Natural England Commissioned Report NECR202

# Increasing the resilience of the UK's Special Protection Areas to climate change

## Overview and key messages

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# Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

## Background

Understanding the ecological consequences of climate change for Special Protection Areas (SPAs) is critical if site managers are to develop adaptive management strategies. This series of case studies highlights how current management might be adapted at site level to address future climate change impacts.

The study identifies some of the greatest barriers to delivering adaptive management, which will require a consensus across a wide number of organisations if the priority actions to increase the resilience of SPAs to climate change are to be delivered.

This report is supported by the following:

- NECR202a - Case study: Minsmere-Walberswick
- NECR202b - Case study: North Norfolk Coast and Great Yarmouth North Denes
- NECR202c - Case study: Peak District and South Pennine Moors
- NECR202d - Case study: Somerset Levels and Moors
- NECR202e - General adaptive management recommendations

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**Further information**
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## Note

This report has been prepared for Natural England and represents a contribution to the evidence base informing the development of adaptive management strategies for the UK's SPAs in relation to climate change. The report's aim is to outline the potential ecological consequences of climate change for SPAs and to discuss potential adaptive management responses. Current management activities and potential adaptive responses for each SPA case study were informed by the discussion deriving from site workshops where major stakeholders for the SPA were represented. The report makes no specific policy recommendations, and the information contained may not be in agreement with other existing management and/or policy-related documents. For a more detailed discussion on Natural England's approach to coastal and fresh water management, please see *The Climate Change Adaptation Manual - Evidence to support nature conservation in a changing climate (NE546)* http://publications.naturalengland.org.uk/publication/5629923804839936

## Executive Summary

- The Natura 2000 network of European protected sites is one of the largest in the world, but there is extensive debate as to how climate change will affect sites within the network and how best to respond to anticipated change.
- Recent work under the CHAINSPAN project has demonstrated that the UK's Special Protection Area (SPA) network will be resilient to climate change in that current protected sites will continue to be important for bird communities in the future. However, the suite of qualifying species at many individual SPAs is projected to change, likely as a result of climate-driven changes to habitats and ecosystems.
- There is a need to develop more site-specific information so that conservation managers can better adapt management strategies to projected future climate change to increase the resilience of their SPA, both for current and potential features of interest.
- This report uses model projections from the CHAINSPAN report to identify a short-list of English SPAs in different habitats most likely to be affected by climate change. These SPAs form the basis for a set of case studies to evaluate how generic habitat-based management suggestions might be adapted for specific SPAs and applied on the ground to increase resilience to climate change, with the intention that the process developed here can be adapted for SPAs across the UK and could even be applied more widely across the Natura 2000 and other protected area networks.
- Each case study used first-hand consultation with SPA site managers to assess 1) how current management might be adapted in the future, or whether current activities promote increasing climate change resilience; and 2) the practicalities of implementing suggested management measures given particular constraints or issues unique to the SPA.
- Consultations with site managers highlighted that climate change adaptation is approached from a broad range of perspectives depending on the management objectives for the site, the amount of land within the SPA that is owned by conservation organisations (which provides greater freedom to manage for conservation outcomes), and particular management constraints imposed by other interests.
- Management approaches could be placed along a continuum, ranging from maintaining current interests to facilitating or enhancing change. Some managers achieved a balance between delivering benefits to current interests while also increasing resilience to future change, either intentionally or as a consequence of delivering current benefits (usually overall habitat quality improvement). Others focused on maintaining current interests but accepted that sudden change would come when the magnitude of climatic impacts exceeded the ability of current resources to resist such change.
- Site managers highlighted the Higher Level Stewardship programme and investment in water infrastructure as two of the most important tools to deliver both current and adaptive management. Managers highlighted a need for increased flexibility in the HLS programme and its successors (e.g. Countryside Stewardship) in order for them to be able to deliver prescribed management and maintain funding, given increasing uncertainty and annual variability in climate. Increased investment in water infrastructure is a key adaptive response to increase climate change resilience (both

to manage flood risk and to increase resilience to drought), and could be supported through contributions from a variety of funding sources, including environmental stewardship, the Environment Agency via the EU's Water Frameworks Directive, or flood levies.

- Constraints on adopting an adaptive management approach arose when adaptive measures conflicted with external interests, mainly agricultural, or where measures were contingent on cooperation with outside agencies (mainly the Environment Agency) which balanced the interests of other groups.
- Managers noted that current SPA boundaries and citations often did not adequately capture the full extent of habitats used by SPA features nor the current suite of species fulfilling qualifying criteria. A re-evaluation of the designation process to create increased flexibility in designations e.g. by the SPA Scientific Working Group and through IPENS (Improvement Programme for England's Natura 2000 Sites) may improve the ability of the SPA designation to provide spatially and temporally accurate information on internationally important areas for birds in the UK.
- Reducing the impacts of predation and human disturbance were viewed as important features of an adaptive management strategy, given the potential for these factors to interact with the projected impacts of climate change, or to prevent potentially range-expanding species increasing in response to climate change. Achieving this will require greater funding and staff resources than available at present.
- Given the current degree of functional connectivity between SPAs at the regional level and the potential for greater connectivity to improve the resilience of the network by providing heterogeneity of habitats and management approaches across landscapes, there is a need to improve coordination and cooperation between conservation organisations within SPAs and across SPAs to formally develop management strategies at multiple scales, with direction and oversight from a governing body (e.g. Natural England).
- This report served to identify some of the key tools that conservation managers rely on to deliver current management, and identified how these tools might be affected by future climate change. It also identified some of the greatest barriers to delivering adaptive management, and highlighted where policy changes and cooperation and negotiation with outside groups and agencies might be required to deliver priority actions to increase climate change resilience of SPAs.

