Natural England Research Report NERR045

Assessing the potential consequences of climate change for England's landscapes: South East Northumberland

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Assessing the potential consequences of climate change for England's landscapes: South East Northumberland

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Published on 27 June 2013

ISBN 978-1-78354-013-6

Project details

This report should be cited as:

SPEAKMAN, L., MACGREGOR, N., VAN DIJK, N, DARCH, G. & NEALE, A. 2013. Assessing the potential consequences of climate change for England's landscapes: South East Northumberland. *Natural England Research Reports, Number 045*.

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Acknowledgements

Natural England would like to acknowledge the support of Steve Scoffin of the Druridge Bay Partnership and Northumberland Wildlife Trust, including the permission to use photographs; and the staff at Northumberland County Council.

Natural England would also to acknowledge Clive Waddington from Archaeological Research Services for permission to use Plate 17 - Archaeological excavations at Low Hauxley.

Natural England - Richard Hall, Nick Brodin, Mike Sutcliffe, Neil Tulloch, Steve Pullan.

Summary

This study considered the vulnerability of the natural environment to climate change in the South East Northumberland Coastal Plain NCA. This area encompasses the low lying plain of the Northumberland coalfield, the coastline, and extensive urban and industrial areas of Newcastle in the south. The area is rich in wildlife, supporting a wide range of important coastal, wetland, woodland and grassland habitats.

The vulnerability of the natural environment in the South East Northumberland Coastal Plain NCA was assessed by considering how it is exposed to changes in climatic conditions, how sensitive it is to those changes (including its ability to adapt, which can be influenced by its current condition) and how much scope there is for conservation management to promote adaptation. This assessment of vulnerability is based on the best available scientific knowledge of how climate change might affect the natural environment and discussions with local experts. The assessment considered both landscape assets (biodiversity, heritage, soils and geology) and its ecosystem service functions.

The assessment highlighted that coastal habitats, such as sand dunes, cliffs, salt marsh and mudflats, are likely to be particularly vulnerable to sea level rise and erosion. In some places along the coast, there is little opportunity for these habitats to adapt to changing conditions as they become 'squeezed' between rising sea levels and hard defences. It is likely that the most significant changes will occur around the southern end of the coastline where there are hard defences. As well as changing the appearance of the coast, a loss of coastal habitats may have an impact on the number and type of bird species the area can support. Loss of saltmarsh and mudflats could also increase the potential for coastal flooding.

Historical sites on the coast are also vulnerable to sea level rise and erosion. The site thought to be most at risk is the Mesolithic site of Low Hauxley where two Bronze Age cairns and three burials have been discovered.

Climate change may also affect wetland areas in South East Northumberland. Wetland could dry out during hotter summers. This would affect the plant, bird and animal species that live in these areas and would also change the appearance of the landscape. Coastal wetlands are also vulnerable to sea level rise and flooding by salt water in winter. Around Druridge Bay this could change the current mosaic of pools, reed beds and coastal grazing into an area of salt-water wetland. If lowland raised bog habitats and fen peat soils at Prestwick Carr dry out, carbon will be released to the atmosphere, contributing to climate change.

Drought may cause stress to trees, making them particularly vulnerable to pests and diseases. Losses of individual trees could affect views, particularly in areas of historic parkland such as Seaton Delaval. Different species and habitats could change the colour and appearance of the landscape over time.

Climate change could bring opportunities for food production in the area and farmers may respond by growing more or changing to different crop types. But, changes in agriculture could have consequences for the natural environment and add to the pressure on soils, water and habitats. Changes in agriculture could also change the appearance of the landscape.

Open cast mining is likely to remain a feature in the landscape and will continue to influence the character of the NCA. Intense rain storms may affect the restoration of old deep cast mines as heavy rain can cause subsidence and landslides in areas of unstable ground. In the urban areas of the NCA an increase in winter rainfall and more intense rain storms could lead to increased flood risk. Urban greenspace and river floodplains which store flood water could play an increasingly important role in protecting urban areas from flooding.

The report also suggests a range of possible adaptation actions to respond to these potential changes.

It is hoped that the findings of this study of climate change vulnerabilities and potential adaptation options will provide a useful starting point for adaptation in the South East Northumberland coastal plain. The actions described in the study are designed to increase the adaptive capacity of the natural environment in the area to the impacts of climate change and ensure that society continues to enjoy the benefits the environment currently provides. While some of the impacts of climate change on the natural environment are uncertain, adaptation action taken now will improve the resilience of the natural environment to change whether this is from climate change or other pressures, and provide a range of other benefits.

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1 Introduction

Context

1.1 England's natural environment is important for the species and ecosystems it supports and for the benefits it provides society. We enjoy a wide range of services from our environment, food and water, clean air, storage of carbon, regulation of hazards such as flooding, opportunities for recreation; and distinctive landscapes, shaped over thousands of years by natural processes and human land use, that give both local communities and visitors a 'sense of place'. The natural environment contributes to our livelihoods as well as our health and well-being.

1.2 However, the natural environment is vulnerable to climate change (for example, Hopkins *et al*., 2007; Mitchell *et al*., 2007; IPCC 2007; Rosenzweig *et al*., 2008; Inter-Agency Climate Change Forum 2010). Landscapes are dynamic and have responded to changes in the past, but the scale and rate of projected change, coupled with existing pressures on the natural environment, is likely to have serious implications for the wide range of benefits and services we obtain from ecosystems and landscapes and the species that they support. At the same time, appropriate land management to preserve and enhance ecosystems can help buffer society from a changing climate (Morecroft & Cowan 2010). Adaptation action for the natural environment will therefore be essential and form an important part of our overall adaptation effort.

1.3 We have a general idea of how the climate might change (for example, Murphy *et al*., 2009), and some information about the possible consequences for different aspects of the natural environment (for example, Hopkins *et al*., 2007; Mitchell *et al*., 2007). However, consequences of climate change are likely to vary greatly from place to place. For the same reason, adaptation is likely to be a very time - and place -specific activity. Several sets of principles have been developed for adaptation (for example, Hopkins *et al*., 2007; Smithers *et al*., 2008; Macgregor & Cowan 2011), which have an important role in guiding general approaches. However, these need to be applied and tailored to specific locations and different landscape and habitat types, to help develop detailed adaptation solutions for different areas.

1.4 A key issue therefore is the scale at which adaptation action should take place – spatially, temporally and institutionally. Spatially, large scale approaches are likely to be important. This is not a new idea in conservation (for example, Noss, 1983), but climate change and its potential to further enhance the 'fluidity' (Manning *et al*., 2009) of landscapes in time and space makes it a particularly relevant issue to adaptation (for example, Opdam and Wascher, 2004). The recently published Lawton Review, Making Space for Nature, sets out a number of recommendations for practical action to achieve a coherent and resilient ecological network in England. The Lawton Review summarises the approach which needs to be adopted to support and enhance England's nature, as 'more, bigger, better and joined' (Lawton *et al*., 2010). Central to the delivery of this vision is a large scale approach to conservation and adaptation. It is also important that we try to take an integrated and sustainable approach to considering vulnerability and adaptation (for example, Macgregor and Cowan, 2011).

1.5 The concept of 'landscape' is particularly useful to address both scale and sustainability issues. As well as providing a spatial dimension, landscape has great potential to act as an integrating framework that can help us to consider a range of aspects of the natural environment in a holistic way, to consider how changes to physical features of the landscape will affect the things that society values and benefits from, and to focus our adaptation responses on maintaining or enhancing those things in the face of inevitable change.

1.6 National Character Areas (NCAs), which make up a well-established spatial framework across England (Figure 1) provide a suitable geographic unit to explore vulnerability and adaptation.

Ranging in size from 1,122 ha[1] to 382,627 ha, they provide an opportunity to consider vulnerability and adaptation at a 'landscape scale'; but are small and distinct enough (each having a well-described and distinctive set of geological, biological and cultural characteristics) to enable us to explore the possible implications of climate change in specific different places.

Natural England's Character Area Climate Change Project

1.7 The Character Area Climate Change Project commenced in 2007. It began with a set of four pilot studies that trialled a methodology that used bioclimatic data, information from national experts, and workshops with external stakeholders. It broadly followed a 'top-down' or hazard-based approach to impact assessment and adaptation (Parry and Carter, 1998; see also Jones and Mearns, 2005). The research reports from these early studies (Natural England 2009a, b, c, d), their summaries and an overall summary were published in 2009. The NCAs studied were:

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

1.8 A second phase of studies commenced in 2009. The second phase built on the lessons learnt in the pilot studies and a revised methodology was developed, focusing on assessing vulnerability to climate change and increasing resilience of the natural environment. This drew on 'bottom-up' methodologies associated with vulnerability assessment (see for example Kelly and Adger, 2000; Downing and Patwardhan, 2005) and the concept of resilience (see for example Handmer and Dovers, 1996). The NCAs in the second phase of studies were:

- Sherwood in the East Midlands, bordering on the Yorkshire and Humber region – rolling countryside, with well established, iconic woodlands and a strong coal mining heritage.
- South East Northumberland Coastal Plain on the north east coast of England – a flat landscape with coastline of sand dunes and rocky outcrops, scarred by a heavily industrial past.
- Humberhead Levels, inland of the Humber estuary – a broad floodplain of navigable rivers, and an important area of lowland peat.
- London[2] – a large city, but with extensive urban green space, dominated by the influence of the river Thames.
- South Downs National Park[3], stretching from Eastbourne to Winchester in the south east of England – a chalk landscape of rolling arable fields and close-cropped grassland on the bold scarps, with rounded open ridges.

[1] Excluding the two smallest NCAs, Lundy and the Isles of Scilly

[2] Rather than a single NCA, the study looked at the whole Greater London administrative area, which overlaps a number of NCAs

[3] This study extended beyond the South Downs NCA to include parts of other NCAs that lie within the National Park boundary

- Lancashire and Amoundness Plain on the Irish Sea coast in the north west of England – a flat, predominantly drained coastal marsh landscape of mostly peat soils which has seen significant coastal development of Victorian coastal resorts.
- Morecambe Bay Limestones to the north of Lancashire and Amounderness Plain – a contrasting landscape of limestone hills interspersed with flat agriculturally-reclaimed flood plains, surrounding the multiple estuaries and mudflats that make Morecambe bay.
- Solway Basin in the far north west of England, bordering Scotland – a broad lowland coastal plain gently rising to the hills behind with large expanses of intertidal mudflats backed by salt marsh.

1.9 The 12 studies completed in the two phases of the project cover a wide range of landscape types across England (Figure 1).

Figure 1 England's 159 National Character Areas, with the 12 areas studied in the two phases of the project highlighted. The South East Northumberland Coastal Plain is shaded in yellow

1.10 This report presents the results of the South East Northumberland Coastal Plain study. Chapter 2 outlines the overall approach taken in this study and the other studies in the second phase of the project while Chapter 3 describes the specific methods used in the South East Northumberland Coastal Plain. The results of the study are presented in Chapter 4 and briefly discussed in Chapter 5.

2 Approach

Introduction

2.1 This study and the others in the second phase of the Natural England Character Area Climate Change project are underpinned by three main concepts: sustainable adaptation; using a vulnerability approach to assess the potential effects of climate change; and using landscape as an integrating framework for adaptation. This chapter defines these concepts and describes how they have been used to inform the methodology used.

Sustainable adaptation

2.2 Adaptation must be sustainable. Four principles for sustainable adaptation have been proposed (Macgregor and Cowen 2011):

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.
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.
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.
4) Approaches to adaptation must be flexible and not limit future action.

2.3 An important aspect of applying the first principle above is to consider, as a starting point, the benefits a system provides, in order to establish objectives for adaptation against which both the consequences of climate change and the sustainability of possible adaptation actions can be evaluated. This thus frames the question from the point of view of 'what are we adapting for?' rather than 'what impacts are we adapting to?'

2.4 An important aspect of sustainable adaptation is to identify action that would maintain or enhance the multiple benefits an area provides to society by reducing vulnerability to a range of possible consequences of climate change (principle 3 above). Therefore, in this project we have not chosen a specific climate change scenario (for example, 2080s, high emissions) to assess the vulnerability of the natural environment or identify adaptation responses. The project aimed to develop adaptation responses which are valid for a broad range of climate changes, using the headline messages from the United Kingdom Climate Projections 2009 (UKCP09) (see Section 2.5 - 2.13). In the face of uncertainty about the magnitude and timing of climatic changes and the cascade of possible consequences for natural systems, we believe this approach is more appropriate than focusing solely on trying to identify and respond to detailed projections of climate impacts. This is one of the key lessons that emerged from the phase one studies (Natural England 2009a, b, c, d).

Vulnerability assessment

2.5 Following the sustainable adaptation framework, a bottom-up, vulnerability based approach to assessing the potential impacts of climate change on the natural environment of the NCAs was taken. Vulnerability has been defined by the Intergovernmental Panel on Climate Change (IPCC) as a function of a system's exposure and sensitivity to climate impacts and its capacity to adapt (IPCC 2007; Figure 2), where:

- sensitivity refers to the degree to which a system is affected by weather or climate related stimuli (Willows and Connell 2003);
- exposure refers to the extent to which the system is subject to the weather or climate variable in question; and
- capacity to adapt refers to the ability of a system to adjust to climate change, to moderate potential damage or to take advantage of opportunities (Willows and Connell 2003).

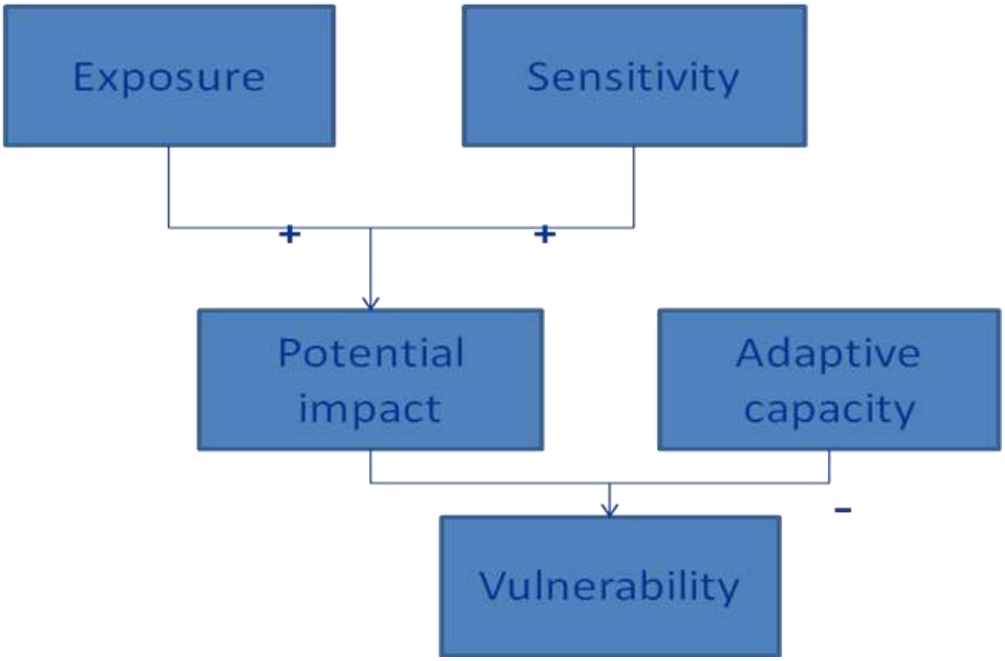

Figure 2 The basic components of vulnerability

2.6 The IPCC vulnerability framework distinguishes between 'natural' and 'human-managed' adaptive capacity (IPCC 2007), and further studies (for example, Williams *et al*., 2008, Steffen *et al*., 2009, Glick *et al*., 2011) have explored in more detail the factors that influence vulnerability in complex natural systems.

2.7 Exposure is determined by two factors. The first of these is the general change in climate variables that occurs in the area of interest. Information on change in climate variables can be found in the United Kingdom Climate Projections 2009 (UKCP09) (Murphy *et al*., 2009). The UKCP09 projections provide probabilistic projections of climate change, assimilated from an ensemble of models and model runs for three emissions scenarios (Low, Medium and High). The projections are presented for 25 x 25 km grid squares across the UK and for seven over-lapping 30-year 'timeslices' (30 year averages of climate variables), moving forward in decadal steps (2010-2039, 2020-2049, until 2070-2099).

2.8 Headline messages for the UK from UKCP09 can be summarised as:

- All areas of the UK get warmer and the warming is greater in summer than in winter.
- There is little change in the amount of precipitation that falls annually but it is likely that more of it will fall in winter with drier summers for much of the UK.
- Sea levels rise and are greater in the south of the UK than the north.

2.9 Second, the exposure of a particular feature (for example, a plant or an animal, or an archaeological feature) may be moderated by the physical structure of the environment in the immediate vicinity. For example, even though an overall area might experience a certain average temperature rise, sites that are naturally cool and shaded (for example, sheltered wooded valleys) are likely to reach a lower maximum temperature than nearby sites in direct sun, such as open hilltops.

2.10 Sensitivity to a climatic change is determined by intrinsic traits of a feature, such as a species' tolerance to changes in temperature or water availability or the type of material used to build a historic property and the extent to which it is affected by flooding. Sensitivity in a particular location is also likely to be exacerbated by the presence of non-climate pressures. For example, areas of blanket bog that are already water-stressed as a result of existing drainage are likely to be more sensitive to additional water shortage in drier summers than are areas in good condition with sufficient water resources. Historic features in a poor state of repair might be more sensitive to damage from heavy rainfall than features that have been well conserved.

2.11 Capacity to adapt is determined by three sets of factors:

- For living things, it is the intrinsic traits of a species that enable it to adjust to changing conditions. This includes the capacity for phenotypic plasticity[4], such as adjustment of an animal's behaviour to use different microhabitats or to be active at different times of the day the ability of an animal, or the seeds of a plant, to disperse to other, more suitable areas; changes in phenology, that is timing of seasonal events such as egg hatching, migration and leafing; and capacity to adapt (in an evolutionary sense) *in situ* to be more adapted to the new conditions, which will be constrained by the existing level of genetic diversity in a population and the species' generation time.
- The local environment, which can either support or hamper a species' intrinsic ability to adapt. For example, a species might have the ability to modify its behaviour to use different microhabitat in its current range, or to disperse to new habitat in a different area, but will be able to successfully adapt only if suitable habitat is available and accessible.
- For both living and non-living features, the ability of humans to manage the system ('adaptive management capacity'; Williams *et al*., 2008). Factors such as the existence of management plans or policies which consider climate change, measurement and monitoring of the impacts of climate change, availability of land for people to allow translocation or migration of wildlife or to move non-living features, and the existence of partnerships to manage features, can all contribute to adaptive management capacity.

Dealing with uncertainty in vulnerability assessment

2.12 There are multiple sources of uncertainty in the vulnerability assessment that make it difficult to make an objective assessment of the vulnerability of features of the natural environment to the impacts of climate change. There are a range of projections of climate change due to natural climate variability, incomplete understanding of Earth system processes and a range of possible scenarios of future greenhouse gas emissions (Jenkins *et al*., 2009). Another source of uncertainty is added when translating the projections into potential impacts on the natural environment: our understanding of how the complex interactions which exist in the natural environment will respond to climate change is limited.

2.13 While acknowledging these various sources of uncertainty, we understand enough about possible climate change and its potential effects on the natural environment to consider a range of plausible future changes. The aim of the vulnerability assessment in these studies was to highlight the relative vulnerability of features in the NCA to the impacts of climate change, based on the best knowledge available at present, Sources of information included expert judgement of Natural England specialists, other experts from outside the organisation, including local experts, and published literature. By setting out each feature in terms of its exposure and sensitivity to climate change and its capacity to adapt, the justification for the assessment was made as transparent as possible.

[4] Phenotypic plasticity is the ability of an organism to change its morphology, development, biochemical or physiological properties, or behaviour, in response to changes in the environment

Landscape as an integrating concept

2.14 The third central concept is the idea of landscape as an integrating framework for adaptation (and for conservation in general). Landscape in this sense is far more than just 'the view' – it is the full set of environmental features in an area and the services they provide. In these studies, landscape was considered in terms of a range of physical features that combine and interact to produce important services and benefits. Three broad categories of benefits were considered: biodiversity, landscape character and other ecosystem services.

2.15 Landscape character refers to the distinct, recognisable and consistent pattern of elements that make one landscape different from another and provide people who live there or visit with a 'sense of place'. The concept of landscape character does not imply any value judgement i.e. it does not make a distinction between landscapes that are better or worse, but considers the distinct, recognisable and consistent pattern of elements that make one landscape different from another. This might include physical features such as hedgerows or buildings but also physical patterns at different spatial scales. These elements come together to influence how people perceive landscapes. National Character Areas are discreet areas that, in broad terms, have a coherent landscape character that differs from that of neighbouring areas. The benefits to people provided by valued landscape character are just some of a wider range of ecosystem services (see below) that landscapes provide, but because landscape character determines how a place 'looks and feels' to people (which was an important aspect of these studies), it was considered in a separate category here.

