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British Ecological Society

NATURAL
ENGLAND

Adapting conservation to a changing climate

11-12 January 2011
Charles Darwin House
London



Programme 11 January

09.00 Registration and Coffee

09.45 Welcome and Notices

Dr. Mike Morecroft, Natural England

09.50 Introduction

Andrew Wood, Director of Science and Evidence, Natural England

Session 1 - The Context for Adaptation

Chair: Andrew Wood, Natural England

10.00 Climate change adaptation and ecosystems: scientific challenges and opportunities

Prof. Bob Watson, Chief Scientific Advisor, Defra

10.30 Conservation in the wider context of climate change adaptation

Prof Andrew Watkinson, Living with Environmental Change Programme

11.00 The European context for adapting nature conservation to climate change

Dr. Jan Plesnik, Agency for Nature Conservation and Landscape Protection, Czech Republic

11.30 Common conservation challenges in a changing climate

Richard Smithers, IALE UK

12.00 Making space for nature in a changing world

Sir John Lawton, Royal Commission on Environmental Pollution

12.30 Lunch and posters

Session 2 - Elements of Adaptation

Chair: Prof. Jane Memmott, University of Bristol

13.30 Resilience to climate change in theory and in practice

Dr. Mike Morecroft, Natural England

14.00 Landscape structure and population resilience

Dr. Tom Oliver, Centre for Ecology and Hydrology

14.20 An ecological basis for adaptation to climate change

Prof. Phil Grime, University of Sheffield

14.40 Connectivity in the context of climate change

Dr. Jenny Hodgson, University of York

15.00 The range expansion of the silver-spotted skipper butterfly: lessons for conservation under climate change

Dr. Jon Bennie, University of Exeter

15.20 Moving plants and animals for conservation when the historic range loses legitimacy: adaptation of translocations to cope with climate change

Dr. Sarah Dalrymple, University of Aberdeen

15.50 Tea

16.10 Breakout Groups

17.10 Feedback

Chair: Dr Humphrey Crick, Natural England

17.30-18.30 Posters and refreshments

19.30 for 20.00

Dinner - Acorn House, 69 Swinton Street, WC1X 9NT (Open only to those who have registered for a place at the dinner and who have paid in advance)

Programme 12 January

Enabling adaptation

Chair: Prof. Jane Hill, University of York

09.00 **Winners, losers and conservation priorities: identifying which species require most assistance to survive climate change**
Prof. Chris Thomas, University of York

09.30 **Adapting the model - predicting the effect of environmental change for conservation**
Prof. Matthew Evans, Exeter University

09.50 **The Climatic Risk Atlas for butterflies**
Dr. Martin Warren, Butterfly Conservation

10.10 **Projecting the benefits of landscape-scale conservation for wildlife and people**
Dr. Kathy Hodder, University of Bournemouth

10.30 **Coffee**

Session 3 - Turning theory into practice

Chair: Dr. Richard Findon, Defra

11.00 **Putting climate adaptation plans into action: an international perspective**
James Watson, Wildlife Conservation Society

11.30 **Embracing adaptation: early days at the RSPB**
Dr. Olly Watts, RSPB

11.50 **Complex land systems: the need for long time perspectives in order to assess their future**
Prof. John Dearing, University of Southampton

12.10 **Adaptation Indicators for Biodiversity**
Mike Harley, AEA

12.30 **Lunch and posters**

13.30 **Breakout groups** (tea and coffee available)

14.30 **Feedback and plenary discussion**
Chair: Dr. Andy Stott, Defra

Session 4 - Adaptation and ecosystem processes and services

Chair: Dr. Harriet Orr, Environment Agency

15.00 **Integrating Climate Change Adaptation and Mitigation**
Dr Pam Berry, University of Oxford

15.30 **Multifunctional Forests**
Dr Mark Broadmeadow, Forestry Commission

15.50 **Future climate, changes in land-use capability, and potential trade-offs between agriculture and forest services. The case of broadleaved habitat networks in Scotland**
Dr. Alessandro Gimona, Macaulay Institute

16.10 **Do wetlands reduce floods?**
Prof. Mike Acreman, Centre for Ecology and Hydrology

16.30 – 16.45 **Conclusions**
Dr. Mike Morecroft, Natural England

Posters

Pippa Gillingham (University of York). Knowledge exchange project on CCA

Rob McCall (CCW). Climate Vulnerability Assessment of Designated Sites in Wales

Rob Brooker (Macaulay Institute). Translocation in response to climate change: a feasibility study in the Scottish uplands

Jennifer Allen (Aston University). Impact of Climate change on the Biodiversity of Development Projects

Catherine Norris (Writtle College). Working towards an improved understanding of the thermodynamic efficiency of different land cover types, using surrogate measures of microclimate and vegetation function.

Poppy Lakeman-Fraser (Imperial College, London). Untangling Interactions: Do climate and land use change interact synergistically to impact biodiversity?

Terhi Riutta (Oxford University). Living on the edge: Quantifying the structure of fragmented woodland landscapes in England

Aletta Bonn (IUCN). Peatlands and the climate challenge

Mark Fessey (Scott Wilson). An Ecological Connectivity Approach to Planning for Adaptive Landscapes: A Case Study of the West Weald

Mike Acreman (CEH). Wetland vision and climate change; tools for impact assessment

Jane Bunting (Hull University). Practical Lessons from Palaeoecology.

Arnaud Duranel (UCL). Assessing the potential impact of climate change on mire habitats in central France - a multi-scale eco-hydrological approach.

Victoria Cadman (Ecological Continuity Trust) Long-term experiments, climate change adaptation and land management.

Keith Kirby and Emma Goldberg (Natural England). How do climate change adaptation guidelines work for woodland ground flora?

Nicholas A. Macgregor, Geoff Darch, Nikki Van Dijk, Louisa Aspden, Simon Bates, Caroline Birchall, Ian Crosher, Clive Doarks, Colin Holm, Andy Neale, Charlotte Reeves, Sarah Robinson, Lydia Speakman, Sarah Taylor, Richard Wilson (Natural England). Assessing the vulnerability to climate change of England's landscapes

Nicholas A. Macgregor, Sarah Taylor, Ian Crosher, Charlotte Reeves, Humphrey Q. P. Crick, Mike D. Morecroft (Natural England). Assessing the vulnerability of the terrestrial natural environment at a large scale

Isabel Alonso (Natural England). Carbon storage by habitat – relation with condition and management options.

Humphrey Crick, Nicholas Macgregor & Mike Morecroft (Natural England). Ecosystem-based conservation in a 4+ degree world.

Clive Bealey (Natural England). The Environmental Change Biodiversity Network (ECBN).

Eleanor Brown, Colin Prosser and Naomi Stevenson (Natural England). Adapting Geodiversity Conservation to a Changing Climate.

Dr Roger Catchpole (Natural England). A spatially explicit assessment of climate change vulnerability at a national scale.

Presentations

Climate change adaptation and ecosystems: scientific challenges and opportunities

Bob Watson

Chief Scientific Adviser for the Department of Environment, Food and Rural Affairs

Climate change will exacerbate the loss of biodiversity, increase the risk of extinction for many species and adversely impact ecosystem services essential for sustainable development. Based on the current understanding of the climate system, and the response of different ecological systems, significant adverse global changes are likely to occur if the global mean surface temperature exceeds 20C above pre-industrial levels and the rate of change exceeds 0.20C per decade.

Observed changes in climate have already affected biological systems in many parts of the world. There have been changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks, and many coral reefs have undergone major bleaching episodes when sea surface temperatures increased by 10C during a single season. There is emerging evidence that the oceans are becoming more acidic, thus reducing their capacity to absorb carbon dioxide and affect the entire food chain.

For the 850 million people who go to bed hungry every night, and the 2 billion others exposed to insect-borne diseases and water scarcity, climate change threatens to bring more suffering in its wake. In this way, climate change may undermine long-term development and the ability of many poor people to escape poverty. During the last 30 years the agricultural growing season in Europe has lengthened but in some regions of Africa the combination of regional climate changes and anthropogenic stresses has led to decreased cereal crop production since 1970. Changes in fish populations have been linked to large scale climate oscillations off the coasts of South America and Africa, and decadal oscillations in the Pacific have impacted fisheries off of the west coast of North America.

The impact of climate change on biodiversity and ecosystem services must be viewed in context of other drivers of change, i.e., conversion of natural habitats, overexploitation, invasive species and pollution. Reducing the loss of biodiversity requires getting the economics rights, e.g., internalisation of externalities, reducing environmentally-damaging subsidies in agriculture, energy and transportation, developing and implementing environmentally-friendly technologies and behavioural changes.

The challenge is to simultaneously limit the magnitude and rate of human-induced climate change, by reducing emissions of greenhouse gases from all sectors, including agriculture, and to reduce the vulnerability of socio-economic sectors, ecological systems and human health to climate variability and change by integrating climate concerns into sectoral and national economic planning. Ecosystems can be used to both mitigate (e.g., reduced deforestation and degradation, reforestation, afforestation, agro-forestry and low- and no-till agriculture) and adapt (e.g., conserving coral reefs and mangrove systems can protect coastal systems from storm surges; maintaining vegetation on hill-sides can limit erosion and land-slides) to climate change.

In summary, climate change threatens biodiversity and ecosystem services, under-mining human well-being, hence there is a need to limit increases in global mean surface temperatures to no more than 20C above pre-industrial levels. However, we are not on course to realise that level of ambition, and hence we need to be prepared to adapt to an increase of 3-40C.

Conservation in the wider context of climate change adaptation

Andrew R. Watkinson.

Living with Environmental Change Programme and University of East Anglia.

The magnitude and rate of environmental change over the last century is such that the current period in the earth's history is often referred to as the anthropocene, reflecting the impacts that humans have had on ecosystems across the globe. The impacts derive from the staggering increase in the human population, currently standing at 6-7 billion and their consumption of resources. Together they are resulting in climate change and pressure on our natural resources, that when coupled with globalization, technological change and increasing urbanization are placing pressures on the food, water and energy that we all require. We, of course, ultimately see these indirect drivers causing biodiversity loss through habitat change, invasive species, over-exploitation, pollution and now climate change. All these interlinked challenges need addressing, but through a much more fundamental understanding of the indirect drivers of change.

At a time of rapid environmental change both decision-makers and the research community face acute pressures to mitigate change and urgently to adapt to it. Ensuring people continue to derive the substantial benefits they do from the ecosystems of the natural environment should be an aim for all. To do this we need foresight of future environmental conditions, an enhanced ability to make best use of existing knowledge, and tools and technologies for those who have responsibilities and duties for managing environmental resources or regulating their use. The scale of the challenge is clearly enormous, as although the international community aims to limit temperature increases to 2 °C, current emissions trajectories indicate that we should plan for a potential increase of the order of 4 °C. This is barely imaginable.

Undoubtedly, new knowledge will be required to address some of the challenges that we face, such as ocean acidification. For others, such as decisions over land use and coastal management, what is required is a much more holistic approach or systems perspective in decision making. This is inevitable given the interlinked nature of the challenges we face and the trade offs and synergies that they embody. Given the time scales for actions there is also an imperative to make best use of the knowledge that we have already acquired through, for example, systematic review and to provide the evidence base for solutions wherever possible, rather than an ever increasing list of problems to be tackled.

In adapting conservation to a changing climate we need to embrace the dynamics of ecosystems and ecosystem processes and move away from a static view of ecosystems and conservation. We need to accommodate change and build on our knowledge and scientific understanding of the challenges we face. The implementation of the response options (adaptation) however requires risk management plans, responsibility for development (leadership), education and communication, links with other actions across sectors, legislation and enforcement, support networks and finance. It also requires vision and the conservation of biodiversity to be seen as part of the solution rather than part of the problem.