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# 1. Background

The Natura 2000 network in the European Union (EU) is one of the most extensive protected area networks in the world, comprising 27,661 sites across 27 countries that protect 17% of the land area (European Union 2009). The network includes a series of Special Protection Areas (SPAs) which are classified under the EU Birds Directive to help "ensure the survival and reproduction.... in their area of distribution" of both rare and threatened birds (listed on Annex I of the Birds Directive) and migratory birds (Article 4, Birds Directive, European Union 2009). Bird populations within SPAs should be maintained "at levels that correspond in particular to ecological, scientific and cultural requirements" or "adapt the population... to that level" (Article 2, Birds Directive, European Union 2009). Within the UK, a total of 270 SPAs had been designated by September 2011, covering about 2.7 million hectares (ha). Eighty-one of these are located in England across one million ha (JNCC 2013). There is considerable evidence that the establishment of SPAs has benefited the conservation of birds and their habitats (Donald et al. 2007).

There is much debate about the likely impacts of climate change on the SPA network. Climate change is anticipated to result in significant shifts in the distribution of species and habitats (Bellard et al. 2012), including European breeding birds (e.g. Huntley et al. 2007), which has led some to question the extent to which the current SPA network will remain a useful focus for conservation activity in the longer-term (Cliquet et al. 2009, Dodd et al. 2010, 2012, Araújo et al. 2011). The Defra-funded Climate Change Impacts on Avian Interests of Protected Area Networks project (CHAINSPAN), which was undertaken by a British Trust for Ornithology (BTO)-led consortium, was set-up specifically to address this issue, by modelling the implications of climate change for UK SPAs (Pearce-Higgins et al. 2011, Johnston et al. 2013). In general, northerly-distributed breeding birds were projected to decline in abundance with increasing magnitude of climate change, whilst populations of southern breeding species and many wintering waterbirds were projected to increase in size. Although latitudinal shifts in species composition were anticipated, the network across the UK generally appeared robust, largely because it comprises a comprehensive network of sites; most designated sites will continue to support nationally or internationally important populations in the future. Suggestions to improve the resilience of the network were made which involved improved management of SPAs, bigger SPAs, increasing the number of wildlife-rich areas and improving connectivity between SPAs. These were supported by more detailed management recommendations for particular habitats and species.

This report was followed by a further assessment of the role of climate change in driving changes in the abundance of birds on SPAs (Massimino et al. 2012), which identified the sites and species where recent population trends in Annex I and migratory bird species are most likely to have been driven by climate change. In particular, a number of SPAs designated for their seabird and waterbird interest were identified where recent population declines appeared unrelated to climate change, suggesting they should be priorities for conservation action.

Together, these two documents identify the sites where recent population trends have tended to be consistent with recent climatic changes, and the likely magnitude of future projected population changes for species at those sites. Although the network as a whole is deemed resilient to climate change, this does not mean that it will protect species from the effects of climate change; more than 50% of waterbird and seabird species were projected to suffer greater than 25% population declines by 2080 (Johnston et al. 2013). Instead, it means that SPAs should remain a focus for conservation action for these species.

Management has the potential to increase the resilience of SPA habitats and populations to climate change impacts (Carroll et al. 2011, Pearce-Higgins et al. 2011), but adapting on-the-ground conservation action to climate change such that it can be applied by land managers requires the development of a set of general evidence-based recommendations for Natural England staff and SPA site managers to inform their decision-making. This requires translating information about projected climate change impacts at a site into a set of potential responsive management measure for that site, in order to identify and prioritise the actions which are mostly likely to be effective in increasing resilience to climate change. This report uses the CHAINSPAN projections to identify a short-list of English SPAs most likely to be affected by climate change. These SPAs form the basis for a set of case studies to evaluate how recommended management measures might be applied on the ground to increase resilience to climate change, with the intention that the process developed here can be adapted for SPAs across the UK.

### *Objective*

Increasing a site's resilience to climate change requires first understanding what the potential consequences of a changing climate are for the ecology of SPA habitats and species, and then adapting management actions to address these consequences. Developing practical adaptive management recommendations for an SPA requires first-hand consultation with site managers to assess 1) how current management might be adapted in the future, or whether current activities are synergistic with increasing resilience; and 2) the practicalities of implementing suggested management measures given particular constraints or issues unique to the SPA. The process developed for the case studies in this report provides a template that can be adapted for developing a set of practical adaptive management recommendations for other SPAs (see Box 2.1), and will also serve to highlight some of the primary constraints to adapting management to climate change that might be more broadly addressed by changes to policy or legislation.

