

CLIMATE CHANGE: BIODIVERSITY AND PEOPLE ON THE FRONT LINE

conference report



This report summarises a conference *Climate Change: Biodiversity and People on the Front Line* held at the Royal Society in London on 9 November 2011, and organised by the RSPB, Natural England and WWF-UK.

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Foreword

Professor Sir Robert Watson, Chief Scientific Adviser, Defra

The devastating impacts of unchecked climate change on nature, and the consequences of these impacts for human societies across the world, make a strong case for urgent and effective action on climate change.

However, the current and potential extent of these threats is not widely recognised or understood.

Snapshots from this report, summarising a conference held at the Royal Society in London, are compelling: the predicted loss of 10% of global species for every 1°C global temperature rise; the prospect of a significant degradation of large areas of tropical forests, our richest terrestrial wildlife habitats and vital components of the global climate system; fundamental changes already apparent in the oceans, from polar regions to food webs and seabird populations in our own waters; and shifts in the ranges of species, raising concerns of wholesale ecological change. These changes affect not just our enjoyment of wildlife, but the fundamental services (provisioning, regulating, cultural and supporting) nature gives us, from food and water, to basic raw materials and our health, to regulating our climate and air quality.

Our fundamental and unbreakable links to the natural world may seem distant to industrial, urban societies, but they are essential to all human life. And for the poorest people sharing our world the fragility of these links is becoming increasingly evident.

Projections from Met Office and other models indicate that we have less than five years left to halt the rise in global greenhouse gas emissions, if we are to have a realistic chance of containing climate change within the globally agreed maximum of a 2°C rise in global temperature. Indeed, the world's current commitments to reduce emissions of greenhouse gases are consistent with an increase of 3°C (50:50 chance) in temperature, a temperature not seen on this planet for around 3 million years, with a serious risk of a 5°C rise – a temperature not seen on this planet for about 30 million years. Nature and ecosystems are already being affected by climate change, and the dangers to them will increase as temperatures continue to rise. The financial, social and environmental costs of taking action now to curb emissions are much less than those we will have to face in a world of dangerous climate change.

That's why the UK government is leading calls to increase Europe's greenhouse gas emission reduction target to at least 30% by 2020 on 1990 levels. The Intergovernmental Panel on Climate Change (IPCC)

projections suggest that developed countries need to reduce their emissions by between 25 to 40% from 1990 levels by 2020 to retain an even chance of meeting the 2°C ambition, yet Europe's target is currently only 20%. Globally, greenhouse gas emissions need to be reduced by at least 50% by 2050 to achieve the 2°C target.

Even with effective climate change mitigation, developing adaptation strategies now for people and nature is essential, to address the changes and uncertainty we're already experiencing, and to prepare for the climate change we're locked into by current and historic emissions. We need to adapt for at least a 2°C rise in global temperature, and anticipate more, in ways to meet the interdependent needs of people and nature. The UK's Climate Change Risk Assessment and development of the National Adaptation Programme give the UK a good start. Internationally our International Climate Fund makes an important contribution, yet a huge scale-up of resources is needed globally to meet the estimated \$100 billion annual cost for mitigation and adaptation in developing countries alone.

I hope this report makes more people realise the urgency and scale of our current predicament. Climate change and biodiversity loss are not seen as critical issues by much of the public, nor by many decision makers, in business and in government. We need to address this, and gain wider understanding and popular support for change that puts halting dangerous climate change at the heart of our policies and practices.

R. J. Watson



01

NATURAL
EVIDENCE
FROM A
CHANGING
WORLD

Our Earth's Changing Climate – observations and projections

Dr Jason Lowe, Met Office Hadley Centre

Three independent analyses¹ of global near-surface instrumental temperature records since 1870 show markedly similar results, both in the clear long-term trend of temperature increase over the period and in the variation between the years, which is influenced by changes in solar forces, volcanoes and the movement of energy around the Earth's climate system, eg by the El Niño and Arctic oscillations. Ranked by temperature, the years 2001 to 2010 included nine of the 10 hottest years, along with the El Niño year of 1998.

Changes in the global average near-surface air temperature result from increases in both land temperature and sea surface temperature, and are mirrored by increases in ocean heat content, sea-level rise and humidity.

The ocean absorbs the majority of the extra heat, leading to an average increase in sea level of approximately 1.8 mm per year over the 20th century, and of around 3 mm per year over the last 15 years or so.

Our knowledge of how gases react radiatively to solar radiation and planetary radiation, and how the atmosphere and ocean respond to heating and cooling, allows us to model the Earth's climate system. Using only natural "forcings" such as solar activity, volcanoes etc, model outputs do not match the observed temperature record over the last century. Adding anthropogenic forcings, including aerosol particles and atmospheric greenhouse gases, produces results with a high level of consistency with observed changes, both globally and over all the continents.

