near shore habitats and steepening of the intertidal beach profiles. This has the potential to put pressure on some coastal wetland/terrestrial habitats that act as valuable carbon sinks (Foresight 2004).
- Northward shift of the southern limit of species ranges (Tasker *et al*. 2008).

2) Increased erosion (High):

- An increase in coastal erosion, particularly on shorelines with hard defences which are less able to respond to rising sea levels, resulting in changes in coastal habitat type and quality, damage to near shore habitats and steepening of the intertidal beach profiles (Foresight 2004, MCCIP 2010; Prosser *et al*. 2010).
- An increase in storm events, resulting in damage to habitats due to erosion and loss.
- Increased erosion of saltmarsh, especially on shorelines with hard defences, likely to lead to increased sedimentation around ports, with implications for dredging and navigation channels. Indirect effects will include changes relating to offshore renewable such as growth in wave/tidal power generation; windfarms in deeper water; greater overall sea area footprint; more cabling and more and different infrastructure. Implications and consequential management requirements of each of these changes will need to be assessed individually and in combination.

9) Adaptation by the fishing industry and coastal communities (High):

- Climate induced changes to population sizes and ranges of fish stocks altering the location of fishing activities and therefore the interaction with the natural environment.
- Flood defence implications for key urban areas likely to include demand for offshore submerged breakwaters.

Medium priority threats

3) Changes to species range (Low):

- Progressive warming of the seas, resulting in changes to designated features including changes to species extent and range (Perry *et al*. 2005, Edwards *et al*. 2008; Perry 2010).

- Deepening of species assemblages range in response to warming seas (Dulvy *et al*. 2008, MCCIP 2010) meaning they now reside outside protected areas (van Keeken *et al*. 2007).

4) Changes to species abundance (Low):

- Progressive warming of the seas, resulting in changes to designated features including changes to habitats and species extent, ranges and population densities (Perry *et al*. 2005)
- Increased abundance of fishes as the northern parts of their range, and reductions at the southern margins (Tasker *et al*. 2008).
- An increase in stress on species with calcium carbonate shells and internal skeletons which are susceptible to acidification of seawater, which is occurring as a result of rising atmospheric levels of carbon dioxide leading to a decline in populations. (Ocean Acidification Reference User Group (2009, 2010).

5) Increased prevalence of invasive species (High):

- Warmer seas may also mean it is easier for invasive non-native species to become established, potentially having a deleterious impact on designated sites (Ruiz *et al*. 1997; 2000).

6) Changes to community composition (Low):

- Invasions of non-native species into new range areas.
- An increase in stress on species with calcium carbonate shells and internal skeletons which are susceptible to acidification of seawater, with a possible long-term impact on the well-being of species groups and composition of habitats (Ocean Acidification Reference User Group (2009, 2010).

7) Changes to ecosystem function (Medium):

- Seasonal shifts in primary and secondary productivity, leading to a loss of synchrony between predator/prey species (Thackeray *et al*. 2010).
- Invasions of non-native species into new range areas (Ruiz *et al*. 1997; 2000).
- Temperature stratification of coastal waters, resulting in longer seasonal stratification and reduced vertical water mixing. This may lead to harmful algal blooms that have been associated with fish kills and benthic (organisms living on the sea bed) mortality (MCCIP 2010).

8) Diffuse pollution (Low):

- Possibility for increased run off of agricultural land (Whitehead *et al*. 2009) and sewage into estuaries causing physical-chemical properties change. This causes eutrophication that alters the ecosystem within the estuary, its habitats and species. Leads to a reduced ability to maintain Marine Protected Area (MPA) objectives and threatens the sustainability of the system.
- Periods of drought followed by heavy rain events may cause the instability of vegetation around coasts and may cause instability of habitats such as cliffs and sand dunes. Drought can also cause contamination issues due to lack of mixing within estuaries.

10) Increased complexity of causal relationships (High):

- Increased challenge of distinguishing cause and effect given additional variables as consequence of climate change will drive a requirement to ensure that monitoring programmes include suitable indicator species & habitats.

Opportunities

Table X Matrix showing the different opportunities for Marine objectives according to their importance and proximity

		Proximity				
		Now	**Short**	**Medium**	**Long**	**Very Long**
Importance	**Major**			a		
	Moderate			b		
	Minor				(c)	

(purple = high; blue = medium; yellow = low). Indirect opportunities are indicated in brackets.

High priority opportunities

a) Coastal changes (Medium):

- Sea level rise causing increased coastal squeeze of protected intertidal habitats leading to an increased requirement for habitat compensation (Foresight 2004). This could result in more widespread managed realignment, linked in with more sustainable shoreline management practices that recognise and promote the ecosystem service of intertidal habitats in flood risk management.

Medium priority opportunities

b) Shifts in species range (Low):

- An increase in warm water species of interest either ecologically and/or economically in the southern waters off England, as a result of changes to species ranges with progressive warming of the seas. There is an additional possibility of more viable fisheries for some species extending into the southern North Sea, with range extensions already of 50 – 400km. Changes provide the opportunity to encourage responsible fishing practises in emerging fisheries which reduce impact on species and habitats of conservation interest.

c) Alignment with mitigation (Low):

- Possible opportunities to protect valuable 'carbon sink' areas (for example, Seagrass).