# 2. Overview of process

## 2.1. Ecological impacts of climate change and general habitat management responses

We first developed a set of general management recommendations to address the potential ecological consequences of climate change for several broad habitat categories, with the intention that these general recommendations could then be adapted more specifically to particular SPAs. Within these broad categories, ecological impacts of climate change and potential management responses were specified for particular habitats. Broad categories and habitats included within them were:

1. Coastal:
   a) Intertidal (mud flats, sand flats, estuaries), saltmarshes, coastal sand dunes and beaches
   b) Coastal grazing marshes
   c) Saline lagoons

2. Freshwater wetland:
   a) Wet grassland
   b) Reedbed and open water
3. Upland:
   a) Alpine and sub-alpine grassland, heath, scrub, upland bogs, marshes, and fens, peatland
4. Heath:
   a) Lowland heathland, dry grassland, scrub, and surrounding arable land

For each habitat, we first identified what projected changes in climatic variables would have the greatest potential to drive future change at the site, the principal mechanism(s) by which they would influence the environment of the site, and the potential ecological outcomes of projected change, for example:

Decreased summer precipitation =>
Increased frequency of summer drought =>
Changes in invertebrate prey community and foraging habitat quality

We then outlined some potential management responses that could address the ecological consequences of projected change and identified what effect these actions might have for breeding and non-breeding populations of current and potential SPA features in each habitat. The potential consequences of climate change for the four major habitat categories, together with a set of general adaptive management recommendations are outlined in Annex 5.

## 2.2. SPA selection for case studies

Using the CHAINSPAN model projections, we created a short-list of English SPAs predicted to experience the greatest site-specific impacts of climate change (based upon projected changes in summer and winter temperature and precipitation from UKCP09) on species' abundance. Here, we considered the modelled projections of species' changes in abundance from 2006 to 2050 under a medium emissions scenario, and to 2080 under a high emissions scenario. Short-listed SPAs had the greatest number of species meeting at least one of the following criteria:

a. number of species that are predicted to decline by more than 25%;
b. number of species that are predicted to increase by more than 25%;
c. number of species that are predicted to lose their qualifying status as a result of their decrease in abundance; and
d. number of species that are predicted to gain qualifying status as a result of their increase in abundance.

Separate shortlists were produced for the main habitats of conservation interest: coastal, wetland, heath and upland. With the project Steering Group, we selected at least one SPA representing each habitat type, also taking into account their geographical proximity to our base and to each other to improve cost-effectiveness when travelling to meetings with site managers during the consultation workshops. Twelve SPAs were short-listed, from which we selected five for the case studies (Table 2.1).

Table 2.1. Short-listed SPAs, main habitats, and which qualifying criteria for short-listing they fulfilled. SPAs selected for case studies are in bold.

| SPA name | Site code | Main habitat(s) | Criteria (see methods) |
|---|---|---|---|
| **North Norfolk Coast*** | **UK9009031** | **coastal** | **a** |
| Stour and Orwell Estuaries | UK9009121 | coastal | c |
| The Wash | UK9008021 | coastal | d |
| Hamford Water | UK9009131 | coastal | c |
| Chichester and Langstone Harbours | UK9011011 | coastal | b, c |
| Breydon Water | UK9009181 | wetland | a, b, d |
| **Somerset Levels and Moors** | **UK9010031** | **wetland** | **a, d** |
| Rutland Water | UK9008051 | wetland | b, c |
| Ouse Washes | UK9008041 | wetland | d |
| Breckland | UK9009201 | heath | b |
| **Minsmere–Walberswick** | **UK9009101** | **heath, coastal and wetland** | **a, b, c** |
| **South Pennine Moors (Phase I and II)** | **UK9007021, UK9007022** | **upland** | **a** |

*Great Yarmouth North Denes SPA (UK9009271, coastal) was selected along with North Norfolk Coast due to its close proximity and its breeding tern interest, which is also an important feature of North Norfolk Coast.

## 2.3. Site consultation workshops

Prior to site workshops, we identified the main climate impacts projected for the SPA based on UKCP09 climate projections for precipitation, temperature, and sea level rise (if relevant), and used this to inform a summary of the primary environmental and ecological consequences of projected climate change for the SPA and to outline a specific set of management recommendations for the current and potential SPA features for the site (see Box 2.1, Phase 1 and 2). Using the SPA-specific CHAINSPAN model projections, we summarised projected changes in populations for species (mainly waterbirds) at the site and highlighted groups of species projected to be most at risk (> 50 % projected population decline) or that would most benefit (> 50 % projected population increase) from climate change. These site-specific projected population changes were placed in the perspective of national population trends using species' assessments from an additional project quantifying the likely risks and opportunities for species in England in response to climate change (Pearce-Higgins et al. 2013).

For each SPA selected for a case study example, the next step was to arrange consultation workshops with the major conservation landowners responsible for the site (see Box 2.1, Phase 3). Representatives generally included Natural England land management advisers or reserve managers, Royal Society for the Protection of Birds (RSPB) conservation officers and reserve managers, National Trust countryside managers, and site managers for local Wildlife Trusts, with water utility companies and local city councils also represented at the South Pennine Moors workshop. At site workshops, we outlined the potential ecological and population changes that might be expected at the SPA with future climate change, emphasizing that whilst model projections provide a general overview of population change for groups of species at an SPA-level, they are generally associated with high levels of uncertainty and projected trends should be interpreted with some caution. Model projections may be most informative in providing perspective on how populations at an SPA might be expected to change relative to trends at the national level, particularly when comparing site-specific projections with the outputs from the risks and opportunities report (Pearce-Higgins et al. 2013). In consultation with site managers, current habitat management actions most important for an SPA's principal habitats and features were identified with respect to water and vegetation management, predator control and reducing the impact of human disturbance at the site. Together with site managers, we then assessed the practicalities of implementing our initial suggested management recommendations for the SPA, identifying which options were most synergistic with current management or would be least constrained by other considerations, and which might be more difficult to implement due to particular constraints. Based on discussion from these consultation workshops, for each SPA case study, we highlight priority management actions for increasing climate change resilience, and identify which are likely to be easiest to implement and which are constrained by other considerations (and what those constraints are).