2.16 Ecosystem services are the wide range of services the natural environment delivers to society (Daily 1997). They can be described as "the processes or structures within ecosystems that give rise to a range of goods and services from which humans derive benefit" (Parliamentary Office of Science and Technology 2007).

2.17 The Millennium Ecosystem Assessment (MA 2005) identified four types of ecosystem services:

- Provisioning services such as food and forestry, energy and fresh water.
- Regulating services such as climate regulation and water purification.
- Supporting services such as soil formation and pollination.
- Cultural services such as recreation, inspiration and sense of place.

2.18 Biodiversity (short for biological diversity) is the variety of all life forms: the different plants, animals and micro-organisms, their genes, and the communities and ecosystems of which they are part. Biodiversity is usually recognised at three levels: genetic diversity, species diversity and ecosystem diversity. As well as being valuable in its own right, it supports ecosystem services and contributes to the character of a landscape.

2.19 Landscape character, ecosystem services and biodiversity are the result of a combination of elements such as habitats, geology, soil types and land use and the interactions between them. A very simple example of this might be trees and hedgerows which combine to give a landscape a wooded character, provide habitats for wildlife and also deliver services such as carbon sequestration or soil conservation. Features such as this that make an important contribution to character, ecosystem services or biodiversity are referred to as 'assets' in this study.

2.20 This study, and the others in the second phase of the Character Area Climate Change project, brought together these three concepts (sustainable adaptation, vulnerability assessment, landscape as an integrating framework) to develop and test a method for an integrated landscape and ecosystem approach to adaptation.

3 Method

3.1 The method we followed in this study (and in the parallel studies noted above) for assessing vulnerability and considering adaptation options consisted of six steps (Figure 3). The starting point was to identify the most important aspects of landscape character, ecosystem services and biodiversity, and the physical assets which make the most important contribution to them. We then assessed the vulnerability of those physical assets, and from this we inferred what major changes to character, biodiversity and ecosystem services might potentially occur as a result.

3.2 We also identified possible adaptation actions to address vulnerability and screened them to identify actions that would have multiple benefits, and any potential conflicts between actions. The remainder of this chapter outlines in more detail how we undertook each of the steps.

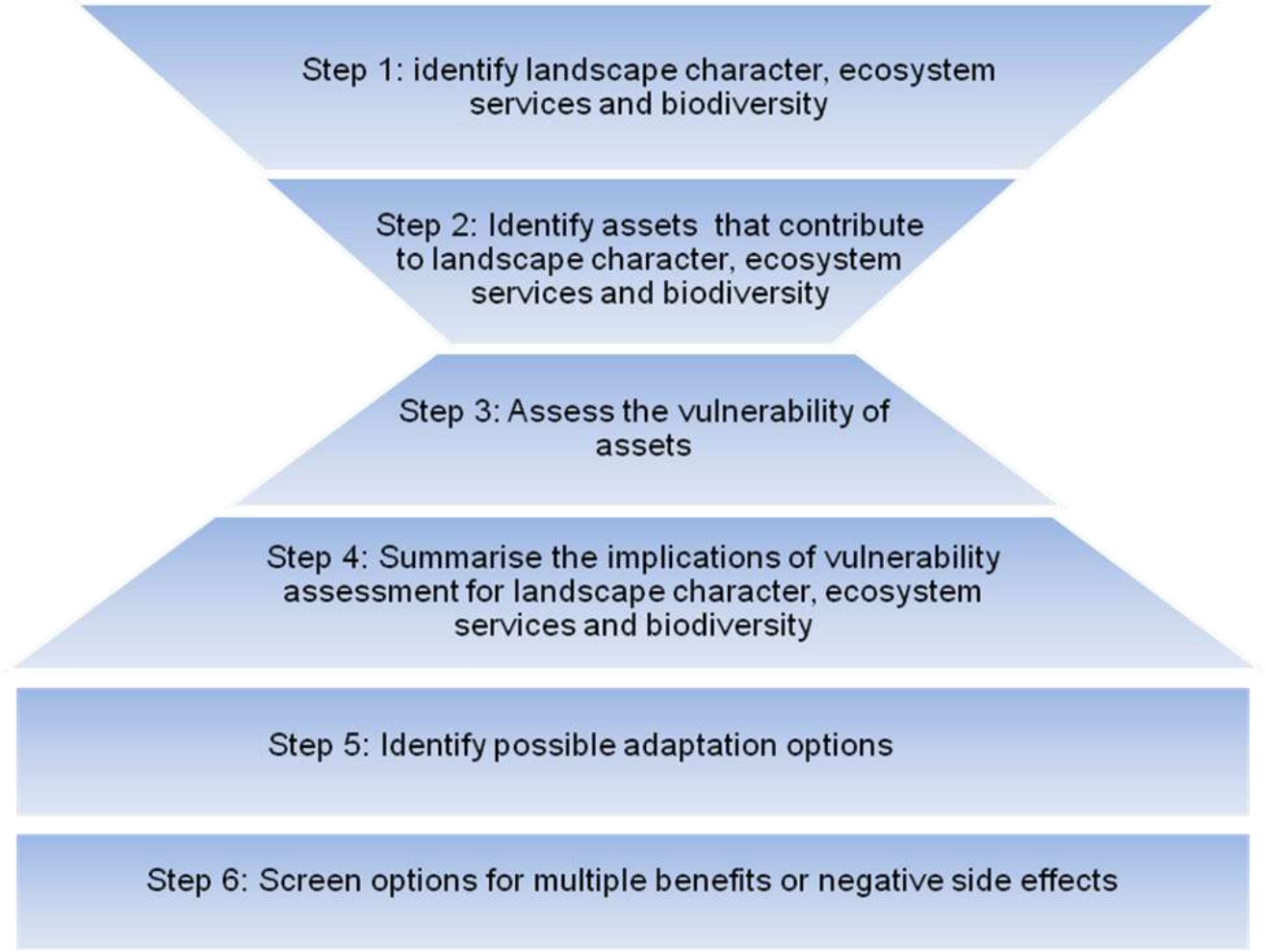

Figure 3 The main steps in the method used to assess vulnerability of the area to climate change and to identify and evaluate possible adaptation options

Step 1 – Identification of important elements of landscape character, ecosystem services and biodiversity

3.3 The most important elements of landscape character, ecosystem services and biodiversity of the South East Northumberland NCA were identified through a review of the current NCA description (Countryside Commission 1998) and consultation with regional landscape specialists currently working to re-define the NCA profile and objectives.

3.4 As urban townscape is not considered in any detail within the NCA description, urban character and ecosystem services are largely excluded from this study. However, stakeholder workshops identified urban greenspace as a facet of urban landscapes that may be vulnerable to climate change, and this has been considered alongside other recreational resources in this report. Although predominantly rural, parts of the character area are urban in nature, with the southern boundary fringing Newcastle and the communities of North Tyneside, with the NCA including large settlements such as Ashington, Blyth and Cramlington.

Step 2 – Identification of assets which contribute to landscape character, ecosystem services and biodiversity

3.5 The assets which contribute to the landscape character, ecosystem services and biodiversity of South East Northumberland were identified under the following headings:

- Geology and soils.
- Habitats and species.
- Historic environment.
- Areas for recreation.

3.6 The assets were identified through reviewing the NCA descriptions and consultation with Natural England regional specialists. In addition, many of the assets were mapped using spatial data held by Natural England. The maps presented in this report illustrate information that we hold on certain asset types and do not necessarily include every asset. There are also some types of assets which do not lend themselves to mapping (for example, aspects of aesthetic value and sense of place).

3.7 The validity of the output of Steps 1 and 2 was checked through correspondence with Natural England staff. Further checking of validity was undertaken at a stakeholder workshop held in November 2009 (see Step 3 below).

Step 3 – Identification of how the assets may be vulnerable to the impacts of climate change

3.8 The relative vulnerability of each asset to the effects of climate change was assessed, considering exposure, sensitivity and adaptive capacity. Vulnerability to both direct and indirect effects of climate change was assessed. The assessment was done using information from subject experts in Natural England and local knowledge of Natural England regional specialists, as well as published and unpublished literature.

3.9 In determining the vulnerability of assets, we considered the following sources of information:

1) **Exposure**

Regional summaries from the UKCP09 climate projections under the medium emissions scenarios for the North East were used to consider exposure (see example below), to provide

broad trends. These were used alongside a consideration of whether assets may be protected from climate changes, for instance by a flood defence.

Climate Change Projections UKCIP, 2010a

Key headline findings from UKCP09 for the North East (2080s, medium emissions scenario):

- The central estimate of increase in **winter mean temperature** is 2.6ºC; it is very unlikely to be less than 1.4ºC and is very unlikely to be more than 4.1ºC.
- The central estimate of increase in **summer mean temperature** is 3.7ºC; it is very unlikely to be less than 2ºC and is very unlikely to be more than 5.8ºC.
- The central estimate of change in **winter mean precipitation** is 14%; it is very unlikely to be less than 2% and is very unlikely to be more than 32%.
- The central estimate of change in **summer mean precipitation** is –17%; it is very unlikely to be less than –35% and is very unlikely to be more than 1%.

(Source: UKCIP, 2010a.)

2) **Sensitivity**

Sensitivity was determined by considering the characteristics of the asset including its tolerance of a gradual directional change in climate, reaction to the impacts of one off 'shock' events, and the impact of a combination of two or more of these factors.

3) **Adaptive capacity**

To determine the adaptive capacity of environmental assets in the face of a changing climate, we considered whether the asset could adapt and retain its value by moving, through changes in habitat composition, or through natural or managed processes.

3.10 Based on our consideration of exposure, sensitivity and adaptive capacity of each asset, we rated the relative vulnerability of assets in the NCA to climate change, using a simple vulnerability rating (see Table 1).

Table 1 Vulnerability ratings used

Description of relative vulnerability	Rating
Asset is likely to be significantly changed or destroyed as a result of climate change. Adaptation action should be implemented as a matter of priority.	More vulnerable
Asset may be changed as a result of climate change. Careful management or monitoring is likely to be required to support adaptation.	Moderately vulnerable
Asset is less likely to be significantly changed as a result of climate change or change may be beneficial. Adaptation action may be necessary, but other assets should be considered with greater urgency.	Less vulnerable

3.11 The results of the vulnerability assessment are summarised in Chapter 4 and are presented in tables in Appendix1.

3.12 The results of the initial vulnerability assessment were summarised in a series of templates (one for each of the categories of assets listed above). These tables were presented to stakeholders at a workshop held in November 2009. The workshops included 29 participants from a wide range of specialisms across the public, private and independent sectors, including academics, local authority officers, consultants and environmental non-government organisations. The workshop was used as a peer review process to ensure that all the key

natural environmental assets within the South East Northumberland Coastal Plain had been adequately captured, and participants were asked to review and comment on the vulnerability ratings. Feedback from the event was used to refine the templates and inform the analysis on the implications of climate change for South East Northumberland NCA.

Step 4 – Identification of potential major changes to landscape character, ecosystem services and biodiversity

3.13 Having assessed the vulnerability of South East Northumberland's important natural assets, we considered what the combined effects of changes to assets deemed to be 'moderately vulnerable' and above would be on the overall landscape character, biodiversity and ecosystem services of the NCA. We considered the possible effects on each of the separate elements of landscape character, ecosystem services and biodiversity that had been identified in Step 1. The results were then summarised as a set of statements about potential major changes. This evaluation was based on the results of the assessment exercise carried out in Step 3, local knowledge of the project team, examination of available literature and through consultation with Natural England regional specialists.

Steps 5 & 6 – Identification and evaluation of potential adaptation actions

3.14 Potential adaptation actions to address the vulnerability of the assets of the South East Northumberland were identified from a combination of published literature (for example, Hopkins *et al*., 2007), along with expert opinion from Natural England specialist staff.

3.15 Again, we aimed to identify responses to climate change which are valid for a broad range of climate variables suggested by the UKCP09 scenarios (for instance, increase in frequency of extreme rainfall events and extreme temperature events such as heat-wave), rather than focusing on a specific narrow scenario.

3.16 A number of principles were followed when deciding which adaptation actions were most appropriate:

- Win-win adaptation response – A 'win-win' adaptation response is a response to climate change that reduces the vulnerability to climate change of more than one characteristic or service of the natural environment, providing multiple benefits (UKCIP n.d).
- Low regrets adaptation response – Adaptation measure that would be relatively cheap to implement and for which benefits, although primarily realised under projected future climate change, may be relatively large (UKCIP n.d).
- No regrets adaptation response – A response to projected climate change impact that is beneficial regardless of whether climate change occurs (UKCIP n.d).
- Avoiding conflict between adaptation responses – It will be important that when implementing one adaption response, the ability to carry out other adaptation responses is not unduly compromised. This is a central tenet of the concept of sustainable adaptation, alongside the principle that adaptation responses should not increase climate change unnecessarily (Macgregor & Cowan 2011).

3.17 To ensure that adaptation actions were as consistent as possible with these principles, we used a matrix to assess whether there were any potential conflicts between adaptation actions for a specific characteristic or service, and to check that 'win-win', 'no-regrets' and 'low regrets' actions were, wherever possible, identified. The full matrix can be seen at Appendix 4.

3.18 The concept of 'adaptive management' was also considered when identifying potential adaptation actions (Holling 1978). Adaptive management has been defined as 'a structured

process of "*learning by doing*" that involves much more than simply better ecological monitoring and response to unexpected management impacts. In particular, it has been repeatedly argued that adaptive management should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies. (Walters 1997).

3.19 Once adaptation actions had been identified for specific assets and services with South East Northumberland, they were grouped under the statements of potential major changes identified in Step 4.

3.20 A second stakeholder workshop was held in March 2010, with a similar group of participants to the November workshop. This event was used as opportunity not only to report on progress on the study, but also to look in further detail at the proposed adaptation responses and to canvas views from many of the organisations directly involved in managing and developing key areas within South East Northumberland. Comments from the workshop were used to further refine the list of proposed adaptation responses.

4 Results

Part 1 – Description of the landscape area

4.1 In this part of the Results chapter, the findings of Steps 1 and 2 of the method are presented. We have identified the main features of the NCA under the headings of landscape character, ecosystem services and biodiversity. We have then identified the main assets which contribute to these services, considering the range of different asset types (though these headings are not explicitly used in this section of the report):

- Geodiversity and soils.
- Habitats and species.
- Areas for recreation.
- Historic environment.

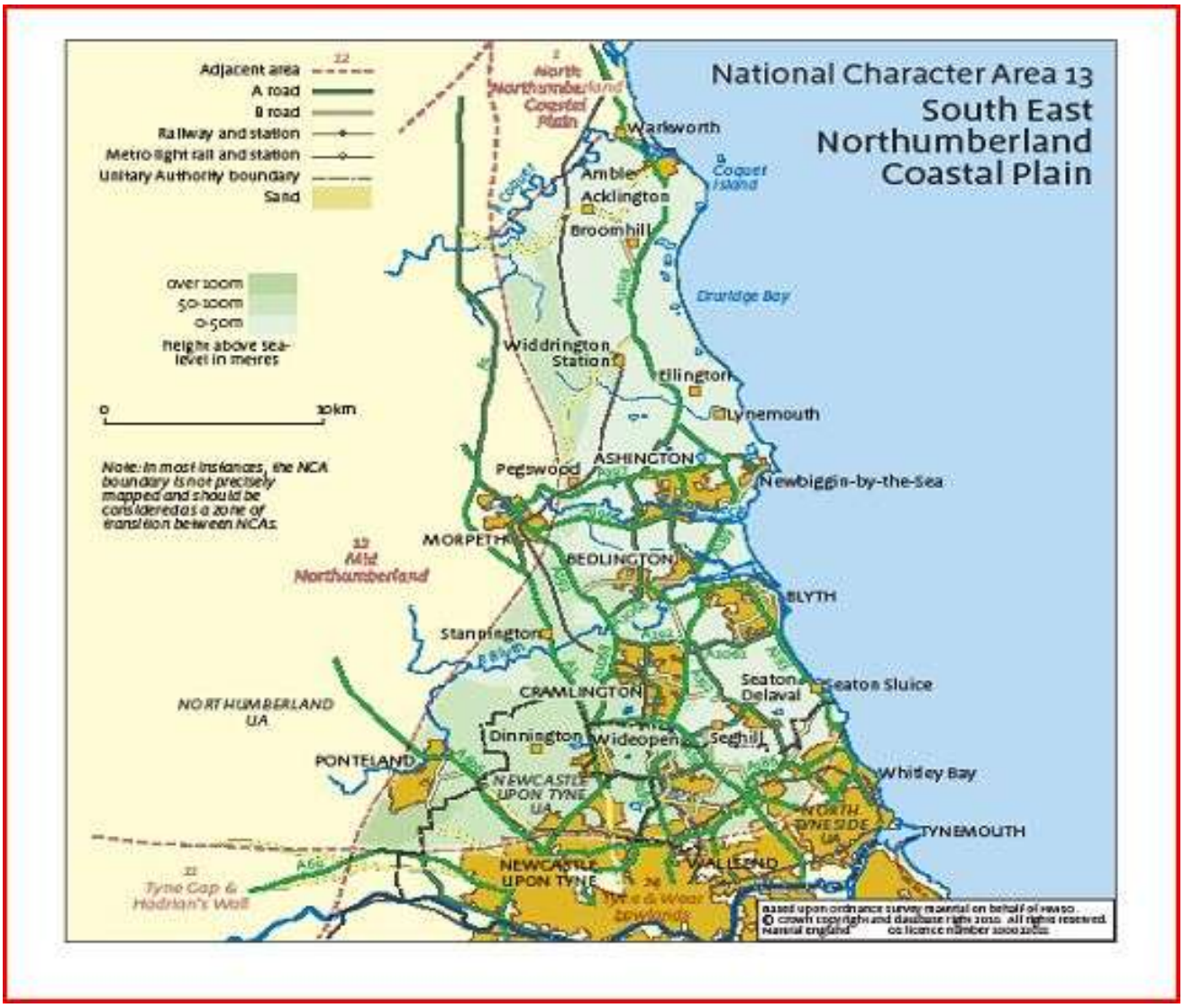

Figure 4 Map of South East Northumberland Plain NCA

Landscape character

4.2 The South East Northumberland NCA extends from the River Coquet to the northern edge of the city of Newcastle and inland to just east of Morpeth. It encompasses the low lying plain of the Northumberland Coalfield, a low coastline of rocky headlands and sandy bays, intersected by river estuaries with associated areas of mudflats and salt marsh and extensive urban and industrial developments to the south. Druridge Bay, the 'jewel in the crown' of this area, is designated as a Heritage Coast (part of the North Northumberland Heritage Coast) on account of its fine landscape qualities: six miles of white sands stretching in an unbroken sweep from Hauxley in the north to Cresswell in the south (Countryside Commission 1996).

4.3 The key landscape characteristics of South East Northumberland NCA have been drawn from established sources such as National Character Area description (Countryside Commission (1998), Natural Area descriptions (English Nature 1998) and Countryside Quality Counts (Natural England 2007) and discussions with local experts.

Plate 1 Sand Dunes at Druridge Bay

4.4 **Flat coastal plain:** This consists of sandstone and mudstone overlaid by glacial debris from the last Ice Age, mainly boulder clay or till. Typically of such deposits, this has led to a relatively featureless landscape with few exposed rocks: the incised river valleys of the Blyth and Wansbeck revealing the coal measures along their steeper banks are a notable exception. The South East Northumberland Coastal Plain is low lying, rarely rising over 70 metres above sea level (Countryside Commission 1998).

4.5 **Sweeping sandy beaches and rocky headlands:** The north of the South East Northumberland NCA is dominated by two bays, Druridge and Lynemouth, fringed with sand dunes. Research undertaken by Knight *et al*., (2002) and Wilson *et al*., (2001) demonstrated that this dune system has been present and active for over 1,000 years. The majority of the dune building and accumulation occurred during the cooler/drier climatic period known as the

Little Ice Age (1550-1800 AD). Hard rock outcrops of sea cliffs, shore platforms and soft cliffs are also a key feature of the coastline, which includes three geological SSSIs including cliffs with some of the best exposure of coal strata in the UK.

4.6 **Denes and wooden river valleys:** While woodland accounts for less than 5% of the NCA, there are a number of prominent blocks of mixed and coniferous woodland mainly planted on reclaimed colliery sites which are still maturing. Woodlands nearer the coast tend to be of smaller stature than those inland. Broadleaved woodland occurs on steeper river valley sides such as along the rivers Wansbeck, Blyth and Coquet, where there area some fine areas of beech woodland.

