An Occasional Report:

A review of current literature on the evidence for climate change and its implications for the Brecon Beacons National Park

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The following is a summary report on a literature review, the bulk of which is provided as an Annex to this summary. A second Annex provides a schematic summary of a range of different climate change scenarios as they affect this NP. A third Annex provides the Association of National Park Authorities (ANPA) position statement on climate change, adopted at the ANPA Buxton workshop during April 2004.

General background

1. This report provides a detailed overview of the published evidence for climate change and how this is predicted to affect the special qualities of the Brecon Beacons National Park. New information becomes available frequently, so this report brings the reader up to date as of December 2005.
2. There is a cross-sector consensus that climate change will affect the UK significantly during the 21st century. Responding to it is now at the heart of European, UK and Wales policies and in the foreseeable future adaptations to it will be necessary in this National Park. The nature and scale of change is becoming clearer and this report gives an indication of what this might entail.
3. The report concentrates on the predicted and observed effects of climate change on the natural world - the biodiversity - in the Brecon Beacons National Park. Comments are made on some of the issues raised although these comments do not necessarily reflect the opinion of the Brecon Beacons National Park Authority (BBNPA).
4. The natural environment in National Parks is vitally important to the future of farming and tourism, yet it is extremely vulnerable to climate change.
5. There is widespread acknowledgement of the important role that National Parks can play in helping Wales and the UK to adapt to climate change, for example as vehicles for promoting integrated planning responses to and assessment of climate change.

The basics of climate change

6. There is still some uncertainty about the detail of impacts and the environment's response to them. But there is consensus that Mid- and south Wales are predicted to become warmer and drier during longer summers, and milder and wetter with more storms and intense precipitation during winters.
7. There is also evidence that warmer conditions might at some point in the foreseeable future lead to the UK becoming much colder each winter as a consequence of global warming. This is explored briefly at the end of the report.
8. The current rate of increase in atmospheric greenhouse gas concentrations is unprecedented in the last 20,000 years.
9. New analyses of data for the Northern Hemisphere indicate that the increase in temperature in the 20th century is likely to have been the largest during any century since 1000AD. Assessments predict an increase in the mean global temperature of between 5℃ and 6℃ by

2100, i.e., in less than 100 years from now. The current rate of temperature increase is about 20 to 30 times as fast as the fastest previous records.

Action to cope with climate change

10. The Wales Assembly Government supports the development of regional climate change models as well as research into indicators of climate change in the environment. Climate change is a significant policy issue within the Environment Strategy for Wales. The UK and Welsh governments believe that we must adapt to changes occurring now in order to mitigate the scale and rate of change in the future.
11. Wales needs to react explicitly to climate change because it is economically and environmentally vulnerable to its effects, not least of all because of the high proportion of upland, freshwater and coastal areas.
12. The 6th European Union Environmental Action Programme puts climate change at the heart of European policy. The Kyoto Protocol will have only a minor impact on slowing climate change owing to all the other factors that have been set in motion by climate change itself.
13. Wales requires integrated planning, co-operation across all sectors and a much greater willingness by decision-makers to understand these new and yet fundamental issues in order to make the right decisions, based upon new analyses and new priorities.
14. The Welsh Local Government Association has launched the Welsh Declaration on Climate Change, which commits local authorities to mitigating and adapting to the effects of climate change. The Association of National Park Authorities has adopted a position statement on climate change, which commits National Park Authorities to similar action (see Appendix 3).
15. The Brecon Beacons National Park Authority has some tools to hand with which to begin to respond to the effects of climate change. These include the National Park Management Plan, Unitary Development Plan (UDP), State of the Park Report (which reports on the Park's environmental, economic and social 'health'), local biodiversity action plan (LBAP), area action plans, responses to strategic consultations and through grants, support and advice provided to people living and working in the Park.

Actions by businesses

16. Carbon sequestration (storage) is a possible area-based response to alleviating climate change. The UK could sequester over 600 tonnes of carbon per year whilst maintaining current food production at a more efficient carbon emission rate. It might be possible to develop a 'carbon budget' for the BBNP, which might be of assistance to businesses that are keen to take part in the UK Emissions Trading Scheme. Spatial planning, combined with good fiscal measures could increase the amount of land available for carbon sequestration in woodlands, meadows and biofuel crops.
17. Significant changes are predicted for livestock farmers although there is confidence that the diversity of techniques and know how in the industry should enable it to keep pace with climate change.

Climate change and the National Park's wildlife

18. There is less confidence that wildlife will adapt in time if at all, without help and considerable flexibility by people.
19. 10% of designated wildlife sites in the UK (Sites of Special Scientific Interest (SSSIs) etc) would be lost during a 1℃ - 2℃ increase in averag e annual temperature. This will have significant implications for the economic value of such sites in future, as well as conservation implications. With a similar temperature increase the range of species present will change in up to 50% of designated sites.
20. Current nature conservation designations and land use planning in Wales could be undermined through the loss of entire vegetation communities, producing significant changes in the landscape. The most suitable response within National Parks would be to maximise biodiversity within the landscape, to 'stockpile' it in anticipation of losing it in future.

21. Wildlife conservation in the UK relies too heavily on maintaining wildlife in defined sites. Wildlife moves around, its needs change over time and this is being accelerated by climate change. Current legislation and prevailing attitudes may not offer sufficient flexibility to accommodate the necessary changes needed for wildlife.
22. There is an argument for making the designated site mechanisms more adaptable, with site boundaries being more flexible. But such a move might become very complicated, controversial and expensive.
23. It might be prudent to develop and adhere to a set of conservation principles rather than making nature conservation even more complicated through the site designation process. In the BBNP, it might be sensible to identify and manage a series of core zones, buffer zones and corridor zones for wildlife.
24. "Near natural areas" is a concept that is gaining ground across Europe and is beginning to be pursued in the UK. The Wales Spatial Plan provides an ideal opportunity to accommodate this approach.
25. Agri-environment schemes are already in a position to help co-ordinate a wildlife-friendly response to climate change. But the new Entry Level Scheme currently being piloted by the Wales Assembly Government might only succeed within an environmentally led spatial planning framework that accommodates climate change.
26. Suggested responses to climate change within protected areas have been discussed at Europarc and are listed within this report.
27. For all species affected by climate change scientists are predicting large-scale responses by them although this is constrained by land availability, time and other limiting factors. On the basis of studies elsewhere, a number of species will become extinct within the Brecon Beacons National Park.
28. Losses to biodiversity caused by climate change are larger than those caused by habitat loss and fragmentation. For local biodiversity conservation in the BBNP it will be prudent to develop habitat and species restoration targets that take account of climate change.
29. The changes in flows and temperature in rivers and streams may have an adverse effect on salmonid fisheries, just at a time in the BBNP when significant efforts are underway to restore them through river habitat restoration and management, bringing benefits to the fisheries businesses.
30. The report provides an extensive summary of the growing evidence for responses to climate change by wildlife. In the context of the BBNP and other upland National Parks lowland raised bog, upland blanket bog, heather-rich heathland and rivers and streams will decline in extent and quality. On SSSIs this is equivalent to a 60% to 80% loss of such habitats in the UK, which has implications for the BBNPA's responsibilities under Part III of the CROW Act 2000. The most appropriate way to mitigate this loss is to bring as much habitat as possible into good ecological condition, to 'stockpile' what is there in anticipation of losses later on, whilst encouraging flexibility of land use for the longer term conservation of biodiversity.
31. For underground limestone caves and karst features, reduced rainfall could lead to a reduction in calcium deposition, causing a decay of existing karst features and sites.
32. Plants will grow larger during longer and earlier growing seasons. This will benefit pest species and aggressive species too. There will be fewer frosts, leading to less die back of plants each winter but an increase in water returned to the atmosphere by evaporation and transpiration from the ground and from plants. Economically damaging species such as bracken, purple moorgrass and *Rhododendron* will benefit from warmer, drier summers. Bracken and purple moorgrass are predicted to spread uphill as heather-rich moorland retreats.
33. There will be more water shortages owing to summer droughts and insufficient capacity to store increased winter rainfall. There could be increased pressure to build more reservoirs in the Welsh uplands.

Key words:
Climate envelope, re-alignment, UK Climate Impacts Programme (UKCIP), IPCC (Intergovernmental Panel on Climate Change), carbon dioxide (CO_2), carbon sequestration, spatial planning, near-natural areas.

Annex 1

INTRODUCTION

"The climate of the Earth has never been stable, least of all during the history and evolution of life on Earth. Glacial periods, for example, have been (globally) 4°-5° C cooler than now, and some interglacials have been (perhaps) 1°-2°C warmer. These prehistoric changes in climate were clearly natural in origin and occurred on a planet inhabited by primitive societies with far smaller populations than at present. Ecosystems and species have moved, often freely, in response to such past changes and have evolved within this climatic history.

Yet the causes of contemporary and future changes in climate, the rate and potential significance of these changes for ecosystems and hydrological systems and for the human species, are all notably different from anything that has occurred previously in history or pre- history. Human perturbation of the atmosphere now dominates the causes of global warming and the rate of warming already exceeds anything experienced in the last 10,000 years. Given the ecological imprint made by our current and growing population of 6 billion and more, the significance of this prospect for the natural world and for human society is qualitatively different from any changes in climate that have been experienced before by life on earth."
After Hulme et al. (2003)

"Climate change is the most significant and far-reaching environmental challenge facing humanity today. Scientists, policy makers and governments from around the world are seeking to understand the nature of the changes that are likely to occur in the 21st century and beyond and the effects these could have on human populations and the socio-economic systems that underpin them. Mitigation measures are being developed to reduce the long-term impacts of human-produced greenhouse gases on the Earth's climate, whilst a wide range of sectors are considering how they might adapt to the inevitable effects of climate change in the shorter term."
(After Mike Harley in Green et al. 2001.)

This report is provided by the Brecon Beacons National Park Authority in response to the cross-sector consensus that climate change will affect the UK significantly during the 21st century. Organisations including the UK Government and its agencies, the Wales Assembly Government, the Country Landowners and Business Association, the Countryside Council for Wales, the Association for National Park Authorities and the RSPB are of one mind about the certainty of climate change. In particular an increase in average daily global temperature is occurring as a consequence of the release of human-made greenhouse gases such as carbon dioxide (CO_2), which trap heat - the greenhouse effect. Whilst this is a natural phenomenon recent industrial and agricultural activities have accelerated it at an unprecedented rate. Responding to it is now at the heart of European policies and in the foreseeable future changes are likely to occur in this National Park. The nature and scale of these changes is becoming clearer and this report gives an indication of what this might entail.[1]

The information provided is drawn from a review of the most recent literature published by a range of official agencies (see references at the end). It concentrates on the predicted and observed effects of climate change on the natural world - its species, habitats and ecosystems - the biodiversity of the National Park. The source material used also includes significant detail about the built environment, land use planning, archaeology, agriculture and farm ecosystems, gardens, grasslands, energy, water resources, the marine environment, tourism, health, business

[1] At the end of this report additional notes are provided on the other major consequence of climate change, namely the effects of global warming on the Greenland ice sheets and the knock-on effects of meltwater on the Gulf Stream. The significance and likelihood of this effect is not yet understood clearly. The weight of effort in the UKCIP has yet to address the alternative climate and habitat scenarios that loss of the Gulf Stream could give rise to although such research is underway (see http://www.soc.soton.ac.uk/rapid/rapid.php).

and indeed all the areas of work that affect National Park Authorities and the public sector in the UK. But these are not dealt with here. More information can be found on the UK Climate Impacts Programme web site (www.ukcip.org.uk) and the Brecon Beacons National Park library also holds a number of the publications.