The process developed here (summarised in Box 2.1) and implemented in five case study examples can be used and adapted for other SPAs, reserves, or protected areas in the UK and internationally to identify future potential climate change impacts and consequences for sites and to guide potential adaptive management responses.

Box 2.1. Summary of process developed to identify the potential impacts and consequences of climate change for SPAs and priority adaptive management measures.

***Phase 1: Identify climate impacts, ecological consequences, and population projections***

Step 1: use the JNCC UK SPA Review (Stroud et al. 2001) to identify qualifying features of the SPA, habitat types, general site description, vulnerabilities, and other designations.

Step 2: use the UKCP09 climate projections online user interface[a] and baseline average datasets[b] to calculate absolute and projected changes in precipitation and temperature for the HadRM3 regional climate model 25 x 25 km grid cell containing (or centred on) the SPA for a:

1) 2050 medium emissions scenario;
2) 2080 high emissions scenario.

For coastal SPAs, calculate relative sea level rise (SLR) for the grid cell with greatest coverage (or average relative SLR of the relevant grid cells for SPAs with long stretches of coastline).

Step 3: use the climate projections to inform the primary ways in which climate change will be likely to affect the site. Identify the main climate-driven causal factor(s), the principal mechanism(s) by they would influence the environment of the site, and the ecological consequences (e.g. increased winter rainfall => increased frequency/extent of winter flooding => reduced quality of winter foraging habitat).

Step 4: use the CHAINSPAN model population projections for the SPA, and for all modelled species under each of a 2050 medium and 2080 high emissions scenario, identify whether the population is projected to change by:

1) 25-50% (a moderate increase or decline);
2) > 50% (a large increase or decline);
3) < 25% (remain "stable").

Also provide national assessment of climate change impacts for species based on the risks & opportunities report (Pearce-Higgins et al. 2013).

***Phase 2: Create SPA-specific management recommendations***

Step 5: use the general management recommendations for the four broad habitat classifications in this report (Annex 5) to adapt a more specific set of recommendations for the SPA's current and potential features. Identify whether measures are likely to benefit or be a detriment to (or have little effect on) the breeding or non-breeding populations of the SPA's features.

***Phase 3: Consult with site managers***

Step 6: in consultation with principal site managers overseeing land management within the SPA, outline current habitat management actions most important for the SPA's features e.g. with respect to water and vegetation management, predator control, reducing impact of human disturbance. Identify and discuss any constraints on implementing current management strategies.

Step 7: with site managers, assess practicalities of implementing suggested site-specific management recommendations and:

1) identify synergies with current management actions;
2) identify constraints associated with implementing suggested management measures;
3) identify priority actions for increasing the SPA's resilience to climate change.

[a] http://ukclimateprojections-ui.metoffice.gov.uk/
[b] http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/download/index.html

## 2.4. Brief assessment of the process adopted

Our approach aimed to present land managers with projected climatic impacts and likely ecological responses and to understand current management priorities and activities, as a precursor to considering potential adaptive responses to climate change and discussing with land managers which responses may be most important / achievable. Each element was essential.

We deliberately used projected impacts on specific populations and species' cautiously, given the associated uncertainties, in order to indicate likely directions of travel for individual sites rather than to make specific predictions. These were complemented by a separate approach of considering ecologically what the impacts of projected climatic change would be on each system. This identified particular responses that might otherwise have been missed, and importantly, also helped inform potential adaptive responses.

It was important to understand the current management activities and priorities of each participating organisation before considering how those might be adapted to climate change. This was achieved by reading existing management plans and information in advance of the workshop, and through discussion on the day. Given this understanding, it was then possible to discuss potential suggested adaptive responses to climate change for each SPA that were identified from a set of general habitat-related responses in advance (see Annex 5). This step was very important as it provided valuable site-specific knowledge and context for each measure (the adoption of many measures were constrained at individual sites), whilst also facilitating good engagement in the process across all workshop participants. Steering group members, many of whom had good knowledge of one or more sites and the issues discussed, and all workshop participants were invited to contribute comments to draft reports produced from the site workshops. The final reports for each SPA should therefore provide a good summary of the likely impacts of climate change on the SPA assemblage, a summary of the potential options for adapting management at each SPA in response to these impacts, and conclude with some recommendations for consideration in future management planning. Although not prescriptive in nature, we anticipate that these reports will provide a valuable resource for anyone drafting management plans for sites located within each SPA.

# 3. Key messages and outcomes

The case study workshops conducted for this project highlighted that climate change adaptation is approached from a broad range of perspectives by site managers across the five case study SPAs. While land managers are generally highly aware of the potential impacts that climate change might have at their site, an adaptive management approach to increase resilience of their SPAs is being adopted to greater or lesser degrees, depending on the management objectives for the site, the amount of land within the SPA that is owned by conservation organisations (giving greater freedom to manage for conservation outcomes), and contingent on the particular constraints associated with management of the SPA imposed by other interests.