Plate 2 Beech woodland - Plessey Woods

4.7 **Major river estuaries:** The area is crossed by two easterly flowing rivers, the Blyth and the Wansbeck. A third river, the Coquet, flows along the northern boundary of South East Northumberland NCA. Tidal mud flats and salt marsh have developed within these river estuaries. The mouth of the Blyth is now a key regional port which once served the Northumberland coal industry. Today it handles up to 1.5 million tonnes of cargo each year and there are proposals to develop the port further. Further north on the Wansbeck estuary is a barrage erected in the 1970s to create an amenity lake, which is now the focal point of the Wansbeck Country Park.

4.8 **Significant urban and urban fringe areas:** The coastal plain is generally urban in the south, but merges northwards into a rural landscape. Overall, urban settlements account for 17% of the NCA and include the northern fringes of Newcastle, and the communities of Longbenton, Cramlington Blyth, and Ashington. The last deep mine in North East England, Ellington, closed in 2005 but its legacy lives on in the pit villages built around the former pit heads which consist of predominantly terraced housing built in parallel rows. Many of these former mining communities have become linked though new housing developments, particularly in the southern part of the area where there has been significant expansion in housing building.

4.9 **Large-scale, open-cast coal mining sites and former colliery and spoil heap restoration:** Thick seams of coal stimulated the development of a major coal mining industry and supported the North East becoming a major industrial heartland throughout the mid 19th and 20th centuries. While the last deep mine closed in 2005, there are still a number of open cast sites within the area and the remains of deep mine spoil heaps and colliery restoration. These restorations have led to relatively featureless agricultural land with strips of coniferous plantation.

4.10 **Regular large open arable fields, wire fences, and gappy hedges:** The coastal plain is dominated by large open regular arable fields, which are interspersed with pastures grazed by sheep and cattle, and urban fringe pony paddocks on the poorer reclaimed soils. The fields are bounded by post and wire fences or hedges. The majority of hedgerows are generally low and gappy with no hedgerow trees, although further north these tend to be in better condition, with some dating back to the Enclosure Movement, and are species rich. Remains of Medieval ridge and furrow cultivation from large scale open fields survive across the area, primarily around Warkworth, Newbiggin and Widdrington (Countryside Commission 1998).

Plate 3 Restored former open cast site near Acklington

4.11 **Significant man-made infrastructure- especially power transmission, road and rail structures and industry:** A key feature within South East Northumberland is transport and power-related infrastructure. A number of key strategic rail and road routes cross the area, predominantly running north-south, bisecting the rivers Blyth and Wansbeck with major bridge structures. The former Blyth power station has left a legacy of power lines and pylons which dominate the area around Cambois and Ashington. Plans to rebuild a power station at Blyth suggest this will continue to be a major feature of the area. Further along the coast is the Alcan Lynemouth power station, which provides power to the aluminium smelter as well as the national grid. On the coast, the off-shore wind farm at Blyth has become a local icon, and further plans for wind farm development across the area and off-shore suggest that wind turbines will become an increasing familiar part of this landscape. In the southern part of the

NCA, former wagon ways, once used to transport coal down to the river Tyne, have become cycle paths and walking routes and corridors for wildlife. The mineral lines effectively divide the landscape into distinctive areas at the local scale.

Plate 4 Pylons around Cambois

4.12 Areas of formal parkland and large estates Within the coastal plain there are number of large country houses surrounded by landscaped parklands with a number of fine veteran trees. A particularly fine example is Seaton Deleval, which has recently been acquired by the National Trust. There are also a number of large public institutions, including hospitals, colleges and prisons and associated grounds.

4.13 Areas of open water and wetland habitats Many areas associated with stretches of open water, ponds and wetland are the result of mining subsistence and have been incorporated into restored landscapes, often as recreational or wildlife assets. One example is Queen Elizabeth Country Park, east of Ashington. Other areas of wetland include the coastal floodplain grazing marsh and reed beds around Druridge Bay and East Chevington, or the floodplains around the rivers Coquet, Wansbeck and Blyth, incorporating areas of wet woodland.

Plate 5 Seaton Deleval Hall

4.14 **Historic landscapes associated with World War Two defences, and prehistoric archaeology:** There are a number of significant Mesolithic and Bronze Age sites around Low Hauxley and Newbiggin by the Sea, medieval stone-built churches and defensive buildings such as Warkworth Castle and Cresswell Tower dating back to the time of the Border Wars. The coast played an important part of Britain's civil defence during World War Two and a significant number of structures survive along the coast.

4.15 **Tranquillity and clear skies along the northern end of the coast:** South East Northumberland is an area of marked contrast, with a predominate urban character in the south, and less developed rural north, which close to the coast offers a real sense of tranquillity, and the lack of urban street lighting ensures clear night skies.

Biodiversity

4.16 For a relatively urban area, South East Northumberland has a wide range of important UK Biodiversity Action Plan (BAP) habitats, and its coastline is part of the Northumbria Coast Special Protection Area (SPA) and Ramsar site because of its importance for over-wintering and migratory birds. The coast includes area of foreshore, mudflats, salt marsh and saline lagoon, and provides important wintering grounds for shorebirds. Two species, turnstone *Arenaria interpres* and purple sandpiper *Calidris maritima*, occur in internationally important numbers; other species occur in nationally important numbers including sanderling *Calidris alba*, golden plover *Pluvialis apricaria*, ringed plover *Charadrius hiaticula*, redshank *Tringa totanus*, godwit *Limosa lapponica*, dunlin *Calidris alpina* and curlew *Numenius arquata*. Several bird species found on the North East coast are dependent on sand eels for a major proportion of their diet, including Eider *Somateria mollissima*, Roseate tern *Sterna dougalii*, Sandwich tern *Sterna sandvicensis*, Arctic tern *Sterna paradisaea*, Common tern *Sterna hirundo* and Puffin *Somateria mollissima*.

4.17 South East Northumberland contains sixteen SSSIs and 51 local wildlife sites, some of which are designated nature reserves (see example below):

Internationally important sites:

- Northumbria Coast SPA and Ramsar.
- Coquet island SPA.

Nationally important sites:

- Northumberland Shore SSSI.
- Prestwick Carr SSSI.
- River Coquet and Coquet Valley Woodlands SSSI.

- Hadston Links SSSI.
- Low Hauxley Shore SSSI.
- Darras Hall Grassland SSSI.
- Big Waters SSSI.
- Arcot Hall grassland and ponds SSSI.
- Brenkley Meadows SSSI.
- Gosforth Park SSSI.
- New Hartley Ponds SSSI.
- Holywell Pond SSSI.
- Willowburn Pasture SSSI.
- Hawthorn Cottage SSSI.
- Tynemouth to Seaton Sluice SSSI.
- Cresswell & Newbiggin Shore SSSI.

European Protected Species:

- Great Crested Newt *Triturus cristatus.*
- White Clawed Crayfish *Ausropotamobius pallipes.*
- Bats.
- Otter *Lutra lutra.*

UK Biodiversity Action Plan Habitats:

- Coastal sand dunes.
- Maritime cliffs and slopes.
- Rocky foreshore and islands.*
- Salt marsh and mud flats.
- Saline lagoons.
- Coastal and flood plain grazing marsh.
- Running water.*
- Shallow lakes and ponds.
- Reedbeds and fens.
- Lowland acidic grassland.
- Lowland meadows.
- Cereal field margins.
- Hedgerows.
- Woodland pastures and parkland.
- Lowland deciduous woodland.
- Wet woodland.
- Lowland raised bog.
- Lowland Heath.
- BAP habitats.

* regionally important BAP habitat

4.18 There are sixteen UK BAP habitats within South East Northumberland NCA and two further regionally important BAP habitats, of which the coastal and wetland habitats are of particular significance. The area also contains a high number of brownfield sites, primarily around Blyth, Ashington and Cramlington, many of which have been left undisturbed for many years resulting in a rich mosaic of habitats (Groundwork Northumberland 2009).

Coastal habitats

4.19 Sand dunes develop behind large sandy beaches which dry out at low tide allowing sand grains to be blown landward and become trapped by dune forming grasses, such as marram grass *Ammophilia arenaria* (Brodin 2001). Sand dunes support a wide range of plants and animals; in South East Northumberland this includes characteristic species such as bloody cranesbill *Geranium sanguineum* and burnet rose *Rosa piminellifolia* as well as being an important habitat for skylark *Alauda arvensis* and meadow pipit *Anthus pratensis*. For dunes to develop and be maintained there must be a sufficient supply of sand grains. Sand dunes are found at Seaton Sluice, Blyth, Cambois, and Druridge Bay. Until fairly recently, huge quantities of sand were extracted by the aggregates industry, which impacted on the stability of the dunes by enhancing rates of coastal erosion, which was further exacerbated by the effects of over grazing. Cessation of extraction and management measures over the last 15-20 years has reversed the situation and resulted in wide spread dune and vegetation recovery.

4.20 Maritime cliffs and slopes, found all along the South East Northumberland coast, were formed through land slippage and coastal erosion. They consist of both hard and soft cliffs. This habitat generally occupies long, narrow strips, being bordered by the sea on one side and agricultural land, development or roads on the other. The largest area (7 ha) lies near St Mary's Island where it is 60 to 260 metres wide, but significant stretches of this habitat are only 10 to 15 metres wide. This is a habitat which supports a wide range of plant species and is an important breeding ground for many birds.

4.21 Rocky shore and sandy beaches are a regionally important habitat and consist of rocky headlands with wave cut platforms backed by dunes or cliffs separated by wide sandy beaches. The rocky shores and its extensive rock pool systems support a wide range of seaweed, algae, fish and invertebrate species, while the sand is important for burrowing worms, molluscs and variety of fish species.

Plate 6 Rock pools at Druridge Bay

4.22 Salt marsh occurs on soft, shallow shores in sheltered coastal areas and estuaries, and predominantly occupies the upper, vegetated portions of intertidal mud flats lying

approximately between mean high water tides and high water spring tides. In South East Northumberland, the main areas of salt marsh are located around the main river estuaries and narrow river channels which offer protection from disruption by rough seas, for example at Blyth and West Sleekburn. Salt marsh is a highly specialised and productive habitat which supports flora which is adapted to cope with sea water. Characteristic species include sea aster *Aster tripolium* and salt marsh grass. As elsewhere in the UK, salt marsh in South East Northumberland is an important feeding ground for migrating and wintering bird species, including wigeon *Anas penelope*, teal *Anas crecca* and redshank *Tringa totanus* (Brodin 2001).

4.23 Mudflats are formed from the deposition of fine sediment in areas of low tidal energy, particularly within river estuaries (Brodin 2001). This sediment is mainly silt and clay with a high organic content. These habitats support a high density of burrowing invertebrates such as lug worms *Arenicola marina*, sand mason worms *Lanice conchilega* and bi-valves. They provide feeding and roosting areas for internationally important populations of migrant waterfowl and are also an important feeding and nursery ground for flat fish. Wansbeck and Blyth estuaries, including the East Pier at Blyth, have been designated SSSIs because of their importance for birds for loafing and roosting.

4.24 Saline lagoons are partially separated from the sea but retain a proportion of their sea water at low tide. These lagoons support a range of invertebrate species which are not found in any other habitats, such as the lagoon snail *Hydrobia ventrosa* found at Cresswell, the largest lagoon in the South East Northumberland and a SSSI (Brodin 2001). They are also an important habitat for waterfowl and seabirds. As well as Cresswell, lagoons are found around Chibburn Mouth and Boghole Quarry.

4.25 Coastal and flood plain grazing marsh is a habitat of periodically inundated grasslands found within the flood plain of rivers and low lying coastal areas. A key area within the NCA is Druridge Pools. These areas usually have high water levels which are maintained by ditches containing brackish or fresh water-ditches rich in plants and invertebrates. They are important for breeding, passage and wintering birds such as lapwing *Vanellus vanellus*, snipe *Gallinago gallinago* and teal *Anas crecca*.

Water bodies

4.26 **Running water:** There are many watercourses running across South East Northumberland. The three main rivers are the Blyth, Wansbeck and Coquet. The river Coquet along the northern border of the area is a SSSI, designated for a range of interests including vegetation such as water crowfoot beds *Ranunculus aquatilis*, birds typical of upland rivers (for example, dipper *Cinclus cinclus*, common sandpiper *Actibis hypoleucos*), aquatic invertebrates and migratory fish such as salmon *Salmo salar* and lamprey *Petromyzonidae*. Otters *Lutra lutra* are also present. The Wansbeck supports large populations of white-clawed crayfish *Austropotambius pallipes* and is one of the best rivers in England for this species (Brodin 2001).

4.27 **Ponds:** South East Northumberland has extensive areas of subsidence ponds formed in hollows created by the collapse of underground mine workings. Many have both aquatic and marginal vegetation and are important for invertebrates such as dragonflies. They can also provide important roosting or feeding sites for birds.

4.28 Reedbeds are wetlands dominated by stands of common reed *Phragmites australis* and are found in areas where the water table is at or above ground level for most of the year. These habitats usually incorporate areas of open water and ditch. Within South East Northumberland they are found at Gosforth Park, East Chevington Burn, Hadston links, and Cresswell ponds. Reedbeds are important habitats for birds including the bittern *Botaurus stellaris*, reed bunting *Emberizidae*, sedge warbler *Acrocephalus scirpaceus* and reed warbler *Acrocephalus schoenobaenus*, as well as mammals such as water vole *Arvicola amphibious* and otter (Brodin 2001).

Plate 7 East Chevington Nature Reserve, reed beds

Woodlands

4.29 There is a limited extent of parkland and woodland pasture and most of it is found in created landscapes in the south of the area, for example, Gosforth Park and Woolsington Hall. Woodland pasture and parkland consists of grassland or heath with an open cover of mature trees that form much of the interest of this habitat; veteran trees may support populations of invertebrates, lichens and fungi and roost sites for birds and bats. In less well managed woodland, the associated grassland may compose of a matrix of scrub and secondary woodland. There are a number of significant blocks of mixed deciduous woodland within the NCA, mainly along the River Wansbeck with small areas along the River Coquet and at Chevington Moor and Stobswood.

4.30 Wet woodland occurs on poorly drained or seasonally waterlogged soils, often on floodplains, and is usually dominated by alder, birch and willow. Wet woodlands are usually found as part of a mosaic with other woodland habitat types. The majority of wet woodland within South East Northumberland occurs on valley sides or valley bottoms such as along the rivers Coquet, Wansbeck and Blyth, and an area of SSSI wet woodland at Gosforth Park.

Grassland and field boundaries

4.31 Unimproved grassland is a declining resource within North East England. If traditionally managed, it is species rich with flowering plants and an important habitat for a range of birds such as skylarks, small mammals and a wide variety of butterfly species and day flying moths, for example, meadow brown butterfly *Maniola jurtina*. It is found both within field margins but also along road verges, as well as more traditionally managed hay meadows (Brodin 2001).

4.32 Hedgerows can be an important habitat for a range of species, particularly in intensively farmed lowlands, as they may offer the only significant refuge for many farmland and woodland species which rely on them for food, shelter and dispersal. As wildlife corridors, they also link semi natural habitats and help facilitate the movements of plants and animals throughout the countryside. South East Northumberland is dominated by gappy hedges dominated by hawthorn, with a relatively poor species mix and few mature trees. This makes them relatively poor wildlife corridors, although in the northern corner of the NCA hedgerows are older and support a greater variety of species. Cereal field margins alongside arable fields are also important wildlife corridors.

Plate 8 Gappy hedgerows near Highthorn

Wetlands

4.33 Lowland raised bogs characteristically consist of a raised mound of peat above a water table which is fed only by rainfall (as opposed to ground water), which results in the development of surface vegetation which is adapted to acid, nutrient-poor conditions (Brodin 2001). Typical species found in this habitat include bog mosses *Sphagnum*, cotton-grass *Eriophorum angustifolium*, sundew *Dorsera* and bog rosemary *Andromeda polifolia*. Prestwick Carr is one of only three areas of lowland raised bog in North East England. However, while it is a SSSI this site has been in unfavourable condition for many years as a result of drainage and colonisation by birch and pine. As part of its current management, drainage ditches have been blocked in order to raise water levels back up and to regenerate the raised mire habitat. There is a significant amount of bare peat exposed which may take some time to be re-colonised.

Plate 9 Prestcarr Carr, lowland raised bog

Plate 10 Prestcarr Carr

Heathland

4.34 Lowland heath is characterised by the presence of ericaceous dwarf shrubs, such as heather, and is associated with areas of open water bogs, scattered trees and shrub, bare ground and acid grassland (Brodin 2001). It is predominantly found in areas below 300 metres in sea level and within South East Northumberland only in fragmented sites such as Arcot Hall in Blyth valley, Newbiggin Golf Club and Havannah Nature Reserve.

Ecosystem services

4.35 The landscape of South East Northumberland delivers a range of services that contribute to the economy (within and outside the Character Area) and people's well being.

Provisioning services (food and forestry, energy and fresh water)

4.36 **Mixed arable farming, livestock fattening and dairying:** At current levels of relatively high rainfall (750mm per annum), the predominantly clay soils of the South East Northumberland support a mix of intensive grassland with arable breaks, typically cereals and oilseed rape, together with livestock fattening and dairying (ADAS, 2010). Often machinery work days in autumn and spring can be limited due to seasonal water-logging (personal communication, Steve Pullan, Natural England Land Management Adviser, November 2009). The smaller pockets of brown earth soils within the South East Northumberland, support arable crops, typically cereals, oilseed rape and some potatoes and sugar beet, with a grass break in the rotation.

4.37 **Water provision:** South East Northumberland NCA does not overlay any major aquifers. Principal surface water resources within the NCA are the lower reaches of the River Coquet (along the NCA's northern border), the River Wansbeck and the River Blyth which all form part of the Northumberland Rivers Catchment Abstraction Management Strategy (CAMS) area. Although the predominant land use in the CAMS area is agriculture, the main use of abstracted water is public water supply (80%), followed by industrial and commercial (11%). The River Coquet is the greatest source of abstracted water in the CAMS area and the Lower Coquet is the only catchment within the NCA categorised as 'over licensed', all others having 'water available' status. Although no ecological problems have been reported in the estuary of the River Coquet due to existing abstraction levels the Environment Agency wishes to avoid any increase in abstraction above current levels whilst further investigations are carried out (Environment Agency 2009).

4.38 **Fishing:** There are small fishing fleets based around the ports of Amble and Blyth.

4.39 **Wind energy:** South East Northumberland has been identified in various local planning documents as an area that offers significant potential for the development of wind energy and, in the future, possibly wave energy. It is currently the home of NREC, a major renewables research centre. Several turbines already exist within the NCA and planning permission is being sought for a number of others. Opportunities have also been identified to develop significant off-shore wind power generation.

© Graeme Peacock/Natural England

Plate 11 Off-shore Wind turbines at Blyth

Regulating services (climate regulation and water purification)

4.40 **Carbon storage:** Soils and bio-mass can perform an important role in sequestering and storing carbon to support climate change mitigation. Peaty soils have a particularly important role in storing carbon, and within South East Northumberland there are 4 km^2 of peat soils, mostly around Prestwick Carr and Pegswood Fen. Improving the condition of the lowland raised bogs around Prestwick Carr would allow further carbon sequestration.

4.41 **Flood alleviation:** The Rivers Wansbeck and Blyth drain a lowland agricultural area with gentle gradients in the west whilst the majority of the population and flood risk to people and property is in the east. The main settlement within the NCA at flood risk from rivers (the Rivers Pont and other minor burns) is Ponteland, while most of the urban areas within the Wansbeck and Blyth catchments are at risk of flooding from the surface water drainage system (Environment Agency 2009b). There are some areas with the flood plains of the main rivers and their tributaries which currently provide flood storage and protecting nearby properties and businesses, and the many ponds and areas of wetland perform similar services, but these are currently not recognised or protected within the local planning framework.

4.42 **Coastal flood and erosion alleviation:** As well as being an important UK BAP habitat, the dunes perform an important role in flood protection. Habitats such as salt marsh and mudflats also protect the coast by dissipating wave energy and thus reducing rates of erosion (Brodin, 2001). Urban green space can also have a flood management role, providing water storage and attenuation. Land sealing in urban areas increases the impact of surface water by reducing infiltration rates to groundwater stores. Green space and woodland helps manage this flood risk by intercepting rainwater and by providing conduits for surface water to infiltrate the soil (AECOM 2010).