There is still some uncertainty about the detail of impacts and the environment's response to them. For example some areas of Britain may become warmer and drier whilst others may become warmer and wetter. Conversely there is growing evidence that in spite of global warming Britain could be plunged into a much colder winter climate caused by higher volumes of polar freshwater entering the Atlantic and switching off the Gulf Stream. This is explored briefly at the end of this report.

The changes that are predicted will produce subtle and gradual changes to the environment that are hard to spot for the unobservant. But there is a growing body of evidence that these subtle changes are more significant to wildlife, whose responses are being observed already. Research is underway and policies are being reviewed in order to develop a comprehensive strategy to adapt to climate change, as well as to achieve benefits wherever possible. For example, the Wales Assembly Government supports regional climate change models to predict effects in different parts of Wales, as well as research into indicators of climate change in the environment. As a consequence, new terminology is emerging to describe what is happening and also to categorise how we respond.

The Department for the Environment, Food and Rural Affairs (DEFRA 2004) is now very clear that climate change is occurring:

- Global temperatures have continued to rise with 2002 joining 1998 in the top 2 hottest years on record
- The Hadley Centre 's groundbreaking carbon-climate model shows that carbon emissions from forests and natural vegetation affected could strongly accelerate global warming in the future
- Measurements have shown that atmospheric concentrations of many greenhouse gases reached their highest ever levels in 2002
- Global temperature rises in the latter half of the 20th century cannot be explained by natural factors. New evidence indicates that increasing greenhouse gas levels due to human activities are largely responsible.

Broadly speaking according to the latest research, mid- and south Wales will become warmer and drier during longer summers, whilst winters will become milder and wetter with more storms and more intense precipitation. On balance this is not viewed as a positive change and positive outcomes are not likely without a willingness and ability by individuals and organisations to adapt effectively to the changes, for the sake of both human and environmental well being. The UK and Wales Assembly Governments believe that we must adapt to changes occurring now in order to mitigate the scale and rate of change in the future. Therefore climate change is beginning to permeate into decision making already.

> "*The scientific consensus about human-induced climate change should sound alarm bells in every national capital and in every local community*," Dr Klaus Toepfer, Head of the UN Environment Programme, March 2001.

The Kyoto Protocol will have only a minor impact on slowing climate change owing to all the other changes that are the product of climate change itself. Wales needs to react explicitly to climate change because it is economically and environmentally vulnerable to its effects.

A range of phenological[2] (relating to times at which biological events occur, i.e., first leaf coming out, first butterfly appearing), physiological (relating to internal processes of plants and animals) and physical changes will occur to the natural and human-made world. This will require a wholesale level of response across a range of activities and policies.

Among the tools available to a National Park Authority for beginning to respond to climate change are the Unitary Development Plan (UDP), the Local Biodiversity Action Plan (LBAP), area action plans, grants and support and advice provided to people who live and work here. Of the important industries in National Parks significant changes are predicted for livestock farming. There is some confidence that the diversity of techniques and know how in the farming industry mean that it should be able to keep pace with climate change.

There is less confidence that wildlife will adapt in time. Wildlife is constrained by evolution, ecology, land availability and human willingness to make the changes to permit wildlife to move to new areas. UK projects (under the UK Climate Impacts Programme UKCIP - see www.ukcip.org.uk) are being undertaken and completed. These include "MONARCH" - Monitoring the Natural Responses of Species to Climate Change. MONARCH is developing possible adaptive responses and policy recommendations for climate change. For more information see www.eci.ox.ac.uk/biodiversity/monarch. "RegIS" - Regional Climate Change Impact Response Studies - investigated the impacts of climate change on two different planning scenarios (*laissez faire* versus proactive responses) in East Anglia and NW England. The RegIS project found that climate change is likely to have a significant impact at a regional level although the scale of impact is still uncertain. Socio-economic development will directly affect the scale of impacts, so that society has an opportunity to anticipate this through its choices of policy and adaptation. See http://www.ukcip.org.uk/pdfs/Regis/ for more information. This project will be followed by ReGIS2, which will assess impacts, adaptation to impacts and policy responses of climate change. The project will develop tools for regional integrated climate change management. See www.eci.ox.ac.uk/biodiversity/regis2.htm for more information.

The remainder of this report provides a brief review of evidence presented in the literature, accompanied by **comments** on what this might mean for the Brecon Beacons National Park. These comments are not opinion as such but food for thought. They do not necessarily reflect the opinion of the Brecon Beacons National Park Authority. National Parks would appear to be well positioned geographically in the UK to play a significant role in helping Wales and the UK to adjust to climate change.

The facts about climate change - the basics

Temperature etc

There is still some uncertainty about the scale of change but most climatologists agree that it is occurring. The Wales Assembly Government (WAG) agrees that rapid change is occurring (WAG 2000, 1). Therefore climate change needs to permeate decision making now. The UK Government believes that we need to change the hearts and minds of the nation and be prepared for the psychological impacts of climate change on tourists and residents (Department for the Environment, Transport and Regions (DETR) 2000, 2).

[2] Phenology is the study of the times of recurring natural phenomena especially in relation to climate change. See also www.phenology.org.uk - the Centre for Ecology and Hydrology is inviting anyone to e-mail their observations of first emergence or sighting of plants and animals each year, in order to record changes in the annual calendars of these species.

The consensus is that the climate is warming up at a hitherto unprecedented rate - global warming. The greenhouse effect, whereby carbon dioxide (CO_2) is trapped naturally by the earth's atmosphere and thereby retaining heat is being 'turned up' too quickly. This is being caused by CO_2 emissions given off by the consumption of fossil fuels - oil, petrol, diesel, natural gas, coal - which the global economy has become too reliant upon. The UK Climate Impacts Programme (UKCIP) has developed 3 scenarios of climate change based upon slight, moderate and high increases in average annual temperature and these are updated periodically. Annex 1 in this report provides a summary of these as they affect mid- and south Wales.

Until recently the atmospheric CO_2 concentration has remained stable for the past 420,000 years. The recent and current increase in CO_2 concentration is unprecedented during at least the past 20,000 years. Atmospheric carbon levels were estimated to be 280 parts per million (PPM) in 1750, they were measured at 315 PPM in 1958 and about 375 PPM in 2000.

The Earth has warmed by about 0.6℃ during the 20th century. Of itself this does not seem particularly significant. Yet new analyses of data for the Northern Hemisphere indicate that this atmospheric temperature increase is likely to have been the largest during any century since 1000AD (CLA 2001). Furthermore the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report predicts an increase in the mean global temperature of between 5℃ and 6℃ by 2100. By comparison temperatures rose by about 0.05℃ to 0.1℃ per century since the last Ice Age. The current rate of increase is about 0.2°C to 0.3℃ per decade (CLA 2001) or 2 - 3℃ per century (20 to 30 times as fast).

The IPCC has predicted recently that contrary to previous forecasts of a 1.5m - 3m sea level rise during the 20th century onwards, the sea is likely to rise between 7m and 13m, although the time scale is unclear. This is as a consequence of the slow spread of heat to water in the deep ocean depths (water expands as it is heated, thereby increasing the volume of water), adding further to the destabilisation of polar ice sheets. Therefore even if CO_2 emissions are stabilised and even reduced, deep ocean heating is likely to continue for the next 1000 years (New Scientist 2000). The increased volume of seawater around the globe will have a direct impact on the exchange of atmospheric gases (mainly nitrogen and oxygen) and this in turn will have a direct effect on the growth rate of plants and the distribution of species that rely upon them. This effect is in addition to the effects of increased air temperatures and changing weather conditions.

In Wales, the period between 1901-1998 has shown warmer autumns and winters, with 5 of the 9 warmest years during 1989-1998. In mid-Wales, the UK Climate Impacts Programme (UKCIP) predicts that winters will become wetter and milder whilst the summers will be drier. The daily intensity of rainfall etc. will increase in winter and decrease in summer (autumn increasing slightly, spring decreasing slightly) (Wales Assembly Government (WAG) 2000, 2). The WAG has identified the need for regional climate change models in Wales, i.e., even in a country as small as Wales there is a need for a regional response to climate change because its effects may differ in different parts of the country.

10% of designated sites in the UK (Sites of Special Scientific Interest etc) would be lost during a 1-2℃ temperature increase, i.e., during the period between 2020-2050, though most of these would be coastal sites drowned by sea level rise (Hossell et al. 2000). The range of plants and animals present on designated sites would change in up to 50% of them sites during a 1℃ rise (i.e., after 2020s). There is still a high level of uncertainty about the impacts of climate change on individual species or these species' contributions to ecosystem functioning (DETR 2000, 2). The MONARCH project is investigating these impacts.

Current National policy responses and research needs

International policy

Whilst great play is made of the Kyoto Protocol (wherein the nations of the world apart from the US have signed up to reducing their own CO_2 emissions), this Protocol will have only a minor impact on slowing climate change. This is due to all the other contributory environmental factors that have been set in motion by climate change itself and over which the Protocol will not exert any influence (Jeff Jenkins, Europarc 2000).

The 6th European Union Environmental Action Programme puts climate change at the heart of European policies (CLA 2001). Environmental Action Programmes are the processes through which the EU states its intent towards the environment. This has an effect on land use planning, agriculture, wildlife conservation, energy and water production and consumption and so on.

National policy

The Wales Assembly Government (WAG) develops its policies with a keen eye on EU programmes. As well as mitigate the effects of climate change, Wales needs to react explicitly because of its

- Lower GDP and poorer skills base, giving Wales a poorer ability to respond to changes
- Relatively higher proportion of Britain's primary and manufacturing industry
- Eco-tourism is so important to the Wales economy
- Rural issues, livestock, forestry - are all affected directly
- Upland ecology is particularly sensitive (see wildlife responses below), as well as coastal ecology
- Relatively higher proportion of Protected Landscape Areas and designated sites in Britain
- High spatial variability in climate, i.e., local climate cells.

Wales requires integrated planning, co-operation across all sectors and a much greater willingness by decision-makers to understand these new and yet fundamental issues in order to make the right decisions, based upon new analyses and new priorities. The WAG, within the UK Climate Impacts Programme (UKCIP), intends to support research into the effects in Wales upon freshwater, uplands, agriculture, forestry, and local climate changes (WAG 2000, 1).