The European context for adapting nature conservation to climate change: from science to policy and practice and back

Jan Plesník

Agency for Nature Conservation and Landscape Protection of the Czech Republic Prague

Climate change threatens biodiversity, ecosystem function, and human wellbeing, with thousands of publications demonstrating impacts across a wide diversity of taxonomic or ecological/functional groups, ecosystems, economics, and social structure. It is pretty obvious that climate change will influence biological diversity at all its three main levels (genes/individuals, populations/species, communities/ecosystems/the landscape) and it is supposed that by the end of the 21st century it will become the most important driver influencing biodiversity. On the other hand, the appropriate biodiversity conservation and management could – to some extent - mitigate the climate change effects on human society and on ecosystem functioning and to help them to effectively adapt to actual and projected climate changes. Nature conservation itself has to adapt itself to climate change by implementing flexible, adaptive,

comprehensive and as much as possible pro-active measures (e.g., increasing landscape connectivity, integrating climate change into land-use planning and mitigating other biodiversity loss main drivers, e.g. natural habitat fragmentation, degradation and loss, invasive alien species, overexploitation, diseases and natural disasters). The Convention on the Conservation of European Wildlife and Natural Habitats, commonly known as the Bern Convention, has adopted recommendations on action that may be taken by authorities at all levels of governance to address the impacts of climate on wider Europe's biodiversity. The European Commission Communication on "Halting the Loss of Biodiversity" (2006) includes four policy areas, one of which is "biodiversity and climate change" with the objective to support biodiversity adaptation to climate change. Biodiversity incl. ecosystems need to be an integrated part of the general mitigation and adaptation efforts. Measures such as really inter-connected protected areas, including the European Union's Natura 2000 network management and adaptive management of the non-reserved landscape are to be seen as central elements for combating climate change. Natural processes should be employed as much as possible in relation to carbon and water cycles, flood protection, soil protection, etc. The production and use of the first and second generation biofuels must not be undertaken at the expense of the environment and society. The EU post-2010 Biodiversity Strategy is scheduled to be adopted by the Council in June 2010. The EU strategy on Invasive Alien Species should appear in 2012. Due to high complexity of the issues involved, decisions taken should be based on the best science available, reducing the high level of uncertainty and involving the evidence from various environmental, political, economic and social conditions. .

Tackling biodiversity loss and climate change in an integrated manner leads to co-benefits. At the same time, failing on effective biodiversity conservation compromises our efforts to combat climate change.

Common conservation challenges in a changing climate

Richard Smithers

International Association for Landscape Ecology (UK), and AEA

The England Biodiversity Strategy (EBS) Climate Change Adaptation Principles' overarching themes are to: take practical action now; maintain and increase ecological resilience; accommodate change; integrate action across all sectors; and, develop knowledge and plan strategically. The principles recognise that conservation organisations cannot deliver the scale or type of action required and are aimed at people responsible for planning and delivery across all sectors identified in the EBS: agriculture; water and wetlands; woodland and forestry; towns, cities and development; coasts and seas.

The EBS principles identify that, if socio-economic adaptation fails to consider the natural environment, the indirect impacts of climate change could be more damaging than the direct impacts, due to changes in working practices, cultural values, policies and use of land and other resources. Yet, while there is growing recognition of the importance of the natural environment for adaptation and delivery of ecosystem services, conservation considerations are not central to much land and resource management.

Conservation thinking in the UK may have shifted progressively from a site-centred, species-orientated, designation-focused approach to one that also embraces a far larger scale but biodiversity remains the focus for action. In doing so, it is allowing continued erosion of our natural environment, polarisation of land use and absolution of society's conscience. Notably, the recent adaptation supplement to the UK Government's economic guidance on assessing spending, investment and policy decisions, the Treasury's 'Green Book', makes no mention of the natural environment.

If conservation is to enable the widest biodiversity to survive and evolve, it needs to become a wholly integrated, not segregated, activity with biodiversity as an emergent property rather than as the focus for action. Government needs to establish and promote a vision and policy principles that recognise: conservation of a healthy and resilient natural environment should be the starting point for all activity, as the basis for a healthy and resilient society and economy; everyone needs to understand their reliance on the environment, the impacts of their actions and take responsibility for alleviating them; people can organise themselves to use resources sustainably if expected benefits are greater than costs associated with rules governing those benefits, loss of short-term economic gains are offset, and potential for cheating is eliminated.

For the vision to become reality requires: outcome as well as process indicators embedded across Government departments and related directly to their policies; valuation of ecosystem services at a site scale that allows extrapolation across a range of scales; and for Government to develop enabling mechanisms. Such mechanisms include: promotion of broad-brush indicative spatial planning; greater integration, simplification and promotion of agri-environment schemes; taxation to enforce the polluter-pays principle; encouraging development of green tariffs and biodiversity offsets; reinforcing that planning's purpose is to conserve and enhance biodiversity and ecosystem services, and strengthening protection of high quality habitats; using the Green Investment Bank to provide long-term, non-commercial loans and grants that stimulate activities enhancing delivery of ecosystem services; and, tax breaks for companies and landowners investing in sustainable land and resource management.

Challenges for conservation organisations are that having focused on their own delivery and been cast as opposers of land and resource management, they now need to support Government in: identifying best practice and providing advice to land and resource managers; securing and brokering funding from the corporate sector; promoting companies and individuals understanding of their impacts and dependencies on biodiversity and ecosystem services and associated risks and opportunities; supporting community action; and, enabling dialogue between Big Society and Government.

Making space for nature in a changing world

John H. Lawton

Royal Commission on Environmental Pollution

The lecture will summarise and bring together the outcome of two reports chaired by the author: the Royal Commission on Environmental Pollution's 28th Report on Adapting Institutions to Climate Change¹, and Making Space for Nature: a review of England's Wildlife Sites and Ecological Network submitted to Defra².

England's protected area network has played a valuable role in slowing down, and in some cases reversing, the seemingly inexorable declines in species and habitats. But despite some undoubted successes, wildlife continues to disappear from the English countryside. Climate change will benefit some species, but the net effects are likely, again, to be negative overall. To deal with these threats, Making Space for Nature concludes that the protected area network needs to be "more, bigger, better and joined", and the lecture will explore what this means in practice. To achieve these ends we need effective institutions, and climate change presents the legal and regulatory framework with some real challenges that may hinder our ability to deliver effective conservation measures over the next 40 years. The lecture will evaluate the pros and cons of the institutional framework underpinning conservation efforts in a changing world.

1 Royal Commission on Environmental Pollution (2010). 28th Report. Adapting Institutions to Climate Change. Cm 7843. The Stationary Office Ltd., London

2 Lawton, J.H., Brotherton, P.N.M., Brown, V.K. et al. (2010). Making Space for Nature: a review of England's wildlife sites and ecological network. Report to Defra <http://www.defra.gov.uk/environment/biodiversity/documents/201009space-for-nature.pdf>

Resilience to climate change in theory and in practice.

Mike D. Morecroft, Humphrey Q.P. Crick, Simon Duffield, Nick A. Macgregor

Natural England

Building resilience is a common aspiration in climate change adaptation strategies. It is however a concept that has been defined in various different ways. Within the context of climate change it most often refers to the capacity of a system to maintain desirable properties or functions in a changing environment. However, historically, within ecology, the term resilience has been used to describe the speed with which a population or community recovers from a disturbance, contrasting this with 'resistance' – the capacity to remain unchanged in the face of disturbance. This understanding is important in terms of recovery from extreme climatic events. Both aspects of resilience can be promoted by a range of measures including:

- Maintaining heterogeneity of landscapes and habitat distributions to increase the chances of suitable microclimate or soil conditions allowing persistence of species even when conditions are generally unsuitable, especially during extreme weather events. These are realistic aspirations: for example on a sunny day, a grassland on a north facing slope may be 15 degrees cooler than a south facing slope and the soil in the interior of a wood will tend to retain more moisture than at the edge.
- Maintaining larger blocks of semi-natural habitat that will maintain larger populations, more likely to survive the effects of climatic extremes such as droughts.
- Increasing the connectivity of patches of habitats to increase the chances of some species relocating to more locally suitable conditions and allow recolonisations following local extinctions.

We are planning for an uncertain future, but this should not be a barrier to building resilience of the natural environment as these measures will confer resilience under a wide range of scenarios.

The resilience of individual species populations is not necessarily the same as resilience of an ecosystem, its processes and services. In some circumstances a change in species complement may increase the resilience of an ecosystem as a whole. For example, allowing the species composition of a woodland to change to include species better suited to a new climate, may allow tree cover to persist, maintaining woodland habitats and landscapes and providing the benefits of shade, carbon sequestration and timber production. Maintaining species diversity is however a good insurance strategy in the face of uncertainty.

Most valuable conservation habitats in the UK are shaped by the interaction of people and the physical environment. Climate change will bring challenges to established patterns of land use and management. Resilience of human communities and management systems is inextricably linked to resilience of our natural environment. How to combine scientific expertise with local knowledge and engagement by land owners, managers and community groups may prove to be one of the most important aspects of building resilience.

In the long-term, if emissions are not effectively controlled, more radical solutions may be necessary and emphasis will need to shift from promoting resilience of current biological communities and ecosystems to accommodating change and promoting the establishment of new ecologies more suited to a changed climate.

Landscape effects on bird and butterfly population resilience

Tom H. Oliver¹, Simon Gillings², Marco Girardello¹, John Redhead¹, Tom M. Brereton³, Gavin M. Siriwardena², David B. Roy¹, Richard Pywell¹, Robert J Fuller²

¹Centre for Ecology & Hydrology, ²British Trust for Ornithology, ³ Butterfly Conservation

There has been much research into the effects of landscape context on the density of species' populations. However, the landscape factors affecting the resilience of these populations has been relatively neglected to date. We present research showing how the heterogeneity of landscapes, both in terms of biotope and topographic diversity, can promote more stable butterfly populations (Oliver et al. 2010). Heterogeneous landscapes may offer a greater range of resources and microclimates, which can buffer populations from environmental extremes and generate more stable population dynamics. In theory, landscapes might be manipulated to create populations more resilient to environmental change (Benton et al. 2003).

However, heterogeneity is only one of many ways to characterise landscapes. Landscapes can be also characterised in terms of the configuration (i.e. connectivity) and the area of different biotope types, and also at a wide range of different spatial scales. In order to determine the most salient landscape characteristics and most appropriate spatial scale, we use an evidence-based approach where data on bird and butterfly density and stability (from 1941 sites over 15 years) are related to a range of different landscape metrics. We find that although the area of key biotopes can best predict mean density, it is the configuration of certain biotopes which is important for population stability. The configuration of biotopes may be important because a well-connected network of key habitat types can facilitate rescue effects after local extinction events- a process particularly important for species with metapopulation structures, such as some butterflies.

These results partly explain why species distribution models, tools that are increasingly used for applied conservation, do not adequately predict population stability. An exclusive focus on landscape structures that promote patch occupancy and density may overlook features important for long-term population persistence such as population stability. Other landscape metrics that take into account habitat heterogeneity or configuration may be required to predict population stability.

Benton, T., Vickery, J. A. & Wilson, J. D. 2003 Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution* 18, 182-188.

Oliver, T. H., Roy, D. B., Hill, J. K., Brereton, T. & Thomas, C. D. 2010 Heterogeneous landscapes promote population stability. *Ecology Letters* 13, 473-484.

An eco-evolutionary basis for adaptation to climate change

Philip Grime, Andrew Askew, Jason Fridley and Simon Pierce

Buxton Climate Change Impact Laboratory

The purpose of this presentation is to describe an international collaboration designed to test our ability to predict and understand future impacts of climate change at scales extending from individual populations to the ecosystem. The predictions under test are based on two simple models linked to plant trait databases. The first is the twin-filter model that differentiates between the sets of plant traits that drive ecosystem assembly, tempo and functioning and those that control the fine structure of the plant community. The second is the seven-step model that predicts the sequence of events as climate change impacts on an ecosystem in the present century.

The main part of our report describes progress in our effort to test model predictions by means of long-term manipulations of climate now applied continuously for 18 years to large plots in an ancient, species-rich, calcareous grassland at Harpur Hill in North Derbyshire, UK. Experimental treatments include warm winters, summer drought and increased rainfall. Subplots are used to examine the effects of climate change on southern invaders, and recently these have also been used to investigate ecosystem responses.

The experiment has revealed that, on a world scale, the Buxton grassland is exceptionally resistant to climate change and we will report on progress in identifying the mechanistic basis of this characteristic and its wider implications for conservation priorities and adaptive management responses in Western Europe.

Connectivity in the context of climate change

Jenny A. Hodgson¹, Atte Moilanen², Brendan A. Wintle³, Jane K. Hill¹ and Chris D. Thomas¹

¹ Department of Biology, University of York

² Metapopulation Research Group, Department of Biological and Environmental Sciences, University of Helsinki, Finland.