Areas of uncertainty

There are large data gaps on many aspects of the effects of climate change on the marine environment; these include:

- Understanding the implications of increased ocean acidification. It is recognised that a tipping point is reached when ocean waters change from over saturated with calcium carbonate to under-saturated. The speed of ocean acidification varies across the globe, and it is anticipated that parts of the Arctic will reach tipping point by 2018. Areas of uncertainty around acidification include a better understanding of the role of upwelling events when deeper ocean waters circulate on to continental shelves or near shore areas.
- The extent and timescale of projected sea level rise on the UK related to a better understanding of the rate and role of sea ice melt.
- Changes in salinity levels and the relationship to climate change; salinity levels in both the North Sea and North Atlantic have fluctuated in recent decades, and it is not yet understood whether there is a relationship to wider circulation patterns within the ocean, or changes in evaporation and precipitation.

- Better understanding of the role of the Atlantic Heat Conveyor which keeps the North Atlantic warmer than other oceans at similar latitudes is required and in particular how this may be impacted by global warming with increased rainfall, melting of sea ice, glaciers and the Greenland ice sheet reducing North Atlantic surface salinity which may to slow down or even stop the formation of deep water affecting thermohaline circulation.
- Understanding the impacts of climate change on inter-tidal habitats including sea-grass beds, mud flats and other soft sediment communities.
- Gaps in research to understand options for management of invasive species and possible effects on biodiversity.

Our ability to respond to the risks

A significant amount of our work on addressing climate change threats to the marine environment will need to be undertaken through close partnership working. We have a key role in providing advice to government and local authorities, and in our ongoing role in monitoring marine protection areas and other designated sites.

Levers

- Natural England together with JNCC has a statutory role to advise Defra on possible locations for Marine Conservation Zones and European Marine Sites - Special Areas of Conservation and Special Protection Areas.
- Natural England has a (non-statutory) remit to report on condition of SSSIs, MCZs and feed into FCS reporting to the EC. Natural England is involved in monitoring the MPAs and is engaged in a 6-year MPA monitoring programme linked with JNCC-led Marine Biodiversity Monitoring and Surveillance Programme.
- Natural England provides advice to public authorities on how to meet the conservation objectives of MPAs to ensure that management measures are appropriate for features to reach favourable or reference condition.
- Natural England sits on the UK Marine Monitoring and Assessment Strategy group involved in setting Marine Strategy Framework Directive targets for the UK, advising Defra throughout the target setting process.
- Natural England advises on plans and projects including aquaculture of non-native species, through the England INNS working group.
- Natural England is a statutory consultee and appointee to the IFCA and will advise on the development of byelaws and measures required to manage new fisheries in MPAs within 0-6nm and MMO out to 12nm.
- Natural England is a statutory adviser to Shoreline Management Plan groups and provides advice on applications including beach nourishment and marine aggregate dredging to ensuring that SSSI features are not damaged and coastal processes are maintained. Natural England also ensures that linkages are made between marine plans and shoreline management plans.
- Natural England is a co-funder of the Marine Climate Change Impact Partnership.

Barriers

- Understanding and ensuring good management will require resources for monitoring. However, funding for direct observations may be limited, with the focus likely to be more risk based and pressure based monitoring.
- Targets will be agreed at UK level across government departments and so may not be sufficiently specific to address local issues in English waters.
- One in one out rules relating to the introduction of new byelaws to manage new fisheries may limit the MMO's ability to put in place required measures.

- Coastal development pressures are likely to limit the opportunities for managed realignment.
- A major response to reducing climate effects on the marine environment is reduction of other (often human) pressures. However, Natural England, as an advisory body, often has limited influence on other sectors that use marine areas.

Our partners and stakeholders

Delivery of the actions required to mitigate the threats and opportunities identified requires the coordinated action of Natural England's functions and a wide range of external organisations.

Natural England's role is as an advisory body and therefore we work closely with other organisations in order to deliver the actions to mitigate climate change. A coordinated approach with JNCC, DEFRA and its agencies, such as the Marine Management Organisation and the Environment Agency, and the regional IFCAs will ensure coordinated advice and guidance.

Key stakeholders, such as NGOs, fishermen and developers also play a significant part in helping Natural England deliver its objectives with the challenges of climate change.

Summary of key responses to priority risks and opportunities

Desired change: existing **marine biodiversity is conserved to the greatest extent possible through appropriate management measures**. This should include conserving protected areas and other high quality habitats and creating new intertidal habitats where current habitats have been lost to sea level rise. As well as protecting habitats and species within Marine Protected Areas (MPA), we must ensure that they are representative of the diversity and variety of species and habitats at regional and national scales, and contribute to an ecologically coherent network at the UK scale. This should include consideration of coastal and estuarine areas, and ensuring the action is taken to limit the negative effects of land use on the marine environment.

- Risks addressed: 1, 2, 3, 4, 5, 6, 7, 8, a, c.
- Natural England's ability to influence this: low (in general) to medium (MPAs and some aspects of Shoreline Management Plans).

Action we could take: **Complete the MPA network and ensure it is ecologically coherent** and ensure that the **MPA network is well-managed and addresses climate change**. This will include recommending MCZs, SACs and SPAs to Defra and advising if ecological coherence criteria are not met. Ensure that advice given to public authorities take account of climate change. Provide advice to ensure that management measures are appropriate for features to reach favourable or reference condition. Ensure integration of Water Framework Directive and MPA objectives to ensure water quality does not affect reaching favourable condition.

- Resources: Moderate.
- Time: short action; medium delay to effect.

Action we could take: **Ensure Marine Strategy Framework Directive targets will result in an overall improvement of the state of the marine environment** by encouraging site based measures which complement wider sea measures. Advise Defra throughout target setting process and work closely with the Joint Nature Conservation Council Committee and other statutory nature conservation bodies.