### *Management approaches*

Management strategies at the five case study SPAs could be placed along a continuum depending on how they considered the future impacts of climate change. The ability of land managers to adopt more adaptive approaches is greatly facilitated by landowner cooperation or outright ownership of land within the SPA.

At one end of the spectrum is an approach which is focused on *maintaining the current interest* of a particular feature or habitat for the time being, while acknowledging that management may need to change in the future to address climate change. For example, management of several sites on the Norfolk and Suffolk coasts emphasized protecting freshwater reedbed from saline incursion (through improved sea defences and water infrastructure to rapidly remove saltwater flooding) as a current priority, while recognising that future sea level rise and increased frequency in storm surges may result in the eventual salinization of this habitat and ultimately loss to saltmarsh or saline lagoon. This approach is most appropriate when the feature being maintained is of high conservation importance, and is not currently or adequately compensated for elsewhere, or there is uncertainty in the likely potential future impact of climate change relative to the potential for management to counter such impacts. At the other end is an approach that has adapted management to *facilitate or enhance the likely rate of change in response to future climate change*. An example of such an approach would be managed realignment or retreat of coastlines, although this had only really been undertaken at a small scale at one or two coastal sites (e.g. Titchwell RSPB reserve’s Coastal Change project).

In between these extremes is an approach that adopts *management that is likely to deliver benefit now, but also increase the resilience of sites to future climate change*. This requires a good understanding of projected climatic changes and their likely ecological impacts. For example, at Minsmere-Walberswick SPA, many current management activities are being undertaken specifically to increase the SPA's resilience to climate change, and with future climate-associated changes to habitats in mind. Management has increased the topographic heterogeneity of freshwater reedbed, which will benefit current SPA features but will also benefit features using the site when it transitions to saline lagoon. Managers have also adopted a more flexible and responsive, rather than prescriptive, approach to habitat management, working with natural year-to-year variation in water levels and salinity as well as natural retreat of the shingle coastal barrier to manage the site's habitats.

A similar approach to the one above is a strategy which might be considered "*unintentionally adaptive*", and is characterised by management that is delivering current benefit but is also increasing resilience to future climate change even if it is not being implemented expressly with climate change resilience in mind. Much of the adaptation in the South Pennines could be described in this way; current management to re-vegetate bare peat and block drainage will likely increase the SPA's resilience to climate change. However, these activities are primarily being undertaken to improve and restore peatland habitat quality, thereby improving water quality and the favourable condition status of Sites of Special Scientific Interest (SSSIs), which were generally considered by managers as more immediately relevant management units than the SPA. Despite the fact that much of the land within the SPA is outside the ownership of conservation organisations or the water utility companies, these groups have succeeded in encouraging landowner cooperation in the more widespread implementation of management activities to improve overall habitat quality and increasing resilience.

A "*flexibly adaptive*" approach, on the other hand, is closer to the approach of management to maintain the current interest of particular sites, but recognises that sudden catastrophic events may make this impractical. Instead of undertaking management to facilitate change, this approach accepts sudden change when the magnitude of climatic impacts exceeds the ability of current management resources to resist such change. Due to an understandable reluctance of many private landowners and other stakeholders to manage to promote change, particularly if such change results in the loss or deterioration of their holdings for other interests, in practice, this 'approach' was widely adopted.

Management at any single site was generally represented by a mix of these different approaches, to varying degrees. At a broader scale, cooperation and coordination across a network of sites might adopt one approach for one site and a different approach for an adjacent site, with the knowledge that change might be better resisted or resilience increased at one site versus another.

### *Constraints imposed on management by other interests*

In practice, the ability to adopt a fully adaptive approach is heavily constrained by external considerations. This was particularly the case at SPAs where land was largely privately owned rather than owned by conservation agencies and managed for conservation. For example, management for current and potential SPA features at the Somerset Levels and Moors is and will likely continue to be constrained by the strong agricultural interest in the area. Freshwater management for SPA features relies on maintaining raised water levels during the winter which can be drawn down slowly over the summer months to provide habitat for breeding waders. This will become an increasingly important strategy if summers become drier. However, it is an approach which conflicts with agricultural interests to keep water levels low for grazing and crops; high water levels restrict agricultural management activities and increase the risk of winter flooding following heavy precipitation – a concern which may become more important given the projected shift of precipitation from the autumn to late winter (UKCP09). Both here and at the North Norfolk Coast, Great Yarmouth North Denes, and Minsmere-Walberswick SPAs, future management will be heavily dependent on working with the Environment Agency. Coastal and flood defence decisions will be contingent on the need to balance conservation interests with economic sustainability, protection of property, and agricultural interests.

Where SPA management is heavily constrained by non-conservation-related activities, climate change adaptation will probably be most effective where it can be linked to increasing the resilience of these other activities to climate change. Thus, the protection of peatland habitats in the South Pennines has been largely funded on the basis of the need to improve habitat and water quality, yet will also deliver improved ecological adaptation to climate change (Carroll et al. 2011). The protection or sympathetic management of vulnerable coastal or inland sites to flooding may be enhanced in cases where such management can be linked to wider flood or erosion protection. Recent severe weather events have particularly highlighted this issue for the Somerset Levels and the Norfolk and Suffolk coasts.

