Climate change theme plan

Developing a strategic approach to climate change adaptation

'Improvement Programme for England's Natura 2000 Sites – Planning for the Future'

www.gov.uk/government/publications/improvement-programme-for-englands-natura-2000-sites-ipens

Preface

IPENS and theme plans

The Improvement Programme for England's Natura 2000 sites (IPENS), supported by European LIFE+ funding, is enabling Natural England, the Environment Agency, and other key partners to plan what, how, where and when to target their efforts on Natura 2000 sites and the areas surrounding them. As part of the IPENS programme, Site Improvement Plans (SIPs) and themed action plans are being developed. SIPs provide an overview of the issues affecting features at the site level and the actions required to address them. Theme plans are high-level plans which aim to improve the way in which we manage a range of key issues on the Natura 2000 site series as a whole (Annex 1). Theme plans can provide an over-arching direction, recommendations or outline approaches to achieve target conservation status of Natura 2000 sites in England, to complement work already underway on individual sites. The plans do not have a legal status, and do not constitute a systematic evidence review, but are based on evidence and expert opinion. They are to inform action and initiatives of Natural England and its partners to help achieve the objectives of Natura 2000.

It is anticipated that Natural England and others, working with stakeholders and partners, will all play a role in implementing the theme plans. In the process of developing the theme plans Natural England has approached key partners and delivery bodies to seek input and agreement on the roles in delivering the improvements, although in some cases these discussions have not yet been concluded. Recommended actions and next steps identified in the theme plans are not necessarily committed or resourced but aimed at informing future resource decisions. Implementation of the theme plan recommendations will be via local prioritised delivery plans and coordinated through the IPENS After-Life Steering group, working with national and local delivery partner organisations.

Audience

The climate change theme plan is primarily aimed at practitioners, including those who will play a key role in taking forward the actions identified in the plan such as Natural England staff, partner agencies and their partner delivery organisations; particularly major landowners including the Environment Agency, Forestry Commission, RSPB, National Trust, local authorities and the Wildlife Trusts. General aspects of the strategic approach recommended and the priority actions identified may also be of interest to managers, Defra and colleagues in the other UK conservation agencies.

Executive summary

This document is the theme plan for climate change produced by the Improvement Programme for England's Natura 2000 sites (IPENS). It describes the importance of climate change adaptation to the achievement of objectives set by the EC Habitats and Birds Directives and recommends a strategic framework for targeting and implementing adaptation actions across the network of Natura 2000 sites in England. Actions to address key constraints to progress are recommended and proposals for implementing the plan are made. It is structured to explain:

- the key issues that need to be considered in developing a strategic approach to climate change adaptation (Section 2);
- the way in which it is proposed that a strategic approach should be implemented for Natura 2000 sites England (Section 3);
- the priority actions that need to be undertaken for the approach to fully deliver its objectives (Section 4).

Overview

Evidence of the impacts of climate change on biodiversity and ecosystems has grown dramatically in the last two decades and is well documented at global, European and UK scales (Morecroft & Speakman, 2013; MCCIP, 2013; IPCC 2014).

There is strong evidence that biodiversity in the UK is being affected by these changes and the impacts are expected to increase as the magnitude of climate change increases (Morecroft and Speakman, 2013). These impacts include:

1. Species shifting to higher latitudes and altitudes to track changes in climatic conditions;
2. Declines in species unable to move quickly enough or without suitable habitat to move to;
3. Advances in phenology in the spring, such as earlier emergence from hibernation and earlier flowering;
4. Breakdown in synchrony between phenology of different species and other ecological associations, such as earlier flowering not being matched by earlier emergence of dependent invertebrates;
5. Risk to wetlands from hotter and potentially drier summers;
6. Increased coastal erosion with sea level rise and increased storminess;
7. Risk that non-native species (including pests and pathogens) may establish and spread.

A reduction in greenhouse gas emissions is essential to prevent the worst impacts of climate change, however adaptation to changing conditions is also essential as impacts are already being seen and will continue for decades even under the most optimistic emissions scenarios. There are strong statutory and policy drivers for adaptation, including the Climate Change Act 2008 and England 'Biodiversity 2020' strategy (2011). The UK National Adaptation Programme recognises four overarching objectives for climate change adaptation:

- building ecological resilience to the impacts of climate change;
- preparing for and accommodating inevitable change;
- improving the evidence base; and
- valuing the wider adaptation benefits the natural environment can deliver.

A national strategy is required to ensure that climate change adaptation is consistently reported across the Natura 2000 network and is embedded into the management of all Natura 2000 sites, so that favourable conservation status can be achieved and maintained in the longer term. Section 3 of the theme plan proposes a two-part strategic approach, comprising a national prioritisation exercise and site based assessment.

Key messages

- Climate change is happening and can be expected to increase in future (IPCC 2014).
- Threats are likely to be greatest in montane, wetland and coastal habitats, because of their direct dependence on factors such as temperature, hydrology and coastal processes.
- Mitigating action to slow and eventually halt anthropogenic climate change is the best long term strategy to reduce the risks to biodiversity. However even if the causes were radically addressed in the next few years, warming and associated changes would continue for several decades. Adaptation action is therefore needed to reduce the adverse impacts of climate change and in some cases take advantage of opportunities it may provide. Simply continuing with current conservation objectives will not be viable in many places.
- Climate change adaptation is normally best integrated into other work programmes, rather than as a stand-alone programme.
- An important aspect of accommodation to climate change is facilitating the movement of species populations in response to changing climatic conditions. Where climate change impacts are causing an irreversible shift in species range or physical changes to a site, a flexible approach to site conservation will be required. This is a particular dilemma at the coast where there is a juxtaposition of freshwater and brackish/saltwater habitats.
- The aim of the strategic approach proposed is to provide a consistent assessment methodology and to focus action towards sites where it is needed most urgently.

Priority actions

To ensure the long term resilience of Natura 2000 sites in England to the effects of climate change and secure good conservation status, it will be necessary to identify and implement appropriate adaptation actions across the network. Once completed, this will feed into the development of plans for biodiversity post-2020. In addition to this, a range of priority actions are suggested, including:

- adapting the strategic approach for marine habitats;
- ensuring our designation processes, including objective setting and condition reporting, facilitate climate adaption;
- monitoring change; and
- making model output more accessible.

Contents

1. General background

Climate change has been identified as a priority theme for the Improvement Programme for England's Natura 2000 Sites project, because of its geographically widespread effects on many interest features and supporting habitats of both Special Areas of Conservation (SAC) and Special Protection Areas (SPA). The impacts of climate change are important in the marine and terrestrial and freshwater environments, however climate change adaptation is more developed and there are more opportunities for intervention on land and associated freshwaters. The focus of this theme plan is consequently on terrestrial sites, but it is recognised that some elements of the recommended approach are relevant to marine sites. Further work is required for the marine environment, therefore this is included as a priority recommendation in this theme plan.

Evidence of the impacts of climate change on biodiversity and ecosystems has grown dramatically in the last two decades and is well documented at global, European and UK scales (Morecroft & Speakman, 2013; Marine Climate Change Impact Partnership report cards, 2013; IPCC 2014). These changes include shifts in species distributions towards cooler regions, increased erosion of coastal habitats and changes in the timing of seasonal events such as leafing emergence and breeding (phenology). Whilst these processes represent a natural adjustment that can help the species, habitats and ecosystem services to persist, there are limitations to the extent of adjustment that is possible. Many species cannot colonise new areas sufficiently quickly to keep pace with climate change, especially in a fragmented landscape. Retreating coastal habitats may be prevented from moving inland by hard coastal defences or lead to the loss of freshwater habitats where they do move. Changes in phenology may lead to a breakdown in interactions between species. Other impacts are also likely to increase in future, for example changes in habitats resulting from changes in rainfall; this includes the potential for more extreme events, such as droughts. In these circumstances a series of other impacts such as wildfires and increased abstraction of water from water courses could be triggered, leading to locally catastrophic results for the natural environment. It is also the case that climate change impacts in other parts of the world can impact on the biodiversity and ecosystems of the UK, either directly, for example through effects on migrant species, or indirectly through socio-economic impacts.

Action to reduce climate change, through reducing emissions of greenhouse gases and promoting carbon sequestration (conventionally referred to as climate change mitigation) is essential to prevent the worst of these impacts in the long-term. However, climate change is already happening now and will continue for the next few decades, even if long-term climate change mitigation is successful. Adaptation to reduce adverse impacts and in some cases take advantage of potential benefits (eg for those species that may be able to expand their range) is also essential and there are strong statutory and policy drivers to do this, including the Climate Change Act 2008 and England 'Biodiversity 2020' strategy (2011).

Definitions

(Source:IPCC (2013 & 2007)

Climate change mitigation: '*An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.'*

Climate change adaptation: *'Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.'*

A variety of adaptation strategies for biodiversity and ecosystems have been identified and adaptation has

developed significantly over recent years, both in terms of high level programmes, particularly the National Adaptation Programme (HM Government, 2013) and practical actions that can be taken at the site level (Natural England and RSPB, 2014).

The 10th UK report under Article 12 of the Birds Directive (JNCC, 2013a) for the period 2008-2012 shows a variety of bird species listed in 'Annex 1' of the Birds Directive are experiencing a climate change related threat or pressure across the range of locations and habitat types where they occur (see Annex 2 of this document). It is expected that a wide variety of SAC features are also being affected by climate change, however Article 17 SAC reporting (JNCC, 2013b) does not show this due to climate change not being specifically included in the pressure and threat categories used. It is expected that the impacts of climate change will increase in the coming decades (Morecroft & Speakman, 2013).

Data from the Site Improvement Plans (SIPs) that have been developed for every Natura 2000 site in England show that based on local site knowledge, climate change effects are already being seen or are expected at a site level across England. This includes marine and coastal sites such as Lundy SAC, sites around the Solent, the Broads (The Broads SAC / Broadland SPA) and several upland moorland sites (North Pennine Moors SAC/SPA, North York Moors SAC/SPA) where particular habitats or species are known to be particularly vulnerable to climate change. Designated features which are at risk at these sites include species and habitats at the southern edge of their climatic range, including many montane species. It also includes species and habitats dependent on specific hydrological conditions, including freshwater and lowland wet habitats. Coastal habitats will be affected by sea level rise as will the species they support, including water bird and wader species. Information is also required on action which would be needed to take advantage of opportunities which climate change may bring for some sites, for example, management to accommodate newly arriving species, in response to shifting location of species' climate envelopes. To improve the consistency of these data across the whole England Natura 2000 network, a common assessment approach is clearly required. This plan seeks to outline a framework approach that may be used to do this.

2. Description of key issues

This section provides an outline of the key elements that needed to be considered in developing a strategic approach to climate change adaptation for England's Natura 2000 network.

2.1 Description of issues and scale of problem

Climate change is happening and can be expected to increase in future (IPCC 2014). The evidence is clearest for rising temperatures (Figure 1) and there is also strong evidence of sea level rise associated with this: over most of the twentieth century this was 1-2 mm per year around the UK, but has increased to 3 mm per year in the last decade. Changes in precipitation are less clear and vary between locations, but most models of the UK climate have indicated a long term trend towards wetter winters and drier summers. There is also an emerging pattern of proportionally more rain falling in heavy storms, particularly in winter and the potential for greater overall variability in precipitation.