- Resources: Moderate.
- Time: short action; medium delay to effect.

Action we could take: **Contribute to shoreline management plans** and ensure marine plans take account of sea level rise. Provide advice on applications for beach nourishment and ensure that SSSI features are not damaged and coastal processes are maintained. Contribute to long

term strategic planning of marine aggregate dredging. Ensure linkages between marine plans and shoreline management plans.

- Resources: Moderate.
- Time: medium term action; medium delay to effect.
- Additional benefits: mitigation, through improved protection and management of coastal carbon sinks such as saltmarshes, sea grass meadows, kelp beds and estuarine sediments. This will retain the sequestration ability of existing habitats and avoid very significant emissions of carbon dioxide by deterioration of such habitats due to poor management, pollution and damage and destruction.

Desired change: A **stronger body of evidence on marine ecosystem processes** and how they are affected by climate change, informed by a comprehensive programme of monitoring.

- Risks addressed: most/all.
- Natural England's ability to influence this: low-medium.

Action we could take: Our **evidence and monitoring** work should include the following, in all cases working closely with the range of other organisations with an interest and specialist scientific expertise in these topics:

  - Ensure marine monitoring programmes can detect change in ecosystems and differentiate between natural and anthropogenic causes in the change.
  - Identify options for pathway management for invasive non-native species.
  - Study range shifts and monitor the emergence of new fish species.
  - Monitor possible effects of acidification.
  - Monitoring the state of our MPAs.

- Resources: Minor.
- Time: medium term action; medium delay to effect.

References

ACREMAN, M.C., BLAKE, J.R., BOOKER, D.J., HARDING, R.J., REYNARD, N., MOUNTFORD, J.O., STRATFORD, C.J. 2008. A method for assessing climate change implications for wetland hydroecology (with case studies from Great Britain). Internal report. Centre for Ecology and Hydrology, Wallingford, UK.

ADAS. 2009. Best Practice for Managing Soil Organic Matter in Agriculture: Manual of Methods for Lowland Agriculture. Prepared as part of Defra project SP08016.

ALBERTSON K., AYLEN J., CAVAN G., & MCMORROW J. 2010. Climate change and the future occurrence of moorland wildfires in the Peak District of the UK. *Climate Research*, 45, 105-118.

ALONSO, I., WESTON, K. & GREGG, R. 2011. Carbon storage by habitat. Review of the evidence of the impacts of management decisions and condition on carbon stores and sources. Natural England Research Report, June 2011.

ARNELL, N.W. 2004. Climate-change impacts on river flows in Britain: the UKCIP02 scenarios. *Journal of the Chartered Institution of Water and Environmental Management*, 18, 112-117.

ARNELL, N.W. & REYNARD, N. 2000. Climate change and UK hydrology. In Acreman, M.C. (ed) *The hydrology of the UK - a study of change. Routledge London*, 3-29.

BAIN, C.G., BONN, A., STONEMAN, R., CHAPMAN, S., COUPAR, A., EVANS, M., GEAREY, B., HOWAT, M., JOOSTEN, H., KEENLEYSIDE, C., LABADZ, J., LINDSAY, R., LITTLEWOOD, N., LUNT, P., MILLER, C.J., MOXEY, A., ORR, H., REED, M., SMITH, P., SWALES, V., THOMPSON, D.B.A., THOMPSON, P.S., VAN DE NOORT, R., WILSON, J.D. & WORRALL, F. 2011. IUCN UK Commission of Inquiry on Peatlands. IUCN UK Peatland Programme, Edinburgh.

BERRY, P.M., HARRISON, P.A, DAWSON, T.P. & WALMSLEY, C.A. (eds.) 2005. Modelling Natural Resource Responses to Climate Change (MONARCH): A Local Approach. UKCIP Technical Report, Oxford.

BOOTH, P., BROWN, I., GUILLAUME, P., TOWERS, W. 2010. Impacts of biomass and bioenergy crops on landscape, land use and the wider environment in Northern Ireland and Scotland - Final Report. Scotland and Northern Ireland Forum for Environmental Research (SNIFFER).

BOURAOUI, F., GALBIATI, L. & BIDOGLIO, G. 2002. Climate change impacts on nutrient loads in the Yorkshire Ouse catchment (UK). *Hydrology and Earth System Sciences*, 6, 197-209.

BRADLEY, I., MOFFAT, A.J., VANGUELOVA, E., FALLOON, P. & HARRIS, J. 2005. Impacts of climate change on soil functions. DEFRA project, report SP0538, London.

BRITTON, A., BEALE, C.M., TOWERS, W., AND HEWISON, R.L. 2009. Biodiversity gains and losses: Evidence for homogenisation of Scottish alpine vegetation. *Biological Conservation*. 142, 8, 1728-1739.

BROADMEADOW, M.S.J, RAY, D. & SAMUEL, C.J.A. 2005. Climate change and the future for broadleaved tree species in Britain. *Forestry* 78, 145-161.

BROWN, C., WALPOLE, M., SIMPSON, L. & TIERNEY, M. 2011. Introduction to the UK National Ecosystem Assessment. In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

CHARLTON, M.B., BAILEY, A. & ARNELL, N. 2010. Water for Agriculture - Implications for Future Policy and Practice Reviewing and modelling the impacts of climate change on future food production. The Royal Agricultural Society of England. 93pp.

