Natural England Commissioned Report NECR081

Adapting Conservation to a Changing Climate

A report on the 'Adapting Conservation to a Changing Climate', conference held on 11-12 January 2011

First published 30 September 2011

www.naturalengland.org.uk

Foreword

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

Background

Climate change is widely regarded as the major long-term threat to biodiversity and ecosystem services and it is essential that conservation adapts to deal with this threat. General principles have been identified and adaptation is starting to happen, but we need to step up the pace.

Effective adaptation requires a strong partnership between researchers, practitioners and policy makers. It is essential that adaptation measures are developed on the basis of sound science, combined with a rigorous assessment of their feasibility and acceptability to society.

This report presents the outcomes of the 'Adapting Conservation to a Changing Climate' conference. A conference jointly sponsored and organised by Natural England and the British Ecological Society and held at Charles Darwin House, London, 11-12 January 2011.

The conference brought together over 120 delegates from research, policy and conservation communities, including a wide range of internationally recognised experts on the adaptation of conservation to climate change.

The report includes the:

- Overview of the conference;
- Summary of the key findings;
- Abstracts from the presentations and posters from the conference; and
- Results of the breakout session.

This report should be cited as:

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

Natural England Project Manager - Simon Duffield, Senior Specialist Climate Change Adaptation, 2nd Floor, Cromwell House, 15 Andover Road, Winchester, SO23 7BT **simon.duffield@naturalengland.org.uk**

Contractor - Tom Oliver (THO), Centre for Ecology & Hydrology, Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford

Keywords - Climate change, adaptation, conservation

Further information
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

ISSN 2040-5545

Contents

Introduction and key messages from the conference 1

Paper Abstracts 3

Climate change adaptation and ecosystems: scientific challenges and opportunities 3

Conservation in the wider context of climate change adaptation 4

The European context for adapting nature conservation to climate change: from science to policy and practice and back 5

Common conservation challenges in a changing climate 6

Making space for nature in a changing world 7

Resilience to climate change in theory and in practice 8

Landscape effects on bird and butterfly population resilience 9

An eco-evolutionary basis for adaptation to climate change 10

Connectivity in the context of climate change 10

Moving plants and animals when the historic range loses legitimacy: adapting conservation translocations to cope with climate change 12

Winners, losers and conservation priorities: identifying which species require most assistance to survive climate change 13

The climatic risk atlas of European Butterflies 15

Projecting the benefits of landscape-scale conservation for wildlife and people 16

Putting climate adaptation plans into action: an international perspective 17

Complex land systems and ecosystem services: the need for long time perspectives in order to assess their future 18

Adaptation indicators for biodiversity 20

Integrating adaptation with mitigation and biodiversity objectives 21

Multifunctional forests 22

Future climate, changes in land-use capability, and potential trade-offs between agriculture and forest services. The case of broadleaved habitat networks in Scotland 23

Do wetlands reduce floods? 24

Posters 25

The effectiveness of Protected Areas under climate change 25

Climate Vulnerability Assessment of Designated Sites in Wales 25

Translocation in response to climate change: a feasibility study in the Scottish Uplands 26

Impact of Climate Change on the Biodiversity of Development Projects 28

Microclimate and vegetation function as indicators of landscape thermodynamic efficiency 28

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? 30
Living on the edge: Quantifying the structure of fragmented woodland landscapes in England 31
Peatlands and the climate challenge 32
Wetland vision and climate change; tools for impact assessment 34
Practical lessons from palaeoecology 35
Assessing the potential impact of climate change on mire habitats in central France - a multi-scale eco-hydrological approach 36
Long-term experiments, climate change adaptation and land management 37
Do the England Biodiversity Strategy Climate Change Adaptation principles work for woodland ground flora? 38
Assessing the vulnerability to climate change of England's landscapes 40
Assessing the vulnerability of the terrestrial natural environment at a large scale 41
Carbon storage by habitat – relation with condition and management options 42
Ecosystem-based conservation in a 4+ degree world 43
The Environmental Change Biodiversity Network 45
Adapting Geodiversity Conservation to a Changing Climate 46
A spatially explicit assessment of climate change vulnerability at a national scale 47
Summary of Break-Out Groups 48
Break-Out Groups: Day One 48
The relative importance of improving connectivity 48
Taking a longer-term perspective 50
Non-native species: why does 'non-native' matter? 52
Under what circumstances should we consider translocation? 54
The use of models 55
Break-Out Groups: Day Two 56
Priorities for future development of policy and practice 56
Key knowledge gaps and priorities for future research on climate change adaptation 60
Delegates 65
Acknowledgments 70

Introduction and key messages from the conference

M.D. Morecroft[1], S. Duffield[1], C. Margerison[2], E. Wayman[1]

[1]*Natural England*; [2]British Ecological Society

Evidence that the climate is changing has grown consistently stronger over the last 30 years and the link to increasing greenhouse gas concentrations in the atmosphere is well established. Global climate models consistently indicate that the climate will continue to change and to a greater extent than experienced in recent decades. Measures to *mitigate* climate change by reducing greenhouse gas emissions are being developed and implemented but will not be sufficient to prevent some climate change, even on a best case scenario. Lags in the climate system mean that warming would continue, even if it were possible to stop anthropogenic emissions immediately. There is therefore a need to *adapt* to climate change. One widely accepted definition of adaptation is *adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities* (IPCC 2007)[1]. In this conservation is like many other human activities, from road construction to health care to flood risk management. Conservation does however face a range of issues that challenge not just our technical abilities but also our basic approach to what we value and protect. On the more positive side, it is becoming clear that there are opportunities to manage the natural environment in ways that help society to adapt to climate change, often termed 'ecosystem-based adaptation', at the same time as protecting biodiversity;.

Conservation has tended to look back to a state before human activities degraded the natural world and has sought to protect or restore the species and ecosystems associated with this earlier state. Climate change presents a profound challenge to this approach. Ecosystems, landscapes and biological communities have been formed by the interplay of physical, biological and human pressures in particular combinations in different places. Climate plays a critical role in setting the limits within which organisms can survive and strongly influences the relationships between species and ecosystem processes; it also determines what forms of agriculture, forestry and other land uses are viable. A changing climate therefore changes the basic parameters that determine communities and ecosystems. Previous states may no longer be attainable and tried and tested management techniques may no longer deliver their intended outcomes. Species will adapt autonomously to changing conditions, both in the classic evolutionary sense and through changing distribution patterns and behaviours. However, the speed of change and the range of other pressures on ecosystems are such that these processes are not sufficient to safeguard biodiversity and ecosystem services.

A variety of principles for climate change adaptation have been identified but we are still at a very early stage in actually implementing adaptation measures. Research on adaptation is however progressing apace. Up to approximately 2000, ecological research on climate change was overwhelmingly focussed on identifying actual or potential impacts of climate change or the contribution of ecosystems to climate change mitigation through carbon

[1] IPCC (2007) 4th Assessment report Working Group 2 Glossary http://www.ipcc.ch/pdf/glossary/ar4-wg2.pdf

sequestration and storage. Since then however, the number of studies on adaptation have steadily increased. Unlike the study of climate change impacts, the science of climate change adaptation is inextricably bound to practical conservation and policy making. It is about human responses and so is practical by its very nature.

It was therefore timely to organise this conference to present recent research results and lessons learnt from experience in starting to introduce adaptation measures, to inform decision making about conservation practice and policy in future. The conference generated a great deal of debate and discussion, some of this in the context of break-out groups, the conclusions of which are reported here alongside summaries of the papers presented.