FIGURE 1 GLOBAL AND CONTINENTAL TEMPERATURE CHANGE

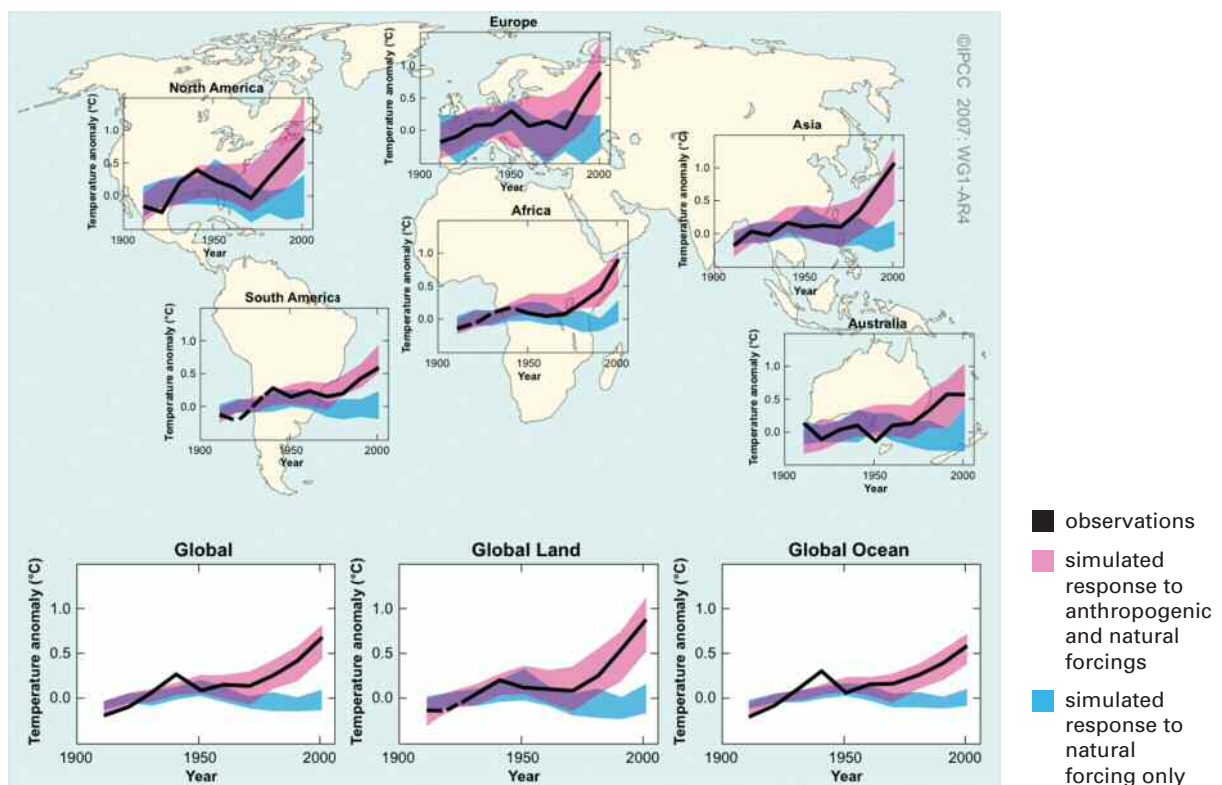
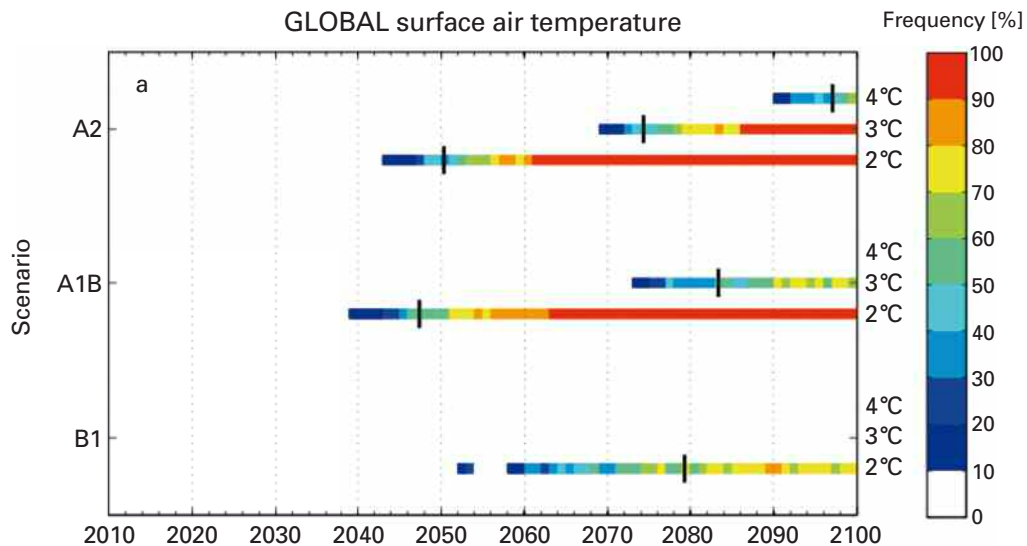


FIGURE 2 WHEN DO THE IPCC AR4 MODELS REACH 2°C, 3°C OR 4°C?



Scenarios of how the world's economies and population might develop allow estimations of the amount of anthropogenic forcing likely to contribute to future climate change. For instance, the Special Report on Emission Scenarios (SRES) B1 scenario depicts a world where population peaks mid-century and the world moves towards a service economy; GHG emissions peak mid-century then start to fall. In SRES A2, emissions climb throughout the century in a much richer world that spends significant amounts on fossil fuel technology. A1B has a more even spread of energy sources and emissions of carbon dioxide are maybe closest to recent trends. Across the scenarios, there is a range of projected warming of around 1°C to 6.5°C in the average global near-surface temperature by 2100. Until around 2040 the curves are very similar, due mainly to similarities across the scenarios in the early years with a smaller contribution from the inertia in the system. Even a model "thought" experiment in which greenhouse gas and aerosol forcings were stabilised in the year 2000 shows some warming during the 21st century, although much less than any of the scenarios with further forcing increases.

For scenarios with no climate mitigation policy included, the climate models start crossing the 2°C line in 2040. Even in the B1 lowest emissions scenario, some of the models start to cross the 2°C line. The higher emissions scenarios reach 3°C and 4°C later in the century.

Global average temperature is only part of the projection. There is considerable regional variation in future average temperature rise. The land warms more than the global average and there is high polar

amplification, due to ice loss. There will continue to be extreme events, such as the European heatwave of 2003, which was linked to more than 30,000 deaths.