It was noteworthy that despite each of the sites being designated SPAs, that across both the South Pennines and Somerset Levels, much of the habitat management undertaken targeted the SSSI features (which in some cases included avian interests, but frequently were focused on botanical interests). In many impacts, management targeting SSSI versus SPA features are complementary (or even identical if targeting avian interests), but when considering potential future shifts in species' assemblages in response to climate change, this may not always be the case.

### *The importance of flexibility in the Higher Level Stewardship programme*

Land managers at all sites depend on Higher Level Stewardship to deliver funding for management on their sites, both on freehold land and also land in private ownership. Delivering HLS-prescribed management within the SPAs plays a large part in maintaining the economic viability of local farming, while local farmers play an important role in delivering prescriptions for site managers. However, climate change may make delivering prescribed grazing management increasingly difficult, which may threaten scheme payments. Projected wetter winters and higher early spring water levels may present a conflict with the timing of grazing management for breeding waders on wet grassland and coastal grazing marsh at many SPAs. Higher water levels on grassland in spring delays the ability to turn out grazing cattle until later in the season which may bring them into conflict with nesting waders, increasing the risk of trampling nests. Warmer winter and early spring temperatures have also increased vegetation growth, and several sites have found it difficult to achieve appropriate vegetation heights for breeding waders given the inability to turn cattle out until later in the season.

Site managers emphasized the importance of increasing the flexibility of HLS prescriptions and reducing derogation requirements as one of the most achievable measures that could improve their ability to increase the resilience of their SPAs to climate change. If this is not possible, then a vital funding source for conservation action may be threatened. Working with local graziers to adapt their stock and grazing regimes to changing conditions (e.g. by using small heritage breeds or ponies which are better adapted to wetter conditions) will be necessary to maintain both effective grazing management and the economic viability of farming with future climate change. However, all land managers expressed concern that implementing grazing management may become increasingly difficult with the aging demographic of farmers.

As this report is being finalised, it appears that many of the issues raised during site workshops surrounding environmental stewardship have been recognised and are likely to be addressed by the new Countryside Stewardship scheme which is currently will supersede the current HLS programme in 2015.

### *Improving control over water movement and storage*

Land managers at all sites with freshwater and coastal interests view greater control over water as a priority measure to increase climate change resilience. Increasing control over water involves installing new or upgrading existing water infrastructure, and also improving the ability to store water during the wetter winter months to counter potentially negative impacts of summer drought. Better water infrastructure will increase the ability to respond to freshwater flooding events, which are projected to increase with climate change, particularly in winter. This will not only benefit the ability to recover appropriate water levels in freshwater habitats, but will also allow managers to respond to freshwater flooding in brackish habitats. In addition, better infrastructure will improve the ability of managers to store winter water and enable them to extract and move it where it is needed in drier months. Superior water infrastructure will also greatly improve the ability to respond to saline incursions in coastal freshwater sites and remove saltwater flooding quickly. Many sites depend on gravity-drained sluices to control water. At coastal sites, managers highlighted the fact that these may become increasingly inadequate for draining saltwater from freshwater habitats following saline incursions due to sediment accretion and sea level rise. Pump infrastructure would bring the dual benefit of being able to move larger volumes of water more quickly and would be less affected by the coastal processes impacting gravity-drained sluices.

It was recognised that such measures are expensive, and as outlined above, the extent to which this is achievable may depend on balancing conservation needs with those of other stakeholders. As a result, it is likely that such measures are most likely be funded where they will also deliver wider benefit through improved flood defences or water management for other interests (e.g. protecting property or for agricultural purposes), or where essential to protect internationally important sites and habitats in the absence of compensation. Given projected shifts in the timing and amount of autumn / winter rainfall to later in the season, the maintenance of high water levels during the winter to reduce the degree of drawdown in summer and so protect freshwater habitats from drought, may become more difficult to achieve because of concerns over winter flooding – although the benefits of maintaining nature conservation areas that can be flooded in winter as washlands as a means of protecting other areas (e.g. urban or agricultural land) should also be recognised. Funding for improved water infrastructure could be supported through contributions from a variety of sources, including environmental stewardship, the Environment Agency via the EU's Water Frameworks Directive, or flood levies.

### *Re-assessment of designated SPA boundaries and qualifying features*

Site managers at every SPA discussed the need for greater flexibility in the SPA designation and more frequent reassessment to address the issue of land use outside the SPA's boundaries by SPA features. In the South Pennines, waders and some passerines frequently use areas of improved or semi-improved pasture surrounding moorland as breeding or foraging habitat. The SPA boundaries, however, encompass only moorland and neglect to include the in-bye land which provides important additional habitat for SPA species. At Great Yarmouth North Denes, breeding tern colonies are highly mobile along the coast for reasons that are not clearly understood, but are likely due to a complex interaction between suitable nesting habitat and disturbance. Some colonies represent a substantial proportion of the Norfolk coast's population (e.g. the newly established colony on the offshore sandbank at Scroby Sands), but exist outside the legal boundaries of the SPA. Breeding terns are tied to early successional habitats, which are inherently transient; this necessitates a more flexible approach to the SPA's boundaries and management, enabling them to shift according to the distribution of a highly mobile feature of interest, although this flexibility is not currently achievable within the existing legislation. Similarly, at Minsmere-Walberswick stone curlews will likely expand into surrounding agricultural areas as there is minimal room for expansion of the population within the SPA's current boundaries. However, extending adequate protection management (fencing and predator control) outside the SPA's boundaries is difficult without sufficient resources. At the Somerset Levels, lapwing and golden plover numbers on the SPA drop when winter water levels are particularly high (R. Archer pers. comm.). It is assumed that these wintering waders move elsewhere to find suitable habitat, but it is unknown at present where they move to and at what scale they disperse. One possibility is that they move to nearby coastal areas within the Severn Estuary SPA; alternatively, they may disperse onto higher elevation agricultural land in the surrounding region but outside of the SPA. This is not a new issue (e.g. Pearce-Higgins and Yalden 2003), and one that has been discussed by the SPA Scientific Working Group.