Summing up the key messages from the conference is not easy. The accounts of the break-out groups reveals the wide range of issues which were raised; from fundamental ecological science questions, to specific policy issues, to the pressures of a growing human population and the need to engage wider society in conservation.   However, we suggest that the following are critical messages:

1) Climate change adaptation needs to start happening to a far greater extent than currently. It was not difficult to find research into possible adaptation strategies, assessments of vulnerability and plans for implementing adaptation. There are many fewer examples of adaptation that is actually happening.
2) Pilot studies need to be established to help address the uncertainties around determining the most effective adaptation measures, for example on the relative importance of increasing connectivity of habitat networks, compared to improving or enlarging existing sites. Good monitoring and assessment of the outcomes are essential.
3) The issues posed by climate change are different depending on the extent to which climate actually changes. To put it crudely, there is a big distinction between dealing with 2°C and 4 °C of warming. At the lower end of the scale, there is plenty of scope to increase the resilience of the landscapes and ecosystems that we currently have. At the higher end, this will not be sufficient and we need to consider much more radical approaches and be prepared to accept species in very different places and place that look very different.
4) Climate change adaptation needs to be developed as part of a wider transformation in the approach of human societies to the natural environment, in which we understand it better and value it more.

Paper Abstracts

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 2^{o}C above pre-industrial levels and the rate of change exceeds 0.2^{o}C 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 1^{o}C 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 socioeconomic 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 2°C above preindustrial 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 3-4°C.

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 Change (RCEP 2010) and Making Space for Nature: a review of England's Wildlife Sites and Ecological Network submitted to Defra (Lawton et al. 2010). 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.

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

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. Oliver[1], Simon Gillings[2], Marco Girardello[1], John Redhead[1], Tom M. Brereton[3], Gavin M. Siriwardena[2], David B. Roy[1], Richard Pywell[1], Robert J Fuller[2]

[1]*Centre for Ecology & Hydrology,* [2]*British 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 increasing 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. Hodgson[1], Atte Moilanen[2], Brendan A. Wintle[3] Jane K. Hill[1] and Chris D. Thomas[1]

[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 Bennie[1], Callum Lawson[1], Chris D. Thomas[2], Jenny A. Hodgson[2] & Robert J. Wilson[1]

[1] *Centre for Ecology and Conservation, University of Exeter,* [2] *University 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. Dalrymple[1] & Mark R. Stanley Price[2]

[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 Reintroduction 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 thoughout 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.

Thomas C.D., Hill J.K., Anderson B.J., Bailey S., Beale C.M., Bradbury R.B, Bulman C.R., Crick H.Q.P., Eigenbrod F., Griffiths H.M, Kunin W.E., Oliver T.H., Walmsley C.A., Watts K., Worsfold. N.T. & Yardley, T. (2010) A framework for assessing threats and benefits to species responding to climate change. Methods in Ecology & Evolution doi: 10.1111/j.2041-210X.2010.0

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

Matthew R Evans

Centre for Ecology and Conservation, School of Biosciences, University of Exeter

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 phenomenonological 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.

Settele J., Kudrna O., Harpke A., Kühn I., van Swaay C., Verovnik R., Warren M., Wiemers M., Hanspach J., Hickler T., Kühn E., van Halder I., Veling K., Vliegenthart A., Wynhoff I. & Schweiger O. (2008) Climatic Risk Atlas of European Butterflies. Pensoft, Sofia and online: www.pensoftonline.net/biorisk.

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 modelled 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

School of Geography, University of Southampton

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.

Carpenter S.R., Mooney H.A., Agard J., Capistranod D., DeFriese R.S., Díaz S., Dietz T., Duraiappah A.K., Oteng-Yeboah A., Miguel Pereira H., Perrings C., Reid W.V., Sarukhanm J., Scholes R.J., Whyte A.,. (2009) Science for managing ecosystem services: beyond the Millennium Ecosystem Assessment. Proc. Nat. Acad. Sci. (106), 1305-1312

Dearing J. A., Braimoh A. K., Reenberg A., Turner B.L. & Van der Leeuw S. (2010) Complex Land Systems: the Need for Long Time Perspectives to Assess their Future. Ecology and Society 15 (4): 21. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art21/

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. pp137.

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.

Harley M. & Hodgson N. (2008). Review of existing international and national guidance on adaptation to climate change: with a focus on biodiversity issues. AEA report presented to the Bern Convention's 'Group of Experts on Biodiversity and Climate Change' at their meeting in Strasbourg on 11 September 2008. http://www.coe.int/t/dg4/cultureheritage/nature/bern/ClimateChange/default_en.asp.

Harley M., Horrocks L., Hodgson N. & van Minnen J. (2008). Climate change vulnerability and adaptation indicators. European Topic Centre on Air and Climate Change Technical Paper, European Environment Agency. http://air-climate.eionet.europa.eu/reports/ETCACC_TP_2008_9_CCvuln_adapt_indicators.

Harley M. & van Minnen J. (2009). Development of adaptation indicators. European Topic Centre on Air and Climate Change Technical Paper, European Environment Agency. http://air-climate.eionet.europa.eu/reports/ETCACC_TP_2009_6_ETCACC_TP_2009_6_Adapt_Ind.

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.

Berry P.M. (Ed.) (2009). Biodiversity in the Balance – Mitigation and Adaptation Conflicts and Synergies. Pensoft Publishing, Sofia, Bulgaria.

Paterson J.S., Araújo M.B., Berry P.M., Piper J.M., & Rounsevell M.D.A.R. (2008) Mitigation, adaptation and the threat to biodiversity. Conservation Biology, 22, 1352-1355.

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 use (Committee on Climate Change 2010). 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 Report (Read et al. 2009) 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 available (Ray et al. 2010) 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.

Committee on Climate Change (2010). The Fourth Carbon Budget. Reducing emissions through the 2020s. Committee on Climate Change, London.

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

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.

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 in 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 subtlety 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 Wilson[1], Dr Rob McCall[2], Dr Clive Walmsley[2]

[1]ADAS UK Ltd.; [2]Countryside 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

Brooker, R.W., Britton, A., Eastwood, A., Ellis, C.[2], Fisher, J., Genney, D.[3], Gimona, A., Lennon, A., Littlewood, N., Mitchell, R., Riach D.

[1]Macaulay Land Use Research Institute, [2]Royal Botanic Gardens Edinburgh, [3] Scottish Natural Heritage

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.

Brooker R., Britton A., Gimona A., Lennon J. & Littlewood N. (In Press) Species translocations as a tool for biodiversity conservation during climate change. SNH Commissioned Report, Project No. 7966. (available shortly online)

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

Jennifer Allen

Aston University

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

C. Norris[1], P. Hobson[1], P. Ibisch[2], J. Finch[1]

[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.

Jørgensen S.E (2006). Application of holistic thermodynamic indicators. Ecological Indicators. (6) p 24-29.

Kay J.J. Allen T. Fraser R. Luvall J. & Ulanowicz R. (2001). Can we use energy based indicators to characterise and measure the status of ecosystems, human, disturbed and natural? Proceedings of the International Workshop: Advances in Energy Studies, exploring supplies, constraints and strategies. p 121-133.

Natural England (2010). Climate change adaptation indicators for the natural environment. Natural England Commissioned Report NECR038.

CSR model – Grime J.P. (1974). Vegetation classification by reference to strategies. Nature. (250) p 26-31.

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?