4.43 **Climate regulation:** Trees in an urban setting can provide an important counter to the effects of urban-heat islands (Gill, 2009). Parks, gardens and street trees can help to reduce the impact of hotter summer temperature by providing natural cooling and shade. Green spaces create cooler microclimates through evapo-transpiration. Water is released through a leaf's pores, and when it evaporates, energy is absorbed from the air giving a cooling effect. In green spaces which are greater than 1 hectare in size, the effect can be sufficiently pronounced to develop a distinctive microclimate (AECOM 20100. Riparian woodland can also provide vital shade to protect fish stocks for example along the river Coquet

4.44 **Water treatment:** The legacy of coalmining has left an extensive network of underground tunnels and former mine workings. There remains the potential for contaminated mine work to leak and cause major environmental damage. In South East Northumberland, the Coal Authority has committed to run the Bates pumping station in perpetuity and therefore the risks of an outbreak are relatively low. The former Bates colliery uses reed beds to treat mine water. The area's heavy engineering heritage has also contributed contamination of both soils and water. Many of the mud flats within the river estuaries of the NCA have high levels of heavy metals, because of their ability to sequestrate contaminants due to their high levels of organic matter.

Cultural services (recreation, inspiration and sense of place)

4.45 **Geology (scientific knowledge):** South East Northumberland's geology consists principally of sedimentary rocks laid down in the Carboniferous period and consists of alternating layers of sandstone, shales, limestone and coal; known as the Scremerston series. There is also a series of eight igneous rock intrusions throughout the NCA, consisting of long thin basalt dykes, providing important evidence of the region's geological heritage. There are three geological SSSIs within the NCA sited along the coast:

- Low Hauxley Shore SSSI contains important Quaternary deposits including fluvial, peat, till, dune sand and soil horizons. It also holds multi-period archaeological material, held within the peat layers including artefacts, pollen and footprints. This site has been valuable in the reconstruction of sea-level history and our understanding of the impact of later prehistoric farming and forest clearance on the landscape. The exposure is kept in a good condition by continued gradual erosion which maintains the visibility of the features and their accessibility for study, although existing coastal erosion is now threatening the most important archaeological site.
- Cresswell and Newbiggin Shores SSSI is an outcrop exposing strata from the Middle Carboniferous period indicating the geographic conditions and tectonic activity (earth movements) during this period. The southern section is also an important location for studying glacial till.

4.46 Tynemouth to Seaton Sluice SSSI on the southern edge of the NCA is one of the best exposures of Coal Measures strata in Great Britain, including important outcrops of sandstone bodies, which have interpreted as braided river deposits. These deposits, which also yield the Whitley Bay non-marine bivalve are of considerable importance for interpreting the palaeogeographical structure of Britain during the Middle Carboniferous Period as they provide evidence to suggest that the Northumberland coalfield was formed in a more elevated area further from the sea than the Pennines.

4.47 South East Northumberland also remains an important area for opencast coal mining, with plans to develop new sites in the next few years as existing sites become exhausted.

Plate 12 Open cast site at Widdrington

4.48 **Historic Environment (Historical knowledge):** South East Northumberland contains a large number of scheduled, ancient monuments, listed buildings and other historic assets which contribute to the overall character and cultural heritage of the NCA.

4.49 The earliest recorded settlers in the area were from the Mesolithic period. The majority of Mesolithic sites in Northumberland are found on the coast, such as at Hauxley and Newbiggin by the Sea. During the Mesolithic period the coast was further east and so these are not true coastal sites but are being exposed along with Bronze Age burial cists as the coast has migrated westward. The Neolithic and Bronze Ages heralded the development of agriculture and a more settled existence although the number of recognised settlements in Northumberland is small. Towards the end of the Bronze Age a period of climatic deterioration put pressure on lowland agricultural sites leading to the development of enclosed fortified settlements.

Plate 13 Archaeological excavations of Mesolithic remains at Low Hauxley

4.50 In the Iron Age and Roman periods, single household non-defensive farmsteads appear on the coastal plain associated with field systems and trackways. Few above-ground remains of these sites survive because of subsequent intensive land use, although many below-ground remains have been identified using aerial photography. In medieval times the fertile soils were farmed with significant settlements at Warkworth, Newbiggin and Widdrington. Remains of ridge and furrow cultivation from large scale open fields survive across the area. In the late Middle Ages the strip field system declined as strips were amalgamated, and in the 18th and 19th centuries the older field patterns were overlain by large, rectangular fields created under the Enclosure Acts. This period also saw the development of substantial planned farmsteads and designed landscapes on large landed estates such as Seaton Delaval and Blagdon.

4.51 Coal has been worked in South East Northumberland since at least the early 13th century. For many centuries, outcrop coal was worked in bell pits to provide fuel for domestic use and the local salt industry. In the 18th and 19th centuries new technologies allowed exploitation of deeper reserves making the area one of the richest coal mining regions in the country. Most of the county's 120 mines were in South East Northumberland, creating an extensive coalfield landscape including many pit villages and bringing about the development of coal trading ports such as Blyth and Amble. The coal industry provided a stimulus to urban development and heavy industry across the South East Northumberland Coastal Plain making it the most densely populated part of Northumberland. In the 1950s and 60s the coal industry declined rapidly leaving a legacy of degraded land, derelict buildings, abandoned waggonways and spoil heaps. Some of this dereliction was cleared through extensive opencast mining and reclamation schemes in the late 20th century.

4.52 The development of the region has been greatly influenced by conflict and this is reflected in the archaeological record within South East Northumberland. The fifth to seventh centuries were an unsettled period when raids by Scots and Picts caused the abandonment of many settlements. Conflict continued through the medieval period when recurrent Anglo-Scottish wars saw the frequent destruction of settlements with only stone-built churches and defensive buildings such as Warkworth Castle and Cresswell Tower surviving from the period. However, in settlements such as Warkworth, where little of the medieval fabric remains, the layout of roads and building plots of the medieval town is still reflected in the modern town.

Plate 14 Low Chibburn Preceptory

Plate 15 World War II Tank traps at Druridge Bay

4.53 The First and Second World Wars left a further legacy of structures in South East Northumberland, where the wide beaches were seen as possible invasion sites. Remains include pill boxes, searchlight bases, gun emplacements and long lines of anti-tank blocks. Notable among these are the hidden pill box within the ruins of the medieval Low Chibburn Preceptory and the camouflaged 'cottage' pill box at Hemscott Hill. Hadston Carrs is the site of a searchlight base left isolated on the beach by erosion of the dunes.

4.54 **Recreation:** With around 17% of the NCA classed as urban, and with the conurbation of Newcastle and North Tyneside (combined population of 472,800) on its southern fringe, the greenspaces, woodlands and recreational resources of South East Northumberland have a particular value to the local community. This is also an area of high deprivation with low car ownership and relatively poor levels of health, which indicates a potentially important role for accessible green space to enhance quality of life and enable more active, healthier lifestyles (Coombes *et al*., 2010).

4.55 There are a number of health walking groups operating in and around South East Northumberland. Key recreational assets include within the NCA include:

- Druridge Bay Country Park.
- Queen Elizabeth II Country Park- Ashington.
- Rising Sun Country Park.
- Plessey Woods Country Park.
- Wansbeck Riverside.

4.56 These country parks not only have facilities for walking, cycling and horse riding, but some also provide opportunities for angling and other water sports, including canoeing and sailing at Druridge Bay and rowing at Wansbeck Riverside Park. There are over fifty local wildlife sites within the NCA, of which a large number have some level of public access and provide attractive greenspace for people to enjoy the outdoors and see nature at first hand. Popular sites include Big Water, Havannah, Weetslade colliery and Holywell Dene. There are also a range of other sites such as the coast and its beaches, woodlands, small corners of greenspace around housing estates, allotments, formal parks and sports pitches which offer a mosaic of locally valued greenspace. Sea angling, sailing, surfing and jet skiing are popular at various locations along the coast, particularly around Blyth and Druridge bay.

4.57 The area contains around 517 km of rights of way, of which 75% are footpaths, 23% bridleway and 2% byways. Despite the large number of horse riders, livery stables and riding schools in South East Northumberland, the area has a very poor and fragmented bridleway network. An important feature of the southern end of the NCA is the network of former wagon ways which have been restored to create all user routes for cyclists, walkers and horse riders. They stretch across Newcastle and North Tyneside from Gosforth to Whitley Bay and provide a range of links down to the river Tyne. Along the Coast is the Sustrans Coast and Castle Cycle Route linking Newcastle to Edinburgh, of which a large proportion of the route, particularly around Druridge bay is off-road. There are also a number of cycle tracks linking Morpeth and Pegswood, Seaton Sluice to Blyth and the eastern edge of Ashington parallel to the A189. While tourism is relatively low key, Druridge Bay and Warkworth remain popular visitor destinations.

Plate 16 Canoeists at Ladyburn Lake at Druridge Bay Country Park

Plate 17 Cyclist on the Blyth Links cycle path

4.58 **Sense of place:** In communities and along the coast there is strong sense of place, based around local distinctiveness reinforced through the area's the industrial heritage but also from the landscape itself. Less visible are the cultural associations of the landscape, the memories and aesthetic values of local people and wider region to the landscapes of South East Northumberland. Druridge Bay is part of the North Northumberland Heritage Coast status in acknowledgement of its natural beauty and scientific interest. It also has important iconic status and is a popular destination for visitors from within and outside the region. But there are many other places and views that have strong cultural resonance including the sites of former coal mines such as Woodhorn, or the lighthouse and harbour at Seaton Sluice. At a very local level, views and the greenspace and trees around people's homes often have high intrinsic landscape value to those individuals.

Supporting services (soil formation and pollination)

4.59 **Pollination:** This is a critical service, without which many plants would not be able to reproduce. While cereal production in South East Northumberland would not suffer significantly if invertebrate pollination broke down, as all cereals are abiotically pollinated and many vegetables produced in the area are derived from seed that is pollinated by seed houses elsewhere, many wild plants rely on invertebrate pollination to set seed.

4.60 **Soil formation:** Soils are an integral part of any land based-based eco-system and interact constantly with organisms within the soil itself, the atmosphere, climate and geology. As such, they are the building blocks of a landscape. There are ten broad soil types within the South East Northumberland of which three key types dominate, accounting for 91% of the soils. These are predominantly boulder clays, brown earth (glaciofluvival drift soils), stagnogleys and gley soils. These predominantly clay based soils support grassland with some arable agriculture, with the more fertile, deeper brown soils supporting more root-based crops. South East Northumberland also contains two important soil types from a biodiversity and carbon storage perspective: Fen Peat around Prestwick Carr, which supports fenland and wet woodland and is an important carbon store; and sand dune soils, which fringe part of the coast. In sites which were once former open cast or colliery workings, soil movement, storage and handling during the restoration process often impacts on soil structure, making it much more vulnerable to compaction.

Part 2 – Results of vulnerability assessment

4.61 This section summarises the assets in each category – geodiversity and soils, habitat and species, areas for recreation, and historic environment – that were deemed to be 'more vulnerable' or 'moderately vulnerable'. Detailed tables of results, including assets assessed as having relatively low vulnerability, can be found in Appendix 1.

Vulnerability of geology and soils to the impacts of climate change

Assets deemed to be more vulnerable

4.62 The combination of existing coastal erosion, together with the impacts of more frequent flood events and storm surges are likely to have a significant influence on geodiversity within the South East Northumberland NCA. Along the majority of this section of the North East coast, the coastal erosion rates are around 0.3 metres per year (Royal Haskoning 2009) but the impact of sea level rise will accelerate that rate and increase the incidences of tidal flooding and inundation. It is a process which will see landward migration of the beaches and dunes, recession of the sea cliffs, and beach lowering due to wave energy at the cliff toe. In addition, there will be dynamic changes in the alignment of river channel outfalls due to increased winter river flows.

4.63 In sections where coastal defences are in place such as around Blyth or Lynemouth and Newbiggin Bay protecting the Alcan Power Station, sea level rise will lead to increased frequency of overtopping, causing localised sea flooding, as well as increased mobility of beach sediments, leading in places to beach lowering and ultimately undermining of defences. The need to protect key settlements and critical infrastructure could see further reinforcement of existing sea defences and possibly the construction of new ones, especially around Blyth estuary where there are aspirations to extend the port and regenerate the site of the former power station. The impact of enhancing these defences in response to projected sea level rise will indirectly impact on certain coastal geodiversity assets in the NCA.

4.64 An area of particular concern from a geodiversity perspective is the coastline around Low Hauxley, which due to its location and geology is forecast to erode by around 42 metres by 2060 (Jacobs 2009). Although rates of erosion are not currently impacting on geological assets, the fact that this is a soft coastline may mean that rates of erosion will increase substantially by 2050 when sea levels are projected to be 30cm higher than today. A large caravan site exists above the southern section of the site and here the cliff has been protected by extensive beds of rock armour, which may require further reinforcement in the future to protect the village. Any extension of this rock armour would obscure the geological features and therefore directly impact on the SSSI.

4.65 Sea level rise is also likely to impact on the dune system around Druridge Bay and a study by Jacobs (2009) looking at the future evolution of the bay estimates that this will have receded by around 17 metres by 2060, will lead to some roll back of the dune system, and its breaching will lead to some tidal flooding of the land behind. However, in the northern section of the bay between Chevington outfall and Hadston Carr, it is anticipated the cliff top dunes may disappear altogether due to the underlying geology and topography. South of Chevington burn, as coastal rollback occurs, maintaining the existing freshwater habitats will not be feasible. It is likely that freshwater habitats will reduce in size and even disappear as coastal rollback occurs and they will turn into brackish or saltwater habitats. This area will also be at increasing risk from tidal inundation with sea level rise.

4.66 The important soils around Prestwick Carr, which support fenland and wet woodland and provide an important carbon store, are also vulnerable. The greatest potential impact to this area is increased summer temperatures drying out the fenland, leading to loss of carbon and increasing soil erosion rates (Natural England 2010). The sand dune soils along the coast are directly at risk from increased sea levels and subsequent erosion (Jacobs 2009).

4.67 As well as direct impacts from climate change on soils from extreme weather events such as flooding or drought, indirect impacts will also result through changes to flora and fauna caused by warmer temperatures and longer growing seasons, which will in turn impact on the nutrient and mineral content of soils. Changes in ground water levels, caused by changes in precipitation patterns, is likely to alter the physical and chemical properties of some soils, which will in turn influence flora.

Moderately vulnerable

4.68 In sites which were once former open cast or colliery workings, the soils are likely to have structural problems as a result of soil movement, storage and handling during the restoration process. In these areas soils will be much more prone to compaction, leading to increased water run-off, diffuse pollution and increased risk of local flooding. Summer drought could also lead to problems with engineered structures such as embankments, where drying out of soils could lead to cracking (Royal Haskoning 2008).

4.69 Appendix 1: Tables A and B summarises the results of the vulnerability assessment for geodiversity and soils in the NCA.

Vulnerability of habitats and species to the impacts of climate change

4.70 Changes in habitat mosaics and species composition, and the fragmentation of habitats as a direct response to climate change, will have an overall impact on landscape character in terms of the diversity, textures and colour. A recent assessment of the vulnerability of England's terrestrial ecology (Catchpole 2010), highlighted that those landscapes, such as those found in South East Northumberland, with a low degree of variation in elevation, large tracts of arable farmland and a general lack of connectivity between areas of natural habitats have reduced adaptive capacity, resulting in a number of BAP habitats being highly vulnerable to the impacts of climate change. Habitats and ecosystems are likely to change character by the alteration in water regimes, increased growth of woodlands and increased oxidisation of peat soils (IACCF 2010).

4.71 Climate change will impact on species, affecting their distribution and abundance, as well as the timing of seasonal events and their use of habitats (IACC 2010). One of the anticipated impacts of climate change is that many species currently at the northerly most range to the south of Northumberland, will extend northwards. Evidence is already emerging of the spread of invertebrates and birds further north into South East Northumberland, including species of moths and butterflies such as the small skipper *Thymelicus sylvestris*, which has been increasingly recorded in the region since 2000 (AEA 2010). Birds are also moving north (Hickling,2006), for example, the Little Egret *Egretta garzetta*, which has been sighted recently in South East Northumberland, but has yet to start breeding here (personal communication British Trust for Ornithology October 2010).

4.72 Predicting the impact of climate change on individual species is complex as they need to be considered as part of a wider ecosystem and it not always easy to determine the interplay between different aspects of that ecosystem on one particular species, including the knock on impacts of change in distribution or community composition on another species. For many species, this detailed information is not available. This study focused primarily on assessing the likely vulnerability of broad habitat/ecosystem types, partly to get around the problem of lack of knowledge of species-specific effects, and because considering changes to a particular habitat enabled us to consider to at least some extent changes to the species it supports. This enabled us to build a general picture of likely implications for the area's wildlife.

More vulnerable

4.73 Many coastal BAP habitats and the species which depend on them are particularly vulnerable to the impacts of climate change, including sand dunes, maritime cliffs, salt marsh and the regionally important rocky foreshore and island habitat. While these habitats are part of

dynamic coastal processes, sand dunes and salt marsh will in many sections of the coast be subject to coastal squeeze and be unable to roll-back resulting in significant habitat loss. The loss of estuarine mud flats is likely to have a particularly devastating impact on key bird species which depend on such as habitats for loafing, feeding and roosting, for which the area is designated as part of the Northumberland Coast Special Protection Area (SPA). Climate change appears to be already having an impact on sand eels, the main food source of a number of bird species which breed along the coast, such as the puffin, and the roseate, arctic, sandwich and common terns (Mitchell, 2006).

4.74 Increase in sea level is likely to increase the rate of erosion at the base of sand dunes and can reduce the amount of material available for dune formation. Stabilisation at the back of dunes, by hard structures including natural geological assets prevents natural land ward movement of dunes, causing dunes to be squeezed out and lost, which is a real risk in South East Northumberland. Druridge Bay is one of the few places in the NCA where sand dunes are not backed by roads or other hard infrastructure and offers one of the best opportunities for roll-back of dunes in the North East (Jacobs 2009).

4.75 Maritime cliff habitats are particularly vulnerable to coastal squeeze since often there is nowhere for the vegetation to retreat to as coastal erosion increases as a consequence of climate change and sea level rise.

4.76 **Rocky shore and sandy beaches:** Research has identified that within the British Isles both native and invasive inter-tidal species are responding rapidly to climate change and act as early warning indicators of changes in environmental temperature. This will subsequently impact on animals further up the food chain and, later, the balance of coastal ecosystems (Mieszkowska 2009). These changes are already affecting Coquet Island, just off Amble. Warm, wet summers, combined with a high level of bird guano, has led to vegetation getting out of control, which consequently has reduced the number of nest sites available to its important colonies of seabirds, such as roseate terns, arctic terns, sandwich terns, common terns and puffins. The bird populations are being even more significantly impacted by the reduction in the availability of their main food supply, sand eels, and there is some evidence that suggests that sand eel distribution and abundance is already responding to climate change impacts (Mitchell 2006).

4.77 The main risk to salt marsh and mud flats is rising sea level and the associated increase in wave energy, leading to erosion of the seaward edge of salt marshes (Royal Haskoning 2009). Sediments usually deposited further up the shore are also prevented from doing so where coastal defences are in place. This can lead to salt marsh and mud flats being lost because of ‘squeeze’ which takes place between the rising sea and defences. Such constraints include the weirs on the River Coquet at Warkworth, the River Wansbeck barrage.

4.78 Warmer temperatures are likely to have a particular impact on saline lagoons. The largest site, Cresswell Pond lagoon, is dominated by *Enteromorpha algae* and this may be exacerbated by hotter summers (Reach, 2003). Creswell Lagoon is also vulnerable to changes in beach morphology, which influences the flow of water in the outfall stream and leads to variations in sea level and salinity, and could be affected in the future by existing coastal defence structures. The lagoon at Chibburn Mouth will be more susceptible to sea level rise since it is nearer the sea and enclosed by dunes. Climate change could also increase the potential risk from the introduction of non-native aquatic plant species, which are more likely to survive in warmer winters, and are likely to disrupt the natural lagoon ecosystems (Natural England 2008b).

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Plate 18 Puffin

4.79 Climate change is already beginning to have some observable impacts on the marine environment, with changes in both the fish and cetacean populations (MCCIP 2011). There have been serious population declines at seabird colonies along and near the East Scottish coast, thought to be caused by a reduction in sand eel (resulting in an effective ban since 2002 on industrial fisheries using static gear in the area in order to control overfishing). The decline in the abundance of sand eel is thought to be due to climate change, with warmer surface water having a detrimental effect on the abundance of plankton on which the sand eels feed, and has been further exacerbated by over-fishing in the North Sea (Mitchell 2006).

4.80 Eider duck *Somateria mollissima*, a cold water species, is a species that may be pushed further north as water temperature rises (Brereton 2010). Eider chicks are subject to artificially high predation levels from large gulls (great black-backed gull *Larus marinus* and herring gull *Larus argentatus*) which are attracted to coastal towns partly due to the availability of food from tourists (personal communication staff at Northumberland Coast AONB). Warmer and drier summers are likely to support the growth of tourism along the coast, with a knock-on impact on a range of species and habitats. There are similar concerns about the populations of other bird species within the SPA, including puffin and arctic tern.