³ School of Botany, University of Melbourne, , Australia.

The role of connectivity in the context of climate change has generated much debate. "Connectivity" can have a variety of meanings, but a review of literature suggests that habitat area and habitat quality have quantitatively bigger effects on populations and range expansions than spatial arrangement of habitat and quality of the intervening non-habitat. Habitat aggregation generally increases the chance of a propagule landing in suitable habitat, and therefore of a patch of habitat being colonised/occupied, but it can only compensate a little for deficiencies in quantity and quality. Under climate change, the benefit of aggregation may be less certain because aggregating remaining habitat within a few regions may leave dispersal barriers that will eventually need to be bridged. When suitable habitat is a very low proportion of the landscape, there will be a trade-off between maximising aggregation and reducing the largest dispersal barriers. Recent theoretical and simulation studies show that a less aggregated, and more "corridory" pattern may maximise the speed of colonisation of an unoccupied landscape, although

this is accompanied by a higher risk of extinction. There is empirical evidence that corridors can increase dispersal rates between patches to some extent, and also “managing the matrix” can result in modest increases in dispersal between nearby habitat patches. However, an increase in dispersal per se is not direct evidence of an increase in population viability. Given enormous uncertainty in how fast and in what direction suitable climate space for species will shift, providing highly tailored “escape routes” for species is probably not feasible. Aiming to maximise the area of habitats that are capable of supporting a high species diversity, whatever their spatial arrangement, could be the most robust conservation strategy.

Hodgson, J. A., Moilanen, A., Wintle, B. A. & Thomas, C. D. (2011) Habitat area, quality and connectivity: striking the balance for efficient conservation. *Journal of Applied Ecology*, In Press.

The range expansion of the silver-spotted skipper butterfly: lessons for conservation under climate change

Jonathan Bennie¹, Callum Lawson¹, Chris D. Thomas², Jenny A. Hodgson² & Robert J. Wilson¹

¹Centre for Ecology and Conservation, University of Exeter, ²University of York

To maintain biodiversity under a changing climate, conservationists will have to allow, and even encourage, species to shift their ranges into areas which may have been climatically unsuitable in the past. However, the development of guidelines for promoting range shifts under climate change is hindered by a lack of examples of successful range expansions by habitat specialist species. A key issue facing conservation managers is whether to concentrate resources on maintaining and enhancing the quality of existing habitat, or on creating new areas of habitat outside of the current range, to increase landscape connectivity and facilitate range shifts.

Here we report on the continuing range expansion of the silver-spotted skipper butterfly *Hesperia comma* in its five main UK population networks, and relate these to the changing climate, microclimate, management and connectivity of habitats in South-East England. A national survey of the species UK distribution and available habitat has been carried out at 9-year intervals since 1982. Since the early 80s, when the species was restricted to core refuge sites on warm, south-facing slopes, *H. comma* has colonised new habitats and expanded from fewer than 70 known sites to over 300. This pattern of expansion is complicated by interannual climate variation, as cooler habitats became suitable in warm years and provided additional stepping-stones of habitat for colonisation, followed by partial retreats from these thermally sub-optimal habitats in cooler years.

Analysing data from the most recent surveys in 2000 and 2009, we investigated the factors influencing the probability of colonisation and/or extinction of *H. comma* within a habitat patch. The probability of colonisation of a new site was found to be a function of the site connectivity and the abundance of the larval food plant, while the probability of extinction was also found to be influenced by microclimate (slope and aspect) and the size of the habitat patch. Using this species as an example we suggest how landscape-scale management may be able to help facilitate colonisations from refuge populations or reserves, while minimising extinction risk and promote adaptation to a changing climate.

Moving plants and animals when the historic range loses legitimacy: adapting conservation translocations to cope with climate change

Sarah E. Dalrymple¹ & Mark R. Stanley Price²

¹ School of Biological Sciences, University of Aberdeen,

² Wildlife Conservation Research Unit, University of Oxford

Moving plants and animals in order to restore extirpated populations is frequently proposed as a tool for improving the status of threatened species. However, the success of such interventions, usually termed ‘reintroductions’, is variable. In several recent reviews of reintroductions, evaluations are hindered by the short

time periods between reintroductions being attempted and reporting of the project outcomes in the scientific and 'grey' literature. Despite these problems, we show that there are lessons for improving reintroduction practice and these revolve around more rigorous demographic monitoring of wild populations and their habitat to better identify areas within the species' range for population restoration.

Reintroductions rely on the concept of 'historic range' but there is a growing body of evidence to suggest that this concept will lose legitimacy due to a changing climate. Indeed, climatic shifts may already be a cause of species decline albeit of lesser current importance than non-climatic habitat loss, degradation and fragmentation for many threatened species.

In anticipation of future habitat loss and shifts of suitable climatic conditions, introductions of species out of their historic and current range have been proposed. These are termed variously as 'assisted migration', 'assisted colonisation' and 'managed relocation' but can all be considered under the IUCN's chosen term of 'conservation introduction'. Very few conservation introductions have been attempted in direct response to projected range shift due to climate change. However, there are various examples of conservation introductions for other reasons (often to avoid disease transmission), which can be used to inform and adapt our conservation strategies. The proposal to move Tasmanian Devils out of their range due to the risk of contracting cancerous facial tumours illustrates some of the risks and controversies associated with conservation introductions. Other examples of conservation introductions such as the contentious movement of the *Torreya* pine across large distances in the U.S. highlight that climate change is already used as a justification for conservation introductions.

Consequently, the IUCN Species Survival Commission has established a task force from within its Re-introduction and Invasive Species Specialist Groups to review and update its 1998 guidelines to explicitly accommodate these issues surrounding conservation introductions.

The Task Force's main objective is to prepare a relatively short set of guidelines on the factors to be considered before deciding to embark on a conservation introduction, and the processes and mechanisms to be followed to arrive at the best decision. The new guidelines will aim to define the critical biological attributes of species which would:

- make them vulnerable to climate change and other major threats, in terms of likelihood of exposure and likely response,
- predispose them to successful establishment at new sites, and
- be likely to be the cause of undesirable or unintended consequences at a new site.

We will also consult with many others on aspects of ecosystem functioning, and the host of non-biological aspects such as policy and legislation, and ethics. The task force will report to the World Conservation Congress in 2012.

Winners, losers and conservation priorities: identifying which species require most assistance to survive climate change.

Chris D Thomas

Department of Biology, University of York, UK

Climate change has already brought about substantial changes to the distributions and relative abundances of species. The composition of biological communities has already changed, and even greater changes are predicted for the near future. Hence, conservation under climate change is about managing change, rather than trying to keep things as they are, or return biological communities to some past, desired composition.

Populations of individual species remain the basic entities that underlie the new, emerging communities and the ecosystem goods and services they deliver. There is, therefore, a strong logic in continuing to target the needs of "species" as a major focus of conservation in regions where this is possible. Vegetation categories cannot be used because they will forever need to be re-designated; and it is unclear whether faster or slower rates of community composition change are "better".

Through collaboration with colleagues from a range of environmental, conservation and academic institutions, we have developed a procedure to assess the threats and benefits experienced by different species under climate change (Thomas et al. 2010). This is akin to the IUCN Red Listing Procedure, but departs from that framework in several respects. Our procedure assesses observed changes to each species over the past 30-40 years of climate change, and combines these observations with modelled projections of likely future change. Greater emphasis is placed on conclusions that are most robust. The results are summarised separately for the parts of the distribution of a species where it used to occur (is it declining within its historic range; if so, how fast?) and the areas of actual and potential expansion. Decline within the existing range is taken as the potential threat, and expansion beyond as the potential benefit. The balance of threats and benefits is then used to assess whether a species is expected to show a net increase or decrease from climate change, either within a region, or throughout the species' distribution.

The result is a list of species threatened by climate change, and a list of species that could benefit. This climate-related information can then feed back into regular species-level assessments of conservation threats and needs. Specific, targeted actions can then be taken to decrease threats and increase benefits. The types of species (as defined by distributional data, life history traits etc.) that benefit or decline can also be assessed, with the aim of developing strategies that will maintain a wider range of species than those assessed directly. This species-specific perspective helps focus conservation actions where it really matters; on those species that really needs human assistance to survive.

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Adapting the model - predicting the effect of environmental change for conservation

Matthew R Evans

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We are in an unprecedented era of environmental change. Environmental change will mean that the suitability of areas for animal and plants species will alter, species will respond to these changes either by adapting to them and remaining within the same geographical area and/or attempting to move. The scale and speed of the envisaged changes will make either of these responses difficult. Conservation policy is also going to have to alter and it is likely that conservation measures in the future will need to be radically different from those currently used. For example, the existing network of protected areas will need modification to allow for the movement of species responding to shifts in the environment; there will also be a need to anticipate the future conservation needs of species that are currently not of concern; we may need to consider translocating founder populations of species into new locations and we may need to contemplate the development of hitherto novel communities as species move into and out of areas. In order to address issues like these, ecologists will need tools that will allow robust predictions to be made about specific systems of interest under novel future conditions. By convention ecologists and conservationists tend to use phenomenological models that rely on functions statistically derived from data; these are good at describing what has happened in the past but for many reasons are poor at predicting the future, especially under novel conditions. Climate envelope models that aim to predict future species ranges are an example of this type of approach, which has been widely criticised. Here I discuss the desirable features that would be found in an approach that was designed to produce robust, rigorous forecasts about the way in which biological systems would react to future changes in environmental conditions. I suggest that such an approach would be provided by the development of process-based models of ecological systems. A rigorous understanding of the processes that underlie a given system would be more likely to provide the ability to accurately forecast the behaviour of the system in novel conditions, than an approach that relies on a description of the system being valid indefinitely. This is similar to the approach that has been adopted in systems biology and is proving successful in understanding the complexity of cellular metabolism. Such an approach would allow predictions to be made about the way in which particular species or communities of species might react to change; models

could be created that allow us to examine different types of intervention aimed at mitigating the impact of environmental change. Developing such an approach will be intellectually challenging but may the urgency of the situation should dictate that ecologists and conservationists engage with the task to create accurate, realistic predictions for specific systems.

The climatic risk atlas of European Butterflies

Martin S. Warren, Alexander Harpke, Josef Settele, Chris van Swaay and Sue Collins

Butterfly Conservation Europe

Butterflies are a well-known and popular group of insects that can play a valuable role as early warning indicators of environmental change. They have short life-cycles and respond rapidly to change. The paper describes the results of the Climatic Risk Atlas of European butterflies, an early attempt assessing the possible effects of climate change on 293 widespread European butterflies. Results will also be given of a new analysis showing the impacts at a country level.

The impact of three future climate change scenarios are modelled, each assuming full or no dispersal into the new climate space. The study shows clearly that climate change poses a considerable additional risk to European butterflies, which are already undergoing a rapid decline. However, the risk varies considerably under the three scenarios:

- Under the extreme high emission scenario, assuming no dispersal, 24% of the modelled species lose more than 95% of their present climatic niche by 2080 and 78% lose more than 50%. Only 6% of species are rated as being at lower risk.
- Under the moderate emission scenario, assuming no dispersal, only 3% lose more than 95% of their climatic niche and 48% lose more than 50%, while 43% are rated as low risk.
- The results show that there is a considerable time lag in the effects of climate change: Until 2050, the effects across different scenarios are still moderate. Under the high emission no dispersal scenario, around 60% of species are still rated as experiencing a low risk until 2050, while in 2080 these are a mere 6%.
- Under the moderate SEDG scenario, 33% of species could experience a net increase in climate niche space until 2050, while until 2080 this option is still potentially available for 30% of the species.

Conservation recommendations are given, including a no regrets approach to managing landscapes that will help conserve biodiversity regardless of climate change. The results are important because butterflies are one of the few groups of insects for which such comprehensive data are available at a European level. As insects comprise over two-thirds of all known species, the results are valuable to help understand the possible impacts of climate change on biodiversity as a whole.