Poppy Lakeman Fraser[1]* and Robert M. Ewers[1]

[1] *Imperial College London, Silwood Park Campus, Ascot*

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

Terhi Riutta[1], Eleanor Slade[2], Yadvinder Malhi[1] and Mike Morecroft[3]

[1]University of Oxford, School of Geography and the Environment; [2]University of Oxford, Wildlife

Conservation Research Unit; [3]Natural England

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 of 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.iucnuk-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.

Bonn A., Allott T., Hubacek K. & Stewart J. (Eds) (2009a) Drivers of environmental change in uplands, Routledge, London and New York.

Bonn A., Holden J., Parnell M., Worrall F., Chapman P., Evans C., Termansen M., Beharry-Borg N., Acreman M., Rowe E., Emmett B. & Tsuchiya A (2009b) Ecosystem services of peat – Phase 1. Report to Defra, project code SP0572.

EFTEC, (2009a). Economic Values for a Healthy Natural Environment. A report to Natural England.

Grayson, R. Holden, J & Rose, R (2010) Long-term change in storm hydrographs in response to peatland vegetation change. Journal of Hydrology, 389, 336–343

Holden, J., Shotbolt, L., Bonn, A., Burt, T.P., Chapman, P.J., Dougill, A.J., Fraser, E.D.G., Hubacek, K., Irvine, B., Kirkby, M.J., Reed, M.S., Prell, C.,

Stagl, S., Stringer, L.C., Turner, A. & Worrall, F. (2007) Environmental change in moorland landscapes. Earth-Science Reviews, 82, 75-100.

House, J., Clark, J., Gallego-Sala, A., Orr, H. & 31 others 2010) Vulnerability of upland peatland services to climate change.

Environment Agency Science Report SC070036/SR in press.

Labadz et al (2010) Peatland Hydrology. Report for the IUCN Commission of Inquiry on Peatlands.

Natural England 2009. No Charge? Valuing the natural environment. Natural England report NE 220.

Parish, F., Sirin, A., Charman, D., Joosten, H., Minaeva, T. & Silvius, M. (eds) 2008. Assessment on peatlands, biodiversity and climate change. Global Environment Centre, Kuala Lumpur and Wetlands International Wageningen, 179 p.

Reed et al (2010) Policy Options for Sustainable Management of UK Peatlands. Report for the IUCN Commission of Inquiry on Peatlands.

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

M. Acreman, J. Blake, J.O. Mountford

Centre for Ecology and Hydrology

D. Gowing

Open University

J.R. Thompson

UCL, University of London

R. van de Noort

Exeter University

A. G. Hughes, A. K. A. P. Barkwith

British Geological Survey

A. Skinner, H. G. Orr, A. O’Neill, K. Tanner, M. Everard

Environment Agency

M. Morecroft

Natural England

R. Shaw

Wildfowl and Wetlands Trust

J. Heathcote

English Heritage

P. Burston

RSPB

H. Perkins

Wildlife Trusts

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 (UKCP09) 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

Department of Geography, University of Hull

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

A. Duranel[1,2], J. R. Thompson[1], H. Cubizolle[2]

[1] *Wetland Research Unit, UCL Department of Geography, University College London*

[2] *Centre de Recherche sur l’Environnement et l’Aménagement (CREANAM), Saint Etienne, France*

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 southwestern 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 occurs 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^{O}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.

Hopkins J.J., Allison H.M., Walmsley C.A., Gaywood M., Thurgate G. (2007) Conserving biodiversity in a changing climate: guidance on building capacity to adapt. Defra, London.

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

Morecroft M.D. & Cowan C.E. (2010) Responding to climate change: an essential component of sustainable development in the 21st Century. Local Economy 25: 1–6.

Smithers RJ, Cowan C, Harley M et al (2008) England biodiversity strategy: climate change adaptation principles. Defra, London.

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

Nicholas A. Macgregor, Sarah Taylor, Ian Crosher, Charlotte Reeves, Humphrey Q.P. Crick, Mike D. Morecroft

Natural England

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

Isabel Alonso, Mike Morecroft

Natural England

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.

Dawson J.J.C., Smith P. (2007). Carbon losses from soil and its consequences for land-use management. Sci. Total Environ. 382, 165-190.

Laffoley D.D., Grimsditch G. (Eds.), (2009). The management of natural coastal carbon sinks. IUCN, Gland, Switzerland.

Thompson D. (2008). Carbon management by land and marine managers. Natural England Research Report 026.

Ecosystem-based conservation in a 4+ degree world

Humphrey Q.P. Crick, Nicholas Macgregor & Mike D. Morecroft

Natural England

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.

Anderson T., Carstensen J., Hernandez-Garcia E. & Duarte C.M. (2009) Ecological thresholds and regime shifts: approaches to identification. TREE 24: 49-57.

European Academies Science Advisory Council (2009) Ecosystem services and biodiversity in Europe. The Royal Society, London.

Faith P.D. (1992) Conservation evaluation and phylogenetic diversity. Biol. Conserv. 61: 1-10.

Hopkins J.J., Allison H.M., Walmsley C.A., Gaywood M. & Thurgate G. (2007) Conserving biodiversity in a changing climate: guidance on building capacity to adapt. Defra, London.

Hossell J.E., Riding A.E. & Harrison P.A (2005). Bioclimatic classification and case study selection. Pp. 13-42 in (Eds Berry, P.M.,Harrison, P.A, Dawson, T.P. and Walmsley, C.A.) (2005) Modelling Natural Resource Responses to Climate Change (MONARCH): A Local Approach. UKCIP Technical Report, Oxford (available only from http://www.ukcip.org.uk).

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington DC.

Petchey O.L., Hector A & Gaston K.J. (2004) How do different measures of functional diversity perform? Ecology 85: 847-857.

Smithers R.J., Cowan C., Harley M., Hopkins J.J., Pontier H. & Watts O. (2008) England biodiversity strategy climate change adaptation principles: Conserving biodiversity in a changing climate. Defra, London.

Sutherland W.J. (2004) A blueprint for the countryside. Ibis 146 (Suppl. 2): 230–238.

Tilman D., Knops J., Wedin D., Reigh P., Ritchie M. & Siemann E. (1997) The influence of functional diversity and composition on ecosystem processes. Science 277: 1300-1302.

Vos C.C., Berry P., Opdam P., Baveco H., Nijhof B., O'Hanley J., Bell C. & Kuipers H. (2008) Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones. J. Appl. Ecol. 45: 1722-1731.

The Environmental Change Biodiversity Network

Clive Bealey

Natural England

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.

Morecroft M.D, Bealey C.A., Beaumont D.A., Benham S., Brooks D.R., Burt T.P., Critchley C.N.R., Dick J., Littlewood N.A., Monteith D.T., Scott W.A., Smith R.I., Walmesley C. & Watson, H. (2009). The UK Environmental Change Network: Emerging trends in the composition of plant and animal communities and the physical environment. Biological Conservation 142: 2814-2832.

Morecroft M.D., Bealey C.E., Howells O., Rennie S. & Woiwod I.P. (2002). Effects of drought on contrasting insect and plant species in the UK in the mid-1990s. Global Ecology & Biogeography. 11: 7-22.

Adapting Geodiversity Conservation to a Changing Climate

Eleanor Brown, Colin Prosser and Naomi Stevenson

Natural England

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.

Prosser C.D., Burek C.V., Evans D.H., Gordon J.E., Kirkbride V.B., Rennie A.F. & Walmsley C.A. (2010) Conserving Geodiversity Sites in a Changing Climate: Management Challenges and Responses. Geoheritage 2, 123 - 136.