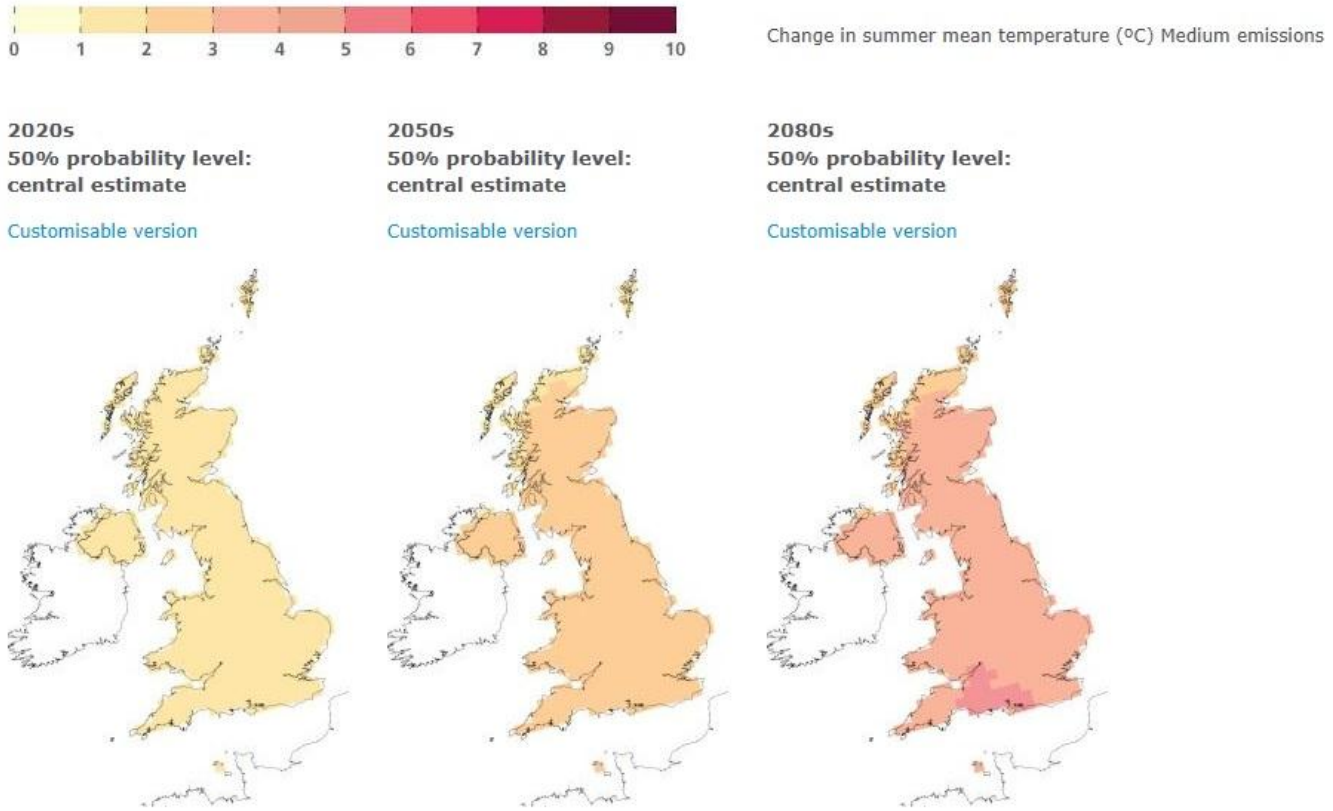
There is strong evidence that biodiversity in the UK is being affected by these changes and the impacts are expected to increase as the magnitude of climate change increases (Morecroft and Speakman, 2013). These impacts include:

1. Species shifting to higher latitudes and altitudes to track changes in climatic conditions;
2. Declines in species unable to move quickly enough or without suitable habitat to move to;
3. Advances in phenology in the spring, such as earlier emergence from hibernation and earlier flowering;
4. Breakdown in synchrony between phenology of different species and other ecological associations, such as earlier flowering not being matched by earlier emergence of dependent invertebrates;
5. Risk to wetlands from hotter and potentially drier summers (see Figure 1);
6. Increased coastal erosion with sea level rise and increased storminess;
7. Risk that non-native species (including pests and pathogens) may establish and spread.

While many of these impacts will be regarded as threats, it is important to acknowledge that climate change may also create opportunities for some aspects of biodiversity. For example, some species will be able to expand their range and colonise new areas, including new species arriving in the UK from continental Europe, and over time valuable new habitats, species and communities may evolve.

Impacts affect all sites to some extent, but the threats are likely to be greatest in montane, wetland and coastal habitats, because of their direct dependence on temperature, hydrology and coastal processes. Climate change has been specifically highlighted as an issue for a number of Natura 2000 sites in the Site Improvement Plans (SIPs) produced within the IPENS project, but as yet has not been included consistently across the English Natura 2000 network. Later sections of this plan make recommendations for a consistent approach for assessing the Natura 2000 network for future updates to SIPs.

Figure 1 Projected change in summer mean temperature (°C) for the 2020s to the 2080s (medium emission scenario, 50% probability) © UK Climate Projections 2009.
URL: http://ukclimateprojections.metoffice.gov.uk/23668?emission=medium [Accessed 18 February 2015]



2.2 Mitigation

Appropriate responses to climate change must include both mitigation and adaptation. The focus of this theme plan is climate change adaptation for Natura 2000 sites, given that this is essential to meet the core objectives of these sites. However it is worth briefly considering the contribution that some sites can make to climate change mitigation.

The main international policy driver for reducing greenhouse gas emissions is the UN Framework Convention on Climate Change which commits the international community to climate change mitigation measures which keep the rise in global temperature below 2°C. Within the UK the Climate Change Act puts the commitment to emissions reductions on a statutory basis and there is a commitment to reducing net emissions by 80% by 2050.

Many ecosystems sequester and store carbon when they are healthy, providing an effective climate change mitigation mechanism. However degradation and intensive management can lead to significant greenhouse gas emissions. Globally, the agriculture, forestry and land use sector accounts for about a quarter of net anthropogenic greenhouse gas emissions mainly from deforestation, agricultural emissions from soil and nutrient management and livestock (IPCC, 2014). Within the UK agriculture is a net source of greenhouse gas emissions, but forestry and other land uses are a small net 'sink', removing greenhouse gases, particularly carbon dioxide from the atmosphere through photosynthesis. There is scope to both cut emissions and increase the uptake (sequestration) of carbon. Whilst this is small relative to the emissions from fossil fuels, it will become proportionally more important as other emissions are reduced to meet the UK's 2050 target.

Natural England reviewed carbon storage by semi-natural habitats and the impacts of management decisions and condition on carbon stores and sources (Alonso and others, 2012). Across the Natura 2000 sites, the best opportunities for mitigation are through the restoration of degraded peatlands. Peatlands only slowly sequester carbon but large stocks have built up since peat formation started after the last ice age, with several metres of peat in some places. Degradation through draining, burning, cutting, air pollution and over grazing, has led to large losses of carbon to the atmosphere, which continue. Further information is provided in a Natural England report (Natural England 2010). Coastal habitats can also store large amounts of carbon and there may be potential to enhance this or reduce losses, but the evidence base is less well developed.

The main opportunity to promote carbon sequestration by the natural environment is through afforestation. This may be possible for some Natura 2000 sites, but in most cases any large scale afforestation would conflict with nature conservation objectives. Reversion from arable to grassland also contributes to carbon sequestration.

2.3 Drivers for taking adaptive action

Initiatives promoting adaptation to climate change operate at international, European and national scales (the Climate Change Act 2008). The United Nations Framework Convention on Climate Change website specifies that adaptation actions comprise five general components:

- observation;
- assessment of climate impacts and vulnerability;
- planning;
- implementation; and
- monitoring and evaluation of adaptation actions.

In 2013 the European Commission adopted an EU strategy on adaptation to climate change. This focuses on three key objectives:

- **Promoting action by Member States:** The Commission will encourage all Member States to adopt comprehensive adaptation strategies.
- **'Climate-proofing' action at EU level** by further promoting adaptation in key vulnerable sectors, including agriculture and fisheries.
- **Better informed decision-making** by addressing gaps in knowledge about adaptation.

In the UK, the Climate Change Act (2008) established a requirement for a National Adaptation Programme (NAP) (HM Government, 2013) and the power to ensure that individual providers of public services report on climate change risks and plans for dealing with them.

The National Adaptation Programme sets out 4 objectives for adaptation in the context of the natural environment:

- To build the resilience of wildlife, habitats and ecosystems (terrestrial, freshwater, marine and coastal) to climate change, so as to put our natural environment in the strongest possible position to meet the challenges and changes ahead.
- To take action to help wildlife, habitats and ecosystems accommodate and smoothly transition through inevitable change.

- To promote and gain widespread uptake in other sectors of the use of adaptation measures that benefit and/or do not adversely affect the natural environment.
- To improve the evidence base, to enhance the knowledge and understanding of decision makers, land managers and others of the impacts of climate change on the natural environment and how best we can influence adaptation or accommodate change.

To help increase the resilience of biodiversity and protected sites and accommodate change at the local scale, action on the ground is required. To aid this, Natural England and RSPB, with support from the Forestry Commission and the Environment Agency, have recently published a report that will help conservation managers to plan for adaptation; 'Climate Change Adaptation Manual: evidence to support nature conservation in a changing climate'(Natural England and RSPB, 2014).

There are also commitments on adaptation in the Biodiversity 2020 strategy (Defra, 2011); including a specific commitment that Natural England will consider the impact of climate change on Sites of Special Scientific Interest (SSSIs). SSSIs are a national tier of protected sites in England, of which 82% by area underpin and support SACs and SPAs.

There is a strong link between climate change adaptation and a number of other management issues for Natura 2000 sites, some of which are the topic of other theme plans, including air pollution, invasive species, coastal management and grazing (Annex1). Habitat restoration and creation will play an important role in increasing the resilience of protected species and habitats to climate change and an approach to this for Natura 2000 sites is described in the Habitat Fragmentation theme plan (Annex 1).

In recent years evidence has been building on the potential to manage ecosystems to help society in adapting to and mitigating the impacts of climate change. Practical examples of this include coastal realignment in the UK and other parts of the world, in which new intertidal habitats are created. These are valuable for the species they support, but also provide a natural flood defence for people which is an issue of increasing importance as the sea level rises. 'Ecosystem based adaptation' (EbA) refers to the use of biodiversity and ecosystem services to help people and the environment adapt to climate change.

2.4 Addressing climate change impacts on Natura 2000 sites

Climate change adaptation is normally best integrated into other work programmes, rather than as a stand-alone programme. This is happening across many conservation organisations, including Natural England's work on site management planning and the development of the new Rural Development Programme Countryside Stewardship scheme. It is also being incorporated into the management of designated conservation sites including SACs, SPAs and SSSIs; and consideration of boundary revisions to some designated sites to reflect changing site conditions is included as an action in this theme plan (see section 4.2, Table 3, priority action 8). An important component of this work is developing the evidence base and sharing knowledge. A working group on climate change adaptation brings together a wide range of conservation organisations, including the Environment Agency, Forestry Commission, Natural England, RSPB and Wildlife Trusts, in support of the National Adaptation Programme.

Climate change is likely to affect most, if not all protected sites, therefore a coordinated, strategic approach is needed to ensure that adaptation is consistently and effectively reported in IPENS Site Improvement Plans (SIPs) and applied to the current and future management of sites. For the Natura 2000 network, it is very important for adaptation to be effective because the condition of SACs and SPAs is fundamental to the delivery of favourable conservation status and other duties under the Habitats Directive 1994. A range of techniques for delivering adaptation and mitigation are available and can be tailored to suit the specific requirements of the Natura 2000 network.

2.5 Elements of adaptation

The National Adaptation Programme chapter on the natural environment recognises 4 overarching objectives for climate change adaptation:

- building ecological resilience to the impacts of climate change;
- preparing for and accommodating inevitable change;
- improving the evidence base; and
- valuing the wider adaptation benefits the natural environment can deliver.

Building ecological resilience to the impacts of climate change

Building resilience is about reducing the adverse impacts of climate change and enabling species and habitats to persist in the face of climate change.

There is evidence that reducing non-climatic sources of pressure or harm, such as pollution or habitat fragmentation, can help to ensure that species' populations are better able to cope with stresses from climate change, and in many cases can be tackled more easily than those caused by climate change. Preventing the introduction of pests, diseases and invasive non-native species will also enhance the resilience of a site to climate change (see Annex 1 for a link to the IPENS Invasive Species Theme Plan) because of the additional stress these species can put on native habitats and species as compared to the arrival of benign colonist species.

Many of these sources of harm will have been identified in the Site Improvement Plans produced by the IPENS programme and actions proposed. However, the impact of climate change on some of these other factors may increase or decrease their potential to influence the conservation status of sites. For example, the impact of climate change on the quantity and quality of water may mean that some sites, where water supply has not currently been identified as a potential issue, will need to be addressed in the future. In terms of possible actions, improved management of catchments, and also more innovative water retention and management schemes, can help to maintain water supply in times of drought, and reduce the risks of flooding in periods of high rainfall.

Similarly, the specific needs of individual threatened species can be addressed by, for example, improving food supply, reducing external pressures or protecting on-site climate refugia, such as north facing slopes where the impacts of a changing climate may be moderated, thus enabling them to persist for longer in their current locations during which time habitat connectivity to facilitate natural species movement and / or alternative sites can be developed.

An important aspect of resilience is maintaining sufficiently large and robust populations that can survive the impact of extreme climatic events such as droughts and heat waves, which may become more frequent with climate change. Larger populations are also more likely to result in species dispersing to new areas locally and further afield.