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Projecting the benefits of landscape-scale conservation for wildlife and people

Hodder, K.H.; Douglas, S; Newton, A; Cantarello, E; Birch, J. Bullock, JM

University of Bournemouth

It is compellingly argued that management which reverses habitat fragmentation and proactively aims for dynamic, connected landscapes should provide numerous benefits both for wildlife and people, and that conferring the ability for species to move will provide increased resilience to climate change. Quantification of these benefits is difficult, given the large spatial and temporal scales involved. However, using scenarios it is possible to demonstrate the potential outcomes of such landscape-scale management. Here we demonstrate such scenarios for 6 sites in England and Wales and discuss the utility and limitations of this approach.

Provision of some services, recreation and aesthetic value, was enhanced by all of the landscape-scale scenarios, and where there were losses, these tended to be compensated by gains. There was a tendency for a shift from food and fibre to carbon storage and recreation. However, there were notable exceptions where premium products, such as meat, significantly increased. Numerous assumptions are implicit in the scenarios but comparison is the aim, rather than generation of absolute values. A number of methodological aspects were of particular note:

- The comparisons were highly sensitive to the value of carbon which dominated any monetary analysis.
- Proxy values are relatively available but should be used with caution: comparison with locally derived values showed that major differences in valuation can accrue.
- Simplified representation of change in ecosystem services may be more appropriate than monetisation where uncertainties may obfuscate the results.
- Inclusion of values that cannot be assessed in monetary terms (e.g. biodiversity) is crucial.

Envisaged increases in priority habitats would provide major contributions to national targets and trade-offs between habitats can be usefully explored through scenarios. Improvements in habitat condition would also be expected, and in urban environments, space-limitation may allow only improvements in quality. Increase in habitat connectivity was indicated but changes in connectivity did not always follow the greatest increase in area - suggesting that spatial planning can increase connectivity while allowing conservation of other habitats. These analyses will be enhanced in future through replacement of generalised values for movement of species in the landscape with more detailed ecological knowledge.

To be realistic, the landscape-scale initiatives must be sustainable economically over the long term. A wide range of commercially exploited ecosystem services indicated by the case studies, such as premium meat, reeds and recreation, shows the way forward for integrating with the local economy. The domination of the combined benefits by carbon values suggests that support of many landscape-scale initiatives through carbon-offset potential should be considered, and other benefits, such as flood mitigation, may be future recipients of Payments for Ecosystem Services.

Although these market forces should be encouraged, the market alone cannot be expected to deliver the full range of ecosystem services and the challenge is to enhance natural assets with economic and social sustainability. The projects examined here showed the key importance of agri-environment schemes in delivering landscape-scale projects. Suitably targeted, this has enormous potential for enabling the restoration of an ecologically functioning landscape and further integration with research on functional connectivity and systematic monitoring will enhance these approaches.

The landscape-scale approach consolidates effort which should prevent lack of coherence and continuity in funding. Nevertheless, even for larger partnership projects, the lack of continuity in funding has been a limiting factor. Realistic landscape-scale initiatives will be well integrated with the local economy, and supported through appropriate policy instruments, to ensure that there is adequate sustainability for large temporal as well as spatial scale.

Putting climate adaptation plans into action: an international perspective

James Watson

Wildlife Conservation Society, New York

The reality of human-forced rapid climate change presents an unprecedented challenge for the conservation of biodiversity. In this talk I will describe how the environmental non-government organisation (NGO) Wildlife Conservation Society (WCS) is tackling this challenge. WCS is a science-based environmental NGO that currently works in 71 landscapes and seascapes in 41 countries across Earth to conserve biodiversity. WCS often works in megadiverse but under-resourced regions characterized by very limited information about the distribution and ecology of wildlife and their responses to climate change. Therefore WCS has an enormous opportunity (and obligation) to protect some of the richest natural regions but will need to develop strategies for conservation under extreme knowledge constraints and resource limitations. To do this, WCS has developed a strategy that focuses on two approaches to protect biodiversity in the face of climate change.

First, the WCS strategy aims to protect and restore natural processes and responses that have enabled species to persist through past environmental change. This includes identifying and protecting important climate refugia (both ecological and evolutionary); conserving the large-scale migration and connectivity corridors that operate at continent scales (including regional networks of habitat patches and habitat 'stepping stones'); maintaining viable populations of all extant species to maximize intra-species genetic diversity and thus allows options for local adaptation; reducing all current threatening processes at the landscape scale; and protecting and restoring key large scale ecological processes (especially hydro-ecology and ecological fire regimes). Underpinning these climatic adaptation responses is an understanding of the special role the Earth's remaining extensive intact landscapes will play in the future protection of biodiversity.

Second, WCS is developing regionally specific adaptation frameworks to allow specific activities to be planned for, and implemented, in a number of landscapes. This involves developing conservative-to-extreme predictions of regional climate change during the next 20 to 50 years across landscapes using the latest IPCC data. Both ecosystems and species are modeled to see how their current distributions will shift under different future regimes and these data are integrated in the planning process. Current threatening processes to species and ecosystems will also be analysed against future climate change scenarios to see how they are likely to vary in their intensity. We will use these models to assess our current activities in each of the landscapes we work in and set new priority actions that take into account the likely impacts of climate change. While the development of these frameworks are in their infancy, I will concentrate on three different case studies from the Albertine Rift, Madagascar, and North America that highlight some of the specific climate adaptation activities being undertaken by the organization.

Complex land systems and ecosystem services: the need for long time perspectives in order to assess their future

John A Dearing

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Over the past decade, ecosystem services have become central to discussions about the sustainable management of land systems. A key review of the science for managing ecosystem services (Carpenter et al. 2009) has highlighted the need for 'networked, place-based and long-term social-ecological research'. The authors argue that concepts and theories should be grounded in real-world observations, but make clear that there is a scarcity of long-term data from monitoring programmes. An emphasis on long records is normally based on a need to understand the dynamic behaviour of coupled socio-ecological systems, which in turn provides insight into complex, nonlinear behaviour like thresholds. Long records give critical perspectives on the modern situation: fast and slow processes; trends and rates; complex behaviour; interactions; modelling; reference states (Dearing et al. 2010).

Where long monitored records do not exist or are too short to capture key system properties there are alternative sources of data for ecological change, particularly in natural archives, like lake sediments. Over the past 50 years the ability to interpret sediment records as proxies for specific environmental processes has become increasingly refined with the use of multivariate statistics and modern day calibrations. Using the categories defined by the Millennium Ecosystem Assessment (2005), we have been able to map proxy records on to the majority of 'supporting', 'provisioning' and 'regulating' services, but not 'cultural' services. For some sub-categories, it is also possible to use more than one type of proxy record to define the ecosystem service. Overall, the 'regulating services' category has the most potential proxy records. These are often the least well monitored, especially in remote areas and developing nations. Proxy records thus have a potential role in not just extending timescales of observation but in providing primary data.

We explore the scope and potential of using multi-proxy records to study multi-decadal changes in the land systems of the lower Yangtze basin. Normalized indices for different ecosystem services (vegetation biodiversity, soil and sediment, surface soil, water quality, air quality) show gradually declining curves indicating widespread loss of service (e.g. increasing soil erosion and nutrient loadings to water bodies) since 1850. In terms of both the rate of change and the difference between the modern and mid-20th century levels, air and water quality are the most degraded ecosystem services. A combined index for environmental change shows the greatest

period of change between the 1950s and 1960s. Overall the worst environmental degradation is associated with agricultural expansion and early economic development. Economic reforms associated with more environmental regulation after the late 1980s may have contributed to 'stabilising' overall ecological degradation.

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Adaptation indicators for biodiversity

Mike Harley

AEA

There is increasing concern in the biodiversity sector about the impacts of climate change on vulnerable species, habitats and ecosystems. The European Commission's Adaptation White Paper recognises that climate change will increasingly drive the loss of biodiversity and ecosystem services and that vulnerability can be reduced by certain (planned) policies, measures and actions. Adaptation indicators can be used to monitor the implementation of adaptation policies and measures, and show whether vulnerability is being reduced through effective adaptation actions.

A conceptual framework for the development of adaptation indicators was established for the European Environment Agency by the European Topic Centre on Air and Climate Change (ETC ACC) (Harley et al., 2008). The framework considers planned adaptation to climate change impacts and captures the 'processes' associated with the development of adaptation policies and delivery of adaptation measures, and the 'outcomes' of adaptation actions. It does not consider autonomous adaptation.

Further work by the ETC ACC (Harley, M. & van Minnen, J., 2009) used case studies to demonstrate the utility of the conceptual framework for adaptation indicators and develop it further for wider application. One study showed how adaptation principles might be used in the development of adaptation indicators for biodiversity. The principles can be linked to a range of generic conservation activities that relate to policies, measures and actions, from which it is possible to exemplify how both process-based indicators and outcome-based indicators can be derived.

The ETC ACC has subsequently used the adaptation principles and associated measures cited in guidance prepared for the Bern Convention's 'Group of Experts on Biodiversity and Climate Change' (Harley & Hodgson 2008) as the basis for identifying a preliminary set of adaptation indicators for biodiversity (Harley & van Minnen, in press). These include six process-based indicators for adaptation policy (e.g. best practice is being communicated and information exchanged on successful adaptation), nine process-based indicators for adaptation measures (e.g. vulnerability assessments of biodiversity and associated ecosystems are being undertaken), and eight outcome-based indicators for adaptation actions (e.g. networks of interconnected protected areas and intervening habitat mosaics are being established to increase permeability and aid gene flow). The next step is to prepare the ground within the biodiversity and related sectors for embedding the indicators as a tool for monitoring and evaluating the implementation and effectiveness of adaptation policies, measures and actions in reducing vulnerability of species, habitats and ecosystems to climate change.

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Integrating adaptation with mitigation and biodiversity objectives

Dr. Pam Berry

Environmental Change Institute, University of Oxford

Climate change is already having an observable impact on biodiversity and the projections of future climate suggest that the impacts could lead to the loss of potentially suitable climate space for some species, as well as to some gains. Current conservation and management strategies that maintain and restore biodiversity can be expected to reduce some of the impacts of climate change; however, there are rates and magnitude of climate change for which natural adaptation will become increasingly difficult.

There are two possible ways of further decreasing the impacts: climate change mitigation and adaptation, and both are considered necessary in order to avoid the undesirable effects of climate change. Already many actions which involve ecosystems are being taken or are proposed to mitigate climate change, such as restoring wetlands or reducing deforestation, but these are often viewed as being insufficient to significantly reduce undesirable impacts, especially in the short-term. Adaptation measures, therefore, are also required and these can have both positive and negative consequences for biodiversity and ecosystem services, depending on the way in which such strategies are implemented. For example, on coasts the use of soft engineering approaches can facilitate the continuation of coastal dynamics and ecosystem processes, thus allowing coastal communities to adapt to climate change.

Mitigation and adaptation measures also have consequences for each other and for biodiversity. Their interaction can have a number of different outcomes for biodiversity and win-win-win measures, that meet mitigation adaptation and biodiversity objectives should be promoted in order to ensure that cost-effective and environmentally sound actions are implemented. (Paterson et al., 2008; Berry, 2009).

This paper will examine some of the challenges and opportunities of integrating adaptation with mitigation and biodiversity objectives and show that there is a need to engage with other sectors in identifying the possible management and policy responses to projected climate change impacts on biodiversity, in order to avoid the degradation and loss of species, natural ecosystems and their services.

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Multifunctional forests

Mark S.J. Broadmeadow

Forestry Commission

Woodland creation has been proposed as a cost-effective measure for reducing net CO₂ emissions, by sequestering carbon in wood and soil biomass and providing woodfuel and timber products that help to reduce fossil fuel use¹. This role in climate change mitigation is gathering momentum through, for example, the work of the Woodland Carbon Task Force and the Woodland Trust's MOREwoods scheme. If the ambition for woodland creation, as laid out in the Read Report² is realised, it would also provide real opportunities for landscape-scale adaptation. As well as expanding, buffering and linking areas of existing ancient and native woodland including through the development of woodland habitat networks, woodland creation has a wider role in helping society to adapt to climate change. Targeted woodland creation can contribute to flood alleviation, reduce soil erosion and limit thermal stress in the riparian environment – while also providing more semi-natural habitat. The important role of tree planting in adapting the urban environment to rising temperature has also been recognised through, for example, the recently launched 'Big Tree Plant' campaign.