National Parks have a role to play in climate change mitigation studies. National Parks were mentioned frequently during the Wales study (see WAG 2000, 2) as vehicles for promoting integrated planning responses to and assessment of climate change (Iain Brown UKCIP, personal communication). So far this has lead to the second phase of the MONARCH project setting up research scenarios in a range of UK locations that include Snowdonia National Park.

Protected wildlife sites

"*While nature conservation policy comprises a variety of instruments ranging from strict legal protection of individuals of defined species, to voluntary schemes aimed at enhancing particular habitats, the prevailing focus is on protected sites. This is a 'static' mechanism, the success of which requires certain specified features of interest (e.g., a habitat type or populations of particular species) to be maintained in a functional state within a delimited area. Even in terms of conventional nature conservation management, there are inherent difficulties in rigid adherence to this approach. It denies the dynamic nature of functional ecosystems and of species' populations. Containing a population within a specific location or constraining a system against natural successional change requires active management."* (Hossell et al. 2000)

In other words, maintaining wildlife populations within defined sites requires considerable resources. Wildlife moves around, its needs change over time and this is being accelerated by climate change. Wildlife's ability to fulfil its needs will be tested severely by climate change and the systems that we currently rely on to 'provide enough space' for nature must be altered. Otherwise some wildlife will run out of space and out of time, leading to its local extinction.

Current Government and local authority legislation and prevailing attitudes may not offer sufficient flexibility to accommodate the necessary landscape-scale changes needed for wildlife to respond effectively to climate change (Hossell et al. 2000). So an integrated approach needs to be encouraged through policy guidance.

Hossell et al. (2000) suggests that the Countryside Council for Wales and English Nature should designate Sites of Special Scientific Interest with an eye to the future, whereby they designate additional and adjacent areas into which the designated habitats and species can shift as their 'climate envelope' shifts too. Hossell also suggests that these agencies should increase their spending power to acquire large tracts of land. Elsewhere Hossell et al (2000, 2003) suggest that where designated site boundaries no longer contain the special interest because it may have shifted elsewhere, conservation policy may need to include the ability to "let go" and also to set better priorities about where protective conservation efforts are needed.

> **Comment: Whilst of course it would be fair to the landowner of a statutory site to amend the designation when the special interest changes, this general suggestion for a more flexible designation system might become very complicated as well as very expensive. It would require strong and well reasoned justification to designate other land based upon its potential to support threatened habitats and species *in the future*, i.e., without any scientific evidence at the time of designation. Predictive science would need to become much stronger than it is currently in UK nature conservation. Also, this approach might still prove insufficient for the most sensitive or vulnerable habitats and species, which are unable to migrate elsewhere or are inextricably linked to particular environmental conditions. For example semi-natural ancient woodland, raised bogs and other mire communities would not be able to respond.**
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> **There are mechanisms available already to achieve some of this, for example the identification of non-statutory wildlife sites or features in the landscape of importance to flora and fauna (Regulation 37, Habitats Regulations 1994). It might also be possible to make more provision for changes in a habitat's or species' climate envelope (the geographic zones in which the climate is suitable for the habitat's or species' existence) through allocating more land for biodiversity in spatial planning strategies.**
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> **Perhaps it would be better to adhere to a set of conservation principles rather than making nature conservation land designation even more complicated. These principles might be:**
>
> - **Bring all existing priority habitats into as good ecological condition as possible in order to maximise survival chances of vulnerable species - to 'stockpile' biodiversity in anticipation of losing it in future.**
> - **Expand all priority habitats wherever possible**
> - **Establish a series of zones for wildlife that permit the development of a hierarchy of land use policy**
> - **Be willing and ready to respond rapidly to the arrival of vulnerable species in new areas through managing that land appropriately.**
>
> **For example the BBNP could develop core zones for wildlife that are linked by corridor zones and buffer zones where land use and other activities are conducive to sustaining and encouraging vulnerable wildlife.**

During a Europarc conference on Protected Areas and Climate Change (2000), the following responses to climate change within protected areas were discussed:

- Ensure the areas are ecologically robust
- Consider deliberate intervention in order to maintain species populations in situ whilst prevailing conditions change
- Include climate change mitigation and adaptation strategies for each species/habitat action plan[3]
- Encourage a policy shift towards large scale habitat restoration and recovery of ecosystem function
- Support appropriate research that includes species by species examination of the most appropriate way to conserve them
- Shifting, dynamic zones are needed for habitats and species to migrate into; more examination is needed on the role of habitat corridors and wider spatial planning
- Bigger wildlife areas needed alongside better ecological co-ordination of close, smaller areas
- Assess future land values and time scales during which these values will change
- Current wildlife and planning legislation is inadequate to address any of these needs
- Property rights create inertia in achieving changes to spatial planning
- Need managed re-alignment of land, during an era when currently there is not enough land available to meet UK BAP targets.

Comment. So perhaps within a National Park the key is to accommodate all these responses in a holistic, dynamic landscape, and permit these changes to continue, thereby intervening less on the small scale, and integrating and observing more. In this way a strategic response could prove most effective but would require serious and long-term co-operation between policy makers and policy implementers. There are already signs that the policy thinking is in the right direction. For example the WAG is supportive of the Environment Agency Wales' Catchment Flood Defence Management Plans (for inland catchments) to achieve integrated flood alleviation. And meeting the targets that are being set in response to the EC Water Frameworks Directive will strengthen this work.

The Forestry Commission recently completed a local consultation within the Brecon Beacons National Park on "Re-shaping the Uplands". In this the FC is planning to replace the large, uniform blocks of coniferous woodland with broadleaf woodland that is better suited to the upland conditions and ecological requirements in the Central Brecon Beacons. On the Continent experiments are underway on permitting large areas to become semi-wild again, where human intervention is replaced by the sole activities of large grazing animals. These large "near-natural areas" are sited in order to link former habitat fragments by allowing the intervening former farmland to revert to its semi-natural state. This approach has arrived in the UK (see for example http://www.kentwildlife.org.uk/beaver/nna.htm). The Wales Spatial Plan provides an ideal opportunity to accommodate this approach.

Agri-environment schemes are already in a position to help co-ordinate a wildlife-friendly response to climate change. (Hossell et al. 2000). They could be used to provide buffers around designated sites, as well as being more species-focussed. Other incentives could be used to provide stepping stones in intensively farmed areas where their take up is poor.

Comment. The WAG has launched a new agri-environment Entry Level Scheme - Tir Cynnal, which requires every farm to adhere to a minimum standard of

[3] Habitat and species action plans are prepared under the auspices of the UK Biodiversity Action Plan and Wales Biodiversity Action Plan. These national plans are implemented through a series of local biodiversity action plans, including that of the Brecon Beacons National Park - "Our Natural World - a local biodiversity action plan for the Brecon Beacons National Park".

environmental management over and above that required by cross-compliance rules. For the more ambitious farms, applying for the existing higher level Tir Gofal payments would be possible particularly where the entry level basic payment has enabled the farm to qualify for Tir Gofal. A further top tier above Tir Gofal is envisaged where groups of farmers and other landowners are paid to work together to achieve area-based environmental benefits, for example on commons. Therefore it may be possible at this level to adjust ecological conditions within areas to make them more responsive to climate change and more receptive to particular habitats and species.

However this might also prove to be complicated and cumbersome, and might only succeed where the scheme is applied in a strategic way, with sufficient help available to farmers at the basic entry tier to anticipate this sort of co-operative work in the future. Also, it might only succeed within an environmentally led spatial planning framework that accommodates climate change. Research into indicators of climate change (WAG 2001) might hopefully be brought to bear on this framework.

Carbon sequestration and land use

Carbon sequestration (storage) is a possible area-based response to alleviating climate change, i.e., the locking up of carbon in order to reduce its contribution, as CO_2, to global warming. The Country Landowners and Business Association (CLA 2001) lists the following benefits from following an explicit carbon sequestration land management remit:

- conversion of arable to agro-forestry locks away 3.1 tonnes of carbon per hectare per year
- whereas conversion of arable to grassland locks away only 0.8 tonnes carbon per hectare per year
- and improving crop and grazing management locks away 0.3 to 0.7 tonnes carbon per hectare per year.

The CLA estimates that through changes in agricultural crops the UK could sequester over 600 tonnes of carbon per year whilst maintaining current food production at a more efficient carbon emission rate of only 0.95 tonnes carbon per hectare per year. The CLA believes that sustainable farming practices can be encouraged through incentives under the Common Agricultural Policy and by encouraging sequestered carbon to be traded, if the amount of carbon sequestered in the soil is calculated. A number of carbon-trading systems have been established in Canada, the US, and Japan. For example, a group of Canadian utility and energy companies have agreed to pay Iowa farmers for sequestering carbon. The price of sequestered carbon is still very varied and in its infancy. More information and advice is available from the UK Carbon Trust (see www.thecarbontrust.co.uk/TheCarbonTrust/Default.htm).

Comment. Would it be possible to include carbon sequestration in the new entry-level agri-environment scheme? It might be possible to develop a 'carbon budget' for the BBNP, which might be of assistance to businesses that are keen to take part in the UK Emissions Trading Scheme[4].

Suggestions such as these are driven by the realisation that the main long-term goal must be to reduce the use of fossil fuels (CLA 2001, The Royal Society 2001). By growing or reverting to woodland and semi-natural meadows and pastures to provide carbon sinks - places used to store

[4] The UK Emissions Trading Scheme (see http://www.defra.gov.uk/environment/climatechange/trading/ukets.htm) allows companies to trade their CO_2 allowances with other businesses.

carbon - the UK could meet 25% of its global carbon sequestration targets by 2050. More than this would not be possible (The Royal Society 2001). This is because woodlands planted as carbon sinks would have limited use once the trees start to emit CO_2, i.e., beyond about 50 years.

> **Comment. Perhaps this reduction in carbon storage capacity in older trees could be avoided by ensuring that other economic products are developed from these 'carbon woodlands' prior to this 50-year watershed, thereby felling and replacing the trees before they reach this age. These second generation products might include conversion as bio-fuels (provided that the CO_2 generated from burning the wood as a fuel is more than balanced by the carbon locked in the parent carbon woodlands!) or other more valuable timber-based products. Also, more effective spatial planning, combined with good fiscal measures could increase the amount of land available for carbon sequestration in woodlands, meadows and biofuel crops.**

Wildlife responses

For all species likely to be affected, scientists are predicting large-scale responses by them. These might include changes in population sizes, changes in the balance between predators and prey (and hence the entire food chain) and changes in competition between different species and individuals of the same species. We must also be prepared for the negative impacts of drought on valuable wildlife and also pest species.

Thomas et al. (2004) predict that between 18% and 35% of all known species will be made vulnerable to extinction, based upon the 3 climate change scenarios (i.e., from minimum to moderate to severe) used by the UKCIP. These losses are larger than those caused by habitat loss and fragmentation. They do not take into account the combined effects of climate change with other causes of extinction such as habitat loss, species invasion, build up of CO_2, disease and so on. In other words, these predictions may underestimate the severity of the events that are unfolding.