CLARK J.M., GALLEGO-SALA A.V., ALLOTT T.E.H., CHAPMAN S.J., FAREWELL T., FREEMAN C., HOUSE J.I., ORR H.G., PRENTICE C. & SMITH, P. 2010. Assessing the vulnerability of blanket peat to climate change using an ensemble of statistical bioclimatic envelope models. *Climate Research* 45,131-150.

CLARKE, S.J. 2009. Adapting to climate change: implications for freshwater biodiversity and management in the UK. *Freshwater Reviews*, 2, 51-64.

CONLAN, K., LANE, S., ORMEROD, S. & WADE, T. 2007. Preparing for climate change impacts on freshwater ecosystems, PRINCE: results. Environment Agency Science Report SC030300/SR, Bristol, UK.

COOMBES, E.G. & JONES, A.P. 2010. Assessing the impact of climate change on visitor behaviour and habitat use at the coast: A UK case study. *Global Environmental Change*, 20, 303-313.

COSTELLO, A., ABBAS, M., ALLEN, A., BALL, S., BELL, S., BELLAMY, R., PATTERSON, C. 2009. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. *Lancet*, 373, 1693-1733.

COYLE, M.D. & WIGGINS, S.M. 2010. European Marine Site Risk Review. Natural England Research Reports, Number 038.

DAVIES, Z.G., WILSON, R.J., COLES, S. & THOMAS, C.D. 2006. Changing habitat associations of a thermally constrained species, the silver spotted skipper butterfly, in response to climate warming. *Journal of Animal Ecology*, 75, 247-256.

DCLG. 2010. PPS25 Supplement: Development and coastal change Practice Guide.

DEFRA. 2006. R&D technical report FD2017/TR: National evaluation of the cost of meeting coastal environmental requirements. URL: **http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2017_5200_TRP_pdf.sflb.ashx**. [Accessed January 2012].

DEFRA. 2008. Research into the current and potential climate change mitigation impacts of environmental stewardship. R&D report BD2302.

DEFRA. 2009. Safeguarding our soils. A strategy for England. 48pp. Defra Publications, London.

DEFRA. 2010. Single Payment Scheme: Cross Compliance Guidance for Soil Management 2010 edition. 73pp. Defra Publications, London.

DEFRA. 2011.=) Water for Life, Water White Paper.

DELLA-MARTA, P.M. AND PINTO, J.G. 2009. The statistical uncertainty of changes in winter storms over the North Atlantic and Europe in an ensemble of transient climate simulations. *Geophysical Research Letters* 36, L14703, 5 pp.

DEPARTMENT OF HEALTH AND HEALTH PROTECTION AGENCY. 2008. Health Effects of climate change in the UK, Department of Health, London.

DEVICTOR, V., JULLIARD, R., COUVET, D. & JIGUET, F. 2008. Birds are tracking climate warming, but not fast enough. Proceedings of the Royal Society B: Biological Sciences, 275, 2743.

DOCKERTY, T, LOVETT, AA AND WATKINSON, A. 2003. Climate change and nature reserves: Examining the potential impacts, with examples from Great Britain. *Global Environmental Change*, 13 (2). pp. 125-135.

DOODY, J.P. 2004. Coastal squeeze - an historical perspective. *Journal of Coastal Conservation* 10, 29-138.

DREWITT, A.L. & LANGSTON, R.H.W. 2006. Assessing the impacts of wind farms on birds. *Ibis* 148, 29-42.

DULVY, N.K., ROGERS, S.I., JENNINGS, S. & STELZENMÜLLER, V. 2008. Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas. *Journal of Applied Ecology*, 45, 1029-1039.

DUNN, S.M. & BROWN, I. 2010. Impact assessment for Scotland: the relationships between climate, water resources, land use and diffuse pollution in a changing world., Proceedings of SAC/SEPA Biennial

Conference - Agriculture and the Environment VIII Climate, Water and Soil: Science, Policy and Practice, Edinburgh, 31 March - 1 April 2010, 37-42.

DURANCE, I, & ORMEROD, S.J. 2007. Climate change effects on upland stream invertebrates over a 25 year period. *Global Change Biology*, 13, 942-957.

EDWARDS, M., JOHNS, D.G., BEAUGRAND, G., LICANDRO, P., JOHN, A.W.G., & STEVENS, D.P. 2008. Ecological Status Report: Results from the CPR Survey 2006/2007. *SAHFOS Technical Report*, 5, 1-8.

ENVIRONMENT AGENCY 2008. Climate change and river flows in the 2050s Science Summary SC070079/SS1.

ENVIRONMENT AGENCY 2010. Managing the Environment in a changing climate.

ENVIRONMENT AGENCY 2011. Wetland vision: adapting freshwater wetlands to climate change Environment Agency project SC090021.

ENGLISH HERITAGE 2008. Climate Change and the Historic Environment. 16pp. English Heritage.

EUROSION 2004. Living with coastal erosion in Europe: Sediment and space for sustainability, PART II - Maps and statistics. Available from URL: **www.eurosion.org/index.html**. [Accessed January 2012].

FAY, P.A., KAUFMAN, D.M., NIPPERT, J.B., CARLISLE, J.D. & HARPER, C.W. 2008. Changes in grassland ecosystem function due to extreme rainfall events: implications for responses to climate change. *Global Change Biology*, 14, 1600-1608.

FENNER, N. & FREEMAN, C. 2011. Drought-induced carbon loss in peatlands. Nature GeoScience, DOI: 10.1038/NGEO1323.