If the new woodlands are to provide the goods and services that society requires of them, they must also be resilient to the impacts of climate change with growth rates maintained where timber production is an objective. Growth rates are likely to increase in the north and west of the United Kingdom as a result of rising temperature and CO₂ levels. In contrast, many woodlands in the south and east may be challenged,

particularly on freely-draining soils, if projections of increasingly frequent and severe summer droughts are realised. The implementation of adaptation measures to increase resilience poses significant challenges to woodland management because of the time-scale involved, coupled to uncertainty in the climate of the future. However, a range of adaptation options are available³, most of which focus on 'conventional' woodland management practice to promote regeneration and reduce other pressures. A key theme is diversification to accommodate uncertainty in the future climate and the threat posed by pests and diseases. While better matching of tree species to site and soil type and greater use of less widespread native species such as lime and hornbeam will increase resilience, there is also likely to be a need to consider the planting of species from continental Europe to accommodate the likely movement in species' ranges.

The expansion of 'multifunctional forests' to tackle climate change could have limited benefit if the principle of 'the right tree in the right place for the right reason' is not followed. In particular, the use of non-native tree species in bioenergy plantations and as wider adaptation measures, coupled with the development of woodland habitat networks facilitating dispersal does represent a potential risk to native biodiversity. However, these risks should not stand in the way of woodlands contributing to the future needs of society; rather they point to the need for best practice in woodland design, sound research to underpin policy, effective monitoring and timely intervention should unforeseen impacts arise.

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² Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (eds) (2009). Combating climate change – a role for UK forests. The Stationery Office, Edinburgh.

³ Ray, D., Morison, J. and Broadmeadow, M. (2010). Climate change: impacts and adaptation in England's woodlands. Research Note 201. Forestry Commission, Edinburgh.

Future climate, changes in land-use capability, and potential trade-offs between agriculture and forest services. The case of broadleaved habitat networks in Scotland

Alessandro Gimona, Laura Poggio, Marie Castellazzi, Iain Brown, Luz-Maria. Lozada-Ellison
The Macaulay Land Use Research Institute

In many ecoregions semi-natural ecosystems are already or are becoming fragmented and embedded in a landscape matrix which often makes species dispersal problematic. This is compounded by the effects of climate change. Current thinking about adaptation measures for climate change include making the landscape permeable enough to facilitate individual movement, so that species can shift their distribution to suitable habitat when part of their current habitat becomes unsuitable. While habitat networks are central to this adaptation strategy it is important to recognize that they are potentially threatened by land use change caused by shifts in land capability and changes in global food demand. In a 40-year time horizon, in particular, global climate-induced shifts in land use are potentially larger and faster than direct effects due to equilibrium between climate and species distributions, and have the potential to cause a large loss of species and ecosystem services. This is due to a combination of factors such as regional effects of climate change on crop yields, population growth, increase global consumption of meat, competition between food crops and agrofuels. In this paper we investigate to what extent forest habitat networks are threatened by land use change mediated effects, and in particular we examine the potential implications of land capability change. We study the feasibility of policy targets for forest habitat expansion and show that forest habitat loss due to conversion to agriculture is a clear potential outcome at least in plausible scenarios. The conservation and adaptation policy issues raised in this work are likely to be common to many areas of the world in which climatic changes will bring an increase in agricultural capability. The paper highlights the need to account for such change as well as for effects at a distance (teleconnections, *sensu* Nepstad). Adaptation and mitigation policies can be improved by spatially targeted conservation incentives and by an improved decision making framework (e.g. UNEP, 2009 <http://www.macaulay.ac.uk/copenhagen/>) that involves land managers and aims to reconcile different interests and values.

Do wetlands reduce floods?

M Acreman

Centre for Ecology and Hydrology

It is widely recognised that wetlands play an important role in the hydrological cycle, influencing groundwater recharge, low flows, evaporation and flood generation. This has led to policies being formulated world-wide to conserve and manage wetlands to deliver key services, including flood risk reduction. However, the term “wetlands” covers many land types, including wet woodlands, reedbeds, peat bogs, fens, wet grasslands and salt marshes. Research has shown that each of these types functions hydrologically in a subtly different way; thus it is difficult to make generalisations about flood reduction services of wetlands. In the past, generic statements have been published about wetlands for which scientific evidence is often limiting or inconsistent, notably the concept of wetlands acting like a sponge. This has been mis-interpreted by some to mean that all wetlands perform all services in the same way to the same degree. There are many quantitative examples of flood reduction by floodplain wetlands published in the scientific literature; for some this has been translated into a high economic value. Floodplain or washland storage has been employed as a flood protection option for some towns and cities, such as Lincoln and Shrewsbury. Generally, the relationship between upland wetlands and floods is more complex, for example whilst some studies suggest these reduce floods, others imply that because wetlands soils are normally saturated, they act as flood generating areas. Few UK wetlands are entirely natural and their management presents another layer of complexity. For example, the relationship between wetlands and floods alters depending on the nature of artificial drainage and vegetation cover; blocking grips can reduce floods as can re-vegetation of denuded surface. Climate change predictions for the UK suggest that flood risk may increase in some areas in the future. Many wetlands could be managed specifically to optimise their flood management potential. However, this may compromise other ecosystem services, such as biodiversity or carbon sequestration; whilst there are win-win situations, the trade-off between services needs to be understood when evaluating management options.

Posters

The effectiveness of Protected Areas under climate change

Pippa Gillingham, Barbara Anderson, John Baxter, Richard Bradbury, Humphrey Crick, Richard Findon, Richard Fox, Jane Hill, Jenny Hodgson, Alison Holt, Mike Morecroft, Tom Oliver, James Pearce-Higgins, Helen Pontier, Deborah Proctor, David Roy, Chris Thomas, Kevin Walker, Clive Walmsley.

University of York

A wide range of species have been shown to expand their ranges in recent years, and some taxa have been shown to retract either uphill or to cooler latitudes. The most likely explanation is that this movement is caused by recent changes in climate, leading several authors to question the potential future utility of Protected Areas (PAs) under future climate change. It is generally accepted that anthropogenic climate change has been taking place since the 1970s. Therefore, the performance of PAs during the 1970-2010 period, as judged by information in the literature and recorded data sources, represents a good first-stab at assessing the effectiveness, or otherwise, of PAs at maintaining biodiversity under climate change.

At a Knowledge Exchange workshop at the University of York, a group of stakeholders and academics prioritised potential topics to do with the role of PAs under climate change. Broadly, topics could be characterised as concerned with genetic diversity, population size, species diversity, community composition and functional diversity. We also considered that we could look at PAs compared to non-PA land, or consider the attributes of PAs (such as size, condition, habitat heterogeneity).

We decided as a group that we were most interested in the responses of species and communities, and that grouping PAs together would be more manageable, as few PA attributes (other than area) are recorded in a systematic manner. In the context of climate change, we decided that looking at species colonising new areas at their northern range margin, or the survival of species at their southern range margins would be of more interest than the response of all species.

We then considered the available data, and decided that although we might be more interested in the survival of species at their warm margins (to determine whether species survive better in PAs than the wider landscape), data are not currently available to answer this for many taxa. We therefore decided to concentrate on the relative frequency with which colonising species occur in PAs compared to both the wider landscape and the PA usage of resident species.

Climate Vulnerability Assessment of Designated Sites in Wales

Lucy Wilson¹ Dr Rob McCall² Dr Clive Walmsley²

¹ADAS UK Ltd.; ²Countryside Council for Wales

There is clear evidence of climate change in Wales and widespread recognition of the need for nature conservation policy and practice to address potential future impacts on biodiversity. It is widely recognised that the semi-natural habitats within our protected sites network form a critical resource in present and future efforts to maintain and enhance biodiversity resilience and adaptive capacity. Understanding the present and near future (next 20 years) extent of vulnerability of these protected sites to climate-induced change is therefore a first critical step in a nationally coordinated approach to biodiversity adaptation.

The Countryside Council for Wales has undertaken such an analysis to identify which protected sites in Wales should be prioritised for practical adaptation actions that improve resilience to climate-induced change. The analysis considered the inherent sensitivity to climate change of the habitats and species for which sites were notified, along with site factors that affect adaptive capacity and resilience, including condition of site features, the extent of management issues and connectivity between the broad habitats within the site and the wider landscape.

The newly completed CCW Special Sites Database provides information on site features and management issues that may be exacerbated by climate change. Assessment of climate impact risks to species and habitat features was conducted by CCW species and habitat specialists, following the methodology used to assess the implications of climate change for implementation of UK BAP targets. The basic connectivity analysis is based on the comprehensive Phase 1 vegetation mapping that has been undertaken throughout Wales. Each of these components is combined to create a ranked Climate Vulnerability Index, covering terrestrial & freshwater SSSIs, SACs and SPAs.

The Climate Vulnerability Index shows good concordance with the few pre-existing vulnerability assessments of individual sites but also highlights the potential vulnerability of previously unconsidered sites. While this may be so, the analysis should not be seen as a replacement for detailed site-based risk evaluation and adaptation investigations – rather as a useful overview of the potential climate vulnerability of special sites across Wales and as such a gateway to a complimentary and more targeted detailed site-based investigations and action.

New information on species and habitat impacts as well as the designation of new sites will inevitably demand that the analysis is repeated in future so the methodological approach used throughout the study has been designed to be both automated and replicable.

Translocation in response to climate change: a feasibility study in the Scottish Uplands

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This poster outlines a project currently being jointly run by Scottish Natural Heritage and the Macaulay Land Use Research Institute, and with collaboration from the Royal Botanic Gardens Edinburgh, with the objective of assessing the use of translocation as a species management tool to enable species to adapt to the threat of climate change.

Background - Translocation is proposed as a tool to mitigate the impacts of climate change on species that are unable to track suitable climatic conditions. Put simply, a species is moved to a new site which will contain in the future a suitable climate, or to “stepping stone” sites from which it can reach climatically suitable sites unaided.

Such translocations have been called assisted colonisation, assisted migration, managed relocation, and even managed invasion. Generally considered an action of “last resort”, their use is highly contentious (Hoegh-Guldberg et al. 2008, Davidson & Simkanin 2008), and numerous potential problems have been discussed, although data are often lacking (Brooker et al. In Press).

The project has two main components:

Activity 1 - A literature review (Brooker et al. In Press) to assess current understanding, identify knowledge gaps, and develop research questions. It specifically assesses the possible use of assisted colonisation for four key species groups of conservation interest in Scotland: lichens and bryophytes, vascular plants, and terrestrial invertebrates.

Activity 2 – Field trials. Our key research question is: can we predict the location of climatically suitable sites? If we're unable to do this, then many other problems (for example the potential impacts of species in their new locations) become irrelevant.

Mountain habitats contain many of the species that are likely to be threatened by climate change, and for which practical conservation measures are needed, making them ideal study systems. We are combining field surveys of our model species, the lichen *Flavocetraria nivalis* (restricted to hill-top locations in the Cairngorms), with climate data to attempt to predict the location of climatically suitable recipient sites.

We are then using trial translocations, with neighbourhood manipulations (neighbour clipping and artificial shelters), to assess the extent to which: 1. our predictions of climatic suitability are correct and 2. the presence of biotic interactions (the occurrence of appropriate "matrix" vegetation) changes site suitability and the accuracy of our predictions.

Outcomes - In addition to providing invaluable information about practical techniques for translocating lichen species and monitoring their success, this project will deliver widely-relevant lessons about whether we can – or cannot – "predict" climatically suitable sites at a local scale relevant to conservation action.

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Davidson, I. & Simkanin, C. (2008) Skeptical of Assisted Colonization. *Science*, 322, 1048-1049.

Hoegh-Guldberg, O., Hughes, L., McIntyre, S., Lindenmayer, D. B., Parmesan, C., Possingham, H. P. & Thomas, C. D. (2008) Assisted colonization and rapid climate change. *Science*, 321, 345-346.

Impact of Climate Change on the Biodiversity of Development Projects

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The aim of the research is to develop guidance on vegetation planting schedules, including species lists, for the habitat creation and planting design required for large scale development sites subject to climate change. Climate change is by no means a new phenomenon, and can be as a result of natural variability or human activity. The temperature rise however over the last few decades has been at a rate quicker than seen before, and the amount of CO₂, a greenhouse gas, entering the atmosphere since the pre-industrial era has increased from 280 parts per million (ppm) to 380ppm, putting human activity partly to blame for global warming.