Plants and animals experience climate through their immediate microclimate. This may differ significantly from the climate measured by weather stations. For example, a plant or insect on a north-facing slope or in shaded grassland may be many degrees cooler than one in full sunlight on a south facing slope. Maintaining environmental heterogeneity by protecting or creating a range of topographic features, soil types and vegetation structures may therefore increase the resilience of conservation sites.

Resilience can be addressed at different spatial scales, which may allow for increased climatic vulnerability in particular places, provided suitable habitats are available elsewhere within a larger, functionally connected, surrounding area. Making Space for Nature (Lawton and others 2011) addressed this, and identified a need for

'more, larger, better and joined up' wildlife sites, which would combine as a coherent and resilient ecological network. An approach to address habitat fragmentation for the benefit of Natura 2000 sites is presented in the Habitat Fragmentation theme plan (Annex 1).

Another aspect of resilience is accepting or even promoting change in one aspect of the environment in order to confer resilience to others. So, for example, where a dominant tree species is vulnerable, diversifying a forest stand or planting different trees in the landscape may enable forest cover and landscape character to remain similar. Accordingly, the first step in considering resilience is determining the target, whether it be a species, habitat or ecosystem, as the actions to promote adaptation are likely to differ according to the objectives.

Recently published research by the British Trust for Ornithology (BTO) has highlighted the important role that SPAs in particular play in assisting bird species to cope with climate change, whilst also confirming that there are significant gaps in the network (Pavon-Jordan and others, 2015). Population growth was twice as fast inside protected areas compared with outside, for the species studied (smew). The study concluded that well-designed protected area networks can help to minimise the effects of climate change on biodiversity by safeguarding high quality habitat as species adopt new distributions. Other work has shown that protected sites more generally are often preferentially colonised by species spreading with climate change (Thomas and others, 2012).

Preparing for and accommodating inevitable change.

While much can be done to reduce the risk of adverse impacts of climate change through building resilience, some change is inevitable, and some may be welcomed. For example, the population and distribution of a rare species struggling to survive at the cold end of its distribution may increase as temperatures rise; as has happened with the Dartford Warbler in England (at the same time as it is losing ground rapidly in the hot, southerly end of its European distribution). Accommodating change applies to both the physical and biological environment. Coastal erosion is a natural process, but will be accelerated by rising sea levels and increased storminess. Where it does not conflict with other priorities (particularly the safeguarding of settlements), managed realignment of the coastline may allow natural erosion processes, and so maintain geological features and coastal habitats. Similarly, there is evidence that restoring the natural, slower flow of meandering rivers and allowing water onto flood plains can, in the right places, benefit biodiversity and enhance the landscape, while also providing flood control for human settlements and developments.

An important aspect of accommodation is facilitating the movement of species populations in response to changing climatic conditions. This applies equally at national, regional and local scales - even down to the scale where the distribution of microclimate suitable for a species may change. Different species have different requirements, but strategies to increase connectivity within the landscape, including creating ecological stepping stones and corridors across otherwise inhospitable countryside, and making the intervening countryside more suitable, are likely to benefit a wide range of species.

In circumstances where climate change impacts are causing an irreversible shift in species range or physical changes to a site (such as coastal squeeze caused by sea level rise), a flexible approach to site conservation will be required. There are a number of examples where this creates a particular dilemma, such as where there is a juxtaposition of freshwater and brackish / saltwater habitats. Allowing habitats to change naturally in these circumstances often requires the removal of artificial barriers – yet these may also be the protection for other designated habitats. Such issues are dealt with in more detail in the IPENS theme plan for inappropriate coastal management (See Annex 1).

Responding to change within the context of Natura sites can be problematic due to the nature of the designation and designated features. Within protected sites, communities and species can change without altering the status of the site, for example species may move to higher altitude, northern slopes or inland within sites. However where change leads to a reduction in the viability of populations or communities, or species migrate over time to

sites outside the designated area, the suitability of the designation will need to be reviewed. Conversely, designated species may colonise sites whose designation does not include them as features. In both these cases a periodic review of the designated features of Natura 2000 sites will be required.

The boundaries of designated SAC or SPA sites in the UK are fixed and are not flexible. This means that where features are likely to move as a result of climate change, the protection afforded by the site does not move with them. The only current mechanism available to deal with this would be to go through the process of boundary amendment which can take some time.

Decisions about when to accept or promote change may need to take account of the wider national or international perspective. Seeking to maintain a population at the southern margin of its range will normally be a lower priority if at the same time it is expanding further north. Flexibility over the boundaries and features of protected sites will need to be part of a sustainable approach to acceptance or promotion of change.

In many cases the cause of population change, including the role of climate change is unclear and site specific research may be required to determine the drivers of observed changes prior to designated features being altered.

Improving the evidence base

The evidence base on climate change and the natural environment has strengthened significantly in recent years and provides a sufficient basis for adaptation actions to start. There remain considerable uncertainties however, and, while these must be acknowledged in adaptation actions, they may also be reduced by research and practical experience.

Better understanding of the processes by which climate change affects the natural environment, including the interactions between species and between organisms and the physical environment, will improve our capacity to anticipate change and to implement effective interventions to reduce adverse impacts. It is also important to monitor changes as they occur and to evaluate the effectiveness of adaptation measures when they are introduced. In this context it is important to maintain consistent long-term monitoring of Natura 2000 sites such that long time series data are available. The developing Long-Term Monitoring Network will contribute to this for some Natura 2000 sites (see Annex 5, Step 6).

The inherent uncertainty in considering and planning adaptation measures nonetheless requires decision making based on different, often less robust , evidence availability than is now customarily used. New approaches, frameworks and parameters in decision making should be developed and employed to encourage adaptation actions which may have less certain outcomes that typically expected currently, yet which are likely to be necessary for the successful adaption of the UK's biodiversity and obligations for our Natura 2000 sites. For example, taking precautionary and / or experimental approaches are likely to become more necessary as ongoing climate change brings us into increasingly unfamiliar situations.

Valuing the wider adaptation benefits the natural environment can deliver.

The natural environment, when managed appropriately, can provide opportunities to help society to adapt to climate change, while also benefitting nature, so called Ecosystem Based Adaptation (EbA). The National Adaptation Programme (NAP) (HM Government, 2013) encourages the use of these ecosystem based approaches to foster adaptation in other sectors wherever possible.

Within the context of protected sites, the opportunities for EbA may be limited. Flood management is a well-known example that might be applicable in certain circumstances.

Adaptation in others sectors could potentially pose a threat to the natural environment, for example

constructing hard sea defences tends to lead to the loss of intertidal habitat which is unable to migrate inland as sea levels rise. This is particularly relevant to land management practices for non-conservation outcomes both within and near to Natura 2000 sites, such as farming, forestry, infrastructure development and water management. Where possible, solutions that work for the natural environment should be preferred.

The following sections of this plan recommend a strategic approach to climate change adaptation for the Natura 2000 network in England. The plan uses or signposts existing sources of evidence. Applying the approach recommended by the theme plan should also help identify evidence gaps and potential barriers to delivery.

2.6 Funding and implementing adaptation measures

To be effective climate change adaptation needs to be integrated into management planning. Climate change adaptation is being explicitly incorporated into the management plans of all of Natural England's NNRs as they are reviewed. Integrated into day-to-day management, many adaptation actions need not incur additional costs, for example changing the timing of other operations.

Climate change adaptation and mitigation are also cross-cutting aims of the new Countryside Stewardship programme and Environmental Stewardship before it. Habitat creation and management may be supported through this and climate change adaptation may be a matter of ensuring that these actions are targeted where they can give most benefit (for example in increasing habitat patch size) or ensuring that proposed actions are sustainable in a changing climate (for example ensuring wetlands are not vulnerable to coastal erosion or reducing water supplies).

In other cases more intervention may be required for example in restoring the hydrological function of a catchment or restoration of a degraded peatland. Countryside Stewardship may also be able to support these actions, but other sources of funding could include the LIFE+ programme. There is also opportunity to integrate climate change adaptation into a wider ecosystem approach. There is increasing interest in Payment for Ecosystem Services and pilot studies have been carried out. Some water companies have for some years supported catchment management, including the restoration of peatlands in the interests of reducing dissolved organic carbon in waters supplies, which also has good benefits for the habitats themselves. At the coast, collaboration with the Environment Agency on shoreline management plans is essential for managed realignment projects which can maintain intertidal habitats in a changing climate and provide adaptation benefits for people. Inland flood defence schemes can also provide opportunities to make habitats more resilient to climate change as well as helping people.

3. A strategy for English Natura 2000 sites – National prioritisation and site based assessment

A national strategic approach is required to ensure that climate change adaptation is consistently reported across the Natura 2000 network and is embedded into the management of all Natura 2000 sites, so that favourable conservation status can be achieved and maintained in the longer term. The strategy recommended here comprises two parts:

i) a national prioritisation exercise based on habitat types and national spatial datasets, to identify which Natura 2000 sites are likely to require action most urgently; and
ii) a site based assessment using local and national knowledge to identify appropriate adaptation responses.

When used together, the approach will enable actions to be prioritised at both a national and site based level for adaptation for the natural environment. The proposed approach and its implementation are outlined in Sections 3 and 4, with supporting detail and results described in Annexes 3, 4 and 5. The relationship between sections 3 and 4 and annexes 3, 4 and 5 is shown in Figure 2.

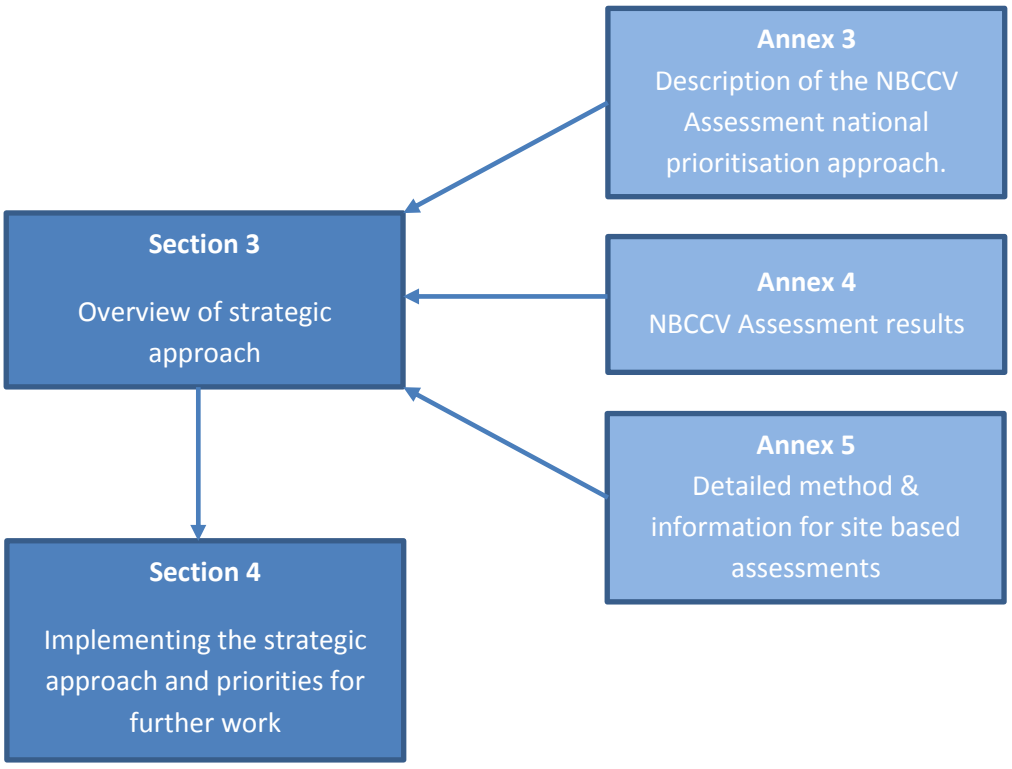


Figure 2. Relationship between sections 3 and 4 and Annexes 3, 4 and 5 of the theme plan

3.1 National prioritisation

Overview of the National Biodiversity Climate Change Vulnerability Assessment (NBCCV Assessment)

National consistency is important in identifying sites which are a high priority for implementing adaptation actions based on assessment of their vulnerability to climate change. To address this, Natural England has developed a model known as the National Biodiversity Climate Change Vulnerability Assessment (NBCCV Assessment) (Taylor and others, 2014) that allows non-specialists to assess the vulnerability of areas of priority

habitat to climate change based on widely accepted principles of climate change adaptation for biodiversity. The assessment provides a high level indication of the relative vulnerability of priority habitats to climate change in different places. It identifies why areas are vulnerable and which possible interventions can have the biggest impact in increasing resilience in a changing climate. This will inform prioritisation of adaptation actions and assist in the development of adaptation strategies for biodiversity both within Natural England and with partner organisations.