The following paragraphs summarise the observed and predicted impacts of climate change on species (from Cook and Harrison 2001, CEH 2001, Honnay et al 2002, Hossell 2000, Hossell et al. 2000, Hossell et al. 2003, Rhys Green at Europarc 2000, Tim Sparks at Europarc 2000, Green et al. 2001, Kirby 2003, Berry and Butt 2002).

> **Comment. The Brecon Beacons National Park is partially equipped to make some responses to these impacts by ensuring that its local biodiversity action plan ("Our Natural World") is implemented effectively. Implementing the various habitat and species action plans should provide more habitat diversity to buffer against the adverse effects of climate change, offering more options for more ubiquitous wildlife to survive and adapt.**
>
> **However, the long-term effectiveness of current conservation efforts could be undermined by the changes outlined in this report, for example the changes in habitat quality and distribution. At the very least it is probably prudent from now on to include habitat and species restoration targets that take account of climate change.**

In order to understand what responses to climate change are needed it is useful to understand the complexity of how creatures are likely to respond. Species respond to stress either by adapting, moving or becoming extinct where neither adaptation nor moving is possible. Adaptation includes physical, physiological, phenological (governed by the prevailing environmental conditions each season such as air temperature, daily amount of sunlight and rainfall) and behavioural adaptation, as well as reliance upon the local environment providing a sufficient range of conditions and opportunities to allow creatures to disperse to new areas or

adapt in other ways. Not all creatures have good dispersal capabilities however and are vulnerable to local extinction without adjacent areas being restored to suitable habitat conditions for them. Even this may not be sufficient for sensitive and vulnerable habitats and species.

For example Honnay et al. (2002) have found that vulnerable ancient woodland plant species need to be able to migrate across distances of between 3000m and 5000m each year (3 to 5 kilometres) if they are to keep up with the effects of climate change. And yet since the last glaciation the furthest that rare temperate plants have ever been recorded to migrate is only 100s of metres per year. Even this was dependent upon chance events (wind, water, carried by animals) and occurred during a period when habitats were less fragmented and isolated than they are today. Honnay et al. found that these specialist ancient woodland plants, which rely upon a wooded canopy, were only able to migrate a few metres per year if at all. So if these species are not to be supplanted by more ubiquitous ones, intervention may be needed such as translocation, ex-situ conservation or releasing the buried seed bank on other areas of suitable land where conservation is currently not a priority.

Annual plants and weeds (as well as invertebrates and microbes) will respond better to climate change. This is owing to their shorter generation times and higher rates of reproduction, thereby increasing their adaptability to new conditions with each successive generation. Whereas longer-lived creatures (specialist birds such as raptors, upland waders, some mammals, perennial plants, trees) will struggle to adapt to changing conditions given their lower reproductive rates and poorer dispersal powers (WAG 2000, 2).

Whilst invasive species will face similar limitations on their dispersal in future, their behaviour as generalists or as species with few or no natural competitors may allow them to respond more rapidly to the effects of climate change than native species. Berry et al. (2003) explain that downy or white oak *Quercus pubescens* is already present on a number of private estates. A major limiting factor to its dispersal is the maximum average summer temperature. The latter is expected to increase in future so where it can overcome barriers to dispersal downy oak may colonise lowland woodlands where other species such as beech may compete less well.

Table 5 (p. 13) in Hossell et al. 2000 provides a useful list of observed and projected adaptations (see www.wildlife-countryside.detr.gov.uk/climatechange/nature/index.htm).

The following sections summarise the evidence for and effects of climate change provided by the natural world in Britain. Such evidence is growing continually, for example:

- Oak trees now come into leaf 50 days earlier than 50 years ago
- Snowdrops, potato aphid, toad migration to breeding ponds, birds nesting and arrival of migrant bird species such as swallow, swift, willow warbler all occurring up to 50 days earlier
- In the Brecon Beacons National Park hawthorn has been observed coming into leaf during November, whilst hazel catkins are appearing in December and January
- Extra atmospheric CO_2 produces a "fertilisation" effect on trees, whereby they increase their rates of photosynthesis, which in turn could have an effect on soil nutrient availability for the trees and other plants
- Earlier bud break could expose trees to frost (even though incidence of frosts will decline)
- Lack of winter freezing - 'vernalisation' - could affect plant seeds that rely on this in order to break dormancy each spring, leading to a decline in the natural regeneration of these species
- Pests will benefit, pathogens will increase more rapidly, deer and grey squirrel will survive winters in greater numbers. Invasive species already present will spread to new areas. Native species will migrate (where possible), invading new areas. The English Channel may limit new migrant species.

- Species in S. Wales at the northern limit of their geographical range may spread northwards or to new areas that provide suitable conditions
- Species in S. Wales at the southern limit of their geographical range may retreat northwards or to new areas that provide suitable conditions

- Flowering plants are likely to exhibit a range of responses: -

  - Already the timing of plant life cycles is changing (e.g. bud burst and germination).

    Future impacts may include: -

  – Changing species distributions
  – Loss of some species but introductions of others
  – Net primary productivity (the volume of living plant material produced) will change in response to changes in temperature and atmospheric CO_2, which will have a direct effect on the rest of the food chain
  – Ruderal, annual 'weedy' species may become more prevalent, at the expense of stress-tolerant perennials.[5]

Changes in population distributions in response to climate change may be inhibited by current landuse in the UK, where the landscape is dissected not only by topography and natural surface features but also, increasingly, by development, transport routes and intensive farming.

Effects on butterflies

Current and future trends

- In general the warmer the average annual temperature the earlier butterflies appear and the wider their distribution. That is, the more warm days an area experiences each year, the more suitable this will be for a range of butterflies, given the right habitats and food plants for their survival.
- The orange tip butterfly photo now flies 2 weeks earlier, coinciding with earlier flowering of its food plant garlic mustard.
- 26 other species now appear earlier in the year.
- Prolonged warm periods also have a direct effect on butterflies' dispersal powers. For example when summer temperatures in France rise above a certain threshold this produces an increase in butterflies crossing the English Channel to Britain - red admiral, pale clouded yellow, painted lady and hummingbird hawkmoth are all examples that have been witnessed in the BBNP (personal observation).
- Longer flight periods mean that for species producing one set of young each year (univoltine), they appear earlier and remain for longer. For species producing several generations each year (multivoltine), more generations are produced per season. This capacity to change life cycle patterns has always been observable within some butterfly species and as a consequence of climate change might be observable in others now. For example, common blue and small heath are known to produce 2 generations each year (bivoltine) in southern Britain but just one generation (univoltine) in northern Britain; the peacock is univoltine in Britain, bivoltine on the Continent.
- During the last 2 decades 14 species have extended their range beyond their previous northern limits; the speckled wood is the most cited example. Another, the chalk hill blue

[5] An increase in annual and 'weedy' species might increase species richness but if this is at the expense of less competitive annual and perennial species, this might be a negative change. Annual species generally have short root systems or lack a large root mass (relying instead on one main taproot). Their proliferation could contribute to a decline in soil water retention and nutrient retention (which already is poor in the hills in the Brecon Beacons National Park), high energy losses and decline in ecological quality.

is no longer limited to warm south-facing slopes of short, tightly grazed chalk grassland but is now recorded 5km further north beyond these habitats in southern England.

- Conversely *extreme high* temperatures exert a negative influence on butterfly distribution owing to the physiological stress it causes them, as well as the loss of food plants. So for species that rely on cooler temperatures such as the [brown argus - choose a species that is characteristic of the BBNP], they may retreat northwards, reducing their distribution in Britain.
- Spring temperature affects caterpillar development, whereby they mature 1-10 days earlier for every 1^0C increase in temperature. Similar related changes have been recorded for nesting birds - long tailed tit nesting 4.1 days earlier and blackcap arriving 2.8 days earlier, and oak leafing 7.8 days earlier, on average. Some birds including the chiffchaff and blackcap may stay on during milder winters rather than migrate and this may displace other migrant warblers from breeding territories when they arrive each spring. (Read more about birds below.)

Effects on fish, amphibians and reptiles

Current trends

- Annual patterns of behaviour in response to environmental factors - phenology - are changing. For example lizards, snakes, the common frog and common newt are breeding earlier each year.

Future trends

- Change in the timing of salmon spawning in response to altered river flow conditions - with the large effort currently underway in the National Park[6] to restore salmon and trout spawning and nursery areas, this could become a significant issue in future
- Increased temperature stress on cold water fish species such as salmon and trout (temperature changes affect oxygen availability in the water, as well as the food chain).

Effects on birds

Current trends

- Earlier breeding, laying larger clutches and raising more young. Almost one third of British birds are laying eggs earlier by 9 days on average
- Increased winter survival rates of resident species (e.g. blue tits and great tits), bringing them into closer competition with migrant species for limited resources such as food and nesting sites
- Changes to breeding ranges
- Changes to wintering ranges (e.g. blackcap and white-fronted goose)
- The *predicted* movements of three genera of birds that include residents and migrants (tits in woodland, leaf warblers in scrub and bush warblers in hedgerows) have been modelled against *observed* or *known* movements. This work has shown that, with the exception of bush warblers especially resident species, resident and migrant birds of all genera cannot move in response to changes to their climate envelope.

[6] Several projects are underway to improve riparian - waterside - habitats in the Brecon Beacons National Park. These include the Wye and Usk Foundation (www.theriverwye.co.uk/newpage3.htm), the Environment Agency Wales' Sustainable Fisheries Programme (see http://www.environment-agency.gov.uk/commondata/105385/sustainablefisheries_e.pdf) including various salmon action plans as well as the "Fishing Wales" Objective 1 project, the surveys and eradication work for damaging invasive species such as Himalayam balsam, giant hogweed and Japanese knotweed and the outputs available from the European Union-funded LIFE Rivers Project (see www.english-nature.org.uk/LIFEinUKRivers) that will benefit both the Wye and Usk rivers.

- Many British species winter in West Africa, where there have been successive droughts during the past 30 years. No one fully understands what triggers species to migrate to Britain but already fluctuations are being observed in numbers of sand martin, sedge warbler and whitethroat. No one knows if the swallow will continue to be able to synchronise arrival from W. Africa with optimal food availability in Britain.