Future projections of climate change, like increase in temperature during the summer months, and heavier rainfall during the winter, means that certain species will be affected by such change on many levels. In nature there is a delicate balance between important cyclical events, like blooming and migration, and the climate. Timing of such events is already occurring earlier than previous years.

Housing developers, as part of their ecological planning, need to know what vegetation would be suitable to plant on brownfield sites that would survive and flourish both now and in years to come, ensuring sustainability is maximised. With the quality of the soil on these sites often being poor, it will make it more difficult for plants to survive. Case studies both in the UK and on the continent will be looked at, including that of the Eastern Quarry in Kent, which is one example of a large scale brownfield housing development site and will be used in the project to help assess such problems. One example on the continent, which matches what is expected in the UK in the future, would be that of the French Causses in central southern France. Exotic species like orchid are expected to become more common in the UK. A suitable palette of vegetation needs to be selected for sites like that in Kent, with species on the continent that currently grow in temperatures predicted for the UK in 2050 being looked at for such suggestions.

It is clear that climate change is already having an effect on biodiversity. Due to the rate at which climate change is happening, species may not be able to keep pace and survive, therefore human intervention is necessary. By identifying what vegetation would be suitable for the UK, planting manuals will be developed for different areas and habitats of the UK, and be available for housing developers to incorporate into their planning stages when considering biodiversity for years to come.

Microclimate and vegetation function as indicators of landscape thermodynamic efficiency

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¹ Writtle College, Chelmsford, ² Eberswalde University for Sustainable Development, Germany

Resilient and functional landscapes are essential for climate change adaptation (Natural England, 2010). The influence of land cover on climate patterns is an important consideration for conservation policy in a warming climate. Applying thermodynamic principles to ecological analysis offers potential for understanding ecosystem resilience and functional integrity.

Ecosystem development and resilience are associated with the growth of three key thermodynamic indicators: biomass, networks and information (Jorgensen, 2006). According to thermodynamic theory, resilient systems have complex structures and functional diversity which enhance energy degradation (Kay et al. 2001). Such ecosystems show cooler surface temperature patterns and are highly efficient at regulating climate extremes. With disturbance, complex structures and functional linkages are simplified - this reduces the ability to degrade energy and moderate temperature, as well as impairing key functional attributes such as water cycles, vegetation diversity/structure and carbon storage. However thermodynamic principles have received little evaluation in the context of terrestrial habitats, despite potential applications for environmental management.

This study has applied thermodynamic indicators to a range of ecosystem types in the UK and Europe. Surface temperature was measured to test energy degradation and temperature moderation, in accordance with thermodynamic theory. Grime's CSR model was applied to compare the functional complexity of vegetation between sites. Soil cores from salt marsh systems were analysed for organic carbon to indicate levels of biomass storage.

Ancient woodlands are shown to attenuate surface temperatures more effectively than native species plantations, an effect observed during winter and summer months. Consistently lower temperatures were observed in European old-growth forests with high proportions of biomass when compared with managed stands of similar species. This suggests greater efficiency of energy degradation in more complex forest ecosystems. Results indicated both lower plant functionality and higher temperature variability in forests subjected to anthropogenic disturbance. Wetland and fen meadow ecosystems showed greater temperature fluctuations, but low overall statistical variance, highlighting the strong thermodynamic influence of water in climate feedbacks. Undisturbed salt marsh contained significantly greater levels of organic carbon than disturbed and reclaimed marsh. CSR functional profiles for these sites were dominated by specialised competitive and stress-tolerant species, corresponding to Jorgensen's thermodynamic indicators of information and biomass growth. By contrast, open sites (meadows and pastures) showed exaggerated temperature fluctuations and statistical variance, with strongly ruderal CSR profiles.

Results suggest an important thermodynamic basis for conservation in the context of climate change. Complex ecosystems have strong conservation value, preventing temperature amplification, maintaining system function and enhancing vital services such as carbon storage. Climate change may drive ecosystems towards critical thresholds of change. Proxy indicators based on thermodynamic theory can provide a framework for understanding the characteristics of resilient and adaptable natural environments.

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Trophic destabilisation in a warmer world: are herbivores locally adapted to their ecotypic host plants or are populations at the leading edge of distributions predisposed to change?

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Climate change and other drivers of global environmental change act simultaneously to shape contemporary ecosystems. Any interactions among global change drivers must be considered when planning conservation measures. In studying both land use change—the greatest current threat to biodiversity—and the impact of climate change—the greatest future threat—we investigate whether they are working synergistically to alter biotic processes. Here, I present the results from a herbivory experiment, designed to investigate how shifting climatic envelopes may impact species interactions when mobile herbivore populations shift their geographic distribution while the relatively static host plants do not.

Species shift their distribution to track environmental conditions which support their physiological optimum, yet differences in host plant biochemistry in novel areas may hinder the successful movement of these herbivores. The attrition of trophic interactions is a relatively understudied phenomenon, yet one which may exert strong influences over the future realised niches of species. Using a herbivore-plant interaction across a latitudinal range in New Zealand, we experimentally translocated Geometrid caterpillars, *Cleora scriptaria*, collected from three regions along a north-south gradient onto *Macropiper excelsum* plants of a natal and novel origin collected along the same latitudinal gradient. This ex-situ greenhouse experiment yielded three main findings. (1) Initially, and contrary to expectation, we found no significant tendency for caterpillars to exhibit higher herbivory levels on plants that originate from their natal region. (2) However, caterpillars in populations at the leading edge of the host plant distribution exhibited a different response to novel host plants than caterpillars from elsewhere in the range. (3) Lastly, to understand how interactions will change as herbivores track climate envelope, we exposed caterpillars to host plants from increasingly distant geographical origins and in alternative directions (north vs. south). There were strong interactions between direction and distance, with herbivory rates diminishing notably as northern caterpillars were moved onto increasingly southerly plants.

Our findings suggest that there will likely be attrition of this trophic interaction as herbivore populations move increasingly poleward. However, the ability of populations at the leading edge of the species geographic range to feed successfully on plants from novel regions indicates that southward range expansion under climate change will probably not be limited by differences in host plants. This expansion may be limited by the widespread fragmentation of habitats in many contemporary landscapes. Mobile species may simply not be able to reach suitable habitats which are isolated by modified and inhospitable environments.

The protection and connection of fragmented ecosystems, particularly at the leading edge of species distributions, may prove key to the persistence of biodiversity in a warmer world

Living on the edge: Quantifying the structure of fragmented woodland landscapes in England

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Forest ecosystems have been widely fragmented by human land use, inducing significant microclimatic and biological changes at the forest edge that may be further influenced by climate change. For example, increased exposure to solar radiation and wind at forest edges reduces soil moisture through increased evapotranspiration. Carbon cycling processes, such as photosynthesis, soil respiration and litter decomposition are controlled by moisture and temperature conditions, and are therefore likely to differ between edges and cores. Moreover, the effects of climate change, such as more frequent summer droughts, are likely to be more pronounced in forest edges than in forest core areas. Fragmentation is also known to

alter species richness, abundances and community compositions of a large number of animal and plant taxa, with resulting effects on ecosystem processes, such as pollination, herbivory and predation.

But what is an edge? The extent of edge differs between species and processes and 100m from the edge is often arbitrarily defined as core habitat, despite many species or processes responding on much smaller or larger scales. If we are to be able to rigorously assess the biological impacts of habitat fragmentation there is a need to effectively quantify the amount of edge habitat within a landscape, and to allow this to be modelled for individual species and processes.

We have developed a technique which allows the degree of fragmentation and the proportion of edge habitat to be quantified for a given habitat and to for this to be combined with the responses of individual species or processes to predict current distributions and future outcomes. In this study we quantified the degree of fragmentation and the proportion of edge in a fragmented forest landscape in England. The distance from within the forest patches to the nearest edge was calculated and the results were classified into 10m categories.

The results showed that forests covered 8% of the total land area in the region. The patch size distribution was highly skewed towards small patches, with mean and median patch sizes of 18 and 4.8 ha, respectively. 32% of the forest area was within 30m and 64% was within 100m of the nearest edge, highlighting that edge habitats in a fragmented landscape form a considerable proportion of the total forest area. Thus, to quantify the carbon balance, biodiversity and the impact of climate change at a landscape scale the effect of fragmentation and the magnitude of the edge habitat must be taken into account. We show how the fragmentation maps and edge estimates generated using this method can then be combined with ecological response functions, for example transpiration of ash trees in relation to distance to the edge or moth species richness in relation to woodland patch size, to allow us to generate biologically meaningful estimates of the impacts of fragmentation.

Peatlands and the climate challenge

Aletta Bonn, Clifton Bain & Mary Church,
IUCN UK Peatland Programme

There is growing recognition of the importance of ecosystem services delivered by the functioning peatland environment to human well-being (Bonn et al., 2009a,b, Holden et al., 2007). The impressive scale and economic value of peatland ecosystem services is significant (EFTEC 2009, NE 2009). Peatlands represent the single most important terrestrial carbon store in the UK biosphere equivalent to many times annual UK atmospheric emissions of CO₂ (Worrall et al., 2010). However, human activity has damaged much of the UK's peatland resource and up to 30 tonnes CO₂ per ha per year are lost from the most degraded areas, thereby contributing to greenhouse gas emissions. Peatland restoration, when appropriately targeted, can offer considerable and cost effective GHG emissions reductions (Parish et al 2008, Worrall et al 2010). Peatland habitats and species are of high conservation importance under national and international wildlife law. Peatlands cover around 10% of the UK land area and provide some of the last remaining tracts of unfragmented semi-natural habitats. Pivotal peatland ecosystem services also include the provision of drinking water, with around 70% of UK drinking water derived from upland, predominantly peatland catchments, breathing spaces for millions of people, and important palaeo-ecological knowledge archives.

Peatlands therefore form a globally and nationally important natural capital. However, much of the resource is in a damaged state. Climate change impacts could result in further deterioration of damaged peatlands (House et al 2010) and peatland species, with an increased risk of loss of carbon stores, reduction in water quality, increase of flood impact, and huge associated costs for the UK population. Peatland restoration and adaptive management is crucial to help mitigate and adapt to impacts of climate change, and thereby to ensure the provision of vital ecosystem services into the future. Peatland restoration and sustainable management will therefore be at the heart of high level strategic decisions being taken at a national and international scale, i.e. the renegotiation of the Kyoto Protocol and other instruments under the UNFCCC, the Convention of Biodiversity (CBD - The Nagoya protocol specifically recommends the restoration of peatlands as major carbon stores), the EU budget reforms and the implementation of the Water Framework Directive (WFD) (Reed et al 2010).

Restoration of peatlands with functioning Sphagnum vegetation is a cost effective way to reduce carbon

loss and contribute to water management (Grayson et al 2010, Labadz et al 2010). In the UK large scale peatland restoration works are underway in collaboration with local land managers and communities, which set national examples of best practice. Managing peatlands sustainably has strengthened communities working together and provided local green jobs in the face of a changing climate.

The IUCN UK Peatland Programme helps build a partnership of science, policy and practice (www.iucn-uk-peatlandprogramme.org). The programme is currently leading a Commission of Inquiry on Peatlands to draw together evidence on the benefits of peatland ecosystems. Through the steering group and Inquiry advisory panel, there is strong ownership of the IUCN UK Peatland Programme from the peatland policy and practice community in the private, NGO and public body sectors.

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Worrall et al (2010) Climate Change Mitigation and Adaptation Potential. Report for the IUCN Commission of Inquiry on Peatlands.

An Ecological Connectivity Approach to Planning for Adaptive Landscapes: A Case Study of the West Weald

Mark Fessey, Scott Wilson

An ecological connectivity approach has been taken to planning for an adaptive landscape. The ecological connectivity approach involves making a number of simplifying assumptions, but in doing so it becomes possible to generate an understanding of genetic diversity within focal species populations across a fragmented landscape. If connectivity is measured for suitably representative focal species, then it also becomes a measure of biodiversity and hence resilience. A key benefit of this approach is that it allows 'adaptation outcomes' to be clearly defined, delivered (i.e. through making the 'tough choices' in a timely fashion) and monitored.