4.81 **Lowland raised bog:** Drier summers may create further problems at Prestwick Carr, with increasing evapo-transpiration from the thick cover of trees and scrub driving down the water table and slowing the recovery of the mire, and drier conditions making the bog more hospitable for invading scrub species. The surface layer of peat is also susceptible to oxidation and decay if not kept wet and covered by vegetation (Natural England 2010). Prestwick Carr is already in a relatively poor condition despite efforts to restore the water

table by removing drainage. It will be important to continue this restoration to remove additional pressure which will further compromise the adaptive capacity of this habitat.

Moderately vulnerable

4.82 A network of wetlands runs close to the coast, particularly around Druridge Bay, in the northern part of the NCA. These are also very vulnerable to the impacts of sea inundation and saline intrusion, leading to the loss of freshwater habitats and the creation of new, more brackish, habitats, which will attract species more able to cope with saline conditions. However, the opportunities for developing multi-functional wetlands throughout South East Northumberland, but particularly around urban areas, as part of a sustainable drainage system and as a response to increasing flood risk, could make wetlands an increasingly important feature of the area.

4.83 Coastal and flood plain grazing marsh is vulnerable to flooding and inundation by the sea. In addition, the drying out of the marsh during periods of drought causes loss of breeding habitat for wetland birds and of muddy pools for feeding. Periods of drought can lead to the spread of injurious weed species such as creeping thistle and ragwort (Crofts & Jefferson 1999, Benstead *et al*., 1997)

4.84 **Running water:** Reduced summer flows within the river catchments, due to rainfall and drought, could lead to a deterioration in water quality, with diffuse pollution becoming a greater issue. Many smaller water courses throughout the NCA will be vulnerable to droughts and may dry out completely in their upper stretches, while thermal stress could impact on a range of species including salmonids (Environment Agency 2008) and water vole. It is predicted that a rise of 1.8Cis likely to lead to a loss of 52% of suitable climate space for water vole within the North East (AEA 2010).

4.85 **Ponds:** Many of the small subsidence ponds and reed beds are vulnerable to warmer summer temperatures and drought. An increase in the number of intense rainfall events will bring greater risks of eutrophication (enriching with nutrients), and increased pollutant loading from the combined impacts of runoff and drier spells could lead to a degradation of water quality, outbreaks of blue green algae blooms, or drying out completely (Conlan *et al*., 2007). Changes in rainfall and temperature may result in permanent pond communities being replaced by temporary pond species. Ephemeral ponds are valuable in their own right but easier to overlook and such ponds are then more vulnerable to loss from ploughing and filling in if they are thought to be unimportant. Most pond taxa are capable of rapid dispersal (Jeffries 2008b), so if the landscape can be adapted to provide sufficient sites then the communities will be sustainable, even if individual ponds change in character.

4.86 The greatest threat to reedbeds is drying out through decreased rain levels and increased summer temperatures, as well as from drainage of surrounding agricultural land. Sea level rise may also threaten some coastal reed beds in the longer term, such as East Chevington Burn.

4.87 Wet woodland on valley sides or valley bottoms is likely to be affected during severe droughts when the reservoir of seepage water uphill has run dry. During average summers conditions, impacts on this ground water source are likely to be limited. Wet woodland along the shallow channel of Seaton Burn will be at greater risk, as will be some other wet woodlands on flatter ground (around Stobswood, Chevington Moor, Choppington and Woolsington) which are likely to be more seriously affected due to not receiving seepage water from higher ground. Prolonged drought occurring over a number of years is likely to lead to a shift in woodland structure towards mixed deciduous woodland (Barsoum *et al*., 2005). Another indirect impact of climate change on this habitat is future flooding prevention measures and river controls erected in response to increased risk of flooding to communities, but which in turn will lead to significant changes in the woodland structure.

Plate 19 Havannah Local Nature Reserve

4.88 **Lowland heath:** Lowland heath is particularly vulnerable to drought, but also to increased summer temperatures, which may increase competition from other types of vegetation encroaching on areas of bare ground, which will change the community composition. Drier summers will also increase the risk of fires (Peňuelas *et al*., 2004).

4.89 Appendix 1: Table C summarises the results of the vulnerability assessment for species and habitats in South East Northumberland NCA.

Vulnerability of historic environment assets to the impacts of climate change

4.90 Many of the historic sites in South East Northumberland have already experienced and have survived the effects of past climate change. However the resilience of many assets may be further tested by the direct and indirect effects of future climate change.

More vulnerable

4.91 The greatest threat to the historic environment within the South East Northumberland NCA is the threat posed to heritage assets on coast by rising sea level and consequential coastal erosion. Damage to assets caused by adaptation strategies, such as 'managed realignment', which involves breaching sea defences (some of them of considerable antiquity), and construction works for a new sea-wall and/or new drainage systems for the realigned area, may cut through buried archaeological sites. The effects of re-wetting buried sites with saline water is hard to predict, but is likely to be detrimental (Archaeological Research Services 2009).

4.92 The site most at risk in South East Northumberland from coastal erosion, which will be exacerbated by climate change, is the nationally important Mesolithic site of Low Hauxley (Archaeological Research Services, 2009). The Shoreline Management Plan for the Northumberland Coast states that the 'Preferred Strategic Option' for this section of coast is

'Do Nothing' (Royal Haskoning 2009). This clearly has major implications for the survival of any further archaeological remains in the vicinity. There are also likely to be implications for a number of World War II defensive structures along the coast, near Low Hauxley.

Moderately vulnerable

4.93 Much buried archaeology in the area is found within agricultural land, where adaptation of farming practices to climate change may bring about increased working of soils and lead to greater disturbance of archaeological sites, particularly with a move from pasture to arable.

Plate 20 Warkworth riverside and Castle

4.94 Climate change is also going to bring increased challenges to the ongoing maintenance and management of historic buildings and sites. Heavy rainfall will bring increased water penetration, with the potential to damage the internal fabric of buildings, including wall coverings and furnishings. There may be problems incorporating improved drainage in listed buildings because of the restrictions of adapting existing roof coverings and rain water goods or issues of cost. More freeze thaw events could also cause problems linked to stone fracture. Fungal infestations (such as wet and dry rot) and insect attack, including by wood boring insects, may increase in humid conditions and impact on timber structures or vulnerable decorative surfaces (English Heritage 2008). Some conservators in the UK have already noticed an increase in occurrences of webbing clothes moth and carpet beetle (National Trust n.d).

4.95 Milder weather will extend the growing season in historic gardens, but may also limit the future of many traditional garden plants, which are less tolerant to higher summer temperatures and drought (National Trust n.d).

4.96 A detailed assessment of the key individual historic assets with South East Northumberland NCA and their vulnerability to climate change is listed in Appendix 1: Table D.

Vulnerability of areas for recreation to the impacts of climate change

Moderately vulnerable

4.97 Climate change is likely to affect the way people interact with and respond to the landscape. Warmer temperatures and reduced rainfall may increase recreational activity within South East Northumberland both from local residents and visitors, perhaps with an increase in water sports and use of the beaches. At the same time, recreational assets such as the rights of way network and country parks are likely to be more regularly affected by extreme weather events. An increase in flooding events could potentially cause significant damage to routes along riversides or the coast, as well as damage to infrastructure such as footbridges. Increased winter rain will increase damage and erosion to paths, particular those on slopes or with poor drainage, due to increase run-off or puddling. In sites which include mowed grassland, such as formal picnic sites, parks or sports facilities, warmer summer temperatures will increase the growing season for vegetation, while also requiring additional cutting back of vegetation to keep paths open. Periods of heat wave could also be detrimental to some sites, particularly those with mowed grass which are particularly vulnerable to drought.

4.98 The results of the vulnerability assessment for areas for recreation are shown in Appendix 1-Table E.

Part 3 – Potential major changes to landscape character, ecosystem services and biodiversity, and possible adaptation actions

4.99 This section summarises the major changes to character, ecosystem services and biodiversity in the area that could occur as a consequence of cumulative changes to assets deemed to be at least 'moderately vulnerable'. Possible adaptation options are suggested for each set of changes.

4.100 (A full list of potential changes to each individual element of landscape character, ecosystem services biodiversity is included in Appendix 2, and adaptation options for each element in Appendix 3.)

Changes to the coastal and estuarine area

4.101 Habitats, soils, geological and historical features at the coast are likely to be highly vulnerable to rising sea level, tidal flooding and changing sediment patterns. Dynamic systems such as sand dunes, beaches, salt marshes and mud flats are likely to respond to changing conditions, although they may become 'squeezed' between rising sea levels and coastal defences or topographical features. The resulting re-shaping of the coastline is likely to have a significant effect on the overall natural feel of significant stretches of the coast, particularly around the southern end of the coastline. Loss of salt marsh, mudflats and other wetland habitats, which largely shape the character of river estuaries, could have a significant effect on the Blyth estuary. As well as changing the appearance of the coast, a loss of coastal habitats may have an impact on the number and type of bird species which the area can support, potentially affecting coastal breeding areas of European importance.

4.102 Changes in the extent and composition of coastal and estuarine habitats are also likely to alter the ecosystem services they provide. Loss of salt marsh and mudflats could increase the wave energy of the sea and potential for tidal inundation. Combined with coastal erosion this could affect important historic heritage (such as at Low Hauxley) and geology along the coast. It is also likely to see damage to facilities such as beaches and rights of way reducing the coast's attractiveness for recreation. Loss or movement of salt marsh and other intertidal habitats could also result in increased emissions of carbon dioxide to the atmosphere.

Plate 21 Druridge Bay

4.103 Suggested adaptation actions to reduce the vulnerability of coastal and estuarine areas to the impacts of climate change include:

- Proactive development of large scale habitat recreation as part of enhancing the green infrastructure within the NCA, with a focus on wetland creation schemes and supporting the roll-back of coastal habitats, including sand dunes and salt marsh.
- Create space to allow dune roll-back. Opportunities to facilitate this exist in the southern half of Druridge Bay.

- Allow for coastal realignment and adequate space and sediment for shoreline adjustment through strategic coastal process unhampered by coastal defences where possible to allow creation of new habitats (salt marsh and mud flats) and support the development of a naturally evolving coastline.
- In seeking to develop, expand and protect ports and communities around the NCA's main estuaries, seek to minimise coastal squeeze by facilitating roll-back of salt marsh and mudflats to support more formal coastal defences, as part of an integrated approach to future port and coastal developments.
- Conserve protected areas and other high quality habitats, particularly those in poor or degraded condition, to enhance their resilience to climate change impacts.
- Continue to monitor the migratory bird population within the SPA to get a better understanding of changes in numbers, distribution and migratory patterns, as well as seeking a better understanding of the influence of changes to the supporting ecosystem on bird numbers and patterns.
- Begin to reappraise the boundaries of protected sites, particularly in the case of coastal SSSIs, to protect their functionality. Review site boundaries of existing coastal geological SSSIs in order to identify where boundary changes are appropriate for the management of the geological assets in the future due to the impact of coastal erosion.
- Influence the implementation of the Shoreline Management Plan 2 (Northumberland) to support the development of a naturally evolving coastline.
- Monitor and record historic sites which are likely to be lost through a combination of inundation and coastal erosion of dunes. A number of World War II defences, including Hadston Cars anti-aircraft searchlight base, are also likely to be at risk and will need monitoring and recording. Where the loss of geodiversity of historic assets appears inevitable, ensure final recording and rescue of key materials. This action is particularly important for Low Hauxley Shore and the northern end of the Seaton Sluice to Tynemouth SSSIs.

Changes to wetlands

4.104 The network of rivers, streams and wetlands in the NCA is likely to be vulnerable to changing precipitation patterns. Reduction of water levels in wetlands during hotter summers could affect the plant and animal species that live in these areas and could also change the appearance of the landscape. If lowland raised bog habitats and fen peat soils at Prestwick Carr dry out, carbon will be released to the atmosphere, contributing to climate change. Reduced summer flows within river catchments due to reduced rainfall and drought could lead to deterioration in water quality, with diffuse pollution becoming a greater issue.

4.105 Coastal flooding and intrusion of saline water into coastal wetlands, particularly in the less developed northern section of coast around Druridge Bay, could change the current mosaic of pools, reed beds and coastal grazing into an area of more brackish wetland. This would change both the composition of wildlife and the visual appearance of the landscape.

4.106 Increased winter rainfall however, could potentially see an increase in multi-functional wetlands, with benefits for drainage and, as part of a more holistic approach to flood alleviation.

4.107 Suggested adaptation actions to reduce the vulnerability of wetland areas to the impacts of climate change include:

- Increase ecosystem resilience of existing wetland habitats by reducing nutrient and sediment loads and increasing water retention capacity.
- Increase water retention capacity within the catchment to support and enhance existing wetlands, and where possible restore hydrological connectivity between open waters and wetlands.

- Conserve protected areas and other high quality habitats, particularly those in poor or degraded condition, to enhance their resilience to climate change impacts. Adopting adaptive management will be key to this approach, requiring the modification of existing management practices and monitoring the results to ensure the response is effective.
- Monitor high risk species including white clawed crayfish.
- Adopt land management practices to maintain and improve water filtration to reduce the risks of diffuse pollution caused by increased rainfall.
- Adopt management practices to restore ground water levels, to enhance moisture content of fen peat soils around Prestwick Carr and Pegwhistle Fen.
- Seek opportunities for enhancing connectivity through the expansion of ecological networks, maintenance of existing high quality habitats, habitat restoration, and habitat recreation. Such networks need to be created with an understanding of their potential permeability to particular species and based around habitat typologies such as woodland, grasslands, and wetlands.

Changes to wooded areas and parkland and associated built heritage

4.108 Significant losses of individual trees within woodlands in the area could have a radical impact on the overall tree canopy, particularly in an area of historic parkland, such as Blagdon or Seaton Deleval with a high proportion of veteran trees. Losses of individual trees could affect views, particularly in areas of historic parkland such as Seaton Delaval. Overall the changes to woodland will be relatively subtle with a change in tree species to those better able to cope with warmer and drier summers, which will alter the colour and texture of such areas, particularly as this is likely to be combined with the earlier greening of woodland. Wet woodland is particularly vulnerable to climate change and it is likely that this habitat will be reduced in the long term, converting to mixed woodland.

4.109 Suggested adaptation actions to reduce the vulnerability of wooded areas and parkland, and associated built heritage to the impacts of climate change include:

- Adopt a landscape scale approach to extend woodlands and buffering to increase the core area to help support wildlife. Mixed planting should be adopted and management should be improved around existing veteran trees.
- Identify areas within the river catchment where there are opportunity to create additional wet woodland along streams and rivers, which will enhance habitat connectivity and also help reduce run-off and pollution in agricultural landscapes.
- In areas of historic parkland such as Seaton Deleval, prepare site management plans to support key landscape assets such as veteran trees and hedgerows, by reducing existing pressures and supporting traditional management and appropriate stocking levels.
- Erection of sympathetic higher capacity rainwater disposal systems for a number of listed historic buildings within the NCA, not just those associated with parkland, including medieval tower houses and churches, country houses and 19th century farmsteads. On-going maintenance of historic properties as storm damage and increased water penetration will have detrimental impact on the fabric of the building, will need to be increased.
- Conserve protected areas and other high quality habitats, particularly those in poor or degraded condition, to enhance their resilience to climate change impacts. Adopting adaptive management will be key to this approach, requiring modifying existing management practices and monitoring the results to ensure the response is effective.
- Undertake monitoring of pests and diseases and seek to develop an appropriate response.
- Identify opportunities to support renewable energy production, including better management of woodlands for wood fuel.

- Increase the mosaic of habitats in the NCA to enhance heterogeneity, which will allow species to take advantage of local changes in microclimate within habitat types. Responses include planting a mixture of woodland trees and increasing riparian shade through flood plain planting. The creation of transitional habitats between grassland and woodland will also provide increased variability of habitats and microclimates.
- Seek opportunities to enhance connectivity through the expansion of ecological networks, maintenance of existing high quality habitats, habitat restoration, and habitat recreation. Such networks need to be created with an understanding of their potential permeability to particular species and based around habitat typologies such as woodland, grasslands, and wetlands.

Changing species composition

4.110 Shifts in the composition of plant communities in response to climate change appears to be a potential impact across habitats, whether caused by increasing saline intrusion into some of the coastal wetlands to create new more brackish habitats, the impact of prolonged periods of drought on woodland or unimproved grassland species, or loss of habitat as a result of increased coastal erosion. Species are likely to shift their ranges to differing extents, and evidence from past climatic changes indicates that this is likely to cause current assemblages of species to change. Over time some species could disappear from the area, and others will arrive. As the ranges of interacting species overlap less (or in some cases more), or as different species increase or decline in abundance, there could be further consequences. This is already being seen in the movement of sand eels and other invertebrates in the North Sea affecting bird abundance on the North East English coast. Likewise, loss of synchronisation in the food chain is which upsetting the balance between species for example, the warmer weather in spring is encouraging golden plover to breed earlier – nine days earlier than 20 years ago, but the craneflies needed to feed chicks are not hatching any earlier (AEA 2010).

4.111 There is increasing evidence of changes in the timing of natural events correlating with changing temperatures, for example, plants coming into leaf or flower earlier, resulting in the landscape ‘greening’ earlier in the year. This phenomenon is likely to continue.

4.112 Suggested adaptation approach is to:

- Undertake monitoring to identify new species appearing within the NCA. Changing conservation objectives may require a radical shift in current thinking; species not currently considered native to the region may have to be favoured and the attitude towards alien and invasive species may have to change.

Changes to agricultural areas and food production

4.113 While the underlying geomorphology that gives the NCA its low lying character is unlikely to be greatly affected by climate change, land use is likely to change in response to changes in temperature and precipitation, which is likely to have a significant effect on the character of South East Northumberland. Climate change could bring opportunities for food and bio-energy production in the area and farmers may respond by growing more or changing to different crop types. Current soil types would suggest that warmer temperatures, with reduced rainfall, will lead to an increasing move towards arable and root crops, which may increase the need for water, leading to greater use of irrigation systems. Such a move could have a very significant impact on habitats such as lowland meadows, hedgerows and coastal and flood plain grazing marsh. A switch from pasture to arable will increase soil disturbance and will impact on carbon stores. New crops, or the removal of field margins and existing hedgerows to facilitate the intensification of agriculture, with a consequent change in growing seasons, increase in soil erosion, compaction or water-logging of soils will alter the landscape character and the ‘sense of place’ it provides.

4.114 It is likely that factors other than climate change may impact on fish stocks and the overall viability of local fishing fleets, certainly in the short term. Warmer temperatures will have a negative impact on salmonid populations which are vulnerable to thermal stress, and impact on the local game fishing industry (Environment Agency 2008).

Plate 22 The fishing fleet at Amble harbour

4.115 Suggested adaptation actions to reduce the vulnerability of agricultural areas to the impacts of climate change include:

- Work with landowners and land managers to maintain and enhance landscape assets, including hedgerows, field patterns, wet ditches and traditional buildings.
- Adopt sustainable management of soil and vegetation through agri-environmental schemes to protect buried sites (including a large number of Neolithic, Bronze Age, and Romano-British sites) likely to be damaged through changes in land use, for example, a move towards arable.
- Seek to reduce sources of harm and pressure on sites not linked to climate change. The legacy of past sources of pressure on the natural environment, such as agricultural diffuse pollution, water abstraction, or development leading to habitat fragmentation, may restrict the ability of habitats to respond effectively to climate change.
- Support farmers through information and advice on diversification into new crops and breeds more resilient to emerging climate conditions, as part of an overall approach to encourage mixed sustainable farming which will protect the natural assets of South East Northumberland.

- Encourage land management practices that reduce negative impacts on soil structure, especially on those soils with a high proportion of boulder clay and vulnerable to compaction and puddling. This may require a change of cropping and stocking patterns.
- Adopt soil moisture conservation measures, particularly in areas with a higher sand content around the southern tributaries of the river Coquet which are likely to be more drought prone.
- Encourage the adoption of measures to reduce soil erosion caused by both water and wind, for example, buffer strips, increases in organic matter, increases in vegetative cover.
- Encourage riparian planting to increase shade and reduce thermal stress to fish.
- Address the issues climate change within the Management Plan for the Marine Protection Area, with particular reference to fish stocks.

Changes to recreation opportunities and facilities

4.116 Possible changes in the way that people use and enjoy the natural environment in the South East Northumberland Coastal Plain, particularly in the summer, are likely to enhance people's quality of life, but may put pressure on recreation facilities such as footpaths and country parks. Recreation facilities could also be directly affected by changes in climate, such as flooding, drying out of grassed areas, and erosion. The challenge will be to maximise the opportunities for increased access to and enjoyment of the natural environment while maintaining and enhancing the necessary facilities.