FORESIGHT 2004. Foresight Flood and Coastal Defence Project. Government of Science, London.

FORESIGHT 2010. The Future of Farming and Food. Challenges and choices for global sustainability. Government of Science, London.

FORESIGHT 2011. Land Use Futures: Making the most of land in the 21st century. Government of Science, London.

FORESTRY COMMISSION 2011. Woodfuel Implementation Plan 2011 - 2014. 20pp. Forestry Commission, England.

FRANCO, A.M.A., HILL, J.K., KITSCHKE, C., COLLINGHAM, Y.C., ROY, D.B., FOX, R., HUNTLEY, B., THOMAS, C.D. 2006. Impacts of climate warming and habitat loss on extinctions at species' low-latitude range boundaries. *Global Change Biology* 12, 1545-1553.

GALBRAITH, C.A., HUGHES, J.& KING, A. 2011. Climate Connections: towards low carbon high biodiversity economies. Scottish Wildlife Trust, Edinburgh.

GARDINER, B., BLENNOW, K., CARNUS, J-M, FLEISCHER, P., INGEMARSON, F., LANDMANN, G., LINDNER, M., MARZANO, M., NICOLL, B., ORAZIO, C., PEYRON, J-L., REVIRON, M-P., SCHELHAAS, M-J., SCHUCK, A., SPIELMANN, M., & USBECK, T. 2010. Destructive Storms in European Forests: Past and Forthcoming Impacts. Final Report to EC DG.

GEßLER A., KEITEL C., KREUZWIESER J., MATYSSEK R., SEILER W. & RENNENBERG H. 2007. Potential risks for European beech (*Fagus sylvatica* L.) in a changing climate. *Trees* 21, 1-11.

GILL S., HANDLEY J., ENNOS R. & PAULEIT S. 2007. Adapting cities for climate change: the role of the green infrastructure. *Built Environment* 3, 115-133.

HARRIES, T., AND PENNING-ROWSELL, E. 2011. Victim pressure, institutional inertia and climate change adaptation: The case of flood risk. *Global Environmental Change* 21, 188-197.

HICKLING, R., ROY, D.B., HILL, J.K., FOX, R., THOMAS, C.D., 2006. The distribution of a wide range of taxonomic groups are expanding polewards. *Global Change Biology* 12, 450-455.

HOPKINS J.J., ALLISON H.M., WALMSLEY C.A., GAYWOOD M., THURGATE G. 2007. Conserving biodiversity in a changing climate: guidance on building capacity to adapt. Defra, London.

HOSKING, A & MCINNES, R 2002. Preparing for the impacts of climate change on the central south coast of England: A framework for future risk management. *Journal of coastal research* Special issue 36.

HOWARD, A.J., CHALLIS, K., HOLDEN, J., KINCEY, M. & PASSMORE, D.G. 2008. The impact of climate change on archaeological resources in Britain: a catchment scale assessment. *Climatic Change*, 91, 405-422.

HUME, C. 2008. Wetland Vision Technical Document: overview and reporting of project philosophy and technical approach. The Wetland Vision Partnership.

IACCF (Inter Agency Climate Change Forum). 2010. Biodiversity & Climate change - a summary of impacts in the UK (Eds. Proctor, D. A, Baxter, J.M., Crick H.P.Q, Mortimer, D., Mulholland, F., Warmsley, C.A) JNCC Peterborough.

IPCC. 2007. Fourth Assessment Report: Climate Change 2007 (AR4).

ISAAC, N.J.B., GIRARDELLO, M., BRERETON, T. M., ROY, D.B. 2011. Butterfly abundance in a warming climate: patterns in space and time are not congruent. *Journal of Insect Conservation*, 15. 233-240.

JEPPESEN, E., KRONVANG, B., MEERHOFF, M., SØNDERGAARD, M., HANSEN, K.M., ANDERSEN, H.E., LAURIDSEN, T.L., LIBORIUSSEN, L., BEKLIOGLU, M. ÖZEN, A. & OLESEN, J.E. 2009. Climate Change Effects on Runoff , Catchment Phosphorus Loading and Lake Ecological State, and Potential Adaptations. *Journal of Environmental Quality*, 38,1930-1941.

JONES, L. 2011. Coastal Margins. In: *The UK National Ecosystem Assessment Technical Report*. pp 411-458. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

VAN KEEKEN, O. A., VAN HOPPE, M., GRIFT, R. E. & RIJNSDORP, A. D. 2007. The implications of changes in the spatial distribution of juveniles for the management of North Sea plaice (*Pleuronectes platessa*). *Journal of Sea Research*, 57, 187-197.

KEITH, S.A. 2010. Impacts of Environmental Change on Ecological Communities. PhD thesis University of Bournemouth.

KEITH, S. A., NEWTON, A. C., HERBERT, R. J. H., MORECROFT, M. D. & BEALEY, C. E. 2009. Non-analogous community formation in response to climate change. *Journal for Nature Conservation*, 17, 228-235.

KUHN, K., CAMPBELL-LENDRUM, D., HAINES, A., AND COX, J., 2005. Using climate to predict infectious disease epidemics. World Health Organization. WHO Document Production Services, Geneva, Switzerland.

LAWTON, J.H., BROTHERTON, P.N.M., BROWN, V.K., ELPHICK, C., FITTER, A.H., FORSHAW, J., HADDOW, R.W., HILBORNE, S., LEAFE, R.N., MACE, G.M., SOUTHGATE, M.P., SUTHERLAND, W.J., TEW, T.E., VARLEY, J., & WYNNE, G.R. 2010. Making Space for Nature: a review of England's wildlife sites and ecological network. Report to DEFRA.