The prioritisation approach presented here uses data from the NBCCV Assessment to summarise the vulnerability of SACs and SPAs based on the relative vulnerability of the priority habitat they contain. Other assessment approaches are available and climate change data and modelling capability are constantly developing and improving. The NBCCV Assessment provides a high level approach based on national scale datasets that can be used in the absence of data or approaches that are designed more specifically for Natura 2000 sites.

The NBCCV Assessment is recommended here as a starting point, to aid decisions about prioritisation of climate change adaptation nationally, or within smaller administrative areas such as Natural England Area Teams. The approach is complementary to other approaches which are available and is not intended as a replacement for local scale assessments to guide actions.

The NBCCV Assessment methodology uses a GIS-based 200 x 200m grid to assess areas of priority habitat for their:

- Intrinsic **Sensitivity** to climate change - assigning a high, medium or low sensitivity classification to habitats based on expert judgement and scientific literature of the likely direct impacts of climate change (Natural England and RSPB, 2014).
- **Adaptive capacity** - a range of different local factors can increase or decrease the ability of the habitat to adapt to climate change. To reflect this, the assessment includes measures of habitat fragmentation, management and condition, and topographic variation.

The sensitivity and adaptive capacity elements described above are then added together to produce an overall national assessment of biodiversity climate change vulnerability. Key outputs are maps which give a visual representation of the areas of priority habitat most vulnerable to climate change effects.

Further detail of the model methodology is presented in Annex 3. Links to maps and results spreadsheets are in Annex 4.

Model limitations

Priority habitats

The approach assesses 'priority habitats', which are those that were identified as being the most threatened and requiring conservation action under the UK Biodiversity Action Plan (UK BAP). Natura 2000 interest features are based on a different classification, as presented in annexes to the Habitats Directive 1994 and Birds Directive 1979. Many Natura 2000 interest features are either species, habitats not covered by UK BAP priority habitats, or are specific components of priority habitats. The assessment cannot for example determine SPA vulnerability based on vulnerability of the bird species for which the SPA is designated, but relies on an assessment of supporting 'priority habitats'. It is therefore difficult to cross reference the two classifications and as a result the NBCCV Assessment can only go some way to identifying the vulnerability of Natura 2000 sites and their features.

Whilst priority habitats are widespread throughout the Natura 2000 network, this makes it difficult, at a national

scale, to assess whether the individual designated features of specific sites are themselves vulnerable and whether they are more, or less, vulnerable than the priority habitats identified through this assessment. The overall scores from the NBCCV Assessment are however useful in identifying which sites need to be considered more carefully in relation to potential climate change impacts, and can help to identify some overarching physical and management aspects that lead to habitats being vulnerable in a wider landscape setting. It is for this reason that the model results are recommended here as the starting point for prioritising the order in which sites should be addressed and for further consideration at the site level. It may be possible in the future to develop complementary approaches, for example based on modelled risks and opportunities for species.

How the vulnerability assessment results relate to site features will need interpretation at the site level as the model is not at a sufficient resolution to pick up, for example, relationships with detailed habitat characteristics such as geomorphology. Neither does it pick up indirect impacts such as warmer weather leading to increased recreational use of a site thereby increasing risk of disturbance to sensitive features. The data can help to draw our eye to potential vulnerabilities. Further steps, in terms of site based assessments (see section 5), will determine the levels of vulnerability of all site features and identify more specific actions. In some cases, where resources allow, other assessment approaches (eg Thomas and others, 2010; Marshall and others, 2009) may be used to provide further information.

Application to terrestrial, marine and coastal sites

The NBCCV Assessment uses the Natural England priority habitat inventory data to identify where habitats are, and therefore only covers terrestrial, freshwater and coastal habitats. It does not cover marine habitats. In the NBCCV Assessment data presented in this Theme Plan, all habitats, apart from marine, are included in the assessment and are treated in the same way regarding the application of the metrics mentioned above.

A further step to be investigated is the potential use of the NBCCV Assessment tool to assess the vulnerability of marine habitats. The tool provides a flexible framework into which a range of available data can be input to represent land use and habitat types and a range of metrics can be assessed (these can be changed from the ones used in the terrestrial assessment). However the applicability to marine SACs and SPAs is as yet untested.

Using a vulnerability based approach

Using a vulnerability approach to prioritising action by definition will mean that the focus will be on the threats that climate change poses to the natural environment. As highlighted previously climate will also present opportunities for conservation as many species will benefit from the projected changes. The site based assessment, although still using a vulnerability approach, also aims to identify opportunities where they exist.

An alternative approach would be to prioritise those sites which are least vulnerable in order to make them as effective as possible as refugia for species in a changing climate. For the purposes of this assessment, it was decided to use the NBCCV Assessment approach to prioritise the most vulnerable sites, given that a key aim of the Natura 2000 network is the protection of features of conservation value. Implementing action to enable vulnerable and subsequently less vulnerable sites to adapt to climate change, is likely to facilitate adaptation across the whole network of sites, thus maximising opportunities for species to move to suitable habitat and climatic space. This should not however exclude the possibility of taking action in less vulnerable sites, or indeed the possibility that resources would not be well spent in a particularly vulnerable site.

Model results

All sites ranking

Table 1 shows the top 10 most vulnerable SACs and SPAs, ranked by average overall vulnerability score, which were identified by the NBCCV Assessment approach described in Annex 3:

Table 1 Top 10 most vulnerable SACs and SPAs, ranked by average overall vulnerability

	SACs		SPAs
1	Dew's Ponds (freshwater)	1	Upper Solway Flats & Marshes (coastal/estuarine)
2	Tankerton Slopes and Swalecliffe (coastal/estuarine)	2	Breydon Water (coastal/estuarine)
3	Solent & Isle of Wight Lagoons (coastal/estuarine)	3	The Swale (coastal/estuarine)
4	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses (lowland wet sites)	4	Foulness (Mid-Essex Coast Phase 5) (coastal/estuarine)
5	Baston Fen (lowland wet sites)	5	Outer Thames Estuary (coastal/estuarine)
6	Solway Firth (coastal estuarine)	6	Crouch & Roach Estuaries (Mid-Essex Coast Phase 3) (coastal/estuarine)
7	Mottey Meadows (lowland wet sites)	7	Blackwater Estuary (Mid-Essex Coast Phase 4) (coastal/estuarine)
8	Grimsthorpe (lowland dry sites)	8	Chew Valley Lake (freshwater)
9	River Mease (freshwater)	9	Gibraltar Point (coastal/estuarine)
10	Ouse Washes	10	Thames Estuary & Marshes (coastal/estuarine)

The full SAC and SPA lists showing average overall vulnerability scores and scores for individual metrics are linked from Annex 4. These data can be ranked within the linked spreadsheet as required.

It was clear from the results that for both SACs and SPAs, coastal/estuarine and lowland wet sites tended to appear at the top of the ranked list (ie most vulnerable), whilst upland (with the exception of montane habitats), lowland dry sites and forests tended to appear at the lower end of the ranking (less vulnerable). Freshwater sites were in both cases distributed through the whole ranking.

Ecosystem ranks

The three most vulnerable sites in each ecosystem category are presented in Table 2. Note that vulnerability can only be compared *within* each ecosystem category and not between categories, as due to the nature of the particular habitats, some categories always appear either high or low in the ranked list of all sites. For example, coastal/estuarine sites tend to be ranked high, forests tend to be ranked low and habitats such as freshwaters occur throughout the rankings. The spreadsheet linked from Annex 4 also includes broad ecosystems, enabling the overall vulnerability scores and individual metrics to be filtered by ecosystem category in order to view the full rankings for each category.

Table 2 Three most vulnerable Natura 2000 sites within each broad ecosystem category

	Coastal / Estuarine SACs		Coastal / Estuarine SPAs
1	Tankerton Slopes and Swalecliffe	1	Upper Solway Flats & Marshes (coastal/estuarine)
2	Solent & Isle of Wight Lagoons	2	Breydon Water (coastal/estuarine)
3	Solway Firth	3	The Swale (coastal/estuarine)
	Freshwater SACs		**Freshwater SPAs**
1	Dew's Ponds	1	Chew Valley Lake
2	River Mease	2	Stodmarsh
3	River Wensum	3	Abberton Reservoir
	Lowland wet SACs		**Lowland wet SPAs**
1	Fenn's, Whixall, Bettisfield, Wem & Cadney Mosses	1	Nene Washes
2	Baston Fen	2	Ouse Washes
3	Mottey Meadows	3	Avon Valley
	Lowland dry SACs		**Lowland dry SPAs**
1	Grimsthorpe	1	Dorset Heathlands

2	Strensall Common	2	Thursley, Hankley & Frensham Commons (Wealden Heaths phase I)
3	Skipwith Common	3	Breckland
	Upland SACs		**Upland SPAs**
1	North Pennine Dales Meadows	1	Bowland Fells
2	Harbottle Moors	2	North Pennine Moors
3	Lake District High Fells	3	South Pennine Moors Phase 2
	Forest SACs		**Forest SPAs**
1	Kennet Valley Alderwoods		None
2	Woolmer Forest		
3	The New Forest		

Critical appraisal of model results

The NBCCV Assessment is a useful tool to guide consideration of vulnerability to climate change for Natura 2000 and other designated sites. However, as with all spatial analysis approaches there are uncertainties in the results it produces, for a variety of reasons, including the use of priority habitats instead of Natura 2000 features (SAC species and habitats and SPA birds) as already discussed and the data available for use in the assessment. Neither does the Assessment itself take account of local onsite knowledge. It is therefore essential that the results of the NBCCV Assessment, the scores and rankings should be critically appraised and ground-truthed against what is known and can be predicted about particular sites at a local level. The site based assessment (section 3.2) will provide data to further inform this critical appraisal process.

The first step should be to explore the detail which sits behind the overall vulnerability scores assigned to each site, to gain a good understanding of why the NBCCV Assessment has resulted in a particular outcome for a site. This needs to be done alongside consideration of the circumstances of the particular site, so local knowledge will be important. Consider the following:

- The **score for each contributing metric** (sensitivity, fragmentation, topography and management and condition). Are any of these scored particularly high or low, and how have they influenced the overall vulnerability score?
- The **position of the site in the overall vulnerability ranking** of all sites. Consider how the metric scores contribute to this, but also the predominant ecosystem class assigned to the site and how that tends to influence position in the ranking.
- **Ranking positions within ecosystem categories** in the context of the overall vulnerability ranking of all sites. A site may appear high in the ranking for a given ecosystem category, but relatively low in the all site ranking.
- Does **site specific information** tally with the overall vulnerability scores and ecosystem rankings? Do the individual metric scores accurately reflect what is known about the site?
- Consider whether particular **designated species or components of the habitat present** on site are more vulnerable than the overall priority habitat led ranking suggests (this may be facilitated by further development of species risks and opportunities approaches, see Table 3, priority action 7). For example, overall the upland sites tend to appear low in the ranking of all sites, but it is known that within this group, montane habitats are particularly sensitive to climate change. Montane, wetland and coastal habitats tend to be vulnerable because of the spatial coincidence of multiple climate change risk factors in these environments; local knowledge will give a fuller picture of the site vulnerability.
- Consider climate change vulnerability which is not picked up by the NBCCV Assessment approach, for example **indirect impacts of climate change and impacts on species and non-priority habitats**. These may

have been identified in IPENS Site Improvement Plans (SIPs). Where this is the case, the SIP should also be considered in priority ranking the SPA or SAC.

Prioritising action

Prioritisation of sites should be based on position in the overall ranked results (Table 1), not the ecosystem categories presented in Table 2 which simply allow comparison between sites with similar habitats. Following the critical appraisal of the priority habitat led model results described above, it may be necessary to promote or demote particular sites between priority categories. Dividing the sites into high and lower priority classes based on position in the appraised ranking allows the identification of priority sites where specific action needs to be targeted first. All sites will need some action, but higher rankings indicate those where action may need to be prioritised in terms of scale and urgency. The following sections suggest the next steps to be taken for both high priority and lower priority sites.

High priority sites

Sites in the high priority group are likely to require the most adaptation and / or resilience action, most urgently. The site based assessment procedure described below and in Annex 5 should therefore be followed for high priority sites in the first instance.

Lower priority sites

It is important to note that sites in the lower priority groups (medium and low) are still vulnerable to climate change, just relatively less so that sites in the high priority group. It is also the case that some individual species in these sites may be highly vulnerable, even if the habitat as a whole is not. In the longer term, some of these sites may act as refugia, where species persist longer than elsewhere. The detail of what action is required should be further explored using the site based assessment (Section 3 and Annex 5) after it has been applied to high priority sites, as time and resources allow and starting with sites in the medium priority group.