Managers also raised the issue that current designations often include features which are no longer relevant because populations have declined below qualifying status, or exclude features whose populations have grown or which have colonised the UK since the last review (Stroud et al. 2001). At the Somerset Levels and Moors, Bewick's Swan have declined substantially at the SPA due to changing migratory behaviour, and may no longer meet the qualification criteria – although this does not appear to result from changes in climatic suitability on site, and contrasts with a more positive trend at the Severn (Massimino et al. 2012). In contrast, bitterns and egrets (both little and great white) have increased both here and at other SPAs, and yet they are not considered a qualifying feature. While the UK's SPA network may be resilient to the impacts of climate change (Pearce-Higgins et al. 2011, Johnston et al. 2013), with sites important now remaining important in the future, the suite of species at each SPA is likely to change at a much faster rate than is captured by the current review process timescale. A more frequent review policy will likely be necessary to adequately capture rapid population change and colonisation that may occur with climate change. Of course, when doing so, it will be important to disentangle potential climate change impacts from other drivers (e.g. Massimino et al. 2012). However, it is also recognised that any such considerations would have to be made carefully, given increasing evidence of the value of such protected areas to facilitate range expansion and colonisation of species in response to climate change (Thomas et al. 2012, Hiley et al. 2013, Johnston et al. 2013). There is a risk that any reconsideration of site boundaries or assemblages may lead to a loss of protected area status or acceptance of loss that otherwise should be compensated for. Clearly this issue would need to be subject to considerable legal and policy discussion in order to ensure that the currently effective SPA network is maintained (Dodd et al. 2010, Trouwborst 2011).

Many of these issues have been identified by the SPA Scientific Working Group and may be addressed through processes such as IPENS (Improvement Programme for England's Natura 2000 Sites). This will improve the ability of the SPA designation to provide spatially and temporally accurate information on internationally important areas for birds in the UK.

### *Increasing cooperation and coordination at multiple scales*

Increasing heterogeneity, both within the SPA and at a landscape-level across a regional network of sites, is regarded as an important measure to increase climate change resilience. The scale at which heterogeneity was considered as part of management plans, however, varied across SPAs and was dependent on the level of cooperation and coordination between management organisations. Most individual units within SPAs are managed by individual organisations to provide variation in habitat, although where these are nature reserves, the main motivation for doing this is often to present a diverse range of bird interest to visitors. At a larger scale, there is often also heterogeneity between sites across SPAs, either as a result of natural topographical differences such as altitudinal gradients across the Somerset Levels and South Pennines, or as a result of varying management approaches. Although there was some evidence of cooperation and coordination between site managers when delivering conservation objectives at the site-level within the context of the entire SPA, this was greater for some SPAs than others. It was therefore acknowledged that the level of cooperation and coordination between organisations could be improved and formalised to develop an SPA-wide approach to deliver appropriate heterogeneity that may be an important component of adaptation (Hodgson et al. 2009), and that direction and oversight by a governing body (e.g. Natural England) might aid in achieving this objective.

Further, given the functional connectivity between neighbouring SPAs, such as the Somerset Levels and Severn Estuary, the North Norfolk Coast, Great Yarmouth North Denes, Broadland and the Wash, etc., with the same individual birds using different sites, there is an important requirement to consider formalising a coordinated management approach across SPAs as well as within them. While most managers recognise the importance of connectivity between regional reserves, developing a regional management strategy to address functional connectivity and to deliver habitat and topographic heterogeneity at the landscape-level is only starting to be more widely considered. Delivering landscape-level management of protected areas can increase the opportunity for habitat compensation across a regional network, and can facilitate the ability of managers to develop an SPA within the region as a potential refuge for other sites. Understanding of the functional links between sites is likely greatest on the Suffolk Coast and developing heterogeneity at the regional level has been an important consideration in management of SPAs from Benacre to Easton Bavents in the north to the Alde-Ore and Deben estuaries in the south. Developing a broader vision of the future and where SPAs should fit into a national or international vision for biodiversity and ecosystem service delivery was also raised as an important issue, particularly for the South Pennines.

Connectivity between SPAs is a further consideration given that future management of any one SPA may also be strongly tied to that of another closely linked or neighbouring SPA or designated site (e.g. Special Area of Conservation, SSSI, etc.).  For example, the future of Great Yarmouth North Denes is heavily dependent on management of the Norfolk Broads, an SPA, SAC, and Ramsar site. The ability to adapt management of an SPA for the projected impacts of climate change will depend on the approach adopted for adjacent designated sites.