4.117 Suggested adaptation actions to reduce the vulnerability of recreation to the impacts of climate change and maximise opportunities include:

- Undertake a more detailed ecosystem services assessment for South East Northumberland to better understand the functionality of existing green space and green infrastructure.
- Increase awareness that a combination of extreme weather events and heavy rainfall will increase maintenance requirements on the rights of way network within the NCA. Improvements to path surfaces, replacement of footbridges and realignment of routes are likely to be required, placing additional pressure on local authority right of way budgets. Opportunities should be sought to improve drainage on existing rights of way, especially on popular routes and routes close to main centres of population, as well as to incorporate appropriate drainage and robust surfacing on new routes developed as part of a green infrastructure strategy.
- Longer growing seasons will also increase maintenance requirements on rights of way and areas of pubic green space. However, risk of drought may require greater use of drought resistant grass mixes for amenity areas.
- Raise public awareness of health and fire risks (especially in areas of open grassland or woodland) associated with periods of heat wave and promote preventative measures they can take to protect themselves and reduce outbreaks of wildfire.
- Development of new recreational routes to take pressure off those routes at risk from erosion, with a particular emphasis on routes close to settlements.
- Incorporate climate change considerations into visitor management strategies for key recreation sites.

Increased risks of extreme flood events

4.118 The topography of this area means that significant areas of the NCA are likely to be at continued or increased risk from both fluvial and coastal flooding as a result of increased winter rainfall and more intense rain storms, with areas around Blyth, Felton and Newbiggin at particular risk, alongside Druridge Bay.

4.119 Urban greenspace, trees and river floodplains which store flood water could play an increasingly important role in protecting urban areas from flooding, could also have beneficial effects for biodiversity and landscape character, and could help to moderate air temperatures within urban areas. Intense rain storms may affect the restoration of old deep cast mines as it can cause subsidence and landslides in areas of unstable ground. There remains an on-going risk of water pollution from former coal mining activity, if current monitoring and pumping regimes are not maintained.

4.120 South East Northumberland NCA is already undergoing quite radical transformation, with major plans for economic regeneration and expansion in housing development through two Growth Points. A direct consequence of climate change will be the increasing need to protect the area's key social and economic assets from flooding. There are proposals with the Shoreline Management Plan to enhance sea defences around critical infrastructure such as Lynemouth power station and a number of coastal communities. Other communities such as Blyth are likely to see measures to protect them from fluvial flooding as well as tidal inundation. As authorities become aware of the risks presented to critical infrastructure by climate change, the area is also likely to see an increase in the use of sustainable drainage systems and land specifically allocated for this purpose. Changes around the edges of communities, with new areas of woodland or wetlands, may enhance the intrinsic aesthetic value of local landscapes and provide new opportunities for recreation.

Plate 23 The Alcan Aluminium Smelting Plant, near Ashington

4.121 Suggested adaptation actions to reduce the vulnerability to flooding:

- Build climate change into the spatial planning agenda. There are real opportunities to build climate change adaptation into the local planning framework. Green infrastructure has a particularly important role to play in supporting community resilience while delivering wider biodiversity and landscape benefits, and needs to be central to the development of the South Northumberland Growth Point. As part of this approach, the existing or potential

functionality of brown field sites should be considered in terms of their ability to support climate change adaptation while also enhancing biodiversity within the NCA.

- Ensure surface mine restoration is undertaken to support climate change adaptation. There are some significant opportunities emerging over the next few years as a number of opencast sites end production and move towards a restoration phase. Such sites could offer opportunities for water storage, water treatment and provide important biodiversity and amenity value. Such opportunities should be sought for the current new round of restoration schemes and be built into future planning consent for new open cast sites. Some sites could be used to compensate loss of farm land on the coast.
- Work to encourage the adoption of softer, more sustainable adaptation measures to increase the resilience of key infrastructure such as roads and bridges, including measures such as sustainable drainage systems, or use of strategic planting.
- Discourage floodplain developments and raise awareness of the implications of these.
- Influence flood defence schemes to facilitate natural river processes, in particular the function of river channels and flood plains to relieve peak flows in suitable areas of the catchment.
- Encourage an increase in urban trees to provide summer shade, but also as part of flood alleviation measures.
- Increase the development of sustainable urban drainage systems able to intercept and store water, including retro-fitting in urban areas with existing surface water flooding problems.
- Undertake a more detailed ecosystem services assessment for South East Northumberland to better understand the functionality of existing green space and green infrastructure.
- Continue pumping operations at Blyth and Whittle and ongoing monitored groundwater rebound, for example, at Lynemouth and Ellington, to minimise the risk of coal mine water outbreak.

Strategic actions

4.122 There are a number of strategic actions that could provide an over-arching framework to delivering adaptation within the South East Northumberland Coastal Plan, and support the specific actions above.

4.123 There needs to be a focus on **catchment scale adaptation** beyond the boundary of the NCA, by implementing measures in the head waters of the three main rivers within South East Northumberland to support integrated water management and reduce flood risks. Decisions need to be made at a catchment level on areas where it might be beneficial to allow flooding, and on the implications of current and future gravel extraction licences upstream. Further work is required to look at opportunities for capturing peak river flows in the floodplains so that water can be stored and used for water supply at times of peak demand and low rainfall.

4.124 **Build climate change into spatial planning agenda** particularly in developing longer term plans for community resilience and sustainable adaptation of key infrastructure. Opportunities exist to incorporate policies at landscape scale for coastal realignment, multi-functional green infrastructure and sustainable drainage systems to help address some of the impacts of climate change, while enhancing and protecting ecosystem services.

4.125 When developing contingency plans for key conservation sites, **learn and apply lessons from other extreme weather events** such as floods or heat waves and their impact on particular habitats or species. We can also look to other locations with similar climates to that which England may experience in future to identify potential threats.

4.126 Undertake **monitoring of pests and diseases** and seek to identify potential problems or impact on habitats or individual species that will require a managed response.

4.127 **Development of multi-functional wetlands.** There are opportunities to develop the network of ponds and wetlands created through mining subsidence to provide water storage, restoration of flood plain function, water treatment, as well as biodiversity and amenity value. Coastal erosion and rising sea level is likely to lead to existing freshwater wetlands becoming increasingly brackish, which will, through positive management, lead to the creation of new habitats.

4.128 There is a need to increase **public awareness and understanding** of the potential impacts of climate change. Decision-makers, and landowners and farmers have a key role in developing appropriate policies and taking action.

4.129 **Monitoring change** and the effectiveness of adaptation measures is critical to an adaptive management approach. Further work is needed to map and research the vulnerability of natural assets to climate change, especially biodiversity and the historic, as knowledge is still incomplete. Long term data sets and studies assessing environmental change will also be very important to inform adaptive management.

Plate 24 Bondi Carrs beach

5 Discussion

Climate change and the vulnerability of landscape character, ecosystem services and biodiversity

5.1 The results of this study highlight that climate change poses a number of risks to the valued aspects of landscape character, ecosystem services and biodiversity in the South East Northumberland NCA. Some of the most vulnerable elements of landscape character and ecosystem services identified in this study are linked to the coastal strip and major river estuaries, with significant potential impacts on the geodiversity, biodiversity and historic environment in this area. While this is an area which already experiences coastal erosion, climate change will further exacerbate these effects, with sea level rise, more frequent flood and storm surge events, and acceleration of the recession of sea cliffs and beaches. By contrast, the flat coastal plain that makes up most of this character area is likely to see relatively minor direct impacts from climate change at the broad scale, and impacts are likely to be quite subtle and emerge gradually over time.

5.2 The assessment of vulnerability is not an exact science. Rather, this study was designed to highlight potential risks of key natural assets and services to help inform and shape potential responses. The assessment of vulnerability was based on a number of factors, including the intrinsic adaptive capacity of an asset to respond to climate change and the potential for managed intervention to enhance adaptive capacity. Some assets, particularly some in-situ, non-living features such as historic, assets have little adaptive capacity by virtue of the fact that they cannot move away from the threats posed by climate change and there is sometimes little we can do to reduce their exposure. Other assets are much more resilient to climate change if an appropriate form of management is applied, for instance many soils can become more resilient to desiccation if managed to optimise soil moisture content, for example by increasing organic matter. By approaching the assessment of vulnerability in this way, the study also provides a spatial analysis of areas likely to be at greater risk from the impacts of climate change, which in the case of South East Northumberland include the coastal strip, the flood plains alongside the three main rivers and their tributaries, and the areas of lowland raised bog and lowland heath around Prestwick Carr and Havannah.

5.3 It is important to note to that although the word ‘vulnerability’, which has negative connotations, is used throughout this report, climate change may also present some opportunities for the natural environment, such as the creation of new habitats and the introduction of new species.

Adaptive response to climate change - effects on landscape character, ecosystem services and biodiversity

5.4 This study identified a number of both strategic and more specific actions to increase the resilience of the natural environment within the South Northumberland NCA to climate change. These actions were then assessed and, wherever possible improved, by screening each adaptive action against its contribution to groupings of assets or services identified in the study, such as landscapes or access and recreation. In addition, an assessment was made of whether an adaptation could be considered a ‘win-win’, ‘no regrets’ or ‘low regrets action.

5.5 What was clear from this assessment was that many of the actions proposed were ‘win- win’ or ‘low regrets’, and would have multiple benefits for a range of asset types. For example, adopting a sensitive restoration of open cast mining sites could not only make a positive contribution to landscape quality, local amenity value (walking, fishing, water sports, nature watching) and biodiversity, but also support climate change adaptation by providing biodiversity resilience through creating new habitat mosaics and strengthening ecological

networks at a landscape scale. It will also contribute to ecosystem service delivery by offering opportunities for flood water storage and management, as well as improvement in water quality through the use of reed beds for treatment.

5.6 Some adaptive responses are not only multifunctional, but may play an important role in addressing the causes of climate change. For instance, protection of salt marsh and measures to enable 'roll-back' will not only reduce the impact of coastal erosion, but will also play a role in sequestering carbon dioxide.

Priority areas for adaptation

5.7 The above responses provide an overall integrated strategic approach for increasing the resilience of the natural environment in South East Northumberland to climate change. It is hoped that this will help to inform adaptation decisions by local communities.

5.8 Demonstration projects to pilot and test approaches to adaptation would be useful to look at how responses to climate change might work on the ground, at a smaller spatial resolution than NCA level. Potential areas for such pilots include:

- Druridge Bay Landscape Partnership Area (to include Coquet Island).
- Prestwick Carr, Havannah Nature Reserve and Big Waters.
- Seaton Deleval Estate.
- Blyth and Wansbeck Estuaries.

5.9 Other pressures and constraints likely to impact on the resilience of the natural environment to climate change in South East Northumberland.

5.10 While climate change is likely to have a significant influence on the natural environment of South east Northumberland, there are many other pressures and constraints on the natural environment that are having an impact now, and will continue to do in the future. These include:

- habitat loss and fragmentation (from changes in management, intensification of agriculture, development, drainage and abstraction);
- invasive/non-native species;
- human disturbance;
- pollution (land, air and water);
- erosion (particularly at the coast but also impacting on terrestrial soils and geology);
- water abstraction;
- drainage or inappropriate river management;
- harvesting and collection of species (including hunting); and
- natural disasters (such as droughts, floods and storms).

5.11 A key mechanism for developing the adaptive capacity of natural assets and ecosystem services will be to look at how existing pressures can be reduced, so that habitats and other natural assets are in the optimum condition to respond and adjust to the impacts of climate change.

5.12 Alongside existing pressures, there are number of indirect impacts of climate change on the natural environment which result from the way society is likely to respond to the challenges presented by climate change. Key drivers likely to impact on South East Northumberland natural environment include:

- **Changing agriculture:** Climate change, changes in global population and pressures on natural resources indicate that agriculture in the UK will need to produce food more

sustainably, increasing productivity while also reducing environmental impacts. The multiple roles of agriculture in providing ecosystem services such as climate change mitigation, flood risk management, biodiversity and recreation is increasingly recognised, particularly the capacity of critical agricultural assets such as soil, water resources and drainage (Government Office for Science 2010). In South East Northumberland, it is likely that there will be an intensification of production, with a move towards arable for fodder or energy crops, such as wheat or oilseeds (ADAS 2010). The renewable energy plants in the Tees Valley and those proposed for Blyth will require millions of tonnes of wheat for the production of biofuel. In the medium term, climate change scenarios for 2030 indicate that while unlikely to enhance the quality of wheat grown in the North East to top milling grades, this wheat will meet the needs of the renewable energy sector. A by-product of biofuel production is distiller's grain, which could be utilised as a quality livestock feed to support a number of intensive beef and/or dairy units (ADAS 2010). Such a move would not only have an impact on the character of the landscape, altering the colours, textures and field patterns, but it is likely to impact significantly on biodiversity potential, leading to fragmentation of ecological networks and pressure on water resources.

- **Renewable energy generation:** The desire to increase the proportion of energy generated by renewables to help meet the UK's carbon targets means that the infrastructure associated with renewable energy is likely to be an increasing feature in many landscapes; the South East Northumberland NCA has been seen as an area where there is significant opportunity to develop renewable energy. Alongside the growth of energy crops, which also include wood fuel, South East Northumberland has also been identified as an area for the development of onshore and offshore wind generation. Blyth is already establishing itself as a major test centre for offshore wind turbines, and a range of wind farm proposals are currently seeking planning permission. Wind turbines are becoming an increasingly common feature of South East Northumberland, the relatively flat topography of the coastal plain will mean that the cumulative impact of these wind farm proposals, if constructed, could have a significant impact on the overall character of the landscape.
- **Development and economic regeneration:** In South East Northumberland there is an aspiration to link the economic regeneration of deprived communities to the opportunity to develop low carbon industries. The housing expansion planned around the two growth points within the NCA will meet the new zero emission requirements, while efforts continue to attract new industries, such as the construction of electric vehicles. Many of the areas identified for such development are on existing brownfield sites, dotted around the fringes of communities such as Blyth and Ashington. While many of these sites are valuable for local biodiversity, many are also performing an important but often unrecognised role in flood alleviation and winter water storage. There could be significant gains for South East Northumberland if development proposals take full account of the current functionality of such sites to ensure that the push towards a low carbon economy goes hand in hand with measures to increase and enhance the adaptive capacity of these areas.
- **Protection of communities and critical infrastructure from the impacts of climate change:** As businesses and local authorities become aware of the increased risks presented by climate change to critical infrastructure and communities, there is likely to bean increase in interventions which seek to reduce impacts, such as the strengthening of coastal defences or an increase in flood defence measures. There is no doubt that hard engineering solutions will impact negatively on the natural assets of the NCA; enhanced coastal defences will lead to coastal squeeze and loss of habitats, and flood embankments will impact on natural river process, leading to canalisation and loss of riparian habitats. However, there are many low cost and effective solutions to climate change impacts which can both protect key economic and social assets but also enhance and protect the natural environment. In South East Northumberland there are major opportunities to develop the role of green infrastructure to support the resilience of local communities, for example the use of sustainable drainage systems, multifunctional wetlands, and the use of tree planting to reduce the impacts of urban heat islands.

Limitations of the study

5.13 While this study serves as a useful starting point to pursuing adaptive responses to climate change in South East Northumberland, a number of limitations should be recognised:

1) The first limitation is around problems of scale. The South East Northumberland NCA covers 436 km^2 and this study provides landscape specific responses that provide general actions for increasing resilience for a wide range of assets within this area. However, some things need to be considered at much smaller scales, and the study was not designed to develop detailed implementation plans for individual sites. More detailed analysis will be required at a much smaller resolution within the areas that this study has assessed as being relatively vulnerable, to assess climate change risks and the potential interactions between proposed responses on a site by site basis.
2) Likewise, some things need to be considered and managed at a scale bigger than this NCA. This applies particularly to hydrology and river systems, which clearly overlap NCA boundaries. While many actions, such as buffering watercourses and re-naturalising catchments, can occur within the Character Area, problems arise when adaptation requires action upstream or downstream of the stretch of river within the Character Area. In particular, reducing water input during peak flows and ensuring flow is moderated over a longer period relies on working at a catchment scale, across a number of NCAs. Further work using a similar method to the one used here but at a larger scale may be required in other parts of key catchments in order to provide a comprehensive evidence base for action at this scale. Similarly, species movements will occur across NCA boundaries, and conservation management should take into consideration possible movements both from and into neighbouring areas.
3) A further limitation of this study arises from its reliance on the opinions of experts and workshop attendees to produce qualitative assessments of vulnerability. While a good range of people have contributed the study, more knowledge exists for some aspects of the natural environment than others. While this study has also tried to supplement professional opinion with published information wherever possible, there are likely to be assets in the Character Area that are less well understood in terms of their vulnerability to climate change than, for example, key iconic and extensively studied assets such as sand dunes and coastal birds. Further ongoing research will help fill these gaps and help develop our understanding not only of the vulnerability of these assets to climate change but also their wider inter-play within the natural environment. Appendix 5 shows the organisations that attended workshops and those organisations that inputted through correspondence.

Conclusion

5.14 The study provides a systematic assessment of the valued assets and functions of the natural environment of the South East Northumberland Coastal Plain. By adopting an integrated approach to a specific location, this study and its sister studies have been able to look beyond the broad principles for adaptation for biodiversity outlined in Conserving biodiversity in a changing climate (Hopkins *et al.,* 2007) to develop more specific adaptation proposals linked to a local landscape and the wider benefits and services it delivers.

5.15 It is hoped that the findings of this study into climate change vulnerabilities and adaptation should provide a useful foundation for both further assessment of vulnerability in this and neighbouring character areas, and for the development of adaptation strategies in the South East Northumberland NCA. We hope the study will provide a useful resource to help inform future planning and policy development by public, voluntary and private organisations across South East Northumberland, and help support future partnership working, as many of the proposed adaptation measures cut across responsibilities and local authority boundaries.

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Appendix 1 Vulnerability tables of key landscape assets

Table A Vulnerability of key geological assets within South East Northumberland NCA to Climate Change

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Coastal cliffs and foreshore (3 SSSIs)	Intense rainfall Drier summers Sea level rise	Sensitive to rain and high winds leading to storm surges. Erosion of softer rock impacting on shales, mudstones, siltstones and sandstone outcrops. Accelerated mass movement in susceptible cliffs as a result of intense rainfall. Erosion of assets by the sea due to tidal flooding.	Management: Increasing pressure to defend such coasts through a variety of engineering techniques particularly in areas of economic and social value leading to loss of adaptive capacity.	**More vulnerable**	(Prosser, Murphy and Larwood, 2006). (Dickson, M.W., Walkden, M.J.A. & Hall, J.W. 2007). (Royal Haskoning 2009).
Sand dunes		Discussed under soils and biodiversity			-
Peat deposits		Discussed under soils and biodiversity			-

Table B Vulnerability of soil assets within South East Northumberland NCA to Climate Change

Asset (numbers relate to soil type (27 in total) as identified in Soilscapes profile)	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes
18. Slowly permeable seasonally wet slightly wet but base-rich loamy soils	Wetter winters Intense rainfall	Sensitive to waterlogging and greater risk of compaction. Also sensitive to diffuse pollution due to increased run-off.	Management: Clay soils will be more difficult to manage because of their high shrink-swell potential. Land management techniques can increase adaptive capacity.	**Less vulnerable**	Soilscapes are a broad grouping of many individual soil types with their own individual characteristics.
17. Slowly permeable seasonally wet acid loamy clayey soils	Wetter winters Intense rainfall	Sensitive to waterlogging and greater risk of compaction. Also sensitive to diffuse pollution due to increased run-off.	Management: Clay soils will be more difficult to manage because of their high shrink-swell potential. Land management techniques can increase adaptive capacity.	**Less vulnerable**	
24. Restored soils mostly from quarry and open cast spoil	Wetter winters Drier summers Intense rainfall	Sensitive to increased soil wetness and compaction leading to accelerated run-off. Risk to engineered structures based on clay caps which will be at risk of cracking due to drying.	Environmental: Most are likely to have soil structural problems due to soil movement, storage, and handling. Management: There will be a range of problems which will need to be resolved on a site by site basis.	**Moderately vulnerable**	These soils are a variable group.
6. Free draining slightly acid loamy soils (east of Fenton)	Drier summers Intense rainfall	Sensitive to drying out and soil erosion.	Environmental: Soil is already drought prone. Soils on steeply or moderately sloping land have lowest adaptive capacity.	**Less vulnerable**	
8. Slightly acid loamy clayey soils with impeded drainage	Wetter winters	Sensitive to waterlogging and greater risk of compaction.	Management: Clay soils will be more difficult to manage because of their high shrink-swell potential. Land management techniques can increase adaptive capacity.	**Less vulnerable**	

Table continued…

Asset (numbers relate to soil type (27 in total) as identified in Soilscapes profile)	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes
4. Sand dune soils (Druridge Bay, Blyth Links, Lynemouth Bay, Cambois)	Sea level rise	Sensitive to loss of land through flooding by the sea or increase in saline conditions.	Environmental: Movement of sand dunes is a natural phenomena. Some opportunities to encourage sand dune roll back, but limited due to coastal squeeze and topographical issues.	**More vulnerable**	
20. Loamy and clayey floodplain soils with naturally high ground water (found along river Blyth valley west of A1)	Wetter winters Intense rainfall	Sensitive to increased flood risk with increasing risk of deposition of sediment from flood waters. Also sensitive to erosion.	Environmental: Cultivated or bare soils have lower adaptive capacity.	**Moderately vulnerable**	
21. Loamy soils with naturally high ground water (S of Coquet Estuary)	Sea level rise	Sensitive to loss of some land through flooding by the sea.	Environmental: Limited opportunities to mitigate against sea inundation.	**More vulnerable**	
27. Fen Peat soils (Preswick Carr)	Hotter summers Drier summers Intense rainfall	Sensitive to drying through a reduction in groundwater. Can lead to loss of peat (carbon stores). Also sensitive to increased soil loss through blowing.	Environmental: Ground water levels are already compromised due to drainage leading to low adaptive capacity.	**More vulnerable**	

Table C Vulnerability of BAP Habitats found within South East Northumberland NCA to Climate Change

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Coastal sand dune	Sea level rise Higher annual average temperatures Drier summers Wetter winters	Sensitive to erosion caused by sea level rise and increased wave energy leading to beach lowering. Change in shoreline position and dune system will impact on sand stability, dune mobility and roundwater levels affecting ecology. Species assemblages will change affecting bird and mammal food sources. Also sensitive to changes in dune hydrology as a result of changes in seasonal rainfall. This could affect dune slacks and vegetation patterns. Sensitive to fire risk.	Environmetnal: There may be some capacity for adaptation as the coastal zone is naturally dynamic- change is not always linear. Creating space to allow dunes to migrate land ward is limited along the coast causing coastal squeeze where dunes are backed by hard structures, for example, Blyth Links or topography.	**More vulnerable**	(Jacobs 2009). (Pye K & Saye S 2005). (Austin *et al*., 2001). (Mitchell *et al*., 2007).
Maritime cliffs and slope	Sea level rise Wetter winters Hotter sumers	Sensitive to erosion caused by increased rainfall which coul result in more rapid retreat of coastal soft cliffs. Sensitive to changes in water balance will impact on invertabrae and wider species assemblages. Sensitive to invasive plant species which may affect composition of cliff vegetation communities.	Environmental: Adaptvie capcity reduced due to coastal squeeze. However, as the coastal zone is dynamic, there might be some natural adptive capacity. Cliff recession is episodic and change is not always linear.	**More vulnerable**	
Rocky shore and island	Hotter summers Higher annual average temperatures	Sensitive to higher sea and and temperatures which will impact on food chain, potentially lading to a significant impact on the bird population.	Environmental: Warmer temperatures already are having an impact on the ecosystem of this habitat.	**More vulnerable**	(Brereton *et al.,* 2010).