Future trends

- Loss of breeding & winter feeding grounds for waders (e.g. redshank) is expected due to sea level rise; this will affect their numbers and distribution in upland areas
- Hot dry summers will lead to more weed infestation of rough pasture, prompting its intensification and consequent loss of nesting habitat for birds
- Farmers may lose the spring cultivation window prior to the bird-breeding season if ground-nesting birds nest earlier in the year.
- On livestock farms despite the grass growing earlier in response to milder winters farmers will not be able to get machinery out and may not be willing to turn out livestock because the ground will also be much wetter or flooded. This might benefit nesting waders but not other ground-nesting birds.
- The arrival and numbers of vagrant species will change
- Where chicks are reared earlier they may be killed by spring chills in damper weather
- Ground feeders (thrushes, blackbirds) may benefit during wet springs from worms, slugs and snails but insect feeders could suffer during summer droughts where invertebrates retreat into ground or die off, making feeding difficult for lapwing, curlew, snipe as well as garden birds.
- Birds at the edge of their northern distribution could benefit - willow tit, nuthatch, nightingale
- Earlier availability of caterpillars for chaffinch, blue tit, great tit and willow warbler could be offset by shortages later in the year.
- Population crashes are possible during autumn storms.
- Gardens will become even more important to the more ubiquitous bird species such as sparrows, thrushes, blackbirds and finches.
- The dipper and red grouse could become more scarce or locally extinct as conditions become too mild for these species, which are at the southern end of their geographic range in south-west Britain.

Effects on mammals

Future trends

- Southern species may move further north (e.g. lesser horseshoe bat) but this is dependent upon the availability of suitable roost areas in buildings, caves and other structures, as well as foraging areas
- As with all animals mammals may survive better during winter, thereby increasing their population sizes and hence the competition for resources including land
- Conversely hibernating species such as bats, dormouse and hedgehogs may be detrimentally affected by warmer winters that disrupt hibernation patterns.
- Alternatively bats might benefit where they enjoy increased insect abundance and milder winters that permit more feeding activity.

Basic responses by plants (after Hossell et al. 2000)

Increases in atmospheric CO_2 concentration will cause plants to increase their rate of photosynthesis (the process by which green plants use energy from sunlight to convert CO_2 and water into glucose, their main 'food'). In response they will improve their water efficiency and reduce their water uptake through their roots, i.e., they will become more drought-resistant and other drought-resistant species may be encouraged. Plants will grow larger during longer and earlier growing seasons. This will benefit pest species and aggressive species too. There will be fewer frosts, leading to less die back of plants each winter but an increase in water returned to

the atmosphere by evaporation and transpiration from the ground and from plants, i.e., more groundwater lost through plants.

Changes in the number, length and strength of rainfall events, drought and storms will be accompanied by changes to surface water run off, soil moisture retention, floods, water-logging, erosion, drought frequency, wind thrown trees and so on.

Current nature conservation designations and land use planning in Wales could be undermined through the loss of entire vegetation communities, producing significant changes in the landscape (Wales Assembly Government 2000, 2).

> **Comment**. **More rainstorms during winter and less rain during summer could amount to less groundwater overall. If rainfall increases during winter, this might exceed what the land absorbs or is held in rivers and reservoirs, with the rest lost as surface runoff. This would amount to an overall loss of water each year, leading to more water shortages. Increased evaporation and transpiration could exacerbate water loss, particularly by plant monocultures - large-scale crops, large-scale areas of uniform landuse. Therefore the most suitable response might be to maximise biodiversity within the landscape as much as possible, to increase the number and extent of habitats in order to reduce this uniformity and maximise water retention. It might also be prudent to investigate the water budget of the current landscape in the BBNP, in order to understand whether this might be improved through different land use patterns.**
>
> **There will be more water shortages owing to summer droughts and insufficient capacity to store increased winter rainfall. There could be increased pressure to build more reservoirs in the Welsh uplands.**

<u>Effects on lowland habitats and plants</u>

Future trends

- Lowland raised bog - drying out and erosion is a possibility, particularly on degraded or otherwise damaged bog surfaces; where the bog surface is not damaged significantly, evapo-transpiration rates could increase; bogs would become susceptible to damage from even the lightest grazing pressure; otherwise species such as *Myrica gale* (bog myrtle) and *Sphagnum papillosum* (one of the cushion-forming bog mosses) could benefit
- Low river flows may need recharging in summer
- There are as yet unknown effects on the nutrient dynamics in soils and water
- Mistletoe could spread further north
- Bluebells could flower earlier in warmer weather or they may decrease if springs become drier
- Pest species such as *Rhododendron* and Himalayan balsam could spread north
- Bird cherry may become locally extinct in its southern range
- These changes are made more complicated by the effects of acid rain, habitat fragmentation, and nutrient enrichment (WAG 2000, 2).

<u>Effects on upland habitats and plants</u>

Future trends

- Upland areas will be particularly vulnerable to changes because exposure to the prevailing climate conditions, as well as soil depth are already primary factors in habitat distribution, more so than in the lowlands, where other landuses also have a large effect.
- Hossell et al. (2000) provides maps that illustrate the vulnerability to climate change for a range of different upland habitats. They show that if the maximum average daily temperature in upland areas increases above 7^{o}C, these areas will lose habitats such as dwarf shrub heath and blanket bog except at locations where temperature stays cool

enough. For example, under the "medium-high" temperature increase scenario of the UK Climate Impacts Programme (which is based upon a $2^{o}C$ increase and 13% increase in annual precipitation), the maximum average daily temperature would rise above $7^{o}C$. This would cause a significant reduction in the extent of habitats such as dwarf shrub heath on the lower hills and slopes, where it would become too warm. On designated sites such as Sites of Special Scientific Interest, this translates to a 60%-80% loss of such habitats.

Comment. Within the BBNP, there has already been a significant and in some areas total loss of such habitats on the lower hills and slopes. This has been brought about for a variety of reasons. These include the loss of controlled moorland burning, an increase in uncontrolled and repetitive burning on the same areas leading to the concentration of unpalatable grasses and the invasion of bracken, and a decline in hardy cattle and ponies on the hill. This has been exacerbated by a simultaneous increase in sheep numbers, producing localised overgrazing in the places where grass is available. This leads to other problems such as soil and peat erosion, soil compaction, increased runoff during times of heavy rainfall and an increased risk of flooding in the lowlands.

The most appropriate way to anticipate further ecological damage caused by climate change is to get the remaining areas into as good ecological condition as possible over as wide an areas as possible in order to maximise the chances for species and habitats surviving.

Climate change could be significant enough to alter the environmental factors that have produced the characteristic upland habitats of moorland and blanket bog. These include:

- **Little seasonal variation in heavy rainfall and temperature (owing to the milder and equable weather provided by the Gulf Stream)**
- **Frequent cloud cover and high winds**
- **Thin mineral soils with low nutrient content (much leaching of soils) or alternatively deep peat layers that are permanently wet, depleted of oxygen that insulate the surface vegetation from underlying mineral soils and ground water.**

Some types of peat systems - mires - may survive the effects of climate change although their species composition may change. The characteristic *Sphagnum* mosses and higher plant species each exhibit their own responses to changes in water and temperature. More aggressive moorland grasses - such as purple moorgrass - would replace these more primitive water-loving plants on warmer or drier peats. Soil fauna would also be affected.

Bracken and purple moorgrass will spread upslope as heather moorland retreats, benefiting from the drier, milder winters during which there will be fewer frosts to damage the bracken fronds and less groundwater flow to inhibit the moorgrass.

Milder conditions may reduce cloud formation around higher altitudes in places like the BBNP (whilst possibly increasing cloud cover elsewhere), as well as squeeze the few Arctic alpine plants out of their moist, cool, high altitude slopes because there is nowhere higher for them to retreat to. They may persist elsewhere in Wales where their gene pool is big enough i.e., where their populations are not already fragmented and small and this is likely to be where hills are high enough to maintain them.

Prolonged dry summers followed by milder winters with more severe rainfall could lead to the drying out and oxidation of peat, followed by peat loss through erosion by wind and rain, with increased sedimentation of lowland rivers.

Predicting the future condition of moorland vegetation is made more complicated by atmospheric nitrogen deposition, acid rain, changes to livestock densities as a consequence of reform of the Common Agricultural Policy (CAP) and the precise response to climate change by different moorland species (WAG 2000, 2). Air-borne nitrogen pollution for example will continue to be concentrated over higher ground, most of which is coincident with National Parks in Britain (ECRC 2004).

Hossell et al. (pp. 14-26 and Appendix IV) provides a detailed account of the effects of climate change on habitats. Whilst this work did not examine effects on every possible species, of those that were studied the effects are predicted as:

- Montane heath - all species are adversely affected; *Salix herbacea* (dwarf willow) would disappear altogether in Wales
- Upland hay meadows - the distribution of *Trollius europeus* (globeflower) and *Geranium sylvaticum* (wood cranesbill) declines; presumably this will also be true where these species occur in permanent pasture as well as meadows
- Upland oak woodland - the composition of the ground flora will change; they may benefit from the increased atmospheric CO_2, average annual temperature and rainfall (Broadmeadow, 2000). This could be manifested by increased productivity (growth, leaf production, acorns) during longer, milder growing seasons with less winter frosts. There is a possibility for an increase in invertebrate, bryophyte, fungi and liverwort biodiversity
- Beech woodland - could expand within mid-Wales, whilst declining in south Wales, but such a shift would be dependent upon the seed dispersal of this species across a landscape of woodland fragments
- Wet heaths - could dry out, to the disadvantage of *Erica tetralix* (cross-leaved heath) and the advantage of *Erica cinerea* (bell heather); this may be unlikely in the BBNP given *E. cinerea's* very limited distribution on just one or two south-facing slopes at the southern edge of the Park
- Blanket bog - impacts will depend upon changes to current levels of year round rainfall and humidity; shallow peat will dry out, be oxidised and cause CO_2 to be released, adding further to greenhouse gas emissions
- Fens - will be affected by reduced summer rainfall accompanied by increased nutrient enrichment caused by higher microbial activity in the drier, warmer soils as well as carried in by groundwater from surrounding land
- Rhos pasture - reduced summer rainfall will cause drying out resulting in reduced water-logging and the loss of characteristic species needing a high summer water table; less water-logging may lead to the spread of dominant species such as *Molinia caerulea* (this might also occur on blanket bog)
- Limestone exposures and karst scenery - the reduced water supply would lead to reduced dissolution of limestone and deposition of calcium carbonate in stalagmites and stalactites; less rainfall and calcium deposition may lead to an increased rate of decay of existing features; drought conditions within the grikes - cracks - on limestone pavement might have an adverse effect on the characteristic flora
- Lakes, rivers, ponds etc - will experience changes in water volume, depth, flows, temperature, oxygen content and nutrient concentrations; increased sediment will arrive from erosion of the surrounding land during extreme rainfall, accompanied by further loss of river banks. Increased acidification is a possibility as well as reduced overall biodiversity. Floodplains may remain flooded for long periods of the year, with adverse effects on breeding birds, mammals and farming activity. More riverside trees may become dislodged during floods, causing economic damage and increased flood risk downstream. Puddles may remain for longer on footpaths, leading to more

damage during the winter and more erosion during the summer (this would occur in the uplands and lowlands).

- Alternatively the demand for increased abstraction during water shortages could lead to drought conditions on floodplain habitats.

Freezing winters? An additional scenario

Potential loss of the Gulf Stream as a consequence of melting Greenland icesheets and increased rainfall

The weight of effort currently underway in the UKCIP is directed at developing scenarios, advice and mitigation strategies in response to a warmer climate. This is highly complex work and must take into account a wide array of existing global phenomena. Through other research there is now a growing body of evidence to suggest that as a consequence of global warming there might in future be a dramatic cooling of the UK's climate each winter.