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

Roger Catchpole

Natural England

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.

Summary of Break-Out Groups

Break-Out Groups: Day One

Each of five topics was considered by two of ten break-out groups. The topics for consideration were:

- The relative importance of improving connectivity
  Is enhancing species' ability to move through landscapes the best measure to adopt for species conservation in a changing climate? Exploring the best ways to achieve connectivity - through bigger sites or more landscape connections ('More, bigger, better, joined')?

- Taking a longer-term perspective
  Have we been too focused on restoring landscapes to those of the late nineteenth century?

- Non-native species: why does 'non-native' matter?
  What is 'non native'? Does it matter? Should we be more open?

- Under what circumstances should we consider translocation?

- The use of models
  How good can models ever be, what role do they have in planning adaptation strategies, what are the potential pitfalls in using them?

For each topic the groups were asked to consider the; ecological issues, the priorities for implementation and action, opportunities and the constraints/risks

The relative importance of improving connectivity

Issues

Participants considered whether enhancing connectivity and the ability of species to move through the landscape is the best measure to adopt for species conservation in a changing climate. Questions raised by the group included whether connectivity is a concept which is adequately understood within ecology and whether, in the absence of complete knowledge, steps can be taken to improve it.

Participants were clear that connectivity *is* important, and that the threats faced by biodiversity necessitate a multiplicity of approaches to restoring and enhancing the natural environment. As the climate warms, it is critical that species are able to move through the landscape – particularly under a scenario in which the temperature increases by four degrees centigrade. Connectivity has been degraded and must be improved.

The ability of a species to disperse, and other life-history traits, will affect how 'connected' the landscape is for them. In aiming to enhance connectivity therefore, consideration is needed regarding which species will form the focus of these efforts. The degree and type of connectivity will also vary depending on the needs of species; for example whether connectivity is being enhanced to enable species to shift their ranges as the climate changes, or to encourage the persistence of a species within its existing range.

In considering enhancing connectivity, and the species which should form the focus of this action, it is important to adopt a global perspective. For example, understanding whether actions would facilitate the movement of a species' leading or trailing edge is significant in informing a cost-benefit analysis of the intervention.

Priorities for implementation and action

Participants concluded that connectivity could best be enhanced by adopting the recommendations of the Lawton Review of England's protected area network. However, augmenting the size and improving the condition of existing sites should form the focus for initial action. Additional protected areas will then be required, with physical connections later developed between them. The implementation of new connections should only be resourced after safeguarding the extension and better management of key existing areas.

As a priority, 'Tier 1' and 'Tier 2' sites, as so characterised by the Lawton Review, should receive better protection through the planning system. Local authorities will already possess maps of 'Tier 2' sites, which allow them to avoid development in ecologically valuable areas. These maps should form a basis for action, as should the results of the National Ecosystem Assessment, particularly as regards recommendations to link up existing flood plains.

Steps should be taken to identify potential sites which should receive protection in the future. In prioritising conservation effort, very threatened habitats may not necessarily be the best focus for action: hard decisions are required.

Site management goals should be strengthened, ensuring that these are sensible and sustainable, with targets set on the basis of the Convention on Biological Diversity.

Fundamental to efforts to enhance and improve connectivity will be communication with policy-makers regarding the importance of this approach in enabling species to adapt to climate change. The ecological science and practitioner communities must communicate the importance of connectivity to policy-makers, developing clear, simple messages. Senior experts should take the lead in communicating recommendations to Ministers.

Opportunities

Green infrastructure development, gardens and the management of urban green spaces all present opportunities to enhance connectivity. Reforms to the planning system should require the provision of green space within new developments, and other climate change adaptation and mitigation measures.

A further opportunity exists in reform of ‘Pillar 2’ (agri-environment schemes) of the Common Agricultural Policy, to improve the targeting of funds.

Constraints/Risks

Participants raised concerns regarding how connectivity could be enhanced at a time of spending restraint by central and local government. Money and human resources will be needed to implement the recommendations of the Lawton Review, marking a step change in conservation effort, but it is not clear from where these will be forthcoming.

Resistance from land-owners and conflicts over land-use change will present significant constraints to approaches to enhance connectivity. Incentives may be needed to overcome these barriers.

The current policy shift from ‘Big Government’ to a ‘Big Society’ may result in the development of a more opportunist and piecemeal approach to nature conservation, complicating attempts to enhance connectivity. A strategic approach, possibly coordinated at the national level, could help to address this risk.

Taking a longer-term perspective

Issues

Societies across the globe tend to possess a ‘vision’ of how the natural environment should appear; a focus on ‘wild’, or less managed nature is common. In Australia and North America the baseline is often the point of European colonisation, whilst in North West Europe, including in England, the target for conservation action is often taken as the pre-Neolithic period. Explicitly and implicitly, communities existing before these reference points are often (generally falsely) assumed to have had little impact on the environment, or to have been living ‘in harmony’ with it.

In practice, society in England tends to most value ‘cultural’ landscapes developed since the Neolithic, with a focus on the nineteenth century. The Victorians made a significant contribution to changing the landscape of England, whilst the rise of the picturesque and romantic movements within art and poetry cemented a particular notion of an ‘ideal’ landscape in popular culture as a reaction against the industrial revolution and the rise of an urbanised population. The nineteenth and early twentieth centuries saw the foundation of ecological societies (such as the British Ecological Society, founded in 1913).

Conservation practice in the present day is increasingly influenced by Europe-wide regulations. Nevertheless, cultural preferences influence the choice of habitats and species included on lists for priority action. Many habitats and species which form the focus for conservation are essentially those of low intensity agriculture, as practised in the late nineteenth century (evidenced for example by concern for farmland birds and many arable weeds).

Constraints/ Risks

Examining past landscapes can provide useful lessons in understanding system functioning and how systems, and human societies, responded to past environmental change. However, there should be recognition that change is to be expected through time, as systems are highly variable. Planning landscape conservation in the present day must be flexible to accommodate change, not simply look to copy the past. Restoration ecology itself is imperfect; it is not possible to recreate past landscapes exactly.

Alternative models

A focus on re-creating the landscapes of the past may stifle attempts to create landscapes resilient to climatic changes anticipated in the future, a shift in thinking which will be necessary. An alternative model to adopt in landscape creation could be to consider the functions a landscape needs to provide (cultural, supporting, provisioning ecosystem services for example). Consideration is then needed of the biodiversity which would be supported as an emergent property of the landscape model. There is a risk that productive, functional landscapes may have limited biodiversity; if the biodiversity which will be supported is unacceptable as an outcome, the original landscape design should be revisited in the planning phase.

Incremental change may however be insufficient to tackle the threats faced by biodiversity: radical change may be necessary. Biodiversity offsetting (defined as measurable conservation outcomes to compensate for the residual impacts on biodiversity from development or damage) may be one such mechanism.

Communication and new approaches

Any radical approaches to nature conservation, moving away from a focus on the 'cultural' nineteenth century landscapes that are highly valued by people, will require careful communication, recognising that there is more than one 'public'. Communities should be involved in decision making regarding landscape and land-use models, recognising the role of the 'Big Society'. New templates and models for how the public wish to see landscapes develop are likely to emerge through this process. In concert with this, ecologists and conservationists should take the lead on communicating the importance of a new approach to landscape-scale conservation, sustainable over the long-term, to people, ensuring that messages are consistent.

'Ecological Restoration Zones', proposed in the Lawton Review of England's protected area network, could provide opportunities to test models of management which integrate local management and strategic, higher level, control.