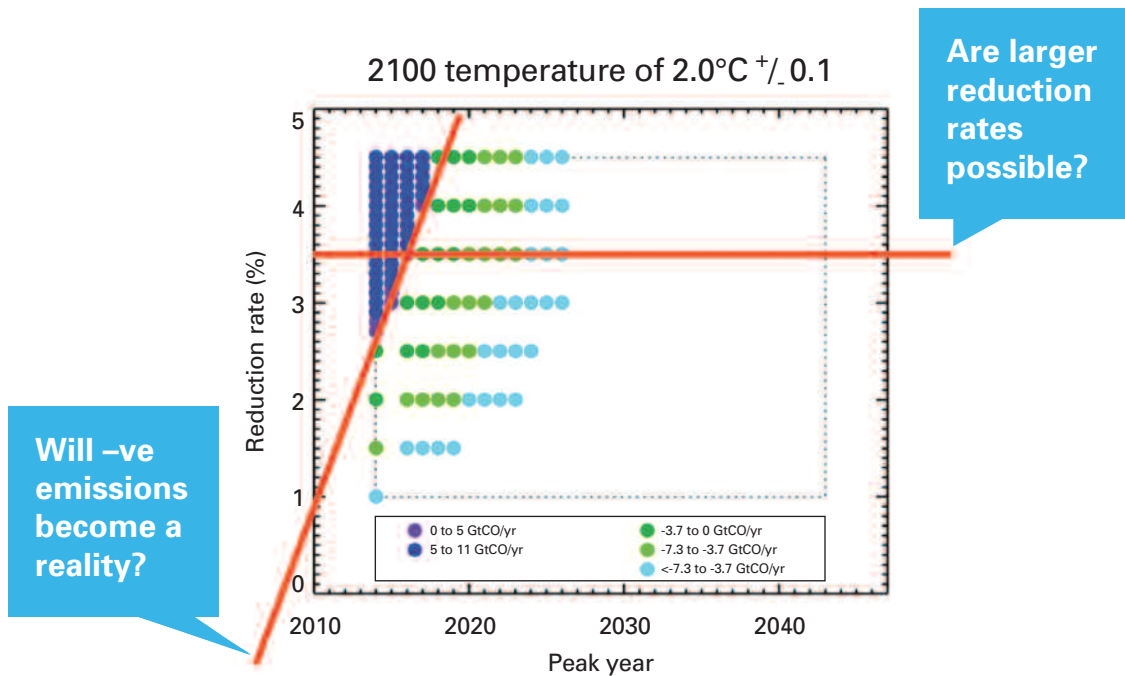
Yet these conditions will be normal by the 2040s and provide a cool summer by the 2070s. Natural variability means there will be periods in which warming slows or reverses for a few years or even a decade.

The regional pattern of precipitation changes is very significant and widespread, increasing and decreasing by 20% or more according to region and season and changing the hydrological cycle. Precipitation is harder to predict than temperature and there are greater differences between the different climate models.

Sea level is expected to increase and the potential accelerated melting of the Greenland and West Antarctic ice sheets could increase the IPCC's projections of 20 to 60 cm rise by 2100. A sea-level rise of less or around 1 m is still considered more likely, although an increase of up to 2 m cannot yet be ruled out.

The most recent climate model simulations include the effects of climate mitigation policy. Using a set of more than 50 versions of the climate model the Representative Concentration Pathways (RCP) 2.6 scenario was considered, which has peak CO₂ emissions in 2020, leading to atmospheric CO₂ concentrations peaking around 2050. In this experiment there is a median warming of 2°C to 2.5°C, much lower than business as usual (A1B, 4.5°C) but the experiment still presents too high a probability of exceeding a 2°C global rise for many stakeholders.

FIGURE 3 IMPACT OF EMISSIONS PEAK YEAR, LONG-TERM REDUCTION RATE AND EMISSIONS FLOOR ON LIMITING WARMING TO 2°C (GLOBAL MEAN).



Simulations with a larger sample of climate models suggest that to limit average global temperature rise to 2°C, global GHG emissions need to peak in or around 2016, with a 3.5% annual emissions reduction thereafter. This is the maximum emission reduction rate believed to be feasible by many analysts. Delaying just a year will require tougher emissions reductions of 4%.

Delaying emission reductions later still would require emissions reductions at even faster rates, which may be neither technically feasible nor affordable. Geo-engineering may offer the possibility of lower or later reductions but is untried, and there are many potentially undesirable side-effects.

One geo-engineering approach would involve the extraction of CO₂ from the atmosphere and there is a growing interest in the cost, technology and political requirements of geo-engineering to assess whether this

route is feasible or not. To move towards negative emissions, combining the burning of biofuels for energy with carbon capture and storage (CCS) plants has been widely suggested, which has direct implications for food supply and biodiversity as land use is switched towards biofuel crops. Yet choosing not to go down this route limits the probability of achieving 2°C level of climate change; and this “safer” level is a negotiated outcome on a continuum of impacts. Indeed some voices are already calling for a warming limit of 1.5°C as a preferable target, but this would be even more of a challenge.

Footnote and reference

1 Met Office Hadley Centre and UEA Climatic Research Unit; NOAA National Climatic Data Center; NASA Goddard Institute for Space Studies.

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Changing Ecosystems – from the globe to our doorstep