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Salt marsh and mud flats (estuaries)	Sea level rise	Sensitive to tidal flooding as a reuslt of rising sea levels and increased wave energy from higher storm surges. Sensitive to accelerated erosion of seaward marsh edge. Could result in loss of base of estuarine food webs and the loss of loafing and roosting site for key bird species. Sensitive to changes in internal creek patterns which could affect internal erosion and sediment transport within the saltmarsh.	Environmental: Salt marsh is likely to experience coastal squeeze when it is trapped between rising sea levels and fixed defences reducing adaptive capacity.	**More vulnerable**	(BRANCH partnership 2007). (Mitchell *et al*., 2007). (Austin, Rehfisch, Viles & Barry *in*: Harrison, Berry & Dawson 2001). Burd (1992).
Saline lagoon	Hotter summers Sea level rise	Sensitive to increased tidal flooding leading to barrier breach and loss of lagoon. Sensitive to increased water temperatures leading to algal bloom. Sensitive to increased salinity impacting on current ecosystem.	Management: Saline lagoons need to be regarded as part of a wider functioning system and loss of a lagoon need to be seen with the overall context of natural coastal processes.	**More vulnerable**	(BRANCH partnership 2007). (Mitchell *et al*., 2007). (Reach 2003).
Coastal and flood plain grazing marsh	Sea level rise Drier summers Hotter summers Wetter winters	Sensitive to flooding and inundation by the sea and saline intrusion leading to loss of fresh water marsh species especially wading birds. Sensitive to periods of drought leading to drying out and loss of habitat for breeding and feeding for wetland birds. Unpredictable inundation of floodplain grazing marsh with increased silt loading.	Management: This habitat could play an important role in flood management and opportunities for habitat creation could compensate for habitat losses causes by sea innundation.	**Moderately vulnerable**	Much depends on management of rivers and floodplain.

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Running water	Hotter summers Drier summers Wetter witners Intense rainfall	Sensitive to drought leading to low flows, poorer water quality and reduced habitat volume. Sensitive to higher temperatures which lead to thermal stress. Increased runoff leading to enhanced nutrient and sediment delivery causing eutrophication and also increased hydraulic scour of rivers. Sensitive to flashier flow regimes which destablise existing riverine sediments and river banks.	Environmental: Species near the southern limit of the temperature tolerance have low adaptive capacity. Mangement: Increased water demand in extreme dry periods exacerbate ecological problems of low river flows and reduce adaptive capacity. Increased pressure for flood defences may lead to less dynamic river systems and impact on proteced species.	**Moderately vulnerable**	(O'Connell *et al*., 2004) (Mainstone C.P 2000). (Conlan *et al*., 2007).
Shallow lakes and pond	Hotter summers Drier summers Intense rainfall Sea level rise	Sensitive to eutrophic symptoms where nutrient loads are high. Greater frequency and duration of toxic algae blooms and increased risk of invasivive plants. Sensitive to drying out which leads to loss of fish spawning habitat. Changes in sedimentation can also affect these. Sensitive to loss of connectivity with other freshwater habitats, for example, ditches Senstive to saline incursions leading to increasingly brackish habitats.	Environmental: Adaptive capacity dependent on water rentention capacity within catchment and hydrological connectivity between open waters and wetlands	**Moderately vulnerable**	(McKee *et al*., 2002). (Balayla & Moss 2002). (Jeffries 2005).
Reedbeds and fens	Drier summers Hotter sumemrs Intense rainfall Sea level rise	Senstive to drought which leads to drying out of the reedbed and reduction in water quality due to less dillution of pollutants. While reedbed may survive innundation, bittern habitat is likely to be more sensitive. Reedbeds close to the coast are sensitive to tidal flooding and loss from natural coastal realignment.	Management: While there are risks to individual sites, there is significant opportunity to improve adaptive capacity within the NCA through habitat creation linked to storage and use of future winter rainfall.	**Moderately vulnerable**	

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Parkland and woodland pasture	Drier summers	Sensitive to drought leading to loss of specialist associated species, for example, fungi, saproxylic invertebrates. Sensitive to fire especially where tall grass heath present. Enhanced risk of disease and loss rates of veteran trees.	Environmental: Habitats on south facing slopes have lower adaptive capcity than those on sheltered valley sides. Veteran trees have lower adaptive capacity than younger trees.	**Less vulnerable**	(Harding & Alexander 1993). (Read 2000). (Bullock, Fretwell & Wainwright 1994). (Rodwell & Dring 2001).
Wet woodland	Drier summers	Sensitive to severe drought in summer when the reservoir of seepage water runs dry. Could lead to significant vegetation change towards mixed decidious woodland.	Environmental: Woodland along shallow channels, for example, Seaton Burn, have low adaptive capacity. Availablility of water, primaily groundwater, for maintenace of habitat contributes to adaptive capacity.	**Moderately vulnerable**	(Rodwell & Dring 2001). (Barsoum, Anderson, Broadmeadow, Bishop & Nisbet 2005).
Lowland meadows (unimproved grassland)	Hotter summers Drier summers Warmer winters Wetter winters	Sensitive to drought and indirect impact of changes in plant phenology and species mix towards stress-tolerant species (i.e deep rooted). Sensitve to fire. Sensitive to more frequent flooding which may change species composition.	Management: A flexible approach to management will increase adative capacity. Main vulnerability is indirect impact of increased intensification of farming.	**Less vulnerable**	(Dunnet *et al*., 1998). (Gowing 2004). (Gowing *et al*., 2002). (Hopkins *et al*., 2007). (Rodwell *et al*., 2007). (Walsmsley *et al*., 2007). (Jefferson & Pinches 2009). (Prestonetal 2002).
Hedgerows	Drier summers Higher annual average temperatures Wetter winters	Sensitive to drought and indirectly to intensification of farming leading to their removal. Wooded species sensitive to to prolonged flooding in growing season.	Management: Adaptive capacity is reduced if an indirect response to climate change is intensification of agriculture leading to hedgerow removal. Opportunity to manage through agri-environment schemes.	**Less vulnerable**	(Broadmeadow *et al.,* 2005). (Broadmeadow 2005). (Broadmeadow 2002). (Pollard *et al.,* 2002). (Viaud *et al.,* 2002).

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Lowland raised bog	Drier Summers Hotter summers Wetter winters	Sensitive to higher temperatures combined with reduced summer rainfall which will increase evo-transpiration, lowering water table. Surface layer of peat is sensitive to oxidation and decay if allowed to dry out. Risk of flooding may lead to bog burst.	Environmental: As ombrotrophic systems, bogs cannot be 'topped up' from water elsewhere if summer rainfall is deficient, so have low adaptive capacity. Management: Summer water deficit could compromise attempts at restoration.	**More vulnerable**	As ombrotrophic systems, bogs cannot be 'topped up' from water elsewhere if summer rainfall is deficient, so may be particulalry vulnerable to climate change.
Lowland heath	Hotter summers Drier summers Wetter winters	Above ground biomass growth sensitive to warmer conditions and longer growing season. Slight increased flowering and acceleration of spring growth. Sensitive to change in soil chemistry due to a decrease in litter fall. Possible impacts on soil fauna. Decreased seed bank of heather. Sensitive to wild fires – can destroy heather seed bank. Sensitive to greater run-off in heavy rain which will increase spring leaching of nitrate.	Environmental: Young heather stands likely to have greater adaptive capacity.	**Moderately vulnerable**	(Peňelas *et al*., 2004). (Gorissen *et al*., 2004). (Emmett *et al*., 2004). (Schmidt *et al*., 2004). (Britton *et al*., 2003). (Pakerman *et al*., 1999).

Table D Vulnerability of South East Northumberland NCA's historic environment to climate change, based on a sample of sites by period and typology

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Low Hauxley Mesolithic Forest Low Hauxley Shore Peat formations Low Hauxley Mesolithic Midden Mesolithic flint sites (for example, Newbiggin Point and Lyne Hill)	Sea level rise Intense rainfall	Sensitive to inundation by the sea and erosion of dunes and beach. This would lead to exposure of artefacts. Sensitive to action of water which may damage assets.	Environmental: Limited ability to adapt due to in-situ and finite nature of asset. Management: Sites require detailed recording.	**More vulnerable**	(Lancaster University Archaeological unit 1995). (Archaeological Research Services 2009).
Neolithic cup and ring marked rocks (eg Jack's Rock, Morwick) Neolithic find sites (for example, Warkworth Moor and flint site at Wheatridge Park)	Drier summers Wetter winters	Sensitive to changes in soil moisture content which may lead to erosion of protective soils and vegetation, leading to erosion of surfaces. Sensitive to changes in agricultural practice as an indirect consequence of climate change, could lead to increase disturbance of sites.	Management: Low adaptive capacity but recording all known buried archaeology will support future management.	**Moderately vulnerable**	(English Heritage 2008).
Low Hauxley Bronze Age Cairns	Sea level rise	Sensitive to inundation by the sea leading to erosion of dunes and beach. Leads to exposure of artefacts. Sensitive to action of water which may damage assets.	Environmental: Limited opportunity to protect site.	**More vulnerable**	(Archaeological Research Services 2009).
Bronze Age find sites (for example, Broomhill pottery and Newbiggin Moor spearheads) Bronze Age cists (for example, Mill Field, Bedlington)	Drier summers Wetter winters	Sensitive to changes in soil moisture content which may lead to erosion of protective soils and vegetation, leading to erosion of surfaces. Sensitive to changes to agricultural practice as an indirect consequence of climate change which could lead to increase disturbance of sites.	Management: Low adaptive capacity but recording all known buried archaeology will support future management.	**Moderately vulnerable**	(English Heritage 2008).

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Hartley West Iron age farmstead (rectangular crop markings) Whinney Hill Farm Iron Age cropmark complex (Bedlington) Pegswood Moor Farm Iron Age and Romano-British settlement Hartley Iron Age/Roman period farmstead Cropmarks and ditches	Drier summers Wetter winters	Sensitive to changes in soil moisture content. Change in soil pH and changes in natural vegetation. Sensitive to disturbance of sites due to changes in agricultural practice.	Management: Low adaptive capacity but recording all known buried archaeology will support future management.	**Moderately vulnerable**	(English Heritage 2008).
Church of St Mary, Woodhorn – pre- 11th Century and later Warkworth Castle – 11th Centrury motte and bailey. 12 & 13th C stone fortifications Bothal castle 12th C castle restored in 19th C as country house Low Chibburn Preceptory Knights Templar site	Hotter annual average temperatures Wetter winters Intense rainfall	Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of stonework, timber. Sensitive to new pest species. Sensitive to ground subsidence caused by drying and cracking of soils. Also sensitive to storm damage.		**Moderately vulnerable**	(English Heritage 2008).
Deserted medieval village sites, for example, Hadston and West Hartford Medieval ridge and furrow cultivation and field systems, for example, Arcot Hall Woodhorn watermill earthworks of leat, mill, dam and sluice gate	Drier summers Wetter winters	Sensitive to changes in soil moisture content and soil pH. Changes in natural vegetation. Sensitive to disturbance due to changes in agricultural practice.	Management: Low adaptive capacity but recording all known buried archaeology will support future management.	**Moderately vulnerable**	(English Heritage 2008).

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Medieval tower houses, for example, Cresswell Tower and Cockle Park Acklinton Park iron works and woollen mill 19th C collieries, for example, Woodhorn Colliery Country houses, for example, Blagdon Hall, Seaton Delaval Hall 19th C planned farmsteads, for example, Cavil Head and Chester House Acklington	Higher annual average temperatures Wetter winters Intense rainfall	Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of stonework, timber. Sensitive to new pest species. Sensitive to ground subsidence caused by drying and cracking of soils. Also sensitive to storm damage.	Management: Opportunity to re-develop farm buildings to accommodate changed agricultural requirements.	**Moderately vulnerable**	(Flooding & Historic Buildings Technical Advice, English Heritage 2004).
Designed landscapes (for example, registered parkland at Seaton Delaval, Blagdon and Woolsington)	Higher annual average temperature Wetter winters Intense rainfall	Sensitive to new pest species and spread of disease. Sensitive to wetter soils in winter and drying out in summer. Unsuitable condition for health of some tree species. Stonework sensitive to water damage leading to decay. Trees sensitive to storm damage.	Management: Some adaptive capacity as these sites are already intensely managed.	**Moderately vulnerable**	
WWII anti-tank defences, for example, Hadston Links WWII pill boxes, for example, Hemscott Hill and Newbiggin Point	Sea level rise Intense rainfall	Sensitive to inundation by the sea leading to erosion of dunes/beach. Sites could be damaged by action of water.	Environmental: Limited adaptive capacity, especially those close to the coast.	**Moderately vulnerable**	(Archaeological Research Services 2009).
Gloucester Hill Heavy Anti Aircraft Batteries	Higher annual average temperature Wetter winters Intense rainfall	Sensitive to increased moisture content in building fabric and increased variability of water table. Could lead to decay of brickwork. Also sensitive to storm damage.		**Moderately vulnerable**	(Flooding & Historic Buildings Technical Advice, English Heritage 2004).

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
WWII anti-glider obstacles	Drier summers Wetter winters	Sensitive to change in natural vegetation and disturbance of sites due to changes in agricultural practice.		**Moderately vulnerable**	(English Heritage 2008).
Hadston Carrs WWII anti-aircraft searchlight base	Sea level rise Intense rainfall	Sensitive to inundation by the sea leading to erosion of dunes/beach. Could cause instability of beach. Sensitive to action of water which may cause damage.		**Moderately vulnerable**	(Archaeological Research Services 2009).

Table E Vulnerability of access and recreation assets within South East Northumberland NCA to Climate Change

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Urban greenspace	Hotter summers Drier summers Intense rainfall	Grass sensitive to drying out. Sensitive to flooding.	Environmental: Degree of adaptive capacity depends on species mix, degree of use, type of use. Popular sites may have lower adaptive capcity due to increased recreational pressure. Management: Already intensively managed so good adaptive management capacity.	**Less vulnerable**	
Linear routes	Drier summers Wetter winters Intense rainfall	Sensitive to erosion casued by soil dessication. Routes close to rivers sensitive to flooding. Damage can include loss of footbridges and fords.	Environmental: Paths on slopes or with poor drainage likely to have lower adaptive capacity. Management: Already managed to some extent so some capacity to manage.	**Moderately vulnerable**	
Water bodies-providing recreational use	Drier summers Hotter summers Wetter winters Intense rainfall	Sensitive to reduction in water levels – could put more pressure on remaining resource for recreation. Sensitve to reduction in water quality due to concentration of pollutants with potential health impacts, for example, blue green algae bloom or vector borne diseases in water areas, for example, malaria. Sensitive to flooding – could increase hazards, for example, unstable banks.	Environmental: Adaptive capacity may depend on water demand for other uses, for example, biodiversity, drinking water.	**Moderately vulnerable**	(Dept Health 2008).
Recreational forests and woodlands	Hotter summers Drier summers Wetter winters Intense rainfall	Sensitive to increased fire risk. Sensitive to increase in ticks and tickbourne diseases. Sensitive to drought which could lead to increased loss of trees and potential hazard from falling branches.	Management: Most recreational woodlands are managed to some extent already so some capacity for adaptation.	**Moderately vulnerable**	
Coastline and beaches	Hotter summers Drier summers	Sensitive to increased recreational pressure on beaches due to more favourable conditions for outdoor recreation.	Environmental: In-situ nature of these assets means adaptive capacity could be low. Beaches constrained by coastal squeeze.	**Less vulnerable**	

Table continued…

Asset	Potential exposure	Sensitivity	Adaptive capacity	Vulnerability rating	Notes and references
Country Parks, Local Nature Reserves	Hotter summers Drier summers Wetter witners Intense rainfall	Sensitive to an increase in vegetation. Need for increased maintenance of paths and more formal picnic areas. Sensitive to drought leading to drying out of vegetated areas. Sensitive to flooding which could damage recreation and access facilities.	Management: Already intensively managed so some capacity for adaptation. More maintenance likely to be required.	**Moderately vulnerable**	

Appendix 2 Implications of vulnerability assessment for landscape character, ecosystem services and biodiversity

In this section, the implications of the vulnerability of specific assets on landscape characteristics, ecosystem services and biodiversity are identified. Having considered the sensitivity and vulnerability of individual assets that help create the distinctive character and functionality of the NCA, it is useful to consider the extent that the impacts of climate change on assets in turn impact on landscape character and ecosystem services.

Landscape character

Flat coastal plain: The change to this key characteristic feature of the NCA is likely to be quite subtle and emerge gradually over time. For example, changes in habitat and species composition, and fragmentation of habitats as a direct response to climate change, will have an overall visual impact on landscape character in terms of the diversity, textures and colour. Changes in phenology are already resulting in the landscape 'greening' earlier in the year, and this phenomenon is likely to continue. However, it is the indirect impacts of climate change that are likely to have the greatest impact on this feature, both through changes in agricultural production and a potential increase in bio-fuels crops.

Sweeping sandy beaches and rocky headlands: The area is likely to see the roll-back of sand dunes in areas where this is possible, but in others, significant erosion of dune systems, as well as soft cliffs, is likely. Areas of salt marsh will also be subject to erosion, and where coastal defences are in place, will experience coastal squeeze, reducing the overall natural feel of significant stretches of the coast. It is likely that the most significant changes will occur around the southern end of the coastline.

Denes and wooded river valleys: Drought, particularly severe drought, can significantly increase the stress on trees and make them particularly vulnerable to pests and diseases. Over time, this could lead to changes in the overall species mix. Significant losses of individual trees within a woodland can have a radical impact on the overall tree canopy, particularly in an area of historic parkland with a high proportion of veteran trees.

Major river estuaries: The character of the river estuaries is largely shaped by the salt marsh and wetland habitats that are found there. These habitats are likely to be very vulnerable to sea level rise and an increase in wave energy. This is likely to have a significant effect on the character of these estuaries, particularly the Blyth, if these areas of saltmarsh and mudflat habitats shrink due to coastal squeeze caused by existing or new coastal defences.