Despite strong aesthetics, it is likely that people would become accustomed to different landscapes, as they have done in the recent past. The National Forest is an example of landscape change perceived positively by the public, whilst forest management could perhaps benefit from a return to a late nineteenth century model. This shift could involve reintroducing traditional management practices, such as coppicing, and greater heterogeneity in forests – for example through a mix of grazing and wood pasture. Forests could be managed locally, with the creation markets for local, and carbon neutral forest products.

Opportunities

Consideration could be given to whether particular areas of England are preserved as nineteenth century showcase or 'theme park' sites. In some sense, National Parks fit closely with a Victorian model or vision of a landscape. However National Parks have failings with respect to biodiversity delivery.

Actions

Engaging communities and land owners in participatory decision-making regarding the landscapes which they would like to see develop will be essential. As one of a number of tools which could be deployed to help with this, virtual reality approaches could prove useful. Such tools, such as the 'Virtual Landscape Theatre' at the Macaulay Land Use Research Institute, allow simulations of possible future landscapes, allowing people's preferences to be assessed. Fundamentally, people must be asked what they want and need from future landscapes, as a means to understand what the society of the UK wants from its landscapes at a national level.

Experts should engage in dialogue with local communities. Once people have the information they need to make informed choices regarding land use, communities can themselves think through scenarios and opportunities, before taking appropriate action.

Consideration should be given to negative consequences which may result from relying on local action however. For example, land owners may withdraw from agri-environment schemes, unless there are appropriate incentives in place to participate. Agri-environment schemes should be better targeted, with financial incentives increased and/or consideration given to developing a compulsory system. Woodland grants should be logged on a central register. Meanwhile, schemes to incentivise local communities to safeguard the wider environment, away from agricultural land, should be developed.

Non-native species: why does 'non-native' matter?

Issues

A distinction should be drawn between invasive and non-invasive non-native species. Many non-native species are relatively benign and therefore the UK could be more accommodating, welcoming these species as additions to our native biota. In doing so, an assessment of risk will be necessary, with the degree of openness time and context specific.

Some non-native species may deliver a positive ecosystem service benefit, for example as pollinators or feedstocks for biofuels. These species may exhibit properties, such as drought tolerance, which will also enable them to fulfil important functions as the native biota of the UK changes – urban cooling for example. Monitoring will be necessary to ascertain the role of non-native species in the delivery of ecosystem services.

Non-native species, which spread through a natural expansion of their range due to climate change, are likely to bring with them associated species (such as their natural predators).

Preventing such natural range expansion is likely to be extremely difficult, costly and therefore a poor use of limited resources.

The spread of invasive species is unlikely to be dependent on climate change. Invasive species may be translocated over large distances by man, introduced deliberately into the wild or spread from urban gardens or glasshouses. Enhancing the connectedness of the landscape, whilst likely to be beneficial in facilitating the spread of native species as the climate changes, may also increase the spread of non-native species, both invasive and non-invasive. Risk assessment and analysis is therefore needed when considering measures to increase connectivity. Climate change may limit the spread of some invasive species however.

The UK impacts of invasive species, such as the fungus-like pathogens in the genus *Phytophthera*, on the biota of the UK may have been underestimated. The impact of *Phytopthera* on biodiversity is a growing issue in the UK, with the pathogens causing a variety of plant diseases, including sudden oak death and potato blight.

Constraints/Risks

The issue of non-native invasive species is a very emotive one for some members of the public, who may not appreciate the reasons for controlling particular organisms, particularly if the methods used involve culling individuals (for example, ruddy duck eradication, or grey squirrel control). Conservationists may be accused of ‘racism’ in tackling ‘non-native’, or ‘alien’ species, highlighting the importance of using appropriate language in communicating the need to tackle invasive organisms. Similarly, conservationists need to develop a common language amongst themselves; many terms are used interchangeably in invasive species ecology, and are not always well-defined.

Controlling non-native species may bring conflicts with trade and industry, for example gardening, horticulture and aquaculture. These conflicts need to be anticipated and managed carefully, again highlighting the need for communication tools.

Actions

Adopting the IUCN definition of invasive alien (non-native) species would be a constructive step towards the conservation science community adequately understanding and tackling their impacts. The IUCN define invasive alien species as *“animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species”.*

Native species can also be labeled as invasive by some ecologists. The year 1500 AD is often used as a cut-off for the identification of alien species; this distinction is unhelpful.

Preventing the spread of invasive species is the most cost-effective means of tackling their impacts; once non-native invasive species arrive on UK shores, managing their effects can prove costly. Global databases can assist with prevention, allowing the dissemination of knowledge regarding the spread of invasive species, and their likely impacts on native biota. Monitoring is essential to generate data to feed into these global resources, and to build up a basic understanding of which non-native invasive species are currently present in the UK, knowledge which is lacking at present.

Active management of non-native invasive species when they do arrive in the UK will be necessary to eradicate them or to at least control their spread. It will be important to assess whether management approaches are succeeding. For example, harvesting the Chinese Mitten Crab, an approach adopted to tackle this invasive alien species, should be assessed to see whether it is the most sensible means of control.

Under what circumstances should we consider translocation?

Issues

In considering translocation as a conservation tool, it is necessary to adopt a Europe-wide perspective. Geographical regions, not nations defined by political boundaries, should form the basis for decision-making regarding which species should be priorities for conservation action. Priorities could be set using various criteria, including: the conservation status of a species; a focus on keystone or flagship species; whether a species is at risk of disease or out-competition; the cost of action; the quality of information possessed by conservationists, or whether a species is endemic to a particular geographical region being considered. Species inhabiting mountain-tops could also form a focus for translocation as a priority as there exists no opportunity to create stepping stones to suitable habitat for them further north as the climate changes.

Predictive models and expert judgement can be used to define thresholds beyond which translocation could be considered. Understanding the demographics of the population at risk, and the causes of the species decline, will also allow an assessment of whether it is appropriate to carry out translocation, either proactively or reactively. Risks associated with translocation (including risk of failure, or of introducing species outside their home ranges) should inform decision-making. Translocation may also be driven by public acceptance and values, on a case-by-case basis.

Investment of resources in translocation would make an immediate difference to iconic species such as the Spanish Lynx, and to herpetiles, which have limited dispersal abilities. Investing effort in translocating those species whose conservation will also benefit other species would also be sensible. Cost-benefit analysis will be needed to assess whether focusing on translocations would divert money from habitat management and population protection.

Constraints/Risks

Translocation should be halted if there are foreseeable problems in the new range of the species, for example pests or disease.

Global funds and local funds, set aside for translocation, may have different aims.

Actions

Translocation can proceed if a species is definitely going to be lost without action, and if a successful translocation is likely. If translocation is deemed to be a sensible option, this should begin as soon as possible in order to optimise success: as a species becomes rarer, conservation effort, including relocation, becomes more costly. An initial assessment will be needed to ascertain whether translocation is acceptable as a conservation measure, whilst practicalities concerning the species in question should be further examined before action is taken.

The use of models

Issues

Modelling is useful. It provides a means to 'see into the future' and provides tools for visualising different scenarios. Modelling provides a guide to where additional data collection is needed, whilst allowing quantitative predictions to be made which incorporate uncertainty; a powerful tool for supporting decisions.

Modelling can help to inform the adaptive management of systems, with models informing management actions, which are then monitored and the results fed back into the model to improve the interventions made.