Dr Mike Morecroft, Natural England

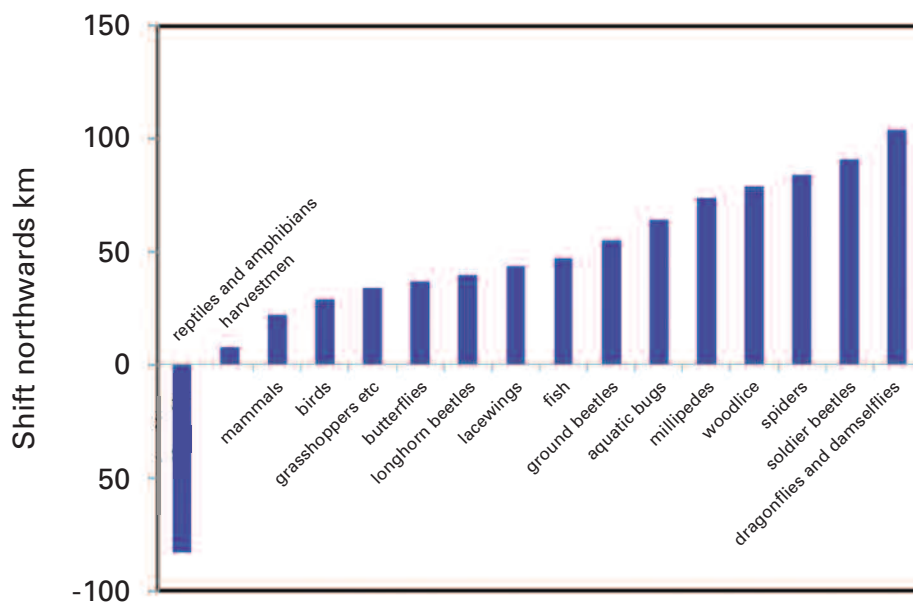
Ecology is profoundly influenced by climate; this is seen in the seasonal rhythm of the English countryside, the change in habitats with altitude and the distribution of the world's major vegetation zones or biomes (such as tropical rainforest). Evidence has been accumulating over the last 20 years that changes in the natural world have been taking place consistent – and corroborating with – the warming trend observed by meteorologists. The last IPCC assessment report in 2007 concluded that 90% of significant long-term biological changes were consistent with warming. Since 2007 the evidence has continued to grow. This evidence of impacts is important because it demonstrates the vulnerability of the natural world to climate change and hence the importance of climate change adaptation and mitigation.

Phenology – the timing of seasonal events such as flowering or egg-laying – is one of the clearest

biological indicators of climate change. A recent paper¹ on 725 UK species or groups of species concluded that 83.8% of trends in spring events were towards earlier timings, with a mean change of 11.7 days. Trends can also be seen at larger scales and in different geographic regions. Phenological change is not necessarily a cause for concern in itself, but it has the potential to affect relationships between species that do not respond to the same extent.

Shifts in the patterns of distributions of species are also becoming increasingly widely recorded. A global study of this phenomenon² found species moving to higher latitudes at a rate of 16.9 km per decade (median value) and to higher altitudes at 11 m per decade (median value). This doesn't mean that all species showed the same change, however, as is well illustrated in the UK (Figure 4).

FIGURE 4 NORTHWARD SHIFTS IN NORTHERN GEOGRAPHICAL LIMITS OF A RANGE OF BRITISH ANIMAL GROUPS³.

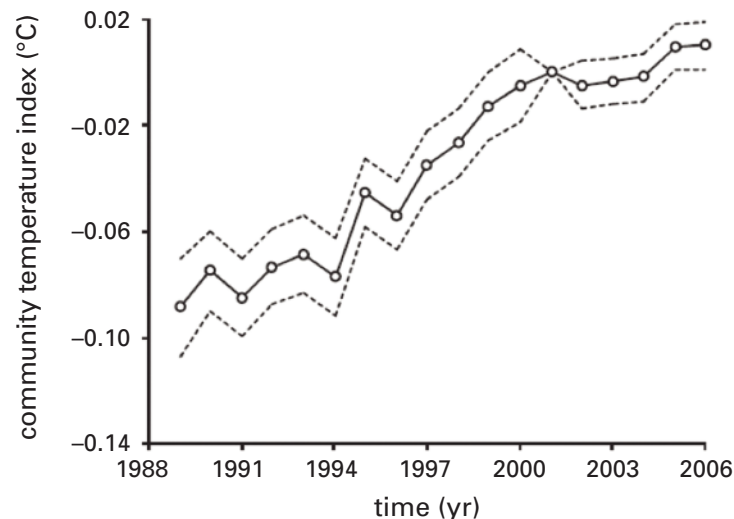


These differences reflect the fact that other, non-climatic factors also have an impact on where species are found and that they differ in the extent to which they are able to move. Some mobile species show dramatic changes: good examples in the UK are the dragonflies. Southern species, such as the small red-eyed dragonfly, are spreading northwards and expanding over large distances. Retreats from southern range edges are less widely reported – it is harder to conclusively record absence of a species than presence. Nevertheless the disappearance of colonies of mountain butterfly species, such as the

mountain ringlet⁴, have been recorded at the low altitude margins of their distributions.

Evidence of changes in the character of whole biological communities as a consequence of climate change have lagged behind that for changes in phenology and distribution, with fewer suitable datasets to call upon and larger changes required to be detectable. However, studies are now emerging; for example, French bird communities have shown a significant increase in the proportion of warmth-loving species since the late 1980s (figure 5).

FIGURE 5 CHANGE IN COMMUNITY TEMPERATURE INDEX FOR BIRDS IN FRANCE: THE INCREASE INDICATES AN INCREASING PROPORTION OF SPECIES FROM WARMER REGIONS⁵.



Shifts in the distribution of biomes have also been observed in some places; for example, there is evidence of shrubs spreading into the tundra in some parts of the Arctic, including photographic evidence from Herschel Island⁶.

Whilst the evidence of the effects of rising temperatures on ecosystems is compelling, these may not be the most serious impacts of climate change in the long term. Extreme events such as droughts, fires and storms can drive ecological change and projections indicate that they are likely to be more common in future. Long-term trends in the incidence of extreme events have not been widely identified yet, but when they have occurred, there is good evidence that they can have major impacts on both species⁷ and ecosystem processes, such as carbon uptake⁸.

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Tropical Forests, Climate and Carbon – an escalating risk

Professor John Grace, University of Edinburgh

The Amazon basin covers 25 times the area of the UK and contains around 20% of the world's carbon stored in biomass, 30% of its biodiversity and 30% of the global river discharge to oceans. It absorbs 1.5 to 2 billion tonnes of CO₂ each year, about as much as India produces. The future of our tropical forests therefore has important implications far beyond their boundaries, and understanding the impact of climate change is of profound importance.