### *Habitat compensation*

Many site managers highlighted the importance of habitat compensation as critical to the integrity of the SPA network, and felt that developing adequate compensation plans should be more closely addressed by government agencies (e.g. the Environment Agency) and conservation organisations. Particularly for coastal sites with a high proportion of vulnerable and valuable freshwater habitats (e.g. North Norfolk Coast, Minsmere-Walberswick), it was generally felt that there was a fair amount of urgency required to ensure that plans to develop suitable habitat in less vulnerable sites inland were given greater attention and action. Habitat compensation should be developed as close as possible to vulnerable SPAs, and new habitat should be of a suitable scale to ensure that the functional integrity of the SPA network is maintained. In practice, achieving such compensation close to the SPAs may be difficult, due to topographical and other land-use constraints, increasing the need to consider these issues at multiple scales (see above). For example, it may be that the most appropriate location for large-scale, sustainable compensatory freshwater habitat creation for the Norfolk and Suffolk coasts may be in the Fens.

### *Reducing the impacts of predation, human disturbance, and illegal persecution*

All site managers acknowledged that controlling predators and mitigating the impacts of human disturbance were priority management actions to protect vulnerable breeding species, but that were generally limited in their effectiveness due to insufficient funding and personnel resources. Both predation and disturbance contribute  additional pressures that can interact with each other and the effects of climate change to affect vulnerable populations (Finney et al. 2005, Langston et al. 2007, Mallord et al. 2007, Murison et al. 2007), and are likely to be significant constraints on the ability of some potentially range-expanding species to increase in response to climate change. Climate change was widely recognised as having the potential to significantly affect human disturbance levels in the future, potentially increasing numbers of visitors to coastal and upland areas during warmer, drier springs and summers, which in the latter case may also increase fire risk. Managers are already finding it difficult to mitigate the impacts of visitors on particularly sensitive species breeding in habitats popular with visitors, including beaches (terns and ringed plover), heathland (nightjar), and upland (breeding waders). Effective visitor management requires a large investment in wardening time in addition to fences and signage. Effective predator control is similarly limited by staff resources, particularly the number of qualified personnel able to undertake lethal control, the difficulties of doing so given public safety considerations in areas with extensive visitor access, and the ability to provide round-the-clock wardening. Improving local resources available for wildfire response is also important.

This could reduce the need for conservation organisations to rely on the fire service and may also improve wildfire risk management by shortening response times.

The impact of regional housing development has implications for SPAs (Liley and Clarke 2003), but has not been widely considered by planning permission authorities at a large scale. Increasing housing development and growing populations of cities in South Yorkshire (Bradford, Leeds) and East Anglia (Norwich) may put greater pressure on nearby natural areas and SPAs to support visitor recreational opportunities. Consideration of local greenspace for recreation in urban environments may help reduce visitor pressure on nearby SPAs and has been an important element of land-use planning elsewhere (e.g. in the vicinity of the Thames Basin Heathlands SPA). Another potential measure to mitigate the effects of increasing development is to implement some sort of compensation scheme whereby housing developers fund conservation management. An increasing movement towards open access on National Nature Reserves was regarded as likely to need careful management so as not to conflict with conservation interests. Managing these interactions will require sufficient resources for conservation staff to ensure that SPA features are not negatively Although not discussed explicitly during site workshops, wildlife crime, especially illegal persecution of raptors, continues to be a problem in some areas, particularly the uplands, and is likely to be an additional pressure (together with predation and disturbance) limiting the capacity of vulnerable SPA species to adapt to climate change. While there is increasing legislative attention addressing this issue, enforcing legal action against offenders is still resource-limited. Increasing the resources available for enforcement and prosecution of wildlife crimes would help in reducing this pressure on SPA features, particularly upland species such as merlin, peregrine, hen harrier, goshawk, and short-eared owl.

These issues are important in a climate change context for both potential range-expanding and range-contracting species. For the former, limitations on breeding success as a result of predation and disturbance may prevent some species taking full opportunity to expand their distribution and abundance in response to climate change. For example, little terns in eastern England may be unlikely to increase as projected by CHAINSPAN for this reason (Pearce-Higgins et al. 2011). For the latter, controlling such impacts may form an important part of compensatory climate change adaptation (Pearce-Higgins 2011). Of further consideration is the potential range expansion of novel predators with climate change, which may themselves qualify as designated features. On the Norfolk coast, Mediterranean gulls appear to have caused significant predation of tern chicks at a colony; further expansion of gull populations in response to climate change may therefore cause a potential conflict between protection and control of designated species.

## 4. Conclusions

This study sought to demonstrate how information about the influence of climate change on SPAs could be translated into a set of adaptive measures for their future management with the aim of increasing resilience. Consultation workshops with site managers at five case study SPAs in four geographical areas resulted in a practical assessment of suggested adaptive management approaches, and importantly, demonstrated the value of the process developed here as a method that could be implemented more widely to inform the development of management strategies aimed at increasing the resilience of protected areas. The consultation process identified some of the greatest barriers to delivering adaptive management, and highlighted where policy changes and cooperation and negotiation with outside groups and agencies might be required to deliver priority actions. The consultation process also served to highlight some of the key tools that conservation managers rely on to deliver current management, and identified how these tools might be impacted by future climate change. Although not formally asked for feedback, many of the workshop participants expressed the opinion that this process had been useful for them, either to help them consider the issue of climate change or as a means of achieving wider engagement with stakeholders across the SPA.

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