LEE, M. 2001. Coastal defence and the Habitats Directive: predictions of habitat change in England and Wales. *The Geographical Journal*, 167,139-56.

LEHIKOINEN E., SPARKS T.H., ZALAKEVICIUS M. 2004. Arrival and departure dates. *Advances in Ecological Research*, 35,1-31.

LINDSAY, R. 2010. Peatbogs and carbon: a critical synthesis to inform policy development in oceanic peat bog conservation and restoration in the context of climate change. University of East London.

MCCIP. 2010. Marine Climate Change Impacts Annual Report Card 2010-2011. (Eds Baxter JM, Buckley PJ, and Wallace CJ). Summary Report, MCCIP, Lowestoft, 12pp.

MCCIP website. URL: **www.mccip.org.uk/**. [Accessed January 2012].

MCEVOY, D., HANDLEY, J. F., CAVAN, G., AYLEN, J., LINDLEY, S., MCMORROW, J. and GLYNN, S. 2006. Climate Change and the Visitor Economy: the challenges and opportunities for England's Northwest, Sustainability Northwest (Manchester) and UKCIP (Oxford).

MCKINNEY, M, LOCKWOOD, J. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Trends in Ecology & Evolution*, 14, 450-453.

MCMORROW, J., LINDLEY, S., AYLEN, J., G. CAVAN, K. ALBERTSON, D. BOYS, ALBERTSON. 2009. Moorland wildfire risk, visitors and climate change: patterns, prevention and policy In: A. BONN, T. ALLOTT, K. HUBACEK & J. STEWART, editor(s). Drivers of Change in Upland Environments. 2009.

MET OFFICE. 2011. Climate: Observations, projections and impacts. 153pp The Met Office, Exeter.

MITCHELL, R.J.; MORECROFT, M.D.; ACREMAN, M.; CRICK, H.Q.P.; FROST, M.; HARLEY, M.; MACLEAN, I.M.D.; MOUNTFORD, O.; PIPER, J.; PONTIER, H.; REHFISCH, M.M.; ROSS, L.C.; SMITHERS, R.J.; STOTT, A.; WALMSLEY, C.A.; WATTS, O.; WILSON, E. 2007. England biodiversity strategy - towards adaptation to climate change. Final report to Defra for contract, CRO327l.

MORECROFT, M.D. & PATERSON, J.S. 2006. Effects of temperature and precipitation change on plant communities. In Morison J.I.L. and Morecroft M.D. (eds.) Plant Growth and Climate Change. Blackwell Publishing, Oxford.

MORECROFT, M.D, BEALEY, C.E., BEAUMONT, D.A., BENHAM, S., BROOKS, D.R., BURT, T.P., CRITCHLEY, C.N.R., DICK, J, LITTLEWOOD, N.A., MONTEITH, D.T., SCOTT, W.A., SMITH, R.I., WALMSLEY, C. & WATSON, H. 2009. The UK Environmental Change Network: Emerging trends in the composition of plant and animal communities and the physical environment. *Biological Conservation* 142, 2814-2832.

MOSS, D., JOYS, A.C., CLARK, J.A., KIRBY, A. SMITH, A., BAINES, D. & CRICK, H.Q.P. 2005. Timing of Breeding of Moorland Birds. BTO Research Report 362. A report to Scottish Natural Heritage and Department for Environment, Food and Rural Affairs. British Trust for Ornithology, Thetford.

MURPHY, P., THACKRAY, D. & WILSON, E. 2009. Coastal Heritage and Climate Change in England: Assessing Threats and Priorities. *Conservation and management of archaeological. sites*, 11, 9-15.

NATURAL ENGLAND. 2009a. No charge? Valuing the natural environment. NE220.

NATURAL ENGLAND. 2009b. Green infrastructure guidance. NE176.

NATURAL ENGLAND. 2010. England's Peatlands: Carbon storage and Greenhouse gases. NE257.

NATURAL ENGLAND. 2011. Monitor of Engagement with the Natural Environment (MENE): Attitudes towards the natural environment - Findings of additional survey analysis. Natural England Commissioned Report NECR055.

NISBET, T., SILGRAM, M., SHAH, N., MORROW, K. & BROADMEADOW, S. 2011. Woodland for Water: Woodland measures for meeting Water Framework Directive objectives. Forest Research, Surrey. Forest Research Monograph, 4,156pp.

OCEAN ACIDIFICATION REFERENCE USER GROUP. 2009. Ocean Acidification: The Facts. A special introductory guide for policy advisers and decision makers. LAFFOLEY, D. d'A and BAXTER, J.M. (eds). European Project on Ocean Acidification (EPOCA). 12pp.

OCEAN ACIDIFICATION REFERENCE USER GROUP. 2010. Ocean Acidification: Questions Answered. Laffoley, D. d'A., and Baxter, J.M. (eds). European Project on Ocean Acidification (EPOCA). 24 pp.

OLDEN, J, LEROY POFF, N, DOUGLAS, ME, DOUGLAS, MR, FAUSCH, K. 2004. Ecological and evolutionary consequences of biotic homogenization. *Trends in Ecology and Evolution* 19, 282-3.

ORMEROD, S.J. 2009. Climate change, river conservation and the adaptation challenge. Aquatic Conservation: *Marine and Freshwater Ecosystems*, 19, 609-613.