Until such point as the site based assessment is applied to lower priority sites, the following actions should be undertaken:

1. Apply best practice management consistent with European conservation objectives for the designated species and habitat interest features in order to achieve and maintain favourable condition.
2. Monitor changes on the site and use an adaptive management approach to site management. Trial management approaches, monitor the results and then amend as necessary (see the Adaptation Manual link below for more information).
3. Discuss and plan for the site to accept potential new species and / or species composition and make space for natural processes to occur where it is beneficial to the site to do so. Climate change and its effects on species and habitats will require site managers to be more flexible, in the context of benefiting biodiversity, to changes in features on site. Monitoring and projecting changes, and adapting management in response and also in anticipation, will be a key approach to this (see the Adaptation Manual link below for more information). Information in the IPENS Invasive Species theme plan (Annex 1) may be of relevance.
4. Take opportunities that arise to improve the resilience of the site by increasing the size of the site, by increasing connectivity with other habitats in the area to make the surrounding land more permeable to species movement, and by influencing sympathetic management adjacent to the site. The IPENS theme plan for Habitat Fragmentation (Annex 1) should be referred to in this context.
5. Consider if particular habitats and / or features on the site are more vulnerable than the overall average vulnerability score has suggested, and use the adaptation manual, among other sources, to plan specific responses.
6. In long term plans for the site, consider which features it may not be possible to retain and therefore may require changing objectives for the site to be reflected in the future.

These actions will ensure that the resilience of these sites is improved against the range of environmental drivers.

3.2 Site based assessment

Having determined the priority group of Natura 2000 sites for taking action to address climate change, a site based assessment is required to determine impacts of climate change on the key features of a site and the actions identified. The assessment process recommended here is based on a similar process which was piloted on five National Nature Reserves (NNRs) in 2014 and has now been adopted as standard for NNRs. The process is designed to be simple, pragmatic and timely. Elements of the suggested assessment process may be applied equally to marine Natura 2000 sites as terrestrial and coastal sites, although not all the sources of information referenced will be relevant to the marine environment.

The expertise of site managers and use of local knowledge of the site and its features is essential. The activities and information sources suggested below may be helpful to inform the site based assessment:

a. Interrogate the individual metrics which contribute to the overall vulnerability score from the NBCCV Assessment to identify broad adaptation action types which should be a priority for implementation. For example, a high score for the habitat fragmentation metric may indicate that creating more habitats, restoring degraded habitat or linking sites should be a priority. On the other hand, a low management score may suggest that improving management and condition is the priority. Scores for individual metrics are provided in the spreadsheet linked from Annex 4.
b. Use other available information, including the Climate Change Adaptation Manual (Natural England & RSPB 2014), to identify specific aspects of the site that might make it more vulnerable. Use the Centre for Ecology and Hydrology (CEH) wetland tool (Acreman and others, 2013) to further assess the sensitivity of the site if wetlands are present. Other assessment frameworks are available (for example Thomas and others, 2010; Marshall and others, 2009) and may be of particular use for some sites, for example where the protection of species is of prime importance.
c. Where relevant, use Forest Research's Ecological Site Classification Decision Support System to provide an indication of the likely change in suitability/ growth of tree species present on the site.
d. Monitor changes at the site, whether in line with management changes or other impacts such as climate change.

Annex 5 sets out a step-wise detailed method for undertaking a site based assessment, which can be summarised as follows:

1. Climate change > 2. Features > 3. Impacts > 4. Vulnerability > 5. Responses > 6. Delivery & Review

It first considers the projected climate change for the region the reserve is located in (1) and the likely impacts on the features (2) of importance on the site (3). Using the information gathered in steps 1-3 a feature based vulnerability assessment (4) is used to identify appropriate response actions (5). The final step (6) is to ensure the actions are implemented and the results monitored and reviewed.

A template is provided in Annex 6 which may be used to record the information gathered in each step of the assessment process.

Case study – Chippenham Fen

In 2014 Chippenham Fen NNR was chosen as a pilot site for the implementation of a methodology to embed climate change considerations into NNR management planning. Chippenham Fen covers 117ha and is designated as a Site of Special Scientific Interest (SSSI), National Nature Reserve (NNR) and Ramsar site. It is part of the Fenland Special Area of Conservation (SAC) which is designated for H6410 *Molinia* meadows on calcareous,

peaty or clayey-silt laden soils and H7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*, as well as S1149 spined loach and S1166 great crested newt (although the latter two features are not recorded on Chippenham Fen NNR). The combination of rainfall draining through a narrow valley and the chalk springs arising on site from the chalk bedrock have allowed calcareous fen conditions to be created. The frequent ditches, pools and wet depressions make this a very diverse wetland, important for plants and invertebrates.

The approach to embed climate change into management planning, involved assessment of vulnerability to climate change and the identification of appropriate adaptation responses. It comprised 4 steps:

1. Identifying the projected climate change;
2. Determining likely impacts in the local area;
3. Assessing the vulnerability of key NNR features; and
4. Identifying appropriate adaptation responses.

The tall fen and fen meadow communities at Chippenham Fen were given an overall vulnerability assessment of 'medium' based on the identification of a range of likely impacts, including:

- increase in extreme weather events, with summer flooding bringing potential benefits, but summer drought being problematic;
- increased wild fire risk during dry weather;
- changes to the aquifer due to potential increased pressure from potable water supply and changes to recharge rates;
- potential for changes to the agricultural system to alter the nutrient loading of water entering the site; and
- shifts in the mosaic of wetter and drier habitat, with drier habitats increasing and a consequent change in species.

A wide range of adaptation measures were identified to help the key features of the site to adapt to the predicted changes, including:

- undertaking survey/monitoring to improve understanding of the hydrology/topography of the site sufficiently to understand what the risks are;
- a need to determine the likely result of all abstraction licences utilised to the full or even if increased outside the site;
- maintenance of appropriate water levels;
- ensuring appropriate cutting regimes;
- consider the possibility of changing management objectives;
- increase the flexibility of grazing / cutting regimes to respond to changes in growth, including sourcing 'holdback areas' off the reserve (the Grazing Theme Plan deals specifically with grazing issues on Natura 2000 sites, see Annex 1);
- increase monitoring to understand/know spatial habitat distribution in order to better understand the spatial effects of impacts such as drought; and
- acceptance of transition to communities more adapted to drier conditions.

Following successful application of the methodology, the adaptation actions identified were incorporated into the NNR management plan.

The framework proposed in this theme plan is based on the methodology used for the NNR pilot sites, but has been adapted for the Natura 2000 network.

4. Implementation and priority actions

4.1 Implementing the approach

To ensure the long term resilience of the English Natura 2000 sites to the effects of climate change, and secure good conservation status, it will be necessary to identify and implement appropriate adaptation actions across the network.

A climate change vulnerability assessment and adaptation approach similar to that described in this plan has recently been trialled on several National Nature Reserve (NNR) sites (see case study in section 3), some of which are also Natura 2000 sites, as follows:

- Chippenham Fen NNIR (part of Fenland SAC);
- Stiperstones NNR (The Stiperstones and The Hollies SAC);
- Aqualate Mere (not a Natura 2000 site);
- Teesmouth NNR (part of Teesmouth and Cleveland Coast SPA); and
- Martin Down NNR (not a Natura 2000 site).

Climate change threats, opportunities and responses to them have been incorporated into the 5 yearly NNR management planning cycle and the trial has demonstrated that the approach can be successfully used to plan for climate change adaptation on protected sites. Further information can be obtained from Natural England.

In order to identify and implement appropriate adaptation measures across the entire English Natura 2000 network, it is recommended that the national prioritisation and site based assessment approaches described in section 3 are implemented as soon as possible so that they feed into the development of plans for biodiversity post 2020.

Implementation would ideally proceed as indicated in steps 1-4 below, with the proposed timescales (2016-2020) being subject to organisational agreement and availability of staff time and / or funding. It would be beneficial to progress a group of between 4-6 sites through the full process early in this timetable as pilot sites. The learning from these first sites should be reviewed to inform implementation of the approach to all high priority sites in the first instance, followed by lower priority sites. Sites listed in Tables 1 and 2 should be used as the initial short-list of candidate sites for consideration as pilot sites.

As implementation will require local site knowledge, it will primarily be a task led by Natural England staff, working together with partner organisations. The approach could also be adopted by partner organisations independently, particularly if NBCCV Assessment output is made more easily available to a wider audience in the future (see further recommendations in section 5.2). It may also be possible to develop a project to coordinate or implement certain elements of the approach, with the possibility of attracting external funding.

The four implementation steps are:

1. Awareness raising

During 2015/2016, as part of the work which will be undertaken to implement the findings of the IPENS project, this theme plan should be disseminated to Natural England site responsible officers and managers and staff in partner organisations with responsibility for site management of Natura 2000 sites. Staff should be made aware of the proposed methodology in preparation for implementation and approval sought from management for the resources required to apply the assessment.

2. Critical appraisal

In 2016 / 2017 undertake a critical appraisal of the NBCCV Assessment results presented in Section 3 and Annex 4 for all Natura 2000 sites, to confirm the priority of each Natura 2000 site for implementing adaptive measures.

3. Update Site Improvement Plans

The Site Improvement Plans (SIPs) produced by the IPENS project for each Natura 2000 site are live documents and where necessary will be updated annually to reflect new understanding about issues affecting the sites. It is recommended that Natural England staff should ensure that actions to implement the site based assessment process (high priority sites) or interim best practice adaptive management and monitoring (lower priority sites) described in section 4 are included in SIPs once priorities have been confirmed, and ideally in the 2017 revision to SIPs. This will ensure that climate change is included in SIPs in a consistent manner.

4. Phased implementation of site based assessment

The site based assessment described in section 3.2 and Annex 5 should be initially applied to high priority sites and then rolled out to lower priority sites in phases in later phases. Ideally, site based assessment would be implemented on all high priority sites by 2020.

4.2 Priority actions

If obligations under the Habitats Directive to protect Natura 2000 sites are to be fully met, the strategic approach outlined in this plan should be complemented by a range of other actions to improve areas such as funding, assessment tools, data and monitoring. Table 3 identifies and summarises priority actions for further work which are discussed in earlier sections and suggests timescales by which they should be undertaken. Incorporation of these actions into Natural England corporate planning, both nationally and for Area teams, will be a task undertaken from summer 2015 onwards, as part of IPENS implementation work following closure of the IPENS project itself (see the IPENS AfterLIFE Implementation Plan which will be available via the IPENS website, URL: https://www.gov.uk/government/publications/improvement-programme-for-englands-natura-2000-sites-ipens).

Table 3 Priority actions

Action no.	Priority action	Lead and partner bodies	Timescales
DEVELOPING THE STRATEGIC APPROACH AND DATASETS			
1	Apply the recommended site based assessment approach to 4-6 pilot sites during financial year 2015-16. Undertake critical appraisal of model results and update SIPs for all Natura 2000 sites by 2017. Undertake site based assessment for all high priority sites by 2020 and lower priority sites thereafter.	Natural England and partner organisations' site staff	2015-2020 onwards
2	Develop a vulnerability dataset for the NBCCV Assessment model specific to Natura 2000 habitats and species.	Natural England	2015 - 2017

3	Identify and apply appropriate assessment methodology to enable consideration of marine sites in the NBCCV Assessment vulnerability assessment.	Natural England	2015 – 2016
4	Explore how to make NBCCV Assessment output more widely available, initially within Natural England via Webmap, then publicly via MAGIC.	Natural England	2015 – 2017
5	Continue to investigate how developing climate change datasets can be best used to inform actions for Natura 2000 sites. Determine how best to use data from Biodiversity 2020 action 1d and refugia data.	Natural England, partner organisations	Ongoing
6	Further develop the approach recommended in this theme plan, including a Geographical Information (GI) based overview to determine the carbon sequestration potential of sites to promote ecosystem based mitigation (EbM).	Natural England	Ongoing
7	Explore how the results of species risk and opportunity approaches can be used to prioritise climate change adaptation action on Natura 2000 sites.	Natural England	2015 - 2018
SITE DESIGNATION			
8	Consider how greater flexibility can be incorporated into current protected site designation processes and how case studies that have successfully accommodated major change at sites can be expanded and built upon. To consider more flexible designation boundaries and features to reflect changing site conditions and species ranges.	Natural England	2015 - 2020
MONITORING			
9	Working with the Natural England Long Term Monitoring Network, create an approach for monitoring change at sites including measures to help understand where climate change impacts are leading to unfavourable condition. Steps needed to improve the collection of monitoring data.	Natural England, Natural Resources Wales, Scottish Natural Heritage, JNCC	2015 - 2020
COMMUNICATION & AWARENESS			

10	Identify mechanisms to improve communication about climate change adaptation and mitigation within and between partner organisations, and with wider stakeholders and the public as messages about climate change are particularly difficult to get across.	Natural England, partner organisations	Ongoing
REPORTING			
11	Engage in any European level work in preparation for the next round of Article 17 reporting, to ensure that climate change effects on SACs are explicit in the pressure / threat reporting categories.	Natural England, JNCC, EC	2015 – 2018

Annex 1. IPENS Theme Plans

The table below provides hyperlinks to the suite of IPENS theme plans, which are available on the Natural England publication catalogue.