Wetland vision and climate change; tools for impact assessment

CEH: **M. Acreman, J. Blake, J.O. Mountford**; Open University: **D. Gowing**; UCL, University of London: **J.R. Thompson**; Exeter University: **R. van de Noort**; BGS: **A. G. Hughes, A. K. A. P. Barkwith**; Environment Agency: **A. Skinner, H. G. Orr, A. O'Neill, K. Tanner, M. Everard**; Natural England: **M. Morecroft**; Wildfowl and Wetlands Trust: **R. Shaw**; English Heritage: **J. Heathcote**; RSPB: **P. Burston**; Wildlife Trusts: **H. Perkins**

The UK climate is projected to change over coming decades. Initial estimates in 2002 predicted wetter winters and drier summers, with the greatest changes in the south and east where in summer soils are likely to become drier for longer (UK Climate Impacts Programme, UKCIP02). These projections have recently been updated (UKCIP09) although the general pattern of change is broadly similar. Such changes will have significant implications for wetlands, which require periodic saturation or inundation. Changes to the hydrological regime

of wetlands are likely to impact on the ecosystems services they provide including flood management, water quality improvement, provision of wildlife habitats and carbon sequestration. Future management, restoration and adaptation of wetlands, particularly delivery of the Wetland Vision in England, will thus require tools to help understand the impacts of climate change so that appropriate adaptation plans can be developed.

This research project, funded by the Environment Agency, Natural England and the Wildfowl and Wetlands Trust, will develop tools to enable the impacts of climate change on wetland hydrology to be estimated. The conceptual framework for the project includes regional differences in climate change and different water supply mechanisms to wetlands (e.g. rain-fed, river-fed, groundwater-fed) and builds on existing wetland assessment frameworks. The tools will vary in complexity from simple look up tables for wetland managers to more elaborate modelling options for detailed impact assessment. The tools reflect available data and the needs of the wetland managers to understand change over a range of spatial and temporal scales. They are designed to predict the impacts of climate change on hydrology for a variety of interest features including vegetation, birds and archaeology.

Practical lessons from palaeoecology

M. Jane Bunting

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An extensive literature has developed in recent years which argues that palaeoecological methods, which provide insights into long-term ecosystem processes (c. 10-10 000 years), need to be seen as part of the conservation toolkit. However, relatively little information about how these insights can be translated into conservation policy and practice has been published.

Palaeoecological data emphasise the transience of plant and animal communities. For example, vegetation communities with no modern analogue existed in Britain as recently as 70-100 years ago, and the composition of native woodland has clearly varied not just in space across the British Isles but in time as well. Using systems based on the descriptions of currently existing communities, such as the NVC or habitats directives, is likely to strait-jacket thinking and could lead to misleading or positively harmful management decisions. Palaeoecological perspectives emphasise that British landscapes have been in a state of change for the last 10 000 years or more; policy frameworks need to be open to ongoing changes in communities, and to the emergence of new combinations of species and habitats in coming years.

The transience of communities suggests that predictions and plans need to be based on understanding species ecology and ecosystem processes rather than on generalising on the basis of community composition. Bioclimatic envelope approaches to predicting changing species distributions are useful tools, but palaeoecological data reminds us that present-day distributions represent the realised niche of a species, not its fundamental ecological requirements. Many species have considerable phenotypic plasticity and can acclimate physiological processes to novel environments; for example, studies show changes in leaf stomatal density in response to changing climate (particularly water availability) and to changing atmospheric CO₂ levels which can have a marked effect on plant growth response to environmental change in field experiments.

Ecosystem processes play out over long time spans, especially for charismatic, long-lived species such as trees. Understanding the local history and long-term trajectory of an individual ecosystem can play a key role in developing an effective management plan and allocating limited resources. Historical documents, the present-day biota and human memory are all imperfect records of the history of plant communities and ecological processes. Palaeoecology (which has its own biases) provides a useful additional source of information, and the poster will present an example from north-east Scotland showing how palaeoecological insights can modify conservation goals at the site level.

Effective conservation policy and practice in a changing world needs to be responsive and flexible; for example, resources based on community classification systems need to either be updated every decade or so (with concomitant large data-gathering costs) or to develop classifications based on structure and process rather than species composition (which is clearly a non-trivial task, since process in particular is challenging to measure in a cost-effective way). Changing climates will bring many ecological 'surprises', and palaeoecological data sets contribute valuable context and perspective for developing a robust framework for twenty-first century conservation practice.

Assessing the potential impact of climate change on mire habitats in central France - a multi-scale eco-hydrological approach

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In the uplands of central France (Massif Central), no less than 79 Special Areas of Conservation have been designated that include acidic mire habitats. These mires are located both at low altitude and at the south-western margin of the geographical distribution of these wetlands in Western Europe, and are therefore likely to suffer early and strongly from climate change.

Accurately predicting the impact of climate change on acidic mires and developing efficient mitigation measures to ensure their long-term conservation require a detailed understanding of the environmental factors driving their dynamics and functioning. This goal can only be achieved through a multi-disciplinary approach, taking account for the links between the different mire ecosystem compartments.

Because these functional links occur at several spatial scales, it is also necessary to use an integrated approach, working at all relevant spatial scales: microtope (vegetation community) – mesotope (hydrogeomorphological unit) – macrotope (wetland site) – wetland catchment – landscape. This integrated approach allows for large-scale models to be validated using detailed results obtained at a smaller scale, and for the latter to be put into context using the former.

We present the objectives and methods of a recently initiated research program which aims at characterising and modelling the eco-hydrology of acidic mires in the Massif Central and at predicting the potential impact of climate change at several spatial scales.

At the site and catchment scales, we will build a Mike-SHE, physically-based distributed hydrological model of two contrasted acidic mires and their catchments, and evaluate the proportion of vegetation variance explained by measured and modelled water tables. By forcing the hydrological model with predicted climatic values for the 21st century, we will evaluate how resilient the hydrology of these systems is to climate change.

At the regional scale, using recent wetland inventories, we will use statistical modelling to characterise the topo-climatic envelope of wetland types, and in particular acidic mires, in the western part of the Massif Central (plateau de Millevaches). The importance of local topography in driving the hydrological functioning of wetlands will be recognised and integrated in the model through the use of a modified Beven-Kirkby wetness index. Because the study area ranges from relatively dry and warm lowlands to cold and wet uplands, we should be able to accurately predict the potential impact of climate change on the distribution of wetland habitats in the upper part of this area, where most wetlands of high conservation interest are found. The project will also develop a network of permanent quadrats representative of these wetlands, which will be precisely located and will therefore provide reliable baseline data for long-term monitoring of mire vegetation.

At the scale of the Massif Central, for which accurate wetland distribution data are not available, we will use species climatic envelope modelling to predict the potential impact of climate change on the distribution of plant species that are characteristic of mire habitats.

Long-term experiments, climate change adaptation and land management

Victoria Cadman

Ecological Continuity Trust

The geographic limits of individual plant species are largely defined by climate, their distribution reflecting the influence of temperature, rainfall and seasonality on plant survival, physiology and growth, as well as ecological interactions, such as competition, pollination and herbivory. These factors in turn influence the distribution of dependent fauna, their competitors, predators and pathogens.

Global temperatures have increased by 0.7 C in the last century and monitoring studies have shown that changes in climate have resulted in changes to natural processes, such as the timing of leafing and flowering. But monitoring alone cannot elucidate the ecological processes by which observed changes are happening.

By manipulating key variables, such as rainfall and temperature, long-term ecological experiments can help us address important conservation questions, such as how, and how quickly, our species, communities and ecosystems adapt to change. Through studying different land management practices, experiments can also help us manage our activities and mitigate our impacts on the natural world.

However, surveys undertaken by the Ecological Continuity Trust show that several unique long-term experiments are under immediate threat. Of the 49 sites identified in herbaceous, heath, fen, bog and montane habitats, 22 were considered to be vulnerable to closure. Since that survey was completed, at least 4 experiments have been terminated, and we are aware of 10 more whose funds are likely to be cut.

A new non-profit organization, the Ecological Continuity Trust, aims to help identify alternative funding sources to sustain existing long-term experiments for future generations. ECT is also working with the National Trust to establish a new long-term experiment designed to study the interactions between land management, nutrient loading and climate change.

www.ecologicalcontinuitytrust.org

Do the England Biodiversity Strategy Climate Change Adaptation principles work for woodland ground flora?

Keith Kirby & Emma Goldberg

Natural England

Climate change adaptation principles have been published as part of the England Biodiversity Strategy (Smithers et al. 2008). We explore what these principles might mean using woodland ground flora as a test group of species. The ground flora forms a significant part of the variation in the botanical composition of British woods; and its characteristics are well-known. About half of the twenty-six principles (in italics below) have direct links to conservation practice at the site level.

Accept that change is inevitable.

Undertake vulnerability assessments of biodiversity and associated ecosystem goods and services.

There is good evidence of phenological shifts and some evidence for changes in species abundance correlated with recent climate change. Species assemblages are likely to re-sort. Within the woodland flora we expect species with the following characteristics to be more vulnerable - northern/Atlantic distribution, woodland specialists, slow colonisers; as compared to southern/continental, woodland generalist, widespread dispersing species.

Conserve existing biodiversity.

Conserve range and ecological variability of habitats and species

Maintain existing networks.

The rarer, more specialised elements of the woodland flora tend to be associated with ancient woodland. This is spread across the country in thousands of small isolated fragments. Hence the conservation of the whole resource, not just the minority within protected sites is critical. Few woodland plants are absolutely confined to woodland; mosaics of habitats allow species to occur more widely through a landscape. It is not clear whether these dispersed populations function as effective metapopulations but there is evidence for some gene exchange between apparently fragmented populations.

Reduce sources of harm not linked to climate

Create buffer zones around high quality habitats

Take prompt action to control spread of invasive species.

Intervention can improve the composition and abundance of the ground flora through offsetting the impacts of changing woodland structure; increased grazing by deer; drift of pesticides and fertilizers from adjacent land; or the shading out of species by invasive plants such as rhododendron.

Aid gene flow.

Establish ecological networks through habitat restoration and creation.

Consider role of species translocation and ex-situ conservation

Increased flowering, eg through increasing light to the ground flora, may be effective in aiding gene flow. Direct spread of species through seed or by vegetative means can be slow for some woodland specialists, such that new networks may be less useful than for some other species groups. By contrast translocation of plants is relatively easy for most species.

Monitor actual impacts and research

Respond to changing conservation priorities

There are reasonably well-established monitoring systems for plants, including a range of long-term monitoring sites. The results from these should start to detect the changes expected (see first two principles) and so feed back into conservation priority and practice.

Smithers et al. 2008. England Biodiversity Strategy: climate change adaptation principles, Defra, London.

Assessing the vulnerability to climate change of England's landscapes

Nicholas A. Macgregor, Geoff Darch, Nikki Van Dijk, Louisa Aspden, Simon Bates, Caroline Birchall, Ian Crosher, Clive Doarks, Colin Holm, Andy Neale, Charlotte Reeves, Sarah Robinson, Lydia Speakman, Sarah Taylor, Richard Wilson

Natural England and Atkins

While landscapes and ecosystems are dynamic and have responded to changes in the past, the scale and pace of potential future climate change is likely to have significant implications for biodiversity and the wide range of benefits humans obtain from the environment. At the same time appropriate land management to preserve and enhance ecosystems can help buffer society from a changing climate (Morecroft & Cowan 2010). Appropriate adaptation action for the natural environment will therefore be essential.

Several sets of principles have been developed for adaptation (e.g. Hopkins et al., 2007; Smithers et al., 2008; Macgregor & Cowan, in press), which have an important role in guiding general approaches. However, adaptation is likely to be a very place-specific activity and the general principles need now to be applied and tailored to specific locations and different landscape and habitat types, to help develop detailed adaptation solutions for different areas.

National Character Areas (NCAs), 159 areas that make up a well-established spatial framework across England, provide a useful geographic scale for research and action. They are large enough to enable us to consider large scale processes such as dispersal of species and movement of water, how people use and value an area, and the interactions between these things, but are also small and distinct enough (each having a well-described set of geological, biological and cultural characteristics) to enable us to explore the possible implications of climate change in specific different places.

We studied climate vulnerability and adaptation in 12 NCAs in different parts of England. The areas studied cover a wide range of landscapes, including upland areas, extensive and intensive farmland, chalk grassland, low lying wetlands, forest and heathland, coasts, urban fringe, and urban areas.