The UK and the NE Atlantic enjoy a warmer climate and milder winters than other areas of the world at the same latitude (such as Canada and Siberia). This is as a consequence of the Gulf Stream, which draws warmer air and water from south of the Equator past the Gulf of Mexico, and onwards north of the UK. Here the warmer water is cooled, becomes denser as a consequence of its salt content and then sinks. This heavier water is then drawn back southwest towards the Tropics - a continuous conveyor belt. A significant body of evidence exists to show that this conveyor has been 'switched off' in the past by a combination of events, resulting in prolonged cold periods. These past events appear to be related to mini ice ages recorded from the earth's history.

Researchers are measuring the volume of melting ice on the Greenland mountain glaciers, with estimates of 100 cubic kilometres melting each year, now entering the northern Atlantic as additional freshwater. Also, one of Greenland's largest glaciers is now advancing at 12 kilometres per year, 'sliding' across its own meltwater. These polar meltwaters, which are produced as a consequence of current global warming, are sinking towards the zone of the Gulf Stream where the heavier salt-laden water has been sinking as it is cooled at the northern end of its journey. Recent records of the salinity of the Gulf Stream conveyor show the sinking and southward-returning water to be significantly diluted. Scientists believe that the sinking water drives the conveyor that gives the UK the Gulf Stream. And yet if this heavy salt-laden water is diluted this will change the water's density, so it will no longer sink and the conveyor will 'switch off'.

In addition, further freshwater is arriving at this sink zone from the Ob, Enesai and Elena rivers carrying the additional rainfall that now falls over Siberia, also as a consequence of climate change. The discharge from these rivers each year has already increased by 180 cubic kilometres as a consequence of global warming. (Warmer air expands in volume, it can therefore hold more water and when this travels from the Tropics to areas like Siberia it cools, producing additional rainfall.)

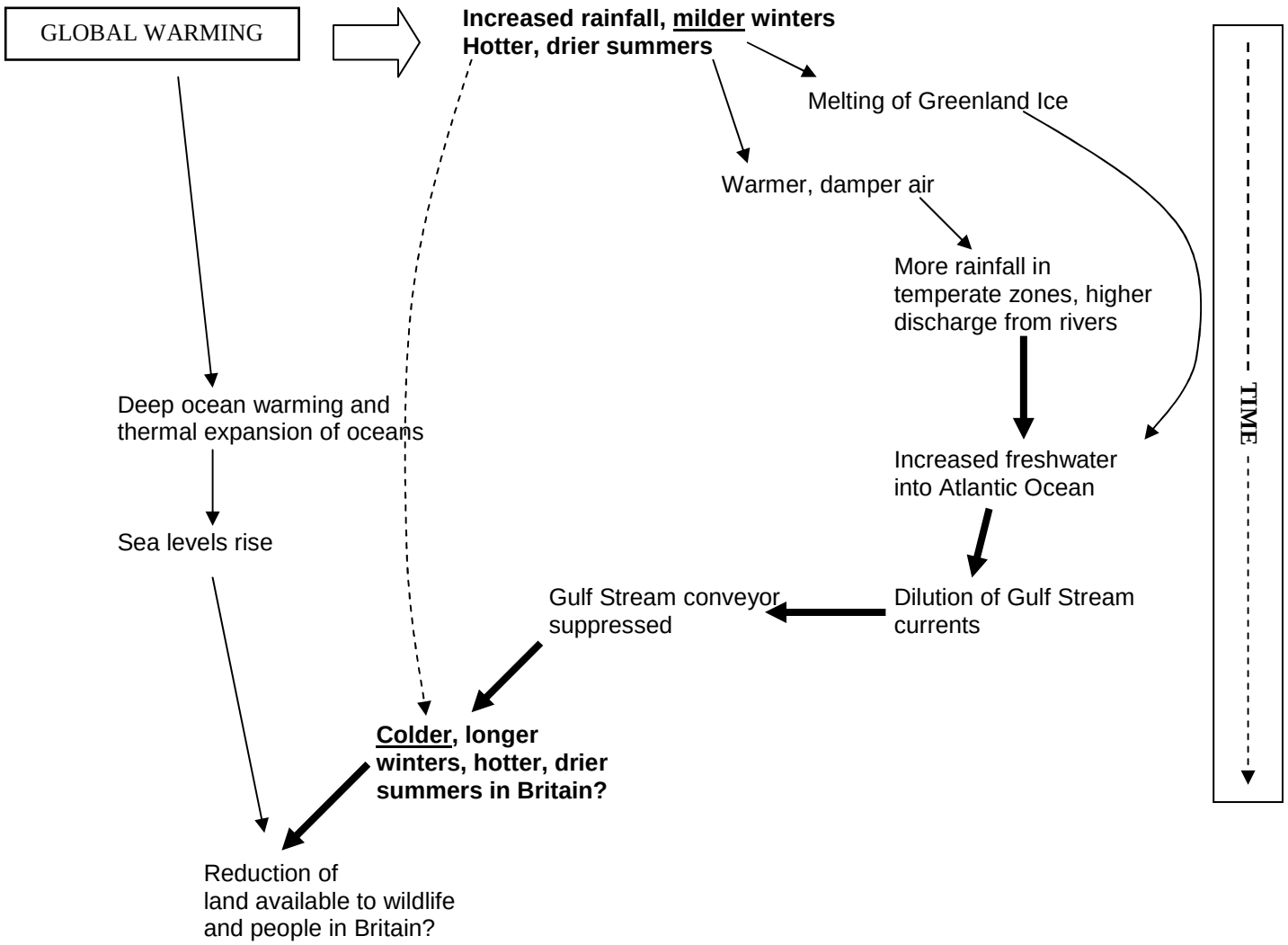
Already the conveyor's salinity has fallen by 20% since the 1970s. Scientists are unsure how much further it must fall before a critical threshold is reached and the conveyor switches off. The significant point is that as a consequence of the melting of the Greenland mountain glaciers and freshwater river discharges, the UK could become significantly cooler each winter in the next 100 years. This takes predictions of warmer, wetter winters in the opposite direction. This isn't to say that the UK's summers would be any less hot but the distribution of milder, wetter weather and warmer, drier weather might be different, with much more widespread snow and ice, during longer, harder winters. So in addition to the likelihood of milder, wetter winters, these might be superseded in time by the sort of colder Arctic winters experienced in other areas of similar latitudes, for example Canada and eastern Europe, which do not benefit from the warming effects of the Gulf Stream.

> **Comment. This would produce different responses in the distribution and survival of habitats and species but these responses might still be felt most strongly in the**

same vulnerable areas, i.e., in the uplands and freshwater systems within the BBNP as well as along the coast elsewhere in Wales.

The next page provides an illustration of the possible relationship between global warming, deep ocean warming and the switching off of the Gulf Stream.

Possible relationship between different forces at work in climate change
(Paul Sinnadurai)



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Appendix 1 Summary table of predicted 'warmer scenarios' changes to weather patterns in Mid-Wales (after Hulme et al. (2002))

Mid-Wales climate change scenarios These figures are adjusted by The UKCIP as accuracy of predictions improve; they are based upon temperature change scenarios caused by a range of low to high CO_2 emission levels				
Scenario →	**2010-2039**		**2070-2099**	
Variable	Winter	Summer	Winter	Summer
Average temperature change	+1°C	+1°C to +1.5°C	+1.5°C to +3°C	+2°C to +4.5°C
% precipitation change	+10	-10	+15 to +25	-20 to -40
% wind speed change	+1	-1	+7	+3
% change relative humidity	?	?	-3	-9
% change average winter snowfall	?	-	-40 to -90	-
% change soil moisture content	?	?	+4	-10 to -40
	Slightly warmer, much wetter, slightly more humid winters	Slightly hotter, less rainfall	Much wetter, warmer, windier, more flooding, extreme cold much rarer	Much drier, less humid, hotter, very hot summers more frequent - droughts?
	Effects will differ between uplands and lowlands and east and west, with wetter, windier west and drier, more equable east. More even temperature ranges between winter and spring, combined with larger annual fluctuations in summer temperatures are predicted, particularly under high CO_2 emission scenarios.			

Appendix 2:

Acting Now for Climate Change
A Position Statement by the Association of National Park Authorities

April 15 2004

What the Headlines might say in 20 - 50 years from now:

The following are fictitious headlines for 20 - 50 years hence. They set the scene for how National Parks might change, either by allowing climate change to happen without any response or by taking steps to manage the changes.

Wildlife disappearing from National Parks as climate change marches on

A report to be published today states that National Parks have underestimated the changes to farming and wildlife caused by climate change, as well as damage to the nation's cultural heritage.

The Parks are fighting a rearguard action to keep back the spread of weeds, bracken and poor quality grasses as important wildlife struggles to survive on some of Britain's most important moorland, coastal grazing marsh and other wetlands. Farmers and other local people are up in arms because the National Parks didn't anticipate the effects this would have on farming and other rural businesses.

Ever keen to stay onside with public opinion, National Parks have always stated that climate change is inevitable and that there isn't much that can be done to prevent it. But their sternest critics have long argued that even if we cannot stop climate change, the Parks should have worked harder to help people and wildlife to cope with its effects on the land.

OR ALTERNATIVELY

Everyone benefits as expanding wildlife pushes the boundaries in National Parks

A report published today announces that new businesses and farm enterprises are flourishing in National Parks. Leading the way in environmental responses to climate change, National Parks have successfully anticipated where new business opportunities will arise.

"The key is persuading people to think differently," says a spokesman. "In the past we have been just like everyone else, with a place for everything and everything in its place - buildings here, farming there, forestry here, reservoirs and waterways there. Whilst the main purpose of National Parks, conserving the landscape, wildlife and cultural heritage has had to squeeze in between.

"Now climate change has forced us to re-think all that. Now that the more extreme activities such as skiing are no longer an option, we recognised early on that if businesses are to survive and flourish we have to increase the Parks' environmental assets. This means modifying the boundaries and attitudes that prevent change, so that more landscape, wildlife and culture can be conserved alongside new enterprises than ever before.

"For example, by growing wood as a biofuel, farmers also lock in carbon dioxide, provide cover for wildlife, influence livestock production and of course support renewable energy generation. This in turn stimulates more renewable energy

initiatives and enriches the landscape for locals and tourists alike. Climate change has been a real launch pad for us."

Floods get the better of National Parks

Flooding in National Parks is now an annual event. This is the conclusion of the Government's environmental watchdog in its annual report published today. The report concludes that not enough has been done within National Parks to prevent this.

"Clearly there are measures to be taken that would benefit the Parks and the economy and lives of people around them", a spokesman says. " Upland areas should include more wooded valleys and hillsides and heather moorland should be in better condition so that we can reduce the amount of runoff that causes floods. This would give us less erosion, less pollution and more space for wildlife to move around in, which is essential for wildlife to adapt to climate change. The last thing we want is people clamouring for more reservoirs to be built in the Parks just to hold back floodwater."