The Amazon is projected to have a 3°C to 4°C average annual temperature rise by 2080–2099, compared to 100 years earlier under the A1B climate change scenario. In 2000 a new theoretical assessment of the forest carbon cycle under changing climate conditions showed that warming would increase the decomposition of organic matter, leading this important carbon sink to become a carbon source after 2050^{1,2}. The dramatic loss of carbon from both vegetation and soils, particularly from the latter, would produce annual losses of around 100 billion tonnes of CO₂ by 2100 and the forest would become savannah. This shift might be triggered by relatively small climatic changes and could happen rapidly as a result of warming and associated drought.

This theory has been tested by experiments and observation, as well as palaeontological studies and mathematical models.

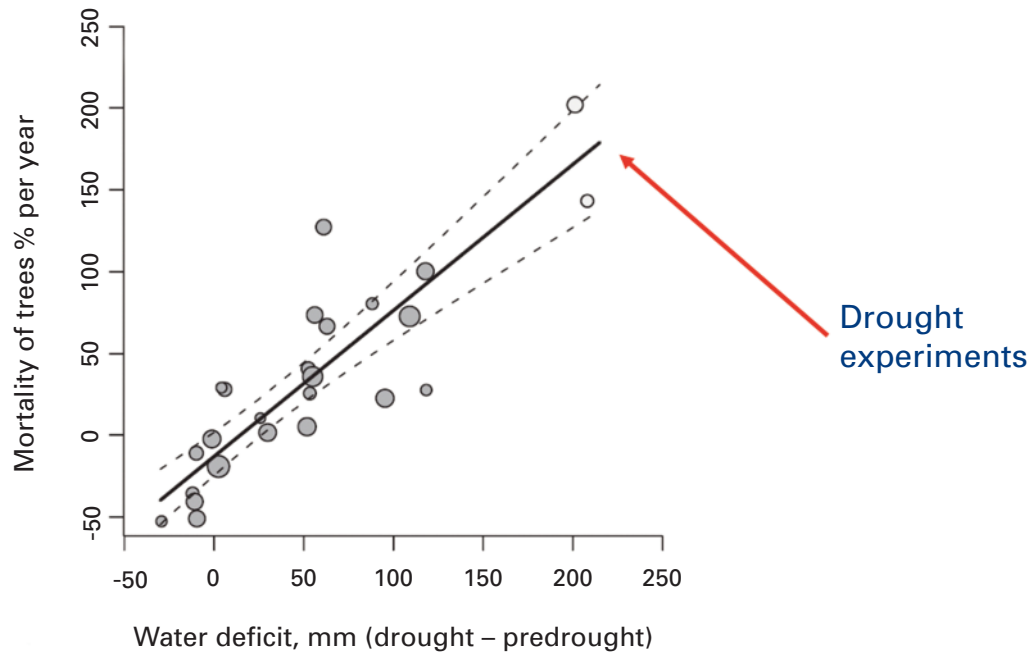
A large-scale drought experiment conducted in the rainforest for a period of seven years showed an increase in tree mortality, from 1% to 4% to 6%, after only three years of drought³. A natural drought in Amazonia in 2005, during a long-term monitoring experiment, found that tree death accelerated most where drought was strongest; locations subject to even mild drying were affected.

The drought sharply reversed decades of carbon absorption, producing CO₂ emissions of more than 3 billion tonnes. Early estimates of the 2010 drought, by the same team, suggest changes in overall CO₂ balance of around 8 billion tonnes.

Palaeontological studies on forests in Bolivia and elsewhere show a shift from rainforest to savannah during periods of drought, and the palaeoecological record shows that switches between forest and savannah have occurred in the past and may be rapid⁴. Slightly different patterns of change may occur at the boundaries where forest spreads into savannah, possibly caused by increased carbon fertilisation at the forest margins encouraging increased tree growth.

Modelling of vegetation changes under climate change scenarios also shows dramatic biomass changes in forests, with a clear tipping point reached in many scenarios. The models project sudden and serious decline in biomass in the Amazon rainforest occurring after the 2050s for all warming scenarios, suggesting a transformation of vegetation away from rainforest to savannah in the latter quarter of this century. However, while drought, warming and disturbance all lead to a change from forest to savannah, increasing CO₂ and anthropogenic nitrogen deposition may favour forest growth, suggesting a more complex pattern of change than the models indicate and a complex dynamic balance between savannah and forest.

FIGURE 6 EFFECT OF A REDUCTION IN SOIL MOISTURE UNDER NATURAL CONDITIONS OF DROUGHT (FILLED SYMBOLS) AND WITH MORE EXTREME DROUGHTS APPLIED EXPERIMENTALLY (OPEN SYMBOLS)⁵.