PARMESAN, C., RYRHOLM, N., STEFANESCU, C., HILL, J.K., THOMAS, C.D., DESCIMON, H., HUNTLEY, B., KAILA, L., KULLBER, J., TAMMARU, T., TENNENT, W.J., THOMAS, J.A., WARREN, M. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature*, 399, 579-583.

PAROLO, G. & ROSSI, G. 2008. Upward migration of vascular plants following a climate warming trend in the Alps. *Basic and Applied Ecology*, 9(2), 100-107.

PEARCE-HIGGINS, J.W. 2010. Using diet to assess the sensitivity of northern and upland birds to climate change. *Climate Research*, 45,119-130.

PEARCE-HIGGINS, J.W., JOHNSTON, A., AUSDEN, M., DODD, A., NEWSON, S.E., OCKENDON, N., THAXTER, C.B., BRADBURY, R.B., CHAMBERLAIN, D.E. JIGUET, F., REHFISCH, M.M. & THOMAS, C.D. 2011. Final Report to the Climate Change Impacts on Avian Interests of Protected Area Networks (CHAINSPAN) Steering Group Defra Ref: WC0750/CR0440.

PERRY, A.L., LOW, P.J., ELLIS, J.R., & REYNOLDS, J.D. 2005. Climate change and distribution shifts in marine fishes. *Science*, 308, 1912-1915.

PERRY, R.I. 2010. Potential impacts of climate change on marine wild capture fisheries: an update. *Journal of Agricultural Science*, 149, 63-75.

PINNEGAR, J., WATT, T. & KENNEDY, K. 2011. Climate Change Risk Assessment for the Marine and Fisheries Sector.

PROSSER C.D., BUREK C.V., EVANS D.H., GORDON J.E., KIRKBRIDE V.B., RENNIE A.F. & WALMSLEY C.A. 2010. Conserving geodiversity sites in a changing climate: management challenges and responses. *Geoheritage*, 2, 123-136.

READ, D.J., FREER-SMITH, P.H., MORISON, J.I.L., HANLEY, N., WEST, C.C. & SNOWDON, P. (eds). 2009. Combating climate change - a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. The synthesis report. The Stationery Office, Edinburgh.

RUIZ, G.M., CARLTON, J.T., GROSHOLZ, E.D. & HINES, A.H. 1997. Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent and consequences. *American Zoologist*, 37, 621-632.

RUIZ, G.M., FOFONOFF, P.W., CARLTON J.T., WHO, M.J. & HINES A.H. 2000. Invasion of coastal marine communities in North America: apparent patterns, processes and biases. *Annual Review of Ecology and Systematics* 31, 481-531.

SAINO N., RUBOLINI D., LEHIKOINEN E., SOKOLOV L.V., BONISOLI-ALQUATI A., AMBROSINI R., BONCORAGLIO G. & MØLLER A.P. 2009. Climate change effects on migration phenology may mismatch brood parasitic cuckoos and their hosts. *Biological Letters* 5, 539-541.

SAINO N., AMBROSINI R., RUBOLINI D., VON HARDENBERG J., PROVENZALE A., HÜPPOP K., HÜPPOP O., LEHIKOINEN A., LEHIKOINEN E., RAINIO K., ROMANO M., & SOKOLOV L. 2010. Climate warming, ecological mismatch at arrival and population decline in migratory birds. Proceedings of the Royal Society Series B-Biological Sciences. DOI: 10.1098/rspb.2010.1778.

SCHMIDHUBER, J., & TUBIELLO, F.N. 2007. Global food security under climate change. *Proc. Natl. Acad. Sci.*, 104, 19703-19708.

SCOTTISH NATURAL HERITAGE. 2011. Commissioned Report 436: Paths and climate change - an investigation into the potential implications of climate change on the planning, design, construction and management of paths in Scotland.

SMITHERS, R.J., COWAN, C., HARLEY, M., HOPKINS, J.J., PONTIER, H. AND WATTS, O. 2008. England Biodiversity Strategy Climate Change Adaptation Principles: conserving biodiversity in a changing climate, Defra, London.

SPOOR, G. 2004. Climate change possibilities and their potential impacts on wetland habitat management. Report to the RSPB.

STEVENS, C.J., QUINTON, J.N. 2008. Policy implications of pollution swapping, J. Phys. Chem. Earth, doi:10.1016/j.pce.2008.01.001.

SWANWICK, C. 2009. Society's attitudes to and preferences for land and landscape. In Land Use Policy Vol 26 (Land Use Foresight Supplement).

TAMESIDE METROPOLITAN BOROUGH. 2010. Longdendale Integrated Transport Strategy. 3pp. URL: **www.tameside.gov.uk/lits/summary**. [Accessed January 2012].

THACKERAY, S.J., SPARKS, T.H., FREDERIKSEN, M., BURTHE, S., BACON, P.J., BELL, J.R., BOTHAM, M.S., BRERETON, T., BRIGHT, P.W., CARVALHO, L., CLUTTON-BROCK, T., DAWSON, A., EDWARDS, M., ELLIOT, J.M., HARRINGTON, R., JOHNS, D., JONES, I.D., JONES, J.T., LEECH, D.I., ROY, D.B., SCOTT, W.A., SMITH, M., SMITHERS, R.J., WINFIELD, I.J., WANLESS, S. 2010. Trophic level asynchrony in rates of phenological change for marine, freshwater and terrestrial environments. *Global Change Biology*, 16, 3304-3313.