Significant urban and urban fringe areas: South East Northumberland is an area already undergoing quite radical transformation, with major plans for economic regeneration and expansion in housing development through two Growth Points. There is a particular demand for affordable housing with plans to focus these around Ashington and the coastal villages around Lynemouth and Blyth, and plans to further develop the Port at Blyth. While the changes such developments will have on the landscape character of South East Northumberland is not caused by climate change, a direct consequence of climate change will be the increasing need to protect the area's key social and economic assets from the effects of climate change. There are proposals within the Shoreline Management Plan to enhance sea defences around critical infrastructure such as Lynemouth power station and a number of coastal communities. Other communities such as Blyth are likely to see measures to protect them from fluvial flooding as well as tidal inundation.

Large-scale, open cast mining and former colliery heaps: Open cast mining is likely to be a continuing feature of the landscape, as the pressure on global energy supplies increases. Intense winter rainfall may have significant impacts on existing restoration schemes, causing problems with subsidence and landslip.

Regular large open arable fields, wire fence and gappy hedges: An indirect consequence of climate change within South East Northumberland is likely to be the intensification of agriculture with a shift towards more arable production. New crops and changes in agricultural production are likely to result in changes in field patterns, the potential removal of field margins and existing hedgerows, as well as new crops such as oil seed rape which will being new colours into the landscape.

Areas of formal parkland and large estates: Historic houses and their associated parkland, such as Seaton Deleval, contribute to the character of the NCA. It is unlikely that these assets will be lost from the landscape in the short and medium term, but the appearance of historic parklands might change if veteran trees are lost, and there is the potential for change in species composition to alter the colour and texture of such areas.

Areas of open water and wetland habitats: Many wetland habitats are very vulnerable to drought, with increased summer temperatures potentially leading to greater incidences of blue algae bloom or such areas drying out. Increased winter rainfall however, could potentially see an increase in multi-functional wetlands, including for recreation, as part of a more holistic approach to flood alleviation. On the coast in the less developed northern section around Druridge Bay, there is likely to be tidal inundation behind the sand dunes, changing the current mosaic of pools, reed beds and coastal grazing into an area of more brackish wetland, which will change the composition of local wildlife and the visual appearance of the landscape.

Significant man-made structures, especially power transmission infrastructure, road and rail structures, and industry: As authorities become aware of the risks presented to critical infrastructure by climate change, the area is also likely to see an increase in the use of sustainable drainage systems and land specifically allocated for this purpose. A greater understanding of the role that green infrastructure may play in supporting the resilience of communities to the effects of climate change may also see changes around the edges of communities, with new areas of woodland or wetlands, which may well enhance the intrinsic aesthetic of local landscapes to the community and provide new opportunities for recreation. An indirect response to climate change, namely the move towards renewable energy, is likely to see new developments of offshore and onshore wind farms. In a predominantly flat landscape this is likely to have a significant impact on the area's overall landscape character.

Historic landscape associated with World War Two defences and prehistoric archaeology: A number of sites along the coast are at direct risk from existing coastal erosion, for example the pre-historic remains at Low Hauxley, and rising sea levels are likely to increase the pressure on, and ultimate destruction of, these sites in the longer term.

Biodiversity

The habitats, and the species which they support, along the coastal fringe of the South East Northumberland NCA are likely to experience the most significant impacts of climate change, due to existing coastal erosion and exacerbated by sea level rise and the influence of the coast on other climatic variables such as annual average temperatures and changes in the level and intensity of precipitation (Royal Haskoning, 2008). It is also likely that a number of species currently at their northern limit on the edge of South East Northumberland may move into the NCA as climate envelopes shift north. The impact of this shift can only be assessed on a species by species basis, with some species complementing current species assemblages, whilst others may well stand in direct competition to existing species in the area impacting on the stability of the particular ecosystem. Biodiversity assets which are likely to have a high degree of vulnerability to climate change include:

The dune system and its ecosystem will be vulnerable to increasing rates of erosion, and for large stretches of the coast the dunes will be limited in their ability to roll back due to hard infrastructure (roads) or underlying geological or topographical features backing onto the dune systems.

Saltmarsh and mudflats within the estuaries will become under increasing pressure from coastal squeeze as their seaward edges are eroded, but opportunities are limited for roll-back due to coastal developments. This will have a knock-on impact on the wider species assemblage of the area, particularly on birds. This impact on bird species will be exacerbated by the warmer sea and land temperatures, which will affect the availability of their main food supply within the inter-tidal rocky foreshore. Loss of saltmarsh and mudflats could also increase the wave energy of the sea and the potential for tidal inundation.

Climate change will impact on the nature of the wetlands within the NCA. Wetlands near the coast will be increasingly vulnerable to saline intrusion and many freshwater sites may become brackish. Sites may become increasingly vulnerable to drying out during periods of drought, becoming more ephemeral. The opportunities of developing multi-functional wetlands throughout the NCA, but particularly around urban areas as part of a sustainable drainage system, could make wetlands an increasingly important feature within the NCA.

Warmer average annual temperatures and changing precipitation rates will see a gradual change to species mix in the NCA's woodlands, meadows and hedgerows, with a move towards more drought tolerant species.

An indirect consequence of climate change is likely to be the intensification of agriculture within the NCA due to more favourable climatic conditions and also pressure from global markets. Such a move could have a very significant impact on a number of habitats such as lowland meadows, hedgerows, and coastal and flood plain grazing marsh, unless it is accompanied by sensitive soil and water conservation to ensure that intensification does not compromise the NCA's existing landscape functions.

Ecosystem services

Provisioning services

Mixed arable farming: Climate change impacts will directly affect the types of crops which can be grown within South East Northumberland. Current soil types would suggest that warmer temperatures, with reduced rainfall, will lead to an increasing move towards arable and root crops, which may increase the need for water, leading to greater use of irrigation systems. Indirectly, climate change impacts on global food production may make this area more important for agricultural production, leading to greater intensification and a move away from mixed farming towards arable production.

Water provision: Reduced summer flows within river catchments due to reduced rainfall and drought could lead to deterioration in water quality, with diffuse pollution become a greater issue. An increased demand for water from agriculture may also have an impact on water supply and quality. On the coast, regular sea inundation may see existing wetlands becoming increasingly brackish. There remains an on- going risk of pollution from former coal mining activity, if current monitoring and pumping regimes are not maintained.

Fishing: It is likely that factors other than climate change may impact on fish stocks and the overall viability of local fishing fleets certainly in the short term. Warmer temperatures will have a negative impact on the salmoniod populations which are vulnerable to thermal stress and impact on the local game fishing industry.

Provision of wood and bio-fuel: Proposals have been put forward to develop a major bio-mass plant at Blyth which, alongside similar facilities in the region, is likely to be a major stimulant to

increased bio-fuel and wood fuel production, with an increase in short rotation willow coppice and introduction of other species grown for wood fuel such as eucalyptus.

Wind energy: With rising energy prices and growing support for renewable energy, it is likely that South East Northumberland will be increasingly important as an energy provider, with an increase in renewable energy structures, including wind farms and solar power units.

Climate regulation

Carbon storage: Soils store carbon, with soils with a high level of organic material such as peat storing the greatest proportion of carbon. The predicted switch from pasture to arable will increase soil disturbance and will impact on carbon stores. Increased temperatures and reduced rainfall is also likely to impact on the small area of peaty fen soils, which will cause drying out and significant losses in carbon.

Flood alleviation: Many areas within the NCA currently act as informal flood water storage, some of this is on farm land, but others are on brownfield sites which have been earmarked for future development for housing or industry. The role of these areas in providing flood water storage could be protected and enhanced through the planning system. Likewise, the planning system can protect and enhance fluvial flood plains. Appropriate action now could both maintain existing functionality and significantly improve current performance.

Coastal flood and erosion alleviation: While sea level rise will impact on existing areas of mudflats and salt marsh, policies which support natural coastal processes will allow these areas to roll back, allowing these services to be maintained.

Climate regulation: To deliver this service, there needs to be a more concerted attempt to plant trees within urban centres and local communities now, so that these areas have mature trees to both counter future impacts of urban heat islands and offer shade in future decades when it is predicted that the impacts from increased summer temperatures will be felt.

Water treatment: There are significant opportunities to enhance the role of natural habitats in water treatment, either through formal sites planted with reedbeds, or the use of greenspace within urban areas to absorb pollutants in run-off from hard surfaces such as roads.

Cultural services

Geological assets: Enhanced rates of coastal erosion are likely to impact on the NCA's geological SSSIs. The main threat is to cliff exposures, especially along the Tynemouth to Seaton Sluice SSSI and Low Hauxley SSSI, being obscured by sea defences or other engineering or construction works. South East Northumberland is likely to continue to be an important area for opencast mining for the next few decades. There are considerable coal reserves under the sea and with rising energy prices it will be increasingly economic to exploit these, perhaps using new technologies such as underwater coal gasification, with potential implications for the natural environment.

Historic assets: Existing coastal processes are already eroding pre-historic sites around Low Hauxley and efforts are being made to capture and record as much of the materials and site as possible for future study, before they disappear forever. Sea level rise, combined with storm surges, puts this site and others, including the remains of Second World War defences, at risk. Other monuments and historic buildings will be at increased risk from extreme weather conditions, or indirectly from the intensification of agriculture. These include known sites and ones which have yet to be identified.

Recreation: Warmer temperatures and reduced rainfall may make the area increasingly attractive to local residents for recreation. Protecting and enhancing the means to enjoy the NCA through continued maintenance and development of the rights of way network and the creation of new green infrastructure to better link communities with their surroundings needs to be integral to the spatial planning agenda for the NCA

Sense of place: It is likely that the landscape of the NCA may change very radically over coming decades, both through the responses of society to climate change and because of existing planned developments in the NCA to encourage investment and expand housing. These profound changes in the physical landscape and on its natural and historical assets may well impact on the way local people feel and identify with their surroundings.

Supporting ecological services

Pollination: Many pollinators are sensitive to changes in climatic variables, with changes in seasons potentially de-aligning the life cycles of pollinator species from the lifecycles of wildflower species. Changes in temperature, humidity and soil moisture may affect pollinator pathogens, while if summer rainfall declines increased exposure of pollinators to pesticides may occur.

Soil formation: Soil formation will be affected by drier summers and wetter winters. In particular soil formation is dependent on soil organisms. Summer desiccation and winter water logging is likely to reduce their activity. In addition, dry soils lead to soil loss through erosion. There are, however, some potentially positive effects of warmer, wetter winters that may increase nitrification and nitrate availability in soils, though the levels at which this is taken up by plants or leaches out of soils is uncertain.

Appendix 3 Adapting actions- adapting landscape character and ecosystem services

The results of this study have shown that the services delivered by the landscape are vulnerable to impacts resulting from climate change. It is, therefore important that appropriate responses are put in place to minimise vulnerability. In this section we present potential adaptation responses to the vulnerabilities identified above. The adaptation actions proposed have been grouped according to whether they address vulnerabilities in landscape character, biodiversity or ecosystem services. In some cases actions are repeated against several aspects of character and ecosystem services. This serves to indicate that they are low regrets or win-win actions.

The adaptation responses proposed have been identified using the expertise of Natural England technical specialists. As with the assessment of vulnerabilities, these initial adaptation responses were refined and added to through consultation with stakeholders.

Actions to address vulnerability of landscape characteristics

Flat coastal plain

- Increase the mosaic of habitats in the NCA to enhance heterogeneity, which will allow species to take advantage of local changes in microclimate within habitat types. Responses include planting a mixture of woodland trees and increasing riparian shade through flood plain planting. The creation of transitional habitats between grassland and woodland will also provide increased variability of habitats and microclimates.
- Seek opportunities for enhancing connectivity through the expansion of ecological networks, and the maintenance of existing high quality habitats, habitat restoration and habitat recreation. Such networks need to be created with an understanding of their potential permeability to particular species and based around habitat typologies such as woodland, grasslands, and wetlands.
- Incorporate large scale habitat recreation as part of enhancing green infrastructure within the NCA, with a focus on wetland creation schemes and supporting the roll-back of coastal habitats, including sand dunes and salt marsh.

Sweeping sandy beaches and rocky headlands

- Create space to allow dune roll-back. Opportunities to facilitate this exist in the southern half of Druridge Bay.
- Allow for natural coastal realignment to provide adequate space and sediment for shoreline adjustment creation of new habitats (salt marsh and mud flats) unhampered by coastal defences.

Denes and wooded river valley

- Adopt a landscape scale approach to extend woodlands, and buffering to increase the core area, to help support wildlife. Mixed planting should be adopted and management should be improved around existing veteran trees.
- Identify areas within the river catchment where there are opportunities to create additional wet woodland along streams and rivers. This will enhance habitat connectivity and also

help reduce run-off and pollution, such as in agricultural landscapes and land identified for restoration following open casting.

Major river estuaries

- In seeking to protect ports and communities around the NCA's main estuaries minimise coastal squeeze by facilitating roll-back of salt marsh and mudflats to support more formal coastal defences, as part of an integrated approach to future port and coastal developments.

Significant urban and urban fringe areas

- There are real opportunities to build climate change adaptation into the local planning framework. Green infrastructure has a particular important role to play in supporting community resilience while delivering wider biodiversity and landscape benefits, and needs to be central to the development of the South Northumberland Growth Point. As part of this approach, the existing or potential functionality of brown field sites should be considered in terms of their ability to support climate change adaptation while also enhancing biodiversity within the NCA.

Large-scale, open cast mining and former colliery heaps

- Ensure surface mine restoration is undertaken to support climate change adaptation. There are some significant opportunities emerging over the next few years as a number of opencast sites end production and move towards a restoration phase. Such sites could offer opportunities for water storage and treatment and provide important biodiversity and amenity value. Such opportunities should be sought for the current round of restoration schemes and be built into future planning consent for new open cast sites. Some sites could be used to compensate loss of farm land on the coast.

Regular large open arable fields, wire fence and gappy hedges

- Work with landowners and land managers to maintain and enhance landscape assets including hedgerows, field patterns, wet ditches and traditional buildings.

Areas of formal parkland and large estates

- In areas of historic parkland such as Seaton Deleval, prepare site management plans to support key landscape assets such as veteran trees and hedgerows, by reducing existing pressures and supporting traditional management and appropriate stocking levels.

Areas of open water and wetland habitats

- Increase the resilience of existing wetland habitats by reducing nutrient and sediment loads and increasing water retention capacity
- Increase water retention capacity within the catchment to support and enhance existing wetlands and where possible restore hydrological connectivity between open waters and wetlands

Significant man-made structures- especially power transmission, road, rail structures and industry

- Work to encourage the adoption of softer more sustainable adaptation measures to increase the resilience of key infrastructure such as roads and bridges, including measures such as sustainable drainage systems, or use of strategic planting.

Historic landscape associated with World War Two defences and prehistoric archaeology

- Adopt sustainable management of soil and vegetation through agri-environmental schemes to protect buried sites (including a large number of Neolithic, Bronze Age, and Romano-British sites) likely to be damaged through changes in land use, for example, a move towards arable.
- Install visually sympathetic higher capacity rainwater disposal systems for a number of listed historic buildings within the NCA including medieval tower houses and churches, country houses and 19th century farmsteads. On-going maintenance of historic properties will need to be increased as storm damage and increased water penetration will have detrimental impact on the fabric of the building.

Appendix 4 Integrated response screening and identification of win-win, 'low regret' and no regret opportunities

Table F Integrated response screening and identification of win-win, 'low regret' and no regret opportunities

Action	Win-win	Low regrets	No regrets	Landscape	Eco system services	Geology & soils	Biodiversity	Historic environment	Access & recreation
Strategic									
Catchment scale adaptation			+	+	+	+	+	+	+
CC in spatial planning agenda	+	+		+	+	+	+	+	+
Learn and play lessons from other extreme weather events to develop contingency plans for key conservation areas	+				+	+			+
Monitor pests		+			+				
Multi-functional wetlands	+		+	+	+	+	+	-	+
Understanding land-use change	+		+	+	+	+	+	+	+
Mine restoration to support cc adaptation	+			+	+	+	+		+
Public awareness		+			+				
Monitoring		+		+	+	+	+	+	+
Landscape									
Space for sand dune roll back	+				+	+	+	-	-

Table continued…

Action	Win-win	Low regrets	No regrets	Landscape	Eco system services	Geology & soils	Biodiversity	Historic environment	Access & recreation
Allow for coastal realignment	+				+	+	+	-	
Landscape approach to woodlands and buffering	+				+	+	+	-	
Work to maintain landscape features with land managers	+				+	+	+	+	
Increase water retention capacity within catchment	+				+	+	+		
Ecosystem services									
Integrated water management of catchment	+			+					
Continuing pumping operations at Blyth and Whittle to minimise coal mine water outbreak			+				+		
Work with land managers to get wider adoption of sensitive farming methods	+			+		+	+	+	+
Support farmer with info and advice on diversification, new crops and breeds more resilient to climate change	+							-	
Identify new opp. for renewable energy, for example, management of woodland for wood fuels and appropriate sitting wind turbines	+			+			+		
Increase development of sustainable urban drainage systems	+					+	+		
Increase in woodland tree cover, esp. in urban areas	+			+		+	+		+
Undertake detailed ecosystem services assessment for SE Northumberland	+			+		+	+		+
Geology & soils									
Influence implementation of Shore line Management Plan	+			+	+		+	+	+
Discourage floodplain development		+		+	+		+	+	+
Flood defence schemes to facilitate natural processes		+		+	+		+	-	+

Table continued…

Action	Win-win	Low regrets	No regrets	Landscape	Eco system services	Geology & soils	Biodiversity	Historic environment	Access & recreation
Final recording of features at risk of loss		+							
Review geological SSSI boundaries		+					+		
Encourage land management practices reduce impacts on soil structure	+				+		+	+	
Adopt land management practices maintain and improve water filtration	+				+		+	+	
Adopt soil conservation measures	+				+		+	+	
Adoption of measures for soil conservation	+				+		+	+	
Adopt measures to restore ground water levels of peat soil in NCA	+				+		+	+	
Biodiversity									
Conserve protected areas and other high quality habitats	+			+	+	+		+	+
Reduce harm & pressure on sites not linked to cc	+			+	+	+		+	+
Monitor migratory bird population in SPA		+							
Monitor appearance of new species in NCA		+							
Increase mosaic of habitats with NCA	+			+	+	+			+
Seek opportunities for increasing connectivity	+			+	+	+			+
Proactive development of large scale habitat enhancement	+			+	+	+		+	+
Create new wet woodland	+			+	+				
Reassess boundaries of protected sites esp. SSSIs		+			+				

Table continued…

Action	Win-win	Low regrets	No regrets	Landscape	Eco system services	Geology & soils	Biodiversity	Historic environment	Access & recreation
Historic environment									
Monitor and record sites threatened with loss		+							
Management of soil and vegetation through agri-env to reduce potential damage to buried sites			+	+	+	+	+		
Installation of higher capacity rainwater disposal systems for historic buildings		+			+				
Enhance flood resilience of historic assets			+						
Access & recreation									
Increase awareness of impacts of cc on rights of way		+							
Improve drainage and surfaces on existing ROW and new routes			+		+				
Use drought resistant grass mixes for amenity areas		+				+	-		
Raise public awareness of health and fire risks during heat waves and preventative measures		+							
Development of new recreational routes to take pressure from risk from erosion	+			+		+			

Appendix 5 Consultees and workshop participants

John Walton	National Trust
Mike Jeffrey	Northumbria University
Lynne Dunnleavy	Northumberland Flood Partnership
David Passmore	University of Newcastle
Clive Waddington	Archaeological Research Services Ltd
Claire Dobinson	North Tyneside Council
Jim Heslop	Environment Agency
Cliff Garside	Environment Agency
Ruth Machen	Northumberland County Council
Tom Cadwellender	Northumberland Coast AONB
Richard Hall	Natural England
Nick Cooper	Royal Haskoning
Matt Wright	Jacobs
Jaqui Huntley	English Heritage
Judy Richmond	National Trust
Nic Best	CPRE
Adrian Hilton	Regional Climate change coordinator
Hugh Clear-Hill	Northumberland County Council
Charlotte Colver	Northumberland County Council
Ruth Machen	Northumberland County Council
Kevin Redgrave	National Trust
Elaine Jaggs	Northumberland Wildlife Trust
Mike Sutcliffe	Natural England
Steve Pullan	Natural England
Vicki Sixsmith	Groundwork Northumberland
Tony Devos	Natural England
Charlotte Colver	Northumberland CC
Sara Rushton	Northumberland CC
Steve Scoffin	Northumberland Wildlife Trust
Peter Wood	British Coal
Peter Glaves	Northumbria University
Mike Pratt	Northumberland Wildlife Trust
Neil Tulloch	Natural England

Natural England works for people, places and nature to conserve and enhance biodiversity, landscapes and wildlife in rural, urban, coastal and marine areas.

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