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Oceans – a world of change

Dr Matt Frost, Marine Biological Association

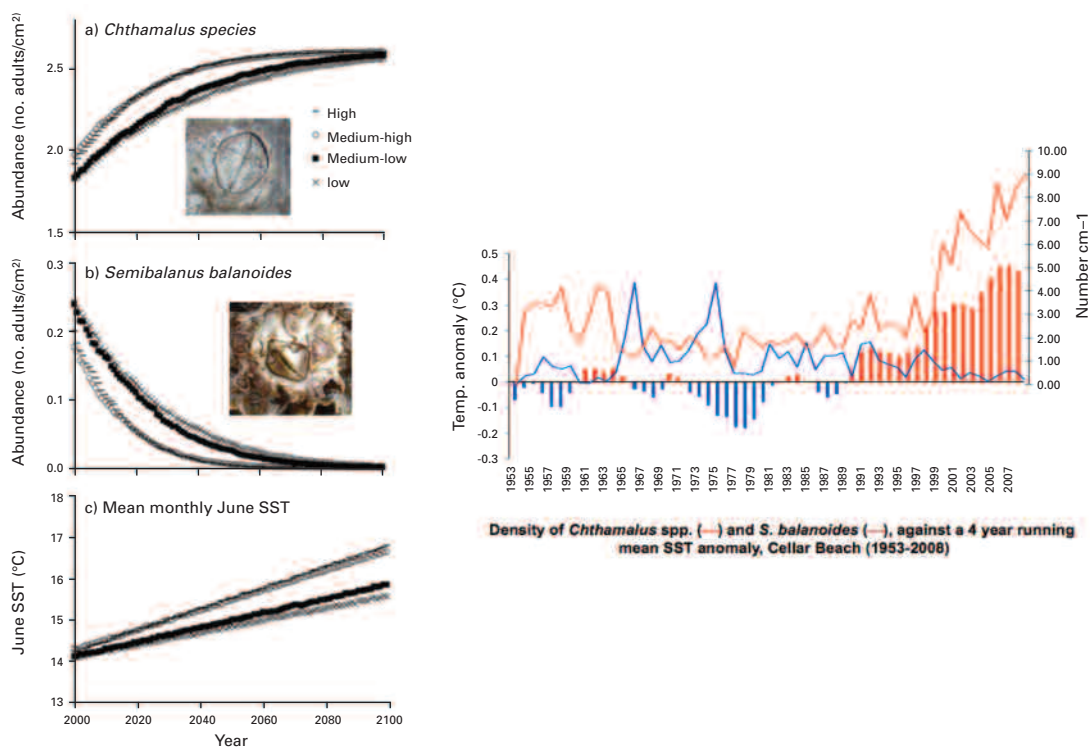
Oceans cover 71% of the Earth's surface and the UK has 3½ times more sea than land. The oceans are more biodiverse: although there are more land species, the oceans have 15 endemic phyla compared with only one endemic phylum on land (and none in freshwater). The marine environment is more sensitive and responds more rapidly to climate change and so is an early warning system¹. Climate change is not the only driver of marine change, and disentangling its impacts from other factors, such as overfishing, is important and also challenging. Other pressures include coastal habitat loss and non-native species².

The rate of sea-level rise is increasing – from 1.8 mm per year from 1961 to 2003 to 3.1 mm annually between 1993 and 2003 – although it is unclear whether this is a real trend or decadal variability³. An average global sea-level rise of between 18 and 59 cm can be expected by 2100, relative to 1980–99. Sea-level rise directly

threatens 30% of global wetlands and 43% of UK salt marshes. How people choose to protect our coasts has a large effect on biodiversity – whether through “soft” defences that allow coastal retreat and harness environmental benefits, or through hard defences that often lead to coastal squeeze^{3,4}. Coral reefs can also be vulnerable to sea-level rise although it depends on the rate of change and type of reef island⁵. Sea-level rise is relative to land movement, such as isostatic adjustment, and varies with geographic location, and so is not an absolute measurement.

Rising temperatures are causing marine species to move faster than on land⁶. Whereas terrestrial species are moving at an average of 17 km per decade, southern species, such as the purple topshell, are moving around the UK coast at 50 km per decade; and North Atlantic copepod plankton are moving up to 23 km per year.

FIGURE 7 SPECIES DISTRIBUTION / RANGE SHIFTS⁸



Looking ahead to projected warming up to 2050, demersal species will be shifting up to 4 km per year and more mobile pelagics, eg mackerel, up to 6 km per year⁷. Cold water barnacles are already losing out to warm water barnacles and will be lost by 2070⁸. A complete redistribution of littoral, demersal and pelagic species is under way.

Not all biodiversity is able to move. Bleaching of coral reefs caused by an increase in ocean temperatures will lead to the loss of many coral reefs with rising sea-surface temperatures. Coral reef growth is also slowing, by 30% since 1998 in the Red Sea, where growth is predicted to stop by 2070⁹.

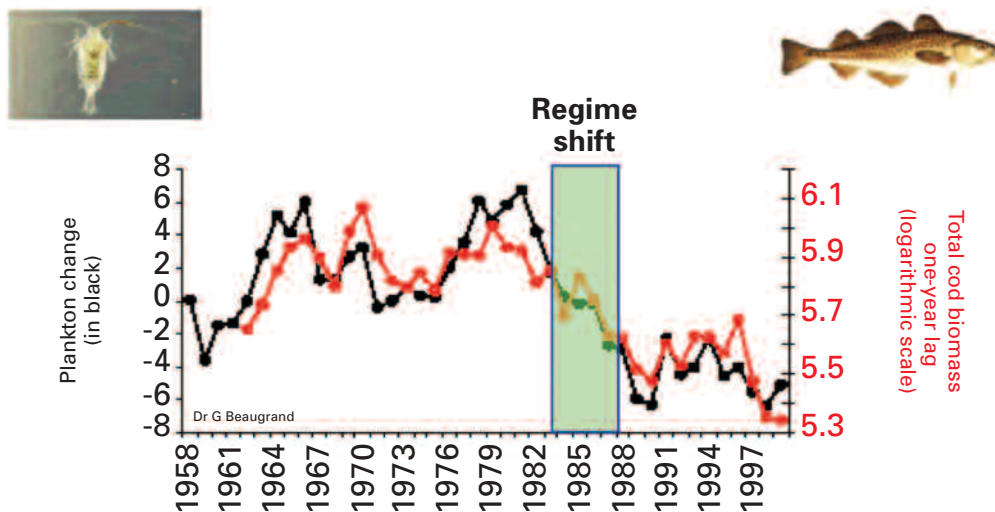
Climate change is assisting the spread of invasive, non-native species, many arriving in ship ballast water. Examples include the Pacific oyster, introduced for aquaculture in the 1970s when the waters here were

believed to be too cold for it to spread. It has escaped and is now beginning to overtake the native oyster here as in other parts of the world.