We developed an approach in which the overall landscape and the benefits it provides (encompassing biodiversity, landscape character, and ecosystem services) provides a framework for a more detailed assessment of assets such as flora and fauna, historic environment, geodiversity, natural resources, and places for human enjoyment and recreation. We used this approach to evaluate qualitatively the vulnerability to climate change of natural assets in the areas studied and consider how this collectively

might affect the overall landscape and the benefits it provides. We also identified possible adaptation responses, focusing on actions that would maintain or enhance multiple benefits provided by a landscape by reducing vulnerability to a range of possible consequences of climate change.

We identified a wide range of potential vulnerabilities, from a range of climate pressures, such as drought affecting ancient woodland, saline intrusion into freshwater wetlands, warming weather driving species to higher altitudes. We also identified indirect effects, such as hotter summers affecting visitor numbers and in turn recreation infrastructure and habitats. We identified a range of adaptation responses, including many opportunities to achieve multiple benefits. Our findings are place-specific but some general conclusions emerged for similar habitat types across the study areas. It is also apparent that action will be required at a range of geographic scales, from individual sites up to scales larger than the areas studied.

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Assessing the vulnerability of the terrestrial natural environment at a large scale

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The natural environment is already being affected by climate change and changes to individual species and whole ecological communities can be expected to increase as the climate continues to change. But different species and communities will not necessarily be affected equally. In addition, consequences of climate change for an individual species or community are likely to vary from place to place. Successful conservation will require an ability to assess the vulnerability of different species, habitats and landscapes to climate change, and to understand the specific factors putting them at risk. In the face of potentially large changes, and limited resources to respond, we will increasingly need new approaches that assess the relative vulnerability of habitats and ecosystems across large areas. The results of such vulnerability assessments will help identify where scarce conservation resources should be targeted.

The IPCC's vulnerability model of exposure, sensitivity and adaptive capacity provides a logical framework, but assessing vulnerability of the natural environment in practice is not straightforward. This is not just because of uncertainties about the scale and timing of climatic changes, but because there are still gaps in our knowledge about species and ecosystem processes and we do not yet have a full understanding of the specific factors that confer a high or low sensitivity or capacity to adapt, or what makes an ecosystem 'resilient'.

Despite these uncertainties, there is a need to explore practical methods to estimate relative vulnerability to inform our conservation efforts. We have begun to address this by developing and testing three different but related methods for assessing the relative vulnerability of natural environment features in three regions in England, covering a wide variety of habitat types.

In southeast England, we used a GIS grid model to input data, including habitat information and topography, and to undertake a spatial analysis at a 200m² grid scale. Vulnerability is based on value (considering factors such as national or international conservation importance), sensitivity of different habitat types to climate change and adaptive capacity (including an assessment of the proximity of habitats to each other, the permeability of the surrounding landscape, topographic heterogeneity and of existing conservation measures currently in place).

In northwest England, we evaluated the vulnerability of the natural environment in each of the 29 National Character Areas (NCAs) in the region. The vulnerability of each NCA was scored using qualitative information about factors such as coastal location, elevation, topography, vegetation diversity, diversity of land cover

and soils, and also using quantitative data such as percentage of open countryside, woodland and cultivated land. This enabled us to assign an overall score of high, medium or low vulnerability to each area.

In the West Midlands, vulnerability assessment is part of a larger study to identify areas for potential habitat expansion. Vulnerability of possible new habitat areas was assessed using a grid square approach, considering each habitat's sensitivity and adaptive capacity. These were integrated to show areas of high, medium and low vulnerability. The key benefit is to identify areas whose suitability for new habitat might be reduced by climate change.

While our findings do not provide a complete answer and should not be used to determine conservation priorities in isolation from other sources of information, they will inform future conservation efforts and help identify areas for further attention and research.

Carbon storage by habitat – relation with condition and management options

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This project aims to review and improve our understanding of carbon storage and fluxes in terrestrial, coastal and marine habitats in England. Land managers can help mitigate the causes of climate change, directly reducing greenhouse gas emissions, safeguarding carbon stores and maximising sequestration by choosing the most appropriate management options and restoring degraded land and marine habitats.

Land use change is a major source of global emissions but there is also increasing evidence that habitat condition has a significant impact on CO₂ fluxes. Practices that result in unfavourable habitat condition and lead to emissions are drainage, cultivation, deforestation and habitat destruction. Conversely, restoration of favourable condition, afforestation and conversion of croplands into grasslands result in net sequestration.

Carbon storage by marine and coastal habitats has been less studied, but recent evidence indicates that they may be of comparable importance to terrestrial habitats. Their carbon storage potential can only be maintained by preserving their health and extent, and controlling inputs from land, as it is very challenging to restore them.

For this project we collated information from the peer-reviewed and grey literature on a variety of habitats of interest for conservation in England (e.g. woodlands, grasslands, bogs, orchards, arable land, estuaries, salt marshes). Where available, we indicated the condition (e.g. undamaged, degraded, restored) and land use changes (e.g. from grassland to arable; from fen to arable; from woodland to grassland). We then recorded the published figures on carbon stores (MtC) and the emissions or sequestration resulting from the management options (MtCO₂-e yr⁻¹). As the original projects all had different objectives and approaches, some conversions and assumptions had to be made to allow for comparisons between habitats.

The amount of published literature continues growing day on day, so this resource, currently as an unpublished spreadsheet, is a snapshot at any given time. However, there is already enough information to be used in the review of Environmental Stewardship options or for recommendations to support future management decisions. For example, the main source of emissions from land use in England is from drained bogs. Only 11% of upland bogs and 7% of lowland bogs in Sites of Special Scientific Interest are in favourable condition, according to Natural England records. The main reasons for being in unfavourable condition are overgrazing, drainage and moor burning. If the 8,000+ ha under these pressures were restored, potentially about 35 Mt CO₂ could be sequestered.

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Ecosystem-based conservation in a 4+ degree world

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Ecosystem-based conservation takes a broad landscape-scale approach to conservation and emphasises the services that the natural environment provides to society. The premise is that healthy, fully functioning ecosystems not only provide important benefits to people but also ensure the conservation of all the elements that make up those ecosystems (Sutherland 2004, MEA 2005).

A range of principles has been put forward to guide adaptation to climate change for conservation managers and policy-makers (e.g. Hopkins et al. 2007; Smithers et al. 2008). However, given current trends, we need to consider more radical solutions to help maintain biodiversity and ecosystem functioning if global temperatures increase by c.4°C.

We highlight three examples where different approaches might be needed in a +4° world compared to a +2° world.

- **Designated Sites:** These provide high quality core conservation habitats for maintaining biodiversity. Current approaches to adaptation aim to improve site resilience by maintaining or enhancing habitat diversity and by reducing pressures from external factors. However, as we move towards a +4° world, bioclimatic zones may shift or an area become subject to a “non-analogous climate” - one with characteristics unrepresented within the current biogeographical region (Hossell et al. 2005). In such cases, the transition to a completely new ecosystem results in a “regime shift” (Anderson et al. 2009). The ecosystem approach to conservation can accommodate such changes, so long as the new systems function in a “healthy” way (EASAC 2009).
- **Conservation Value:** The conservation “value” of sites is currently assessed in terms of specific lists of species and habitats. A +4° world, with regime shifts and the formation of novel plant and animal communities, suggests that new approaches to measuring conservation value will be needed, such as Functional Diversity (Tilman et al. 1997; Petchey et al. 2004) and Phylogenetic Diversity (Faith 1992).
- **Connectivity and Permeability:** Another key conservation strategy to aid adaptation to climate change is the creation of landscapes in which there are networks of habitat patches of high conservation value, connected by corridors or “stepping stones” of habitat that facilitate movement between patches (Hopkins et al. 2007, Vos et al. 2008). In addition, the “permeability” of the “matrix” surrounding these patches should also be improved to promote dispersal. Under a +4° world the wider countryside matrix will be under increasing anthropogenic pressure from a range of factors. Conservation may thus need to move to providing large, buffered areas of high ecosystem quality that, for some species, will provide sufficient opportunities for longer distance dispersal between these core ecosystem areas, as the intervening land becomes more hostile.

A +4° world is likely to emphasise the value of an ecosystem approach to conservation, and conservationists will have to develop new and more flexible approaches to conservation through their adaptation strategies. Given the long lead times often required for conservation planning at the landscape scale, we need to start thinking about these sorts of solutions now.

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The Environmental Change Biodiversity Network

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Atmospheric pollution and climate change present major threats to biodiversity in the UK and their impacts are particularly difficult to identify with a high degree of confidence. There has been a gap between wide scale but relatively superficial monitoring programmes and those which are very detailed but geographically restricted

There is a need for improved monitoring of air pollution and climate change impacts on biodiversity and better integration between existing initiatives. The ECBN is an extension to the existing UK Environmental Change Network (ECN) and is a scientifically robust and cost effective solution. Measurements are made at each site covering a range of aspects of the physical environment and biodiversity.

Sites are distributed across the UK according to cover the range of variation in climate and projected changes in temperature and rainfall and air pollution. Sites started monitoring in 2008. There are currently 16 ECBN sites on NNRs in England plus 13 in Wales. ECN sites are reporting significant changes in climate, environmental chemistry and biodiversity over the long-term monitoring periods necessary to detect them. (Morecroft et al 2009). Data from shorter periods of extreme weather events are also giving insights into future changes in biodiversity (Morecroft et al 2002). The extended ECBN, linking with Natural England's Long-term Integrated Monitoring Project will enable more powerful and frequent analyses on these effects.

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Adapting Geodiversity Conservation to a Changing Climate

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Climate change presents opportunities and challenges for geoconservation. It is important to conserve geodiversity sites including the 1200 geological Sites of Special Scientific Interest (SSSIs) and 3000 Local Geological Sites in England, because they underpin many ecosystem services on which society depends and they reveal evidence of the history of our planet, including past climate and environmental changes which can be used to inform adaptation strategies.

Geodiversity includes the natural range of geological (i.e. rocks, minerals and fossils), geomorphological (landform and processes) and soil features. England has a tremendously rich geodiversity that defines our characteristic landscapes as well as being of great scientific importance. It also provides or underpins many ecosystem services such as buffering from flooding, water supply, soils for food production and building materials including clay for bricks and aggregates for roads and forms the landscapes of many of our most popular tourist areas.

Geodiversity is of great scientific and educational importance. It provides evidence on how dynamic earth processes and biodiversity respond to climate change, which can help us understand resilience, scales and

rates of change and natural versus human-induced change. Climate change – which can happen rapidly - poses a threat to geodiversity with both direct and indirect impacts on our important sites, features and processes (Prosser et al., 2010). Inland sites may be lost to increased rates of weathering or vegetation growth whilst coastal foreshore and cliffs can be lost to sea level rise or through being obscured behind coastal protection. Experience in the UK to date suggests that whilst the direct impacts of climate change will affect geoconservation, the human response to climate change, for example coastal protection schemes to counter erosion arising from sea-level rise, is likely to be a greater threat to our geodiversity.

Climate-change impacts on biodiversity are recognised as being a major challenge for conservation, in spite of the uncertainty of the nature of the changes engendered and the response of biodiversity to it. Many authors have proposed principles and guidance to assist with adaptation strategies; the geoconservation community urgently needs to develop key principles and evidence-based guidelines for the conservation of geodiversity in a changing climate and is taking the first steps toward doing so.

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A spatially explicit assessment of climate change vulnerability at a national scale

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A national climate change vulnerability assessment for England has identified specific areas of landscape where there is a high degree of exposure to climate change, a low adaptive capacity and the presence of potentially sensitive habitats. Adaptive capacity, in this study, has been defined through a biophysical assessment of landscape heterogeneity and a generalised model of the permeability of landscapes to species movement. Even without consideration of coastal areas and freshwater systems, the analysis has indicated that a significant proportion of England is likely to be vulnerable to climate change. The assessment has been applied to a clearly defined range of priority BAP habitats so that specific adaptation measures can be supported. More specifically, it will help to inform where the future allocation of limited resources might need to occur as well as where conservation management practices might need to change. It will also help to provide a spatially explicit, repeatable framework for enhanced monitoring and further research.