Theme plan topic	Hyperlink
Atmospheric nitrogen deposition	http://publications.naturalengland.org.uk/publication/6140185886588928?category=5605910663659520
Climate change	http://publications.naturalengland.org.uk/publication/4954594591375360?category=5605910663659520
Diffuse water pollution	http://publications.naturalengland.org.uk/publication/5848526737113088?category=5605910663659520
Grazing	http://publications.naturalengland.org.uk/publication/4839898496368640?category=5605910663659520
Habitat fragmentation	http://publications.naturalengland.org.uk/publication/5004101806981120?category=5605910663659520
Hydrological functioning	http://publications.naturalengland.org.uk/publication/6400975361277952?category=5605910663659520
Inappropriate coastal management	http://publications.naturalengland.org.uk/publication/6371629661683712?category=5605910663659520
Invasive species	http://publications.naturalengland.org.uk/publication/6130001713823744?category=5605910663659520
Lake restoration	http://publications.naturalengland.org.uk/publication/5583022327857152?category=5605910663659520
Public access and disturbance	http://publications.naturalengland.org.uk/publication/6621454219083776?category=5605910663659520
River restoration	http://publications.naturalengland.org.uk/publication/5478339747774464?category=5605910663659520

Annex 2. Climate change effects on birds

Data in the table below is taken from the 2013 Article 12 report and shows records of climate change effects impacting or threatening Birds Directive Annex I birds (JNCC, 2013a).

Species (B = breeding, NB = non-breeding)	Pressure (P) / Threat (T)	Impact / threat description	Impact level (High / Medium / Low)
Bittern (B)	P&T	Climate change / changes in abiotic conditions	H
Bittern (NB)	P	Climate change / changes in abiotic conditions	H
Roseate Tern (B)	T	Climate change: excess rain or snow leading to flooding and other effects	H
Arctic Tern (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Avocet (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Bittern (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Black-headed Gull (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Black-tailed Godwit *limosa* (B)	T	Climate change / changes in abiotic conditions	M
Black-tailed Godwit *limosa* (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Common Gull (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Common Tern (B)	T	Climate change / changes in abiotic conditions	M
Common Tern (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Cormorant *carbo* (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Corncrake (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Curlew (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Dunlin (race *alpina*) (NB)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Dunlin (race *schinzii*) (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Gannet (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Golden Plover (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Golden Plover (B)	P&T	Climate change - phenology mismatch	M
Great Crested Grebe (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Guillemot *aalge* (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M

Guillemot *albionis* (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Herring Gull (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Knot (NB)	T	Climate change / changes in abiotic conditions	M
Little Tern (B)	T	Climate change: excess rain or snow leading to flooding and other effects	M
Merlin (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Oystercatcher (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Peregrine (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Redshank (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Ringed Plover (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Ruff (B)	P&T	Climate change / changes in abiotic conditions	M
Ruff (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Short-eared Owl (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Shoveler (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Spotted Crake (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Svalbard Light-bellied Brent Geese (NB)	P&T	Climate change - phenology mismatch	M
Wigeon (B)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	M
Avocet (B)	T	Climate change / changes in abiotic conditions	L
Purple Sandpiper (NB)	P&T	Climate change / change of conditions including habitat, phenology of migration, and population declines	L
Turnstone (NB)	T	Climate change / change of conditions including habitat, phenology of migration, and population declines	L

Annex 3. National Biodiversity Climate Change Vulnerability Assessment Method

Overall vulnerability assessment

The use of the NBCCV Assessment overall vulnerability data allows the application of a considered approach to target climate change adaptation action at sites that are the most vulnerable based on model metrics as applied to priority habitats.

The version of the data used here includes 4 of the metrics used in the national assessment method (Taylor and others, 2014): sensitivity to climate change, habitat fragmentation, topographic heterogeneity and management and condition. The model adds together scores from the individual metrics to produce an overall vulnerability score for each grid square in the model. This version of the data is referred to as the 'Overall Vulnerability' for the 'All Priority Habitats' dataset. As all terrestrial and coastal priority habitats found in the Natural England priority habitat inventory are included in the assessment, when 2 or more habitats are found within a 200m grid square the most vulnerable habitat overall gives its score to that square. This gives us one 'overall vulnerability' score for each 200m grid square across the country.

The grid squares and their overall vulnerability scores were then extracted where they fall within a Natura 2000 site boundary. This allowed a comparison of the vulnerability scores between Natura 2000 sites. Maps showing a visual representation of overall vulnerability by site are available for use by site managers and responsible officers for the site based assessment described in section 3. Links to maps and spreadsheets of results are in Annex 4.

Ranking the results

A means of ranking the Natura 2000 sites according to their vulnerability was then devised, in order to help prioritise action. A single vulnerability score was calculated for each Natura 2000 site by averaging the overall vulnerability scores of each model grid square within the site boundary. Sites were then ranked based on these 'average overall vulnerability scores'. An average value was also calculated in a similar manner for each of the contributing metrics to allow ranking by any of these elements if required. Using this approach, some sites have the same overall vulnerability average score. Where this occurs, the sites are given equal ranking in the list.

Rankings are helpful as they show how vulnerable sites are based on the area of priority habitat within the site (number of squares) and how vulnerable that priority habitat is (the total score for each metric or overall vulnerability), presented as an average score for each site. This allows sites to be ranked from most to least average overall vulnerability score (and other useful metrics eg most fragmented). Ranking sites by other methods are also possible, eg ranked sites by the score from the most vulnerable square within that site; however the average score was thought to be a useful and straight forward approach to highlight differences in vulnerability.

The ranked lists based on overall vulnerability data for SACs and SPAs were divided into thirds (33% of sites each), to give high (top 33%) and lower (bottom 66%) priority classes to be used as indicators of the urgency of action required.

Ranking within ecosystem categories

Further to the ranking of all terrestrial and coastal sites by overall vulnerability, these sites were subsequently ranked within 'broad ecosystem' categories using the same scores. This further refinement was made for convenience as it was assumed that information on the vulnerability ranking of sites within predominant ecosystem categories might be useful for site managers wanting to compare similar sites. The sites were

therefore assigned to one of six broad ecosystem categories based on either i) the predominant habitat type in the site if that habitat is a SAC interest feature or a SPA supporting habitat, or ii) where a SAC is designated for species only, the supporting habitat for that SAC species interest feature. The categories used were:

- Coastal / estuarine
- Freshwater (open water, rivers, canals and sites with great crested newt)
- Upland (including heath, blanket bog, montane habitats, northern hay meadows)
- Lowland wet sites (including raised mire, fens, wet grassland)
- Lowland dry sites (including lowland heath, grasslands, improved grassland and sites designated for bats with predominantly suburban / industrial habitats)
- Forests

Critical appraisal of results

As outlined in section 3.1 of this plan, the NBCCV Assessment is a useful tool to guide consideration of vulnerability to climate change for Natura 2000 and other designated sites. However, as with all spatial analysis approaches there are uncertainties in the results it produces, not least that in this case the model is based on priority habitat vulnerability, rather than Natura 2000 interest features, and so it is vitally important that the model results are critically appraised before being used. Advice for this critical appraisal process is in section 3.1 and is not covered in any more detail here. Modelled priorities may need to be adjusted in light of the information evaluated by the critical appraisal, to ensure they reflect as accurately as possible evidence on the ground.

Annex 4. NBCCV Assessment Results

Results from the NBCCV Assessment are available in spreadsheet and map format on the Natural England publication catalogue page for the Climate Change Theme Plan:

http://publications.naturalengland.org.uk/publication/4954594591375360?category=5605910663659520

The following are available:

Spreadsheets:

1. NBCCV Assessment results spreadsheet for SACs.

2. NBCCV Assessment results spreadsheet for SPAs.

Both spreadsheets include overall climate change vulnerability scores, ranked overall vulnerability scores and scores for each of the four contributing metrics to the overall vulnerability scores (fragmentation, sensitivity, topographic variety and management and condition). Please refer to the 'READ ME' tab on each spreadsheet for an explanation of the content.

Maps:

1. Overall climate change vulnerability scores for SACs.

2. Overall climate change vulnerability scores for SPAs.

3. Ranked overall vulnerability scores for SACs.

4. Ranked overall vulnerability scores for SPAs.

Maps and spreadsheets should be used in conjunction with this theme plan and detailed information about the NBCCV Assessment model (Taylor and others, 2014).

Additional maps are provided in an annex to the habitat fragmentation theme plan (see Annex 1), including national coverage overall vulnerability and fragmentation scores, which may also be of use when evaluating the climate change vulnerability of Natura 2000 sites.

Annex 5. Site based assessment detailed method

A stepwise process for undertaking a site based assessment is presented in this annex. It is assumed that the main audience for this will be practitioners and site managers and it is intended to be a relatively simple, pragmatic approach. Initial sources of further information are suggested for each step. These are not intended to be comprehensive, but provide a starting point for further investigation.

Step 1 – Considering Climate Change

The purpose of step 1 is to give you a good understanding of the projected climate change in terms of the key weather variables (rainfall, temperature, extreme events, storms, sea level rise) in your area, the timeframe over which it will occur and the uncertainty around these metrics.

The evidence that the Earth's climate has changed as a result of human activities has become increasingly clear in recent decades, and there is strong evidence that we can expect further changes over the rest of this century and beyond. Within the UK, the main source of information on past trends and future projections is currently the UK Climate Projections 2009 (UKCP09).

The maps, graphs and key findings within UKCP09 are the best way to see projected changes in the UK climate at a national and regional level. UKCP09 provides mapped projections of climate change at 25 km grid resolution, for climate variables such as temperature and precipitation, both seasonally and annually. Climate projections are available for three greenhouse gas emissions scenarios, seven 30-year time periods and a range of probability levels, to show the spread of possible outcomes. UKCP09 also provides maps of climate projections for the UK at different levels of global average temperature rise. UKCP09 shows that the extent of change in our climate will be influenced by timescale, the extent to which greenhouse gas emissions are controlled, and the sensitivity of the climate system.

All areas of the UK are projected to get warmer, more so in summer than in winter. Changes in projected summer mean temperatures are greatest in southern England. Rainfall patterns are subject to more uncertainty but UKCP09 projections indicate a long-term trend towards proportionately more rain falling in winter and less in summer. There is also increasing evidence of proportionately more rain falling in heavier storms. It therefore makes sense to plan for greater variability in rainfall patterns and the possibility of more floods and droughts. Warmer temperatures in summer months will drive increased evapo-transpiration which may exacerbate the effects of dry summers.

As highlighted above, to capture the inherent uncertainty UKCP09 presents a range of projections covering different scenarios and timeframes. This approach helps explain the potential variation in future climate change, however although the range of possible change is important to consider, when making site based decisions on management a simplified metric is sometimes more useful.

For the purposes of this work it is recommended that the projections from a medium emission scenario (SRES A1B) should be used as a guide, although the consequences of a high emissions scenario (SRES A1Fi) should also be considered as a sensitivity analysis. This emission scenario represents a middle path and represents a sensible first step.

A single emission scenario will not capture the full range of possible future climates. There is also a high level of uncertainty in relation to our understanding of the natural environment's response to climate change and the effectiveness of adaptation measures. This is therefore used as a pragmatic first step to help site managers to envisage the sort of changes to plan for; adaptation measures should be designed to be as robust as possible to a

range of climate change scenarios. Climate change projections also suggest that there will be little divergence in climate change under the different emission scenarios until the middle of the century giving us time to review and adjust our use of projections in the light of experience and new evidence.

Suggested initial information sources:

- UKCP09 Briefing Report (Jenkins and others, 2009) - Full scientific summary of the range of UKCP09 scenarios and time frames.
- Simplified regional climate change predictions based on UKCP09 projections for the 2050s together with key national changes – See Annex 7.