At the community level, and over decades, warm water plankton communities are spreading northwards and cold ones retreating¹⁰. This is fundamental, affecting primary production and the base of the food chain, producing community changes higher up the ecosystem. For example, changes in communities of planktonic copepods, such as changes in their size and mismatches in timing of their occurrence with cod larvae, have reduced the abundance of cod species^{11, 12}. It is difficult – but important – to identify climate change from other impacts such as overfishing. Smaller, mid-trophic level species track climate change signals well, whilst larger species tend to lose the climate signal due to the influence of other pressures: they are nonetheless still being affected by climate change.

FIGURE 8 INCREASING SEA SURFACE TEMPERATURE AND MARINE ECOSYSTEMS ^{11, 12}

Changes in plankton (size, species etc.) affects whole ecosystem



Ocean acidity has been stable over the last 420,000 years, but is now starting to become more acidic as a result of higher atmospheric CO₂ concentration. As well as a temperature threshold, coral is also affected by pH and atmospheric CO₂ above 480 ppm is expected to reduce marine carbonate ion concentrations to levels at which corals will no longer be the dominant reef organisms, and algal reefs will become dominant¹³. An increasingly acidic environment will affect other calcifying species, including calcareous plankton, sea urchins, oysters and clams, potentially putting entire ecosystems at risk. In contrast, increased oceanic CO₂ may benefit marine photosynthetic organisms, including phytoplankton and algae.

Greater research effort is needed to understand the impacts of climate change – which are already large and expected to increase – on the marine environment. Just 5% of the scientific impacts literature focuses on the marine world, and key research is collated by the UK Marine Climate Change Impacts Programme.

Marine climate change impacts will also be felt by vulnerable economies. Poorer countries are very reliant on fish for protein and more than a billion people rely on the sea for their primary source of protein. Whereas wealthier countries can adapt their equipment and target new fisheries as fish populations change, poorer nations often do not have the investment capital required to adapt to changing circumstances¹⁴. Adaptation needs to increase resilience and reduce other pressures, most obviously over-exploitation of fish stocks. The marine world also offers mitigation potential, such as wave hubs, windfarms and carbon capture and storage; and these may also offer opportunities to protect the oceans and their life.

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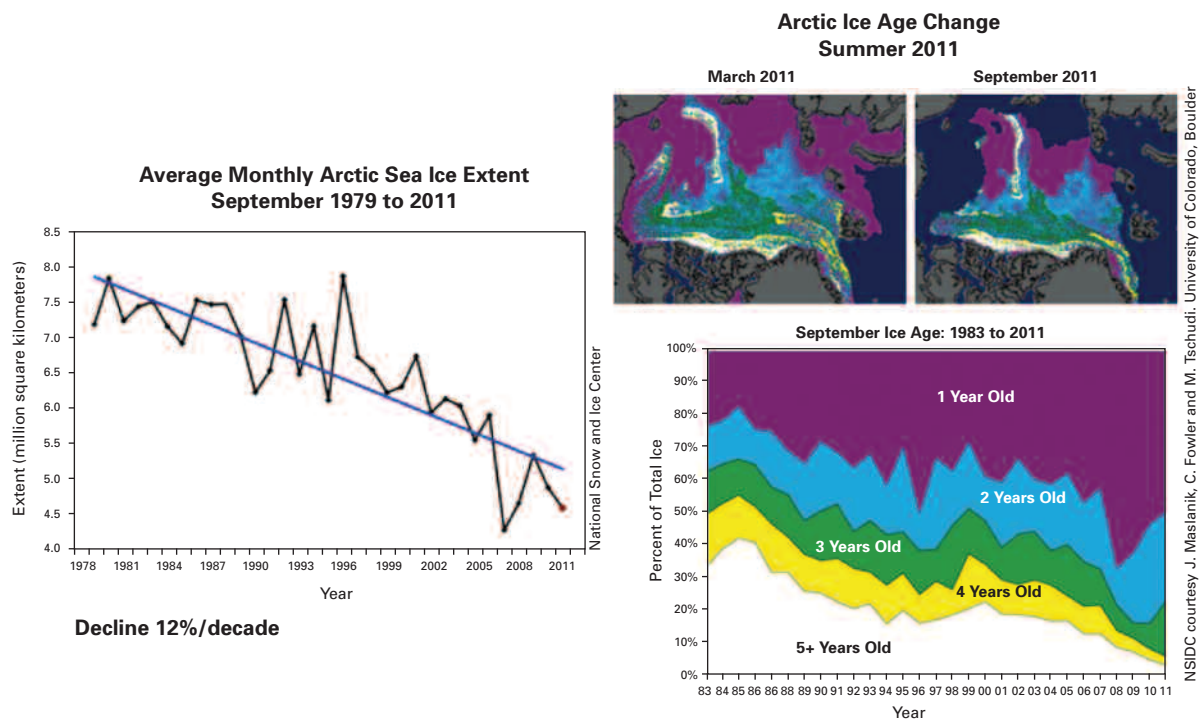
Poles Apart – wildlife at hotspots for warming

Dr Colin Summerhayes, Scott Polar Research Institute

The Arctic is the fastest warming place on the planet, open to intruding, warming air from land and sea and subject to polar amplification with multiple feedbacks¹. Since around 1980, warming has reduced the extent of sea ice, causing the ocean to absorb heat and the atmosphere to warm further. Very stable air close to the surface accumulates heat and adds to positive feedback. Arctic temperatures have increased by 2–3°C since 1900, with a warm period in the 1930s and 1940s, and temperatures are now back to those levels or higher after a cooler period from 1955–75¹. Arctic sea ice has declined by 12% per decade 1979–2011, as has the extent of thick multi-year ice, thus expanding the area of thin one-year-old ice, which is more prone to melting².

Ice loss today is much greater than in the 1930s, when the warming signal was regional, not global¹. Then there was still extensive ice cover in the Beaufort and Chukchi Seas in the summer; today there is none. The Arctic is heating up because it is open to warmth from surrounding areas, eg to warm water brought in from the Atlantic through the Fram Strait between Svalbard and Greenland, and from the Pacific through the Bering Strait, as well as to warm air coming in from all directions³.