The watchdog argues that National Parks aren't able to keep up with the Government's planning guidance for climate change and that they are failing to prevent householders and businesses from putting themselves in the way of flooding. However this is not all the fault of Parks. "If they had more teeth to lead initiatives and other organisations had not been too distracted by their own climate change agendas, then perhaps we would all recognise the crucial strategic role that National Parks can play."

OR ALTERNATIVELY

Neighbouring authorities embrace their National Parks as they take on climate change together

Today sees the launch of a series of 'bio-regional environment plans' linking environmental initiatives between National Parks and neighbouring local governments. The strategic and geographic location of National Parks is proving crucial in Britain's efforts to adjust to climate change.

By working together, local governments and National Parks achieve more for sustainable development, economy, farming and quality of life than by working independently. This also assists other organisations, who otherwise must establish separate partnerships with each local government and Park.

With a higher proportion of Britain's natural assets, National Parks provide the core to these plans.

"We are already working on flood abatement zones, where we will plant more woodland, carry out more habitat restoration in the uplands, lowlands and coastal areas and encourage farmers to work together to help us achieve this. Elsewhere, we are benefiting from pooling resources to maintain and repair roads and footpaths, which otherwise continue to deteriorate through increased usage during these long dry summers and wet winters."

OR ALTERNATIVELY

National Parks helping farmers to keep up with climate change

Everywhere in Britain farm businesses are adjusting to the changing weather patterns. Farmers in National Parks are being particularly successful.

By being more sensitive to the effects of climate change such as drought, flooding, changes to biodiversity and adverse effects on livestock, National Parks give farmers an early warning system for farming to adapt. Given a head start on farmers outside National Parks, some farmers have reduced their flocks and herds, are choosing hardier breeds, which cope better with extreme weather conditions, and they are farming more extensively. These changes help them to avoid the annual struggle of putting animals out onto increasingly saturated pasture each spring and more extensive farming allows the growth of more cover. Others are choosing to keep their animals

in for longer in air-conditioned sheds, especially during the hotter, drier summers when pregnant or young stock might suffer from heat stress and lack of forage. Breeding patterns have been altered too to avoid lambs and calves being exposed to extreme weather and lack of grass or water, and this has had an effect on the timing of livestock sales too. Others are choosing to diversify with new crops and renewable energy generation.

Also with today's agricultural farm payments geared to producing environmental and wildlife benefits alongside food production, farmers in National Parks have an additional headstart given the high proportion of Britain's biodiversity that survives there.

Position Statement

Learning to live with climate change

The Earth's climate is warming faster than before because the atmospheric carbon dioxide (CO_2) concentration, together with other greenhouse gases, is at its highest level for almost half a million years – and it continues to rise steadily.

CO_2 as well as other greenhouse gases in the atmosphere, has increased, especially during the last century. This is as a result of our reliance upon carbon-based fossil fuels - oil, petroleum, diesel, natural gas and coal - to provide energy for industry, vehicles and domestic use, as well as to make other oil-derived products such as plastics. Global warming is currently the main indicator of climate change and people everywhere are affected by it, including Britain.

National Park Authorities need to adapt and respond to the changes that are forecast. They are strategically and geographically well placed to help develop effective responses to climate change, benefiting Britain's environment, businesses, residents and tourists alike.

Climate change scenarios for the UK published in 2002 (see www.ukcip.org.uk) show that average temperatures across the country are expected to increase by between 2 and 3.5 ℃ over the coming century, a significant increase. The effects will differ slightly across the UK but generally this means warmer and milder winters with more storms and precipitation (rain and snow) and longer drier summers with more droughts and water shortages. An alternative possibility is that Britain could experience much colder winters caused by the melting of Polar ice sheets altering the Gulf Stream. In either case National Parks would be equally exposed to the environmental changes affected by these different scenarios (warmer and wetter winters or colder winters, with hotter, drier summers).

> *"The climate of the Earth has never been stable, least of all during the history and evolution of life on Earth. Glacial periods for example have been (globally) 4□- 5□C cooler than now, and some interglacial periods have been perhaps 1□- 2□C warmer. These prehistoric changes in climate were clearly natural in origin and occurred on a planet inhabited by primitive societies with far smaller populations than at present. Ecosystems and species have moved, often freely, in response to such past changes and have evolved within this climatic history.*
>
> *"Yet the causes of contemporary and future changes in climate, the rate and potential significance of these changes for ecosystems and hydrological systems and for the human species, are all notably different from anything that has occurred previously in history or pre-history.* ***Human disturbance of the atmosphere now dominates the causes of global warming and the rate of warming already exceeds anything experienced in the last 10,000 years****. Given the ecological imprint made by our current and growing population of 6½ billion and more, the significance of this prospect for the natural world and for human society is qualitatively different from any changes in climate that have been experienced before."*
> After Hulme et al. (2003)

Large areas such as National Parks possess a range of different habitats, land uses and businesses that are vulnerable to a greater or lesser degree to the effects of climate change. The geographic distribution of National Parks in Britain means that some Parks will experience more extreme climatic events and changes than others. Regional studies[i] have been completed for the whole of the UK and these summarise the changes that are forecast.

As a whole, Britain's National Parks are vulnerable to the most significant effects of climate change.

This remains true whether Britain is heading for a warmer and wetter climate with extreme events or a climate with more severe winters. If we assume the warmer and wetter scenario, these effects include:

1. Coastal squeeze - loss of coastal habitats between the sea wall and rising sea level.
2. Changes in rainfall affecting freshwater and tidal systems, as well as changing tidal influences caused by sea level rise, with more saltwater intruding into coastal freshwater systems, leading to changes in habitat distribution, water levels and water quality.[ii]
3. More flooding in winter and spring, lower river flows during summer, increased public pressure for building flood protection works such as flood storage reservoirs.
4. Increased water abstraction during water shortages may exacerbate drought conditions on floodplain habitats.
5. Increased risk of uncontrolled moorland fires.[iii]
6. Reduced size and change in quality of some of the most southern and eastern peatland ecosystems (blanket bog, raised bog and dwarf heath communities) accompanied by increased dominance by bracken and unpalatable grasses such as purple moorgrass.
7. Decline and loss of important species, increase of others.
8. Carbon dioxide emissions from within National Parks may increase as peatland ecosystems and forestry plantations degrade and erosion increases, so that without appropriate intervention, National Parks might be contributing even more carbon dioxide into the atmosphere.
9. Risk of lost income for habitat-related enterprises; for example grouse shooting, angling, water recreation, farm-based tourism.
10. Erosion of soft and hard features on coastal cliffs.
11. Decay and loss of limestone features in cave systems through reduced summer rainfall and therefore the reduced volume of dissolved calcium carbonate supplying the caves; drought conditions on limestone pavement.
12. Risk of increased exposure and disturbance of historic environment features through erosion and soil expansion and contraction; the latter also affecting agriculture adversely.[iv]
13. Increased vulnerability to spring floods by ground-nesting birds such as lapwing, curlew, redshank, skylark and wildfowl. Rainfall and water level are critical factors for these species when nesting. Tree nesting species will perhaps be vulnerable to storms and egg chilling or wet nests.
14. Continued erosion and further pressure on national trails; increased road traffic with more visitors during warmer weather, leading to more CO_2 emissions and faster deterioration in road surfaces, requiring more maintenance; higher fuel and water consumption by vehicles.
15. A range of impacts on livestock farming - see Annex 1.

Safeguarding the Parks' assets and ensuring that these can evolve with climate change requires a complex and measured response.

We must identify where the most significant changes are likely to occur and develop strategies to mitigate the adverse effects whilst benefiting from the positive effects.

Already action is underway in Britain to manage the effects of climate change on coastal habitats[v] through the setting back of sea defences - coastal re-alignment - allowing tides to flood hitherto protected land. Realignment will be needed inland too.

We recognise that good governance is crucial to the successful achievement of common goals in adapting to climate change. We believe that adapting to it is similar to other organisational processes of change where through learning, innovation and open-mindedness we can develop effective ways forward.

Together with partners we will learn through ongoing UK research how climate change will affect the Parks' special qualities[vi]. Where we require additional information we will encourage others to develop integrated impact assessments.

Preparing for climate change - what we can do now and in future

Urgent action is needed now in some parts of the UK to mitigate the most significant effects of climate change in the future.[vii] We recognise that there is considerable public uncertainty about climate change and as in all things in life, scepticism is greatest when negative outcomes are forecast or vested interests are at stake. Conversely optimism is greatest when positive outcomes are forecast, i.e., people tend to hear what they want to hear. We must work hard to help people to understand that climate change is already underway.

In order to assist farmers to take advantage of the reforms of the Common Agricultural Policy beyond 2005, which from now on require a substantial commitment to good environmental management and care of natural resources, we will be vigilant to the adverse effects of climate change on farming. We will argue for agri-environment schemes to be targeted at the areas and agricultural systems that can best mitigate severe effects and take advantage of any environmental benefits of climate change that may emerge.

We will help to ensure that the best advice and services are available to farmers and indeed to all businesses in the Parks. We recognise that appropriate advice and services will be needed to encourage suitable activities such as:

- Carrying out assessments on the regional capacity for renewable energy industries
- Supporting renewable energy industries and energy crops and carbon sequestration (storage)
- Encouraging carbon neutral activities[viii]
- Minimising waste
- Increasing the uptake of agri-environment schemes
- Resisting new uses of fossil fuels such as coal mining
- Working with The Carbon Trust[ix] to assist agriculture businesses to adjust to the Climate Change Levy (DETR 2000), whereby carbon emissions can be traded through the UK Emissions Trading Scheme.

Environmentally led activities such as these can assist economic diversification, provided there is equitable access to market. They can also enrich the experience for tourists, as well as influence evolving landscapes within the Parks. We believe that in order to achieve long-term economic security in a changing climate people must understand the central role that the environment plays.

> *"Climate change is the most significant and far-reaching environmental change facing humanity today. Scientists, policy makers and governments from around the world are seeking to understand the nature of the changes that are likely to occur in the 21st century and beyond and the effects these could have on human populations and the socio-economic systems that underpin them. Mitigation measures are being developed to reduce the long-term impacts of human-produced greenhouse gases on the Earth's climate, whilst a wide range of sectors are considering how they might adapt to the inevitable effects of climate change in the shorter term."*
> (After Mike Harley in Green et al. 2001.)
>
> > **"The potential effects of climate change must be … built into all aspects of the planning process so that it is sufficiently responsive to cope with the impacts of change as they arise."**
> (Wales Assembly Government 2001)

We recognise that the consequences of climate change must be managed in order to ensure that our purposes and duties can be achieved. We believe that now more than ever before the natural and historic environment is vitally important to the future of farming, tourism, recreation and new businesses and that it provides a strong magnet for tourists keen to experience the Parks' special qualities. Taking steps to conserve these qualities benefits the economy and quality of life within and beyond National Parks.