To use models most effectively they should be validated, and the sensitivity of the model to the assumptions used should be quantified. Those developing and utilising models should also be explicit about the caveats which affect use of the model, for example the model's generality and applicability.

Constraints/Risks

There are constraints to the use of models; the greatest being that models are only ever as good as the data which are fed into them. Making the data used in scientific publications freely available could assist collaboration which may then result in improvements to this initial data. Validating models through empirical evidence is also important, demonstrating the importance of experimentation.

Greater resources are needed to develop as high quality models for ecological impacts as exist for physical data (as Global Climate Models). Larger, regional and landscape models may be most applicable to modelling ecological impacts due to the holistic nature of many ecological issues.

A range of parameters need to be incorporated into models to ensure they are as accurate as possible, whilst developing these models at appropriate spatial scales. Processes underlying a system need to be understood in order to accurately model how a system might change through time, for instance due to climate change. In understanding climate change impacts on a system, it could be helpful to input data from physical Global Climate Models into biological models.

Different drivers (such as anthropogenic impacts) will interact in a complex manner and will alter the predictions of models, which will themselves already be complex due to the range of inputs included. When creating models it is important to aim for 'appropriate parsimony', simplifying complicated systems to produce models which can be useful.

Break-Out Groups: Day Two

The aim of the groups was to identify:

- priorities for future development of policy and conservation practice;
- key knowledge gaps;
- priorities for future research on climate change adaptation;

Priorities for future development of policy and practice

Approach

Leadership

- There is a need for cross-Government recognition of the value of biodiversity, embedding this recognition in policy appraisal and Government practise.
- Greater, more targeted funding is needed to investigate the interventions needed to best adapt the UK's natural environment to a changing climate.

Scale and flexibility

- There is a need to set conservation objectives which are flexible and relevant at a range of different scales (European, national, local).
- Similarly, national level policy needs to be more flexible and relevant to the small scale. Small scale energy may be better delivered locally.

Integration

- Integration is needed across stakeholders. Engaging a range of stakeholders is necessary for adaptation to proceed effectively. Greater dialogue is needed between policy-makers and researchers; this could be facilitated by a structured system for communication and interaction. Economists and business are often overlooked by conservationists but must be included in dialogue. The views of local communities must also be taken into account.
- Integration is necessary at the practical, site management stage, between organisations and practitioners in the management of land.
- All site management plans should make use of climate change projections, integrating this current knowledge into management interventions.
- Adaptation and mitigation actions must also be linked and integrated into current conservation practise. 'Win win' situations must be found to facilitate this. A focus on

mitigation only, in policy and practise, has the potential to undermine necessary efforts to adapt to climate change.
- To facilitate integration, modelling, visualisation and use of scenario planning should be improved so that adaptation planning can be developed in a participatory way.

Ecosystem Services

- It is important to recognise that the relationship between species and ecosystem service delivery is complex. Policy-makers are increasingly focused on ecosystem service delivery, but policies focused on securing ecosystem services will not always protect biodiversity. 'Win-win' situations do exist (for example in securing carbon sequestration through woodlands or peatlands) but there is a need to acknowledge that both ecosystem services and biodiversity protection cannot be delivered in every case, and to tailor policy specifically to protect biodiversity where necessary.
- The International Platform for Biodiversity and Ecosystem Services (IPBES) has potential as a resource for policy-makers, encouraging informed decision-making which takes into account the value of nature. It is not clear yet how IPBES will choose to focus its work, whether seeking to fill knowledge gaps, running assessments, or examining policy tools. The capacity of the Platform to deliver is also unclear at present.

International perspective

- Many targets for nature conservation in the UK are set internationally, providing an international context for site management and conservation practise, whilst policies developed at national level need to be aligned with European and with international policy. Practitioners and policy-makers in the UK need to consider the European and global context when developing actions to adapt conservation to climate change.
- In considering UK biodiversity in an international context, questions arise regarding how best to spend limited resources on nature conservation. Does it matter if a species goes extinct in one country if it is abundant in another, for example?
- A changing climate, and the spread of non-native species which this will facilitate, will also necessitate judgements regarding the acceptability of novel communities of species emerging: are we happy with novel communities of species in the future or the arrival of non-natives in a location? Likewise, judgements will be needed regarding the acceptable timescales across which change can occur: should we be concerned with the rate at which biodiversity distributions and ecosystem processes are changing?
- Society must consider how it views biodiversity and what it wants from biodiversity in the future. Is the provision of ecosystem services or a moral imperative to conserve biodiversity acting as a driver?

Levers

Fiscal

- Ecosystem services need to be valued to ensure that they are properly accounted for in decision-making, not simply viewed as a cost-neutral externality. Monetary valuation, such as Payment for Ecosystem Service (PES) mechanisms (e.g. asking users to pay for the environmental cost of water abstraction), is one approach. Non-monetary valuation should also be explored.
- In developing mechanisms to value ecosystem services, and building these values into policy-making, putting a price on nature can aid understanding of the cost of inaction in conservation.

- Economic mechanisms will be needed to deliver the reforms to England's protected area network called for in the Lawton Review, due to the agricultural nature and ownership of 75% of England's land.
- Biodiversity offsetting represents one mechanism by which finance may be channelled into adaptation measures. Biodiversity offsetting could proceed through a market-based mechanism, creating a trade in biodiversity 'debits' and 'credits', which puts a market value on biodiversity; through a 'fee in lieu' system, with developers paying into a pooled fund to deliver offsets, or through developers providing offsets themselves on a site-by-site basis.
- A carbon market for peatland represents another means by which market forces could be brought to bear on biodiversity conservation.

Incentives

- Providing incentives for sustainable land management can be a powerful tool. The Common Agricultural Policy (CAP) is one mechanism through which incentives can be delivered. CAP funds should be re-directed to incentivise the delivery of ecosystem services, and the incorporation of climate change considerations within agri-environment schemes.

Regulation

- The role of regulation was considered with specific reference to the Common Fisheries Policy.

Knowledge Transfer

Communication

- Improving public understanding of climate change and its implications for biodiversity is vitally important. Communication by the research, policy and practice communities to all tiers of society, through the media and other routes, must be encouraged and enhanced. Communication should not just target the 'usual suspects' but also hard to reach groups.
- Greater understanding is needed of the barriers to effective action to tackle climate change, and steps taken to address these barriers.
- Positive messages must be communicated to counter apathy or an unwillingness to accept change on the part of stakeholders or local communities. The benefits and opportunities offered by measures taken to adapt to climate change must be shown more clearly.
- 'Biodiversity' is not helpful as a term when communicating with the public. Simple, easy to understand messages about the importance of nature and wildlife must be developed. Charismatic species could provide a useful tool to engage public interest.
- The provision of environmental information through education, to adults and to young people, is vital. Initiatives such as 'Eco-Schools' help to engender understanding in young people and their parents. Courses, such as those run by the Field Studies Council, are also important for building adult learners' appreciation for the natural world.

Localism

- Conservation agencies could play a role in providing information to communities at a local scale, so that local people can best decide what is important for their area.

Communities could become engaged with climate change adaptation actions by encouragement to participate in local or national monitoring schemes and surveys (e.g. OPAL projects).

- A focus on localism and local action carries both opportunities and risks for adapting conservation to a changing climate. Local people can act as a force for conservation, with local groups (such as Wildlife Trusts) adopting ownership and management of Local Nature Reserves. However with localism may also come less strategic approaches to conservation and site management, and a focus on the local may make a 'landscape scale' approach harder to deliver.
- In empowering local communities to meet conservation challenges, whilst avoiding risks to effective delivery, capacity building will be important. Local autonomy can deliver nature conservation objectives if operating with guidance from a national strategy.
- Local authorities and communities delivering practical conservation action should be given advice and guidance, with the facility to share information between authorities and promote best practice. Knowledge exchange between not only local communities themselves but with practitioners, business and others will be important.