THOMAS, J., SIMCOX, D., WARDLAW, J., ELMES, G., HOCHBERG, M. & CLARKE, R. 1998. Effects of latitude, altitude and climate on the habitat and conservation of the endangered butterfly *Maculinea arion* and its *Myrmica* ant hosts. *Journal of Insect Conservation*, 2, 39-46.

THOMSON J.D. 2010. Flowering phenology, fruiting success and progressive deterioration of pollination in an early-flowering geophytes. *Phil. Trans. R. Soc. B*, 365, 3187-3199.

TRIVEDI, M.R., MORECROFT, M.D., BERRY, P.M., AND DAWSON, T.P., (2008). Potential effects of climate change on plant communities in three montane nature reserves in Scotland, UK. *Biological Conservation*, 141 (6).

UK MARINE MONITORING AND ASSESSMENT STRATEGY 2010. Charting Progress.

WALLISDEVRIES, M.F. & VAN SWAAY, C.A.M. 2006. Global warming and excess nitrogen may induce butterfly decline by microclimatic cooling. *Global Change Biology*, 12, 1620-1626.

WALMSLEY, C.A., SMITHERS, R.J., BERRY, P.M., HARLEY, M., STEPHENSON, M.J., CATCHPOLE, R., 2007. MONARCH: Modelling Natural Resource Responses to Climate Change - a synthesis for biodiversity conservation. UKCIP Technical Report. UKCIP, Oxford.

WARNER, D. 2011. A revisit to previous research into the current and potential climate change mitigation effects of environmental stewardship (BD5007) Report to DEFRA. University of Hertfordshire.

WARREN, M.S., HILL, J.K., THOMAS, J.A., ASHER, J., FOX, R., HUNTLEY, B., ROY, D.B., TELFER, M.G., JEFFCOATE, S., HARDING, P., JEFFCOATE, G., WILLIS, S.G., GREATOREX- DAVIES, J.N., MOSS, D., THOMAS, C.D. 2001. Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature*, 414, 65-69.

WEATHERHEAD, E.K. & KNOX, J.W. 2009. Demand forecasting water resources for agricultural irrigation. Technical Report for the Environment Agency, Cranfield University, August 2008.

WHITEHEAD, P. G., WILBY, R. L., BUTTERFIELD, D. & WADE, A. J. 2006. Impacts of climate change on nitrogen in lowland chalk streams: adaptation strategies to minimise impacts. *Sci. Total Environ*. 365, 260-273.

WHITEHEAD, P.G., WILBY, R.L., BATTARBEE, R.L., KERNAN, M. & WADE, A.J. 2009. A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences-Journal-des Sciences Hydrologiques*, 54(1), 101-123.

WINDER, M & SCHINDLER, D.E. 2004. Climate Change uncouples trophic interactions in an aquatic ecosystem. *Ecology*, 85, 2100-2106.

WINTER, T.C. 2000. The vulnerability of wetlands to climate change: a hydrologic landscape perspective. *Journal of the American Water Resources Association*, 36(2), 305-311.

Other sources of information referenced but not cited

DEFRA

DEFRA. 2010. Air Pollution: Action in a Changing Climate. 24pp.

DEFRA. 2010. DEFRAs Climate Change Plan 2010.

HM GOVERNMENT. 2011. The Natural Choice; securing the value of nature. TSO (The Stationery Office), Norwich.

English Heritage

ENGLISH HERITAGE. 2008. Conservation Bulletin Issue 57: Adapting to a changing climate.

Environment Agency

Shoreline Management Plans. **www.environment-agency.gov.uk/research/planning/104939.aspx**. [Accessed January 2012].

ENVIRONMENT AGENCY. 2011. Preliminary Flood Risk Assessment. **http://learning.environment-agency.gov.uk/courses/FCRM/capacity/pfra/responsibility_213.html**. [Accessed January 2012].

ENVIRONMENT AGENCY. 2010. Managing the Environment in a changing climate.

Environment Agency Catchment Flood Management Plans, Environment Agency website. **www.environment-agency.gov.uk/research/planning/33586.aspx**. [Accessed January 2012].

DCLG

Planning Policy Guidance (PPG) and Planning Policy Statements (PPS) **www.communities.gov.uk/planningandbuilding/planningsystem/planningpolicy/planningpolicystatements/**. [Accessed January 2012].

DCLG. 2007. PPS - Planning and Climate Change - Supplement to PPS1.

DCLG. 2010. PPS25 Supplement: Development and coastal change Practice Guide.

DCLG. 2011. Draft National Planning Policy Framework.

Marine Climate Change Impacts Partnership (MCCIP)

MCCIP website. **www.mccip.org.uk/**. [Accessed January 2012].

Natural England

CREEDY J. & DUFFIELD S.J. 2010. Land use strategy 2009-2013, Natural England.

ENGLISH NATURE 1995. English Nature Research Report 153. Accessible natural greenspace in towns and cities: Review of appropriate size and distance criteria.

ENGLISH NATURE. 2006. England's Eco-system Services - Research report 701.

NATURAL ENGLAND 2011a. A National Climate Change Vulnerability Assessment: Technical Information Note 095.

NATURAL ENGLAND. 2011b. Marine Function Handbook 2011-12.

Front cover image:
Danebury Hillfort, nr Stockbridge, Hampshire.
© Natural England / Simon Duffield

NATURAL ENGLAND

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

© Natural England 2012

Catalogue Code: NE318

www.naturalengland.org.uk

Natural England publications are available as accessible pdfs from:
www.naturalengland.org.uk/publications

Printed on stock comprising 75% recycled fibre.