Step 2 – Considering interest features at risk

The purpose of step 2 is to ensure that you have identified the key primary and secondary features of interest on the site.

The impact of climate change is both feature and location specific. It is therefore important to have a clear understanding of the key features of interest before exploring potential impact and vulnerability of sites.

Natura 2000 sites are designated for a range of interest features which occur on site, based on habitats and species listed in Annexes to the Habitats and Birds Directives (Habitats Directive Annex I habitats and Annex II species; Birds Directive Annex I birds and regularly occurring migratory birds not listed on Annex I). Supporting habitats for designated species may also be considered as features of importance and included in the assessment.

Please identify all the features of interest for which the site is designated (those which are both a primary reason for designation and those which are not a primary reason for designation) to enable you to carry out the next step of identifying climate change impacts.

Suggested initial information sources:

- European Site Conservation Objectives
- Site detailed held on the JNCC website: Special Protection Areas; Special Areas of Conservation

Step 3 – Understanding likely climate change impacts

The purpose of step 3 is to give you an understanding of and help you record the expected broad impacts of climate change on the natural environment, and more specific knowledge of the likely impacts on the designated features of your site

Climate change is already affecting our wildlife, habitats and ecosystems in a number of ways, even though the amount of climate change has been relatively small, so far. An understanding of the likely impacts of climate change on the designated features of sites is an essential next step in determining likely threats and / or opportunities.

The projected scale and rate of climate change, coupled with existing environmental pressures, has serious implications for the natural environment and the services it provides. Climate affects most areas of life, directly or indirectly, and climate change will have wide-ranging impacts. At a global scale, the reports of the IPCC

Working Group 2 cover impacts and adaptation. A comprehensive national overview of the key climate change risks to the UK, including the natural environment, is presented in the Climate Change Risk Assessment (2012).

While the emphasis has generally been on the direct impacts of climate change, the way society responds to climate change will also impact on the natural environment. In some cases, these indirect impacts could be greater than the direct impacts. For example, climate change could affect the amount of land used by agriculture and forestry, the choice of crops grown, and decisions on flood protection and water utilisation.

All of these have implications for the natural environment and may influence Natura 2000 sites. Many of these indirect impacts are likely to be subtle and gradual, and will be the result of many individual decisions taken at the local level, but there may also be some larger, step-change adaptation actions and tipping points that affect the natural environment.

The evidence base for the impacts of climate change is developing rapidly, in the UK the evidence has been synthesised into a series of marine and terrestrial report cards which summarise the evidence.

Headline messages from the UK Terrestrial Biodiversity Climate Change Impacts Report Card 2013

- There is strong evidence that climate change is already affecting UK biodiversity. Impacts are expected to increase as the magnitude of climate change increases.
- Many species are occurring further north and at higher altitudes than in previous decades, including some species which have colonised parts of the UK from continental Europe.
- Recent rates of change in distributions differ between species. Some species, including many plants, are intrinsically slow to disperse and fragmentation of habitat may contribute to some species spreading more slowly than would be expected from climate change alone.
- Warmer springs in recent decades have caused a trend towards many biological events (eg flowering, budburst, laying and hatching of eggs) occurring earlier in the year. The rates of change vary among species, which may alter the interactions between species.
- There is evidence of changes in the composition of plant and animal communities, consistent with different responses of different species to rising temperature.
- Species differ in their responses to variation in precipitation. The effects of climate change are less certain for precipitation than for temperature, but potential changes could lead to substantial changes in biodiversity and ecosystems.
- Some habitats are particularly vulnerable to climate change. The risks are clearest for montane habitats (to increased temperature), wetlands (to changes in water availability) and coastal habitats (to sea-level rise).
- Climate change exacerbates the risk that non-native species (including pests and pathogens) may establish and spread.
- We expect there to be regional differences in the impact of climate change on biodiversity, reflecting different species, climate, soils and patterns of land use and management.
- The protected area network, which includes Sites of Special Scientific Interest and National Nature Reserves, will continue to have a valuable role in conservation, although there will be changes in populations, communities and ecosystems at individual sites.
- Climate change will interact with, and may exacerbate, the impact of other continuing pressures on biodiversity, such as land use change and pollution.
- Extreme weather events, such as droughts and floods, have clear impacts on ecosystems

and the ecosystem services they provide. Climate change may alter the frequency and severity of such events. Extreme events associated with climate change may have a greater impact on biodiversity and ecosystems than changes in the 'mean climate'

Suggested initial information sources:

- LWEC climate change impact report cards - Latest scientific reviews of climate change impacts in the terrestrial environment.
- Marine climate change impacts partnership – Latest scientific reviews of climate change impacts in the marine environment.
- Natural England's Adaptation Manual habitat sheets provide more specific guidance on the potential impacts of climate change on priority habitats.
- Climate change risk assessment (2012)

Step 4 – Assessing vulnerability of designated features

The purpose of step 4 is to give you an understanding of how vulnerable the designated features of your site are to climate change, and enable you to record the list of features/impacts/vulnerabilities you have identified. In some cases the features on the site may benefit from climate change.

The vulnerability of species and habitats to climate change is influenced by four factors:

- The changes in climate, type, magnitude and timescale, that are likely to occur in the local area;
- The intrinsic sensitivity of the species, ecosystem or other feature of the site to those climatic changes;
- The site-specific conditions that could make things better or worse;
- The capacity to manage those conditions.

Sensitivity is an important element of vulnerability and one about which some generalisations can be made at a national level, which are often a useful starting point for site-specific vulnerability assessments. Table A1 presents a basic classification of UK habitats according to their relative sensitivity to climate change. This is derived from a similar table originally published in the England Biodiversity Strategy - Towards adaptation to climate change (Defra, 2007) and revised in the development of Natural England's National Biodiversity Climate Change Vulnerability model (2014) and in producing the Natural England / RSPB Climate Change Adaptation Manual (2014).

The high sensitivity habitats are those whose existence is dependent on specific climatic, hydrological or coastal conditions, which projections indicate will change with climate change. The low sensitivity habitats are those which are determined by other factors such as grazing and geology, or with more generalist species, and where climate plays a lesser role. It should be noted that these broad habitats include a wide range of vegetation types within them, some of which will be Natura 2000 interest features in their own right, and that these classifications are generalisations which should not be over-interpreted. It is also the case that the species' abundance and composition of low or medium sensitivity habitats may change even if the type of habitat remains broadly the same. This may result in substantial ecological change.

Table A1 **Relative sensitivity of habitats to climate change (classification adapted from Mitchell and others (2007))**

Habitat	National sensitivity classification
Coastal saltmarsh	High
Montane	High
Saline lagoons	High
Standing water	High
Lowland fen	High
Rivers and streams	High
Upland hay meadows	Medium
Coastal grazing marsh	Medium
Lowland raised bog	Medium
Floodplain grazing marsh	Medium
Purple moor grass and rush pasture	Medium
Coastal vegetated shingle	Medium
Lowland meadows (wet)	Medium
Reedbeds	Medium
Blanket bog	Medium
Coastal sand dunes	Medium
Upland fens and flushes	Medium
Lowland heathland	Medium
Upland heathland	Medium
Intertidal mudflats	Medium
Lowland beech and yew woodlands	Medium
Wet woodland	Medium
Upland mixed ash woods	Medium
Upland oak wood	Medium
Maritime cliff and slope	Medium
Limestone pavements	Low
Lowland meadows (dry)	Low
Deciduous woodland	Low
Lowland calcareous grassland	Low

Lowland dry acid grassland	Low
Upland calcareous grassland	Low
Arable field margins	Low
Ancient species rich hedgerows	Low
Lowland wood pasture and parkland	Low

Species also will differ in their sensitivity to climate change. The reasons for this sensitivity vary and may be complex. In some cases, the limitations on a species' range are set by physical conditions, for example the failure to set viable seed at low temperatures. A classic example of this is the northern limit of the small leaved lime, *Tilia cordata*, which is part of the SAC feature H9180 *Tilio-Acerion* forests of slopes, screes and ravines, a priority feature for the UK. In other cases, interactions with other species are the determining factor. For example, most alpine plant species can survive at higher temperatures than they typically occur at but do not do so in natural conditions because they cannot compete with taller, faster growing species typical of lower altitudes. Species may alternatively depend positively on the presence of another species, for example as a food source or host. Conservation adaptation actions may be able to address these issues, for example controlling competitors so reducing a species' vulnerability to climate change.

The relationship between the current range of many species and climate implies that climate change will lead to changes in distribution. However, this needs to be interpreted with care as many other factors will influence a species' distribution, including the availability of habitat within the new climatically suitable areas, and the ability of a species to move. Nevertheless, as a general rule of thumb, a species at its northern range margin in Britain is likely to increase and spread further north, while one at its southern range margin is likely to decline and its geographic extent contract.

The relationship between the distribution of a species and climate can be modelled using what are sometimes termed 'climate envelope' models, which quantify the relationship between distribution and climatic variables using a range of mathematical techniques. These relationships can then be used to project future changes on the basis of climate change scenarios. This technique has been developed over the last twenty years in the UK, and projected changes in distribution are available for many species. One of the most influential projects of this sort in the UK was MONARCH (Modelling Natural Resource Responses to Climate Change). Another, which modelled a wide range of species in Britain, was BRANCH (Biodiversity Requires Adaptation in Northwest Europe under a Changing climate). Results from both of these projects continue to be valuable, although it remains necessary to be aware of the uncertainties associated with modelled data. Atlases of climate envelope projections have also been completed for both breeding birds and butterflies at the European scale (Huntley and others, 2007, Settele and others, 2008), and used to assess species movements in and out of protected areas. Natural England also intends to publish a report on this topic in 2015 using updated methodology (Pearce-Higgins and others, in prep). A similar approach has also been developed for woodlands through 'Ecological Site Classification', which models the future 'suitability' of NVC woodland types and individual species.

Climate envelope modelling has proved a valuable guide to species sensitivity to climate change. It is useful in identifying where to prioritise action – for example in places where a species is likely to be at risk or to have an opportunity to colonise. However, it has limitations which need to be understood in using its results. These include the following:

- If current distributions are determined largely by factors other than climate, such as soil conditions associated with a particular local geology, the relationship between present day distribution and climate

will be weak and of limited value in projecting future change. In the cases of rare, localised species, it is frequently not possible to derive any relationship to climate.

- Climate change may result in climatic conditions for which there is no present day comparison, and projections based on present climate will be unreliable.
- Climate and distribution are typically mapped at a large scale (tens of kilometres). The actual distribution of species may, in practice, be determined at a much smaller scale, strongly influenced by microclimates. So, for example, a species may be restricted to the coolest parts of a grid square, or north facing slopes, whereas the climate value for that square reflects an average.
- Distribution maps for some species may not be accurate. Britain has better datasets than most other countries, but there are still gaps in the distribution record in more isolated areas and for harder to identify and less charismatic groups of species. Future climate projections rely, to some extent, on distributions outside the UK, where climate conditions that projected in the UK in the future, are already present.
- Local climate variations and microclimates may provide conditions in which a species can survive locally, where one would not expect it to on the basis of larger scale patterns in climate. These localised areas of suitable climate are sometimes termed microclimatic refugia.
- Climate envelope models simply indicate where climate conditions may be suitable, but not whether a species can reach a new potential location or whether other requirements such as habitat or food supply will be available there.

Whether Natura 2000 features are vulnerable to climate change will depend not only on whether they are inherently sensitive to climate change, but also the level of climate change they will be exposed to (exposure), the ability of the species or habitats to respond to climate change (intrinsic adaptive capacity) and the ability of conservation management to alleviate climate change impacts (extrinsic adaptive capacity).

At the site scale the exposure to climate change will vary due to a range of factors such as physical attributes like local topography, soil type, the availability of water. It will also be influenced by biological factors such as the type and structure of the vegetation and sward and the ability to manage them. For example, coastal grazing marsh is inherently sensitive to climate change due to sea level rise and coastal surges, however the vulnerability of grazing marsh can be influenced not only by location specific coastal processes that might moderate or exacerbate these factors, but by also man made interventions. Teesmouth NNR (part of Teesmouth and Cleveland Coast SPA) for example is in part protected by a well maintained sea wall designed to protect large infrastructure (oil refinery), the enclosed coastal habitats are therefore at a lower vulnerability than would normally be expected, reducing the exposure to climate change. Terrestrial inland sites where the means to control the quality and quantity of water are in place would be in a similar situation. The converse is also true where man made features like coastal defences create coastal squeeze and an inability for species and habitats to naturally adapt.