Support mechanisms

Monitoring

- Monitoring independently of targets is important. Long-term monitoring of environmental change can provide an early warning system for conservation practitioners and policy-makers.
- Theimportance of long-term monitoring needs to be recognised, with the provision of adequate funding to support this

Science and evidence

- Maps of existing protected areas, models of likely future climatic change and assessments of the distribution of species and habitats should be drawn together as a first step in identifying potential new protected areas which might prove significant for species under a changing climate. Such an approach would help to identify where new colonies for protected sea birds would be best located, for example.
- Modellers and ecologists should work together to undertake a systematic review of how a range of species are likely to fare as the climate changes. This could lead to the development of a list of priority species, which may be different to species currently prioritised by policy and targets. This is turn could lead to directed action focused on these species, with site-management 'climate proofed' to take into account the results of the models.
- Policy on the re-introduction or translocation of species should be re-considered.

Deliverables

Protected areas

- The forthcoming Defra Natural Environment White Paper should implement the recommendations of the Lawton Review of England's protected area network in full. All semi-natural habitats should receive greater protection, from so-called 'Tier 1' to 'Tier 3' sites. Existing sites should be restored and managed, with new sites created. Ecological Restoration Zones should be developed, as called for in the Review, and attention paid to the creation of networks of protected sites across the UK.

- Under a changing climate it is highly likely that the UK's protected areas will alter: the species or feature for which the site is dedicated may shift in distribution or become extinct for example. Consideration needs to be given to necessary amendments to policy and legislation to accommodate change in this series of sites. Greater flexibility is needed to ensure that the UK's 'core network' of protected areas is not lost (e.g. to development) as climate, and species composition at the site, changes.

National Ecosystem Assessment

- The Natural Environment White Paper should endorse the emerging recommendations from the National Ecosystem Assessment.

Bioenergy

- Bioenergy policy needs to be better informed by ecology. Policies should be based on evidence for the positive and negative impacts of biofuels, and an understanding of the environmental sustainability of these crops.
- An appraisal is needed of the combined effects on the environment of policies aimed at mitigating climate change (e.g. biofuel policy and the expansion of wind farms).

Key knowledge gaps and priorities for future research on climate change adaptation

Ecosystem services

- Although policy-makers are increasingly prioritising ecosystem service delivery from the natural environment within policy, significant gaps exist in scientific understanding of how ecosystems operate. Key knowledge gaps are:
  - The relationship between biodiversity and ecosystem services – and how far prioritising ecosystem service delivery will deliver conservation of biodiversity.
  - The role of an individual dominant species (or key species) in ecosystem service delivery.
  - The importance of scale to ecosystem service delivery: are ecosystem services delivered by small sites?
- Other gaps exist in scientists' characterisation of ecosystem services in the landscape, with a need identified to map and quantify ecosystem service delivery at a local, regional and landscape scales. Mapping current provision and where demand will exist for services (and which services) in the future, is another key area for research focus.
- Valuation of biodiversity and ecosystem services is another significant challenge, with questions over how benefits from ecosystems can be valued accurately.

Ecological aspects of adaptation and resilience

Communities (natural) vs species

- Research questions include:
  - The role of community structure and the role of individual species in resilience to climate change. There is a need for experiments to test these hypotheses.

- The implications of climate change for food web structure. Research to date has often focused on habitats and species, rather than the relationships between species at different trophic levels.
    - The implications for competitive interactions within communities is less well known as much work focussed on climate envelopes.
    - Understanding the impacts of climate change on species and habitats at regional (biogeographic) and global scales.
    - How resilience to climatic change can be built within a species' population.
    - Whether results from studies on well-recorded taxa, such as birds and butterflies, demonstrating climate change impacts and adaptation responses, can be extrapolated to other less well-documented taxa with accuracy.
- There is a need to broaden research on adaptation to climate change beyond well studied organisms. For example, studying the responses of soil microbes and fungi under a changing climate.

Thresholds/Trigger points

- Greater understanding is needed of thresholds and 'tipping points'. How can we identify whether a system may be approaching a tipping point: how many species do we need to lose before critical point is reached?

Genetics

- Research is needed into the extent which within-species plasticity (population genetics and phenotypic plasticity) will enable species to be resilient to change, or to adapt.

Connectivity

- Whilst connectivity is generally considered important for species dispersal under a changing climate, this remains a contentious point within ecology which is yet to be resolved definitively. Key research questions concern the relative importance of connectivity to species survival, and whether it is in fact possible to achieve functional connectivity within a landscape.
- Field-scale trials of connectivity for selected species would provide valuable information to begin to resolve these issues.
- Understanding species life history traits is also important when considering the efficacy of connectivity as a conservation measure. Particularly significant is considering what affects the ability of a species to disperse, including fecundity, population density and phenotype.

Knowledge transfer

Behaviour

- Understanding how to influence people and change behaviour is a significant topic of research within the social sciences. Natural scientists should engage with this area of research to ensure necessary action is taken at all levels and that society understands the importance of the essential services provided by the natural environment.

Knowledge to action

- Understanding the barriers which need to be overcome, and how to tackle these to translate knowledge into action, is important and another area where natural scientists could benefit through dialogue with social scientists.
- The UK possesses significant expertise in long-term monitoring of environment and species change. Greater efforts should be made to share this expertise with others globally who could benefit from this.

Communication

- Interdisciplinary research and communication, between natural and social scientists, economists, practitioners and other stakeholders should be a priority, including joint research projects and communication regarding the tools needed to support adaptation.
- In communicating with the public and others, useful lessons may be learned through the marketing approaches adopted in other spheres, for example campaigns around drink driving or stubble burning.

Educational tools

- Practical planning tools based on the ecosystem approach could be developed for land managers and practitioners, along with training courses on climate change adaptation measures. Thought should be given to the materials needed for these, and who should be encouraged to attend.

Management

- The effectiveness of different types of management in conferring resilience and the interactions between management and climate change (and other drivers) was idenfied as an area where further research was required. With the results feeding back into future policy.
- Specific mention was made to the need to determine the benefits of land-sharing in delivering appropriate management.

Drivers

- The indirect impacts of climate change are likely to be as significant for biodiversity as the direct effects. The response of humans to climate change, through behaviour change and economic effects, will have a huge effect. An interdisciplinary approach, between natural and social scientists, economists and others, is necessary to model and better understand these likely impacts.
- Population growth and demographic change is likely to have a significant role to play in environmental change. Again an interdisciplinary approach is needed to understand what these impacts are likely to be.

Support mechanisms

Data and knowledge sharing

- Much data already exists which will be useful in understanding impacts on biodiversity under a changing climate, and how adaptation could tackle these. Data should be brought together, for example through an EU portal, to improve accessibility and availability for researchers and practitioners.
- Improving links between organisations which may hold data or wish to use it would assist data sharing and help to identify gaps where these exist. Local fora could be established to aid links between academics, land managers, local authorities, business and others.
- Producing maps of marine resources would be particularly useful as a focus for future research effort.