We recognise that maximising the survival of habitats and species can help some of our wildlife to adjust to climate change and we are already working hard to conserve biodiversity. We will work with our partners to identify areas where important habitats can expand and we will encourage and carry out management activities that help to achieve this. In this way we will help to 'stockpile' biodiversity in readiness for the changes ahead.

The International Union for the Conservation of Nature (IUCN) is investigating the development of different zones[x] within Protected Landscapes in order to safeguard their special qualities as well as permit the development of sustainable activities. We are keen to learn whether zones can assist National Parks in Britain to evolve in response to climate change. We will work with our partners to develop integrated regional responses and adaptation plans.

We champion the conservation of biodiversity, historic and cultural heritage within these protected landscapes and we seek to develop strong partnerships that will work to conserve those features most affected by climate change.

Whilst we can take steps ourselves to conserve these special qualities, we aim to work collaboratively with all our partners and customers to adapt our businesses, services and advice most effectively to meet the challenges of climate change. This requires each of us to identify where our priorities for action lie, where best we can deploy our different services and expertise and how we can collaborate most effectively.

> "*The scientific consensus about human-induced climate change should sound alarm bells in every national capital and in every local community.*"
> Dr Klaus Toepfer, Head of the UN Environment Programme, March 2001.

- We will monitor the effectiveness of our actions for adapting to climate change.
- We will be champions for better energy efficiency and increased use of renewable energy and fuels within the Parks.
- We will champion the management of land for carbon sequestration.
- We will ensure that through our decisions, advice and actions, we as National Park Authorities reduce our contribution to global warming.[xi]
- We will ensure that our own land and other assets are managed in the best ways to adapt to climate change.
- We want to ensure that the Parks continue to attract sustainable business investment that is in keeping with the Parks' special qualities. Therefore we will help to improve the lands' capacity to buffer the extreme effects of climate change, which might otherwise undermine business assets and financial support services within these vulnerable landscapes.[xii]
- Through programmes such as the Local Authority Carbon Management Programme and through information and advice we will work closely with other local authorities and partners to help businesses, communities and individuals to develop appropriate responses.
- Where appropriate we will support innovative proposals for adapting to or even profiting from climate change.
- We will provide up to date information on the impacts of climate change on National Parks and the actions being taken to adapt and respond to this.

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Annex I Impacts of climate change on livestock farming

Livestock may become more prone to increased heat stress each summer, causing health problems including poor blood circulation, death of embryos (MAFF 2000) and reduced food intake. These combined effects would reduce livestock productivity, fertility and hence marketability. For example, ewes and lambs could suffer heat stress during gathering, handling and transport, whilst rams could suffer heat stress during early July-August tupping. Therefore livestock systems would need to adjust to avoid these stresses.

The other main changes to livestock farming are likely to include:

- Difficulties with putting out livestock and getting onto the land owing to increased winter rains
- Main pastures requiring more management each summer
- Increased slurry storage needed during winter
- Re-designed farmyards requiring better drainage, better covered areas, better air conditioning for livestock
- Availability of water and shade, as well as winter flooding will affect livestock distribution (MAFF 2000), as will the spread of bracken, unpalatable grasses and weeds and the decline in some priority habitats
- Increase in CO_2 will increase the carbon:nitrogen ratio, thereby reducing grass palatability still further (MAFF 2000), although the growing season will be longer each year during milder winters
- Livestock finishing and reproductive seasons altered (MAFF 2000)
- Early lamb survival may be improved by the early warmth and grass growth; on the other hand increased rains and chills could have the opposite effect, as could grass availability during hotter drier summers affecting lamb growth and ewe condition
- Moorland burning may become impossible during wetter winters (NAW 2000, 2), therefore requiring more burning during September and October
- Cost and quality of forage crops and feeds may change, as might the global livestock industry (MAFF 2000).

These changes might leave farmers facing difficult choices such as using hardier breeds that might cope with less palatable grasses and harsher and more difficult conditions, allowing more shelter to develop to provide shade or alternatively avoiding these problems by farming animals indoors for much longer each year. For the latter scenario this might have a significant adverse impact on the efforts to promote British meat as environmentally friendly niche products if the animals are kept indoors. Not to mention the adverse impact of losing grazing livestock from habitat management systems, the additional consequences this might have for agri-environment schemes and agricultural subsidies and the landscape consequences in terms of additional livestock buildings.

The UK Climate Impacts Programme (UKCIP) provides a series of sector studies on the potential impacts of climate change. These include agriculture, the built environment, biodiversity, grasslands, gardens, health, local authorities, marine environment, planning, water demand and biodiversity. These are available at www.ukcip.org.uk/sector_study/sector_study.html.

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[i] Regional reports from the UK Climate Impacts Programme (UKCIP) are available for the South-west, South-east, North-west, North East, London, Northern Ireland, Yorkshire and Humber, East Midlands, Wales and Scotland. See www.ukcip.org.uk/sub_uk_pub/sub_uk_pub.html.

[ii] Freshwater systems will experience changes in water volume, depth, flows, temperature, oxygen content and nutrient concentrations; increased sediment will arrive from erosion of the surrounding land during extreme rainfall, accompanied by further loss of river banks. Increased acidification is a possibility as well as reduced overall biodiversity. Floodplains may remain flooded for long periods each spring, with adverse effects on breeding birds, mammals and farming activity. More riverside trees may become dislodged during floods, causing economic damage and increased flood risk downstream. Puddles may remain for longer on footpaths, leading to more damage during the winter and more erosion during the summer.

[iii] The risk of moorland wildfires will increase unless estate managers carry out more controlled burns. Wild fires affect biodiversity, cultural heritage, livestock, people and landscape. Mitigating the risk to people may require more closure days on the hills. Also, more people visiting the Parks during longer, drier summers will put increased pressure on sensitive habitats, requiring effort to conserve them, maintain and control access and provide relevant information.

[iv] Soil shrinkage during drought could have significant economic consequences linked with crop failure, subsidence, flash flooding (because water bypasses the dried, compacted soils) and increased machinery costs. Pesticide run off might increase too, increasing water pollution. Unlike clay soils, peat soils do not 're-seal' after cracking but continue to dry and become eroded. This would affect most of the upland areas and lowland wetland areas within National Parks, with significant consequences for soil structure, water retention and tourism, not to mention biodiversity, landscape appearance and cultural heritage.

[v] Sea level rise is caused by a combination of three factors. The first, 'glacial rebound', is where the landmass of Britain is tilting back to a 'normal' position after having been weighed down by the glaciers of the last Ice Age, so that the northern coastline is rising and the southern coastline sinking. The second factor is 'thermal expansion' whereby the oceans' deep waters expand over the coming decades as they are warmed by global warming, causing tides to be higher. The third factor is the addition of more freshwater to the oceans from the melting mountain glaciers of Greenland, again caused by global warming. Along the coasts in southern Britain these factors are combining to raise the average sea level so that intertidal habitats are being squeezed between the sea wall/sea defences and the rising tides - coastal squeeze. So sea wall defences are being re-aligned - set back - to protect these habitats.

[vi] Already Snowdonia is one of the 50-odd Environmental Change Network monitoring sites in the UK, where all environmental parameters are recorded by the Centre for Ecology and Hydrology. Snowdonia is one of only 2 upland sites based in a National Park, the other being near Aviemore in the Cairngorms. Other National Park based stations include the River Exe in Exmoor and the River Bure on the Norfolk Broads. Snowdonia NP also monitors a range of arctic-alpine plants and provides one of the project sites for MONARCH II - Monitoring the Natural Responses to Climate Change (see www.eci.ox.ac.uk/biodiversity/monarch.html), where the responses of upland heath and oak woodland will be monitored.

[vii] The UK Government's Chief Scientist Sir David King wrote extensively in the US journal "Science" in January 2004 and repeated his message in March 2004. He warns for example that the combined effects of rising sea levels and larger storm surges could increase coastal flooding by up to 30 times the present rate of occurrence, i.e., a major flood once every 3 years rather than once every 100 years. If the UK does not take action now then perhaps 3.5 million people will be at risk in future, leading to more substantial and expensive disruption than if the UK acts now. He estimates the cost of tackling climate change to be around 1% of gross domestic product (GDP). This figure could be offset by the risks associated with doing nothing.

[viii] Carbon neutral activities can be achieved where the amount of CO_2 generated by an activity is offset by other activities that sequester CO_2. Alternatively activities can use techniques and materials that inherently use or emit less CO_2.

[ix] The Royal Commission on the Environment has set a target for reducing greenhouse gas emissions by 60% by 2050. This will be met in part by implementing the UK Emissions Trading Scheme through The Carbon Trust (see www.thecarbontrust.co.uk/TheCarbonTrust/Default.htm). This target will only be achieved through innovation, introduction of low carbon technologies and a determination to see things through.

[x] See www.cf.ac.uk/cplan/sacl/ for a discussion of developing zones in National Parks. It explores:

> Core Zones - designed to provide secure habitats for wild fauna and flora and cultural heritage.
> Buffer Zones surround protected areas, which filter out negative impacts moving into and out from these areas.
> Corridor Zones link core zones with one another, and either remain under natural vegetation (where habitat restoration may therefore be necessary), or are managed to ensure that human land-uses are compatible with the maintenance of a high degree of biological connectivity.
> Multiple-Use Zones are areas devoted primarily to human use, but managed to facilitate the creation of broader landscapes that are hospitable to wild species and where activities are limited by environmental carrying capacity.

[xi] Guidance is provided for local authorities in `*Climate change and local communities - How prepared are you?* - An adaptation guide for local authorities in the UK.' This is available on www.ukcip.org.uk/pdfs/UKCIP_Climate_Change_Local_Communities_lr.pdf. The report and adaptation guide is aimed at local authority officers and councillors in the UK. It compliments the Local Government Association's 'Community leadership and climate change' report and the forthcoming Planning Policy Guidance on Planning and Climate Change from the Office of the Deputy Prime Minister.

[xii] All industries are underpinned by financial services. Increasingly, due diligience assessments carried out by insurance companies incorporate projected impacts of climate change. Forecasts are used to identify business and economic benefits to businesses, catalyse changing business practice and to develop mitigation and adaptation scenarios. 70% of all business activity is affected by the weather. Worldwide economic losses due to natural disasters are doubling every 10 years, totalling almost US$1 trillion during the past 15 years, with annual losses estimated at US$150 billion during the next 10 years (Tyndall Centre for Climate Change). Given the economic costs of all the effects of climate change (not just the dramatic or catastrophic ones) the financial sector will have to adopt measures to mitigate these costs. For example financial services associated with a 1in 50-year flood risk must change given that such floods now occur *more than* once every 50 years and are forecast to occur once every 3 years in future. Flooding disrupts the economy, employment, trading and damages assets, leading to considerable insurance claims and subsequent increases to insurance premiums, which have the potential to discourage future investment.