The adaptive capacity of species and habitats to respond to the impacts of climate change will be influenced by the condition of the sites. Sites that are in sub-optimal condition and under pressure from other factors are likely to have a lower ability to respond to climate change than habitats and species that are in optimal (favourable) condition so are considered to be at higher risk. It is also important to consider the site in terms of the wider landscape: small or isolated sites are likely to have a reduced ability to recover from climatic events compared to large sites situated in landscapes with high levels of semi-natural habitat.

Vulnerability should therefore be assessed by gauging the impact of local conditions (the degree of exposure) on the inherent sensitivity of the key species and habitats.

The suggested approach is to consider the vulnerability of the features identified in step 2 against broad weather variables – rainfall, temperature, extreme events with a simple High, Medium or Low assessment – using the impacts identified in step 3. The template in Annex 6 can be used to capture this information The "other" weather box should be used to capture other climate change variables such as sea level rise, storms and indirect impacts such as changes in access, or agricultural practice. The reason behind the assessment can be captured in the reasoning column.

When considering vulnerability, assign a level of confidence to that judgement (high, medium, low). This will then enable evidence gaps to be identified and / or issues around the communication and synthesis of the existing evidence.

Suggested initial information sources:

- For habitats use the Adaptation Manual habitat sheets
- For the wider area use the National Biodiversity Climate Change Vulnerability Assessment
- For wetlands the CEH Wetland Tool for Climate Change
- For species, Natural England is in the process of publishing a report that focuses specifically on how species distributions may change as the climate changes and what the implications of these changes may be for their conservation (Pearce-Higgins and others, in prep).
- A series of Natural Character Area climate change vulnerability reports have been produced by Natural England for a range of landscapes across England, covering the following Natural Character Areas:

  South East Northumberland
  Humberhead Levels
  North Kent
  Sherwood
  South Downs National Park
  Cumbria High Fells
  Dorset Downs and Cranborne Chase
  Shropshire Hills
  The Broads

These will be useful if your site falls within one of these areas, but they also provide a methodology for climate change assessments and a large amount of transferable information on natural environment assets and ecosystem services.

Step 5 – Identifying adaptation responses

The purpose of step 5 is to identify adaptation responses to address the identified impacts and vulnerabilities of the site features. Evidence gaps should also be identified and an action plan to fill them created.

The next step is to consider how to respond, or adapt to, the vulnerabilities and risks climate change brings to biodiversity and Natura 2000 sites. Responses should also make the most of any opportunities identified. This includes looking for actions that have multifunctional and 'win-win' benefits, such as soft engineering approaches to flood management which can provide society with flood defence and also enhance biodiversity, and green infrastructure provision which can provide natural environment enhancements alongside recreational space and a reduction in the urban heat island effect. This is known as ecosystem based adaptation; see part 3 of

the Adaptation Manual for more information on ecosystem services and climate change.

More formally, adaptation can be defined as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

These elements should be considered for Natura 2000 sites, the requirements of the designations are likely to drive the actions and so the ability to consider some of the broader concepts may be limited and should be implemented as opportunities arise.

A useful way of ensuring a long-term, integrated approach to adaptation, including the synergies and trade-offs associated with cross-sectoral adaptation is to use the principles of sustainable adaptation (Macgregor & Cowan, 2011):

- 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.
- Adaptation should not solve one problem while creating or worsening others. Action that has multiple benefits and avoids creating negative effects for other people, places and sectors should be prioritised.
- 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.
- Approaches to adaptation should be flexible and not limit future action.

Within the UK, the Government's National Adaptation Programme sets out four focal areas for adaptation in the natural environment.

- Building ecological resilience to the impacts of climate change;
- Preparing for and accommodating inevitable change;
- Improving the evidence base; and
- Valuing the wider adaptation benefits the natural environment can deliver.

All of these focal areas will be of importance for Natura 2000 sites.

Responses are likely to cover all four aspects of adaptation identified in the National Adaptation Programme (NAP) (HM Government, 2013). Building resilience is likely to be the initial major focus whilst climate impacts are relatively modest; it is also most closely aligned to current best conservation practice. However, over time, as the climate changes and its impacts increase, the other elements will become increasingly important. It is therefore essential to factor in these measures now, especially for those that will take a relatively long time to implement.

Suggested initial information sources:

- For habitats use the Adaptation Manual habitat sheets.
- For species Natural England is in the process of publishing a report that focuses specifically on how species distributions may change as the climate changes and what the implications of these changes may be for their conservation.

Step 6 - Delivery & review

Step 6 is all about ensuring that we learn from what we do. It describes the management cycle that covers how climate change adaptation is embedded in other work, how it is monitored and reviewed.

Adaptive management

Adaptation is an iterative process that calls for close monitoring and regular review to ensure that the management of the N2K network is continually adapting to a dynamic world, where what is known about the past, present and future is rapidly changing. The knowledge of the effectiveness of our responses, both generically and at a site level is also developing.

Adaptive management is a commonly used management concept, not specific to climate change adaptation that describes what is required. It is based on a cycle of action, monitoring, review, and, if necessary, revision of actions. It is especially relevant to climate change adaptation, where the nature of impacts and the effectiveness of adaptation measures will become clearer over time. It is also an approach that ensures that lessons are learnt and built on due to the ongoing process of evaluation and review. To achieve this, the steps set out above should be fully embedded in the management and planning of sites and the network as a whole. It should not be considered as an additional extra, but mainstreamed and aligned with the existing management planning cycle.

Monitoring and reporting

Effective long term monitoring of changes in the species, habitats and other features of the site is an essential prerequisite for this approach, as is monitoring of the success or failure of any measures put in place. This may be partially delivered by the long-term monitoring network (LTMN), which builds on the work of the Environmental Change Network (ECN) and earlier proposals to develop an Environmental Change Biodiversity Network (ECBN). Other datasets and monitoring schemes, such as those for birds, butterflies and plants run by NGOs and statutory agencies, may also make a helpful contribution.

Long term monitoring provides a baseline against which the future state of the environment can be assessed in a reliable historical context and it allows unanticipated changes to be identified. The LTMN will collect data relating to the effects of climate change, air pollution and land management on biodiversity across 40 core monitoring sites, using standard methodology. Most of the sites are National Nature Reserves, and many are also Natura 2000 sites. This monitoring will enable Natural England to advise others (such as Defra) on mitigation or adaptation actions and inform the adaptation of Natural England's own interventions and activities. Data gathered by the LTMN will become an essential resource to inform the monitoring of climate change effects, and further joint work is required to identify how representative the core monitoring sites are of the wider Natura 2000 network and to develop approaches and protocols to facilitate the monitoring and reporting that is required for Natura 2000 sites.

Annex 6. Site based assessment recording template

It may be helpful to use the template below to record the site based assessment, as suggested in section 3.

Site name:								
Comments on climate change projections and likely broad impacts (steps 1 and 3)								
Designated interest features (step 2)	**Vulnerability of interest features to broad weather variables (high, medium or low) (step 4)**				**Reasoning**	**Confidence (high, medium, low)**	**Adaptation responses identified (step 5)**	**Implementation and review (step 6)**
	Rainfall	***Temperature***	***Extreme Events***	***Other***				
Eg Lowland raised mire								
Nightjar								

Annex 7. Simplified regional climate change projections for 2050

The maps below present simplified regional climate change projections based on:

- CP09 Climate change projections using a medium emissions scenario (Jenkins and others, 2009);
- Projections for the 2050's
- Projections for temperature and precipitation are regional
- Projections for extreme events, storms, sea-level rise and acidification are national (but relevant across all regions)

National projections can be summarised as:

- Increased variation within and between years in temperature and rainfall patterns
- Increased frequency of extreme events such as drought and heat waves
- More precipitation will fall in the form of extreme rainfall events
- Sea level rise around the UK is projected to be between 12 and 76 cm for the period 1990–2095
- The shelf seas around the UK are projected to be 1.5 to 4ºC warmer and ~0.2 practical salinity units (p.s.u.) fresher (lower salinity) by the end of the 21st century.

East of England

- Increase in winter mean temperature is 2.2ºC (1.1 - 3.4ºC.)
- Increase in summer mean temperature is 2.5ºC (1.2-4.3ºC).
- Increase in summer mean daily maximum temperature is 3.4ºC; (1.3-6.0ºC)
- Increase in summer mean daily minimum temperature is 2.7ºC (1.2ºC -4.7ºC)
- Change in annual mean precipitation is 0%; (–5- +5%.)
- Change in winter mean precipitation is 14% (3-31%)
- Change in summer mean precipitation is –17% (–40 - 14%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

East Midlands

- Increase in winter mean temperature is 2.2ºC (1.1 - 3.4ºC.)
- Increase in summer mean temperature is 2.5ºC (1.2-4.2ºC).
- Increase in summer mean daily maximum temperature is 3.3ºC; (1.3-5.9ºC)
- Increase in summer mean daily minimum temperature is 2.7ºC (1.2ºC -4.6ºC)
- Change in annual mean precipitation is 0%; (–5- +6%.)
- Change in winter mean precipitation is 14% (2-29%)
- Change in summer mean precipitation is –16% (–38 - 13%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

North East

- Increase in winter mean temperature is 2.0ºC (1.1 - 3.1ºC.)
- Increase in summer mean temperature is 2.5ºC (1.2-4.1ºC).
- Increase in summer mean daily maximum temperature is 3.2ºC; (1.0-5.7ºC)
- Increase in summer mean daily minimum temperature is 2.5ºC (1.0ºC -4.4ºC)
- Change in annual mean precipitation is 0%; (–5- +5%.)
- Change in winter mean precipitation is 11% (1-24%)
- Change in summer mean precipitation is –15% (–30 - 1%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

North West

- Increase in winter mean temperature is 1.9ºC (1.0 - 3.0ºC.)
- Increase in summer mean temperature is 2.6ºC (1.2-4.2ºC).
- Increase in summer mean daily maximum temperature is 3.3ºC; (1.0-5.8ºC)
- Increase in summer mean daily minimum temperature is 2.5ºC (1.0ºC -4.4ºC)
- Change in annual mean precipitation is 0%; (–6- +6%.)
- Change in winter mean precipitation is 13% (1-27%)
- Change in summer mean precipitation is –18% (–37 - 8%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

South East

- Increase in winter mean temperature is 2.2ºC (1.1 - 3.4ºC.)
- Increase in summer mean temperature is 2.8ºC (1.3-4.6ºC).
- Increase in summer mean daily maximum temperature is 3.7ºC; (1.4-6.6ºC)
- Increase in summer mean daily minimum temperature is 3ºC (1.3ºC -5.1ºC)
- Change in annual mean precipitation is 0%; (–5- +6%.)
- Change in winter mean precipitation is 16% (2-36%)
- Change in summer mean precipitation is –19% (–41 - 7%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

South West

- Increase in winter mean temperature is 2.1ºC (1.1 - 3.2ºC.)
- Increase in summer mean temperature is 2.7ºC (1.3-4.6ºC).
- Increase in summer mean daily maximum temperature is 3.8ºC; (1.4-6.8ºC)
- Increase in summer mean daily minimum temperature is 2.9ºC (1.2ºC -5.0ºC)
- Change in annual mean precipitation is 0%; (–6- +6%.)
- Change in winter mean precipitation is 17% (4-38%)
- Change in summer mean precipitation is –20% (–42 - 7%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

West Midlands

- Increase in winter mean temperature is 2.1ºC (1.2 - 3.2ºC.)
- Increase in summer mean temperature is 2.6ºC (1.2-4.4ºC).
- Increase in summer mean daily maximum temperature is 3.6ºC; (1.3-6.5ºC)
- Increase in summer mean daily minimum temperature is 2.7ºC (1.1ºC -4.8ºC)
- Change in annual mean precipitation is 0%; (–6- +6%.)
- Change in winter mean precipitation is 13% (2-27%)
- Change in summer mean precipitation is –17% (–37 - 6%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

Yorks & Humber

- Increase in winter mean temperature is 2.2ºC (1.1 - 3.4ºC.)
- Increase in summer mean temperature is 2.3ºC (1.1-3.9ºC).
- Increase in summer mean daily maximum temperature is 3.1ºC; (1.2-5.4ºC)
- Increase in summer mean daily minimum temperature is 2.6ºC (1.1ºC -4.4ºC)
- Change in annual mean precipitation is 0%; (–4- +4%.)
- Change in winter mean precipitation is 11% (1-24%)
- Change in summer mean precipitation is –19% (–36 - 1%.)

Brackets indicate changes which are very likely to be exceeded, and very likely not to be exceeded (10 and 90% probability levels, respectively)

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