Risk assessment

- Comprehensive assessments of risk should be made to understand whether adaptation approaches in place at present are likely to prove effective under a range of climate change scenarios, for example protected areas.
- Risk assessment across biogeographic ranges would set British conservation targets in a wider and potentially more relevant context in terms of species/habitat distribution.
- Risk assessment could be applied to habitats, species and ecosystem services to provide an indicator of the threats posed by climate change. Assessments of risk across scales should be communicated effectively to policy-makers.

Monitoring

- Long-term monitoring will be vital as a means to assess the success of adaptation interventions. Significant gaps exist in the monitoring of urban and marine environments, whilst there is a need across habitats to better monitor those taxa for which little trend data exist.
- There is a need more generally for more comprehensive monitoring, whilst sites currently used for long-term monitoring should be maintained and expanded, with a network of long-term monitoring sites developed across the UK.
- Hindcasting, making use of paleoecological data, is also a research need.
- Practitioners could assist in better monitoring of the natural environment.

Invasive Species

- Greater research effort is necessary to understand the impacts of those species newly identified as invasive, or likely to become invasive in the future, on ecosystems. This includes efforts to understand the timescales over which particular species are projected to become invasive and cause problems.
- Following on from an increased appreciation of the likely impacts of invasive species, practical approaches can be developed to prevent or tackle the spread of invasive species, including legal frameworks for action.

Predictions and impacts

- Further research is needed to understand the current impacts of climate change on species and habitats and how this may change in the future. Models can assist with climate change projections, and the testing of adaptation interventions to assess how these may hypothetically affect biodiversity.

Distribution shifts in time and space

- Rather than focusing only on changes in species distribution, greater research is needed to understand evolution and selection at the ‘micro’ scale.
- Greater research effort is needed to understand the implications of phenological shifts (changes in the timing of biological events, such as first flowering or emergence from hibernation). Phenological shifts could provide useful early indicators of the likely impacts of climate change on ecosystems.

Delegates

Mike Acreman, Centre for Ecology & Hydrology

Jennifer Allen, Aston University

Penny Anderson, Penny Anderson Associates Ltd

Malcolm Ausden, RSPB

Sallie Bailey, Forestry Commission

Valerie Bain, HR Wallingford Ltd

Peter Baker, CABI

Nadia Barsoum, Forest Research

Simon Bates, Natural England

Clive Bealey, Natural England

Natalie Bennett, Natural England

Jon Bennie, Exeter University

Pam Berry, University of Oxford

Caroline Birchall, Natural England

Jacqueline Bodimead, Anglia Ruskin University

Aletta Bonn, IUCN UK Peat Programme

Deborah Boobyer, Defra

Nieves Bottomley, Defra

Richard Bradbury, RSPB

Peter Bridgewater, JNCC

Mark Broadmeadow, Forestry Commission

Rob Brooker, Macaulay Institute

Dave Brooks, Rothamsted Research

Eleanor Brown, Natural England

David Bullock, National Trust

Jane Bunting, University of Hull

Victoria Cadman, Ecological Continuity Trust

Rory Canavan, Ove Arup

Roger Catchpole, Natural England

Alistair Chisholm, REgrowth

Mary Christie, Scottish Natural Heritage

Sean Crawford, Policy Adviser Defra

Humphrey Crick, Natural England

Ian Crosher, Natural England

Alan Crowden, BES Bulletin Editor

Sarah Dalrymple, University of Aberdeen

Neil Davidson, UE Associates

Zoe Davies, DICE

Terry Dawson, University of Southampton

John Dearing, University of Southampton

Maria Dickinson, Imperial College London

Julian Doberski, Anglia Ruskin University

Simon Duffield, Natural England

Arnaud Duranel, University College London

Steve Dury, Somerset County Council

Les Edwins, RSPB Volunteer

Cordula Epple, UNEP-WCMC

Karl Evans, University of Sheffield

Matthew Evans, University of Exeter

John Fellowes, Kadoorie Farm & Botanic Garden

Mark Fessey, Consultant-URS/Scott Wilson

J Finch, Writtle College

Richard Findon, Defra

Aldina Franco, University of East Anglia

Franz Essl, Environment Agency

Pippa Gillingham, University of York

Alessandro Gimona, The Macaulay Institute

David Gowing, Open University

Tim Graham, Lancs Biodiversity Partnership

Phil Grime, University of Sheffield

Richard Handley, Environment Agency

Alice Hardiman, RSPB

Mike Harley , AEA

Jane Hill, University of York

Kathy Hodder, Bournemouth University

Jenny Hodgson, University of York

Isla Hoffmann Heap

Neil Ireland, King's College London

Catherine Jones, Royal Holloway, Univ. London

Hayley Jones, Rothamsted Research

Eveliina Kallioniemi

Keith Kirby, Natural England

Konstantin Gavazov, EPFL & WSL, Lausanne

Horst Korn, BfN - Germany

Poppy Lakeman Fraser, Imperial College London

Emily Lambert, University of Aberdeen

Callum Lawson, University of Exeter

Sir John Lawton, Royal Commission on Environmental Pollution

Aidan Lonergan, RSPB Futurescapes

Jamie Lorimer, Kings College London

Nicholas Macgregor, Natural England

Ceri Margerison, British Ecological Society

Pierre Mariotte, EPFL & WSL, Lausanne

Roger Martin, Population Matters

Rob McCall, Countryside Council for Wales

Annette McGrath, National Forest Company

Jane Memmott, Journal of Applied Ecology

Veronica Mendez, University of East Anglia

Mike Morecroft, Natural England

Catriona Morrison, University of East Anglia

Rachael Moss, Field Studies Council

Catherine Norris, Writtle College

Jonathan Oldham, Field Studies Council

Tom Oliver, Centre for Ecology & Hydrology

Harriet Orr, Environment Agency

Gian Marco Palamara, University of Sheffield

Rachel Pateman, University of York

James Pearce-Higgins, British Trust for Ornithology

Danielle Peruffo, University of East Anglia

Jan Plesnik, Agency for Nature

Helena Richards, Field Studies Council

Terhi Riutta, University of Oxford

Sarah Robinson, Natural England

Kathryn Ross, Bournemouth University

David Roy, Centre for Ecology & Hydrology

Deepa Senapathi, University of Reading

Joanna Shackleton, Field Studies Council

Daniel Simmons, The Ecology Consultancy

Eleanor Slade, WILDCRU

Richard Smithers, International Association for Landscape Ecology

Andrew Stott, Defra

Andrew Suggitt, University of York

Jim Swanson, Hartpury College - UWE

Sarah Taylor, Natural England

Chris Thomas, University of York

David Thompson, Committee on Climate Change

Graham Tucker, IEEP

Grace Twiston-Davies, University of Reading

Siobhan Walker, West Sussex County Council

Clive Walmsley, Countryside Council for Wales

Martin Warren, Butterfly Conservation

Andrew Watkinson, Living with Environmental Change

James Watson, Wildlife Conservation Society

Olly Watts, RSPB

Erica Wayman, Natural England

Barbara Woods

Acknowledgments

We are grateful to:

Natural England and the British Ecological Society for supporting the meeting, in practical and financial terms;

Conference Centre Staff, Charles Darwin House; and

The conference advisory group who made an important contribution to planning the conference: Chris Thomas (University of York), Jane Hill (University of York), Pam Berry (University of Oxford), Rob Brooker (Macaulay Institute), Olly Watts (RSPB), Mark Broadmeadow (FC), Helen Pontier (Defra), Richard Findon (Defra), Sarah Dalrymple (University of Aberdeen), Clive Walmsley (CCW), Deborah Proctor (JNCC), Richard Smithers (AEA)