FIGURE 9 ARCTIC SEA ICE DECLINE



This warming and its side effects have caused a variety of impacts on biodiversity. For reindeer and caribou, 34 out of 43 wild herds have declined in numbers and the caribou population has decreased by 57% over 30 years⁴. This is due to a number of complex factors, to which climate change has contributed with increased rainfall on snow causing icing, preventing caribou digging down to reach the grass below. Polar bears too are declining: in eight of the 12 populations with sufficient data to monitor trends, only three of the 12 populations are stable, and only one (a small group of 284 bears in McClintock Channel) shows signs of increase⁵. The marine ecosystem is in transition, with mixing of species across the Bering Strait leading to changes in distribution and community composition of species, affecting species higher up the food chain including seabirds⁶. A systematic monitoring observatory is needed to understand what is controlling the extent and development of these changes⁶.

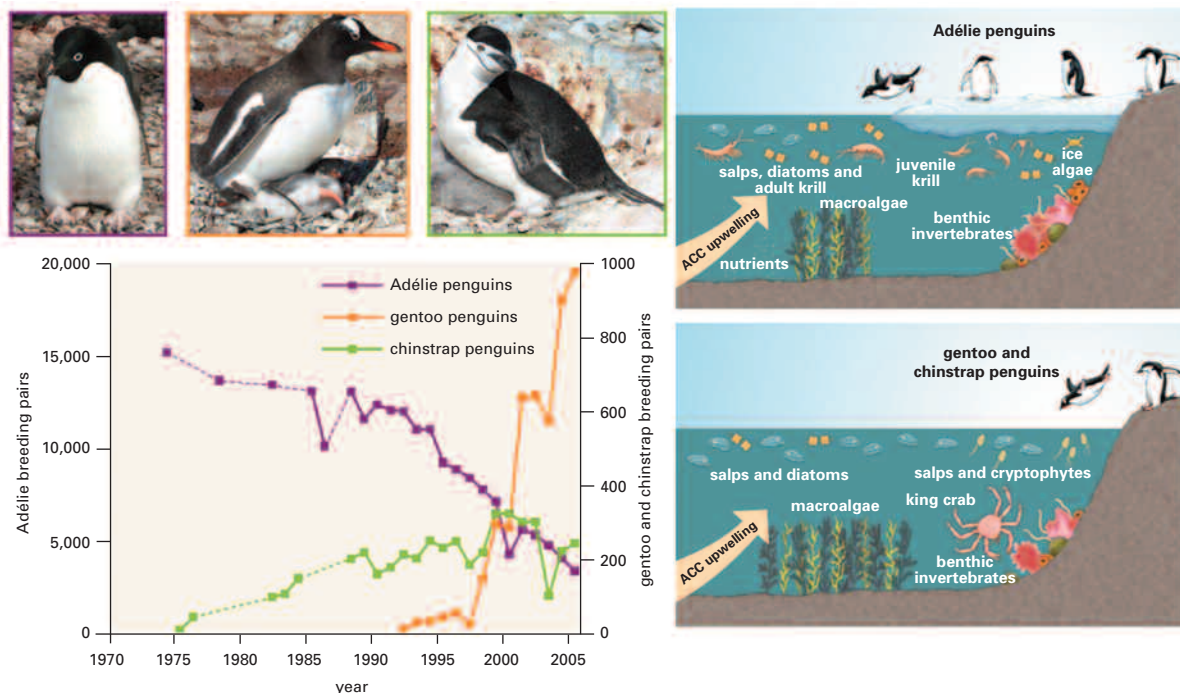
Antarctica is protected from warm air intrusion from lower latitudes by circumpolar winds. These have been strengthened by the increased pole-to-equator pressure gradient, which has steepened due to global warming⁷. In addition, the ozone hole has strengthened surface winds by a further 15% in the autumn. As a result, East Antarctica is cooling, and sea ice is increasing by 1% per decade⁸. The changing patterns of air pressure have deepened the low pressure cell in the Amundsen Sea, allowing warm air to be drawn in from the north along the Antarctic

Peninsula, causing the temperature to increase there by 0.53°C per decade since the 1950s^{7,8}. Winter temperatures on the western side of the Peninsula have increased by 1.03°C per decade, and annual fluctuations correlate with the loss of around one-third of the sea ice over the last 50 years, when sea temperatures have increased between 0.5°C and 1°C. There is growing evidence of polar amplification in Antarctica as well as in the north.

Biodiversity changes are evident, particularly on the Peninsula. Near Palmer Station on Anvers Island, around 65°S, Adélie penguins have decreased from around 15,000 to 5,000 breeding pairs over 40 years, with increased snowfall affecting early nesters and loss of sea ice reducing food⁹. Gentoo and chinstrap penguins have arrived from the north, but are still in much lower numbers. Chinstraps arrived in the mid-1970s and are oscillating around 200 pairs over the last 20 years, whereas gentoos arrived in the early 1990s and have continued to increase, currently to some 1,000 breeding pairs.

Krill numbers have undergone a ten-fold decrease over the last 40 years, a result of the losses of sea ice reducing shelter and algal food¹⁰. In response, the numbers of salps have increased but these are much less nutritious. Newly arriving species include potentially serious invasive species, including king crabs and spider crabs¹¹, which are expected to have a negative impact on other benthic biota, as crabs are new to Antarctica.

FIGURE 10 POPULATIONS SHIFT AS OCEAN WARMS AND SEA ICE MELTS⁹



More snowfall buries early nesting Adélie's; less sea ice removes their food



Exactly how the remarkably diverse Antarctic benthos will react to the changes is not known, but increasing numbers of species are likely to be adversely affected¹². The southern ocean is warming faster than many other parts of the world ocean and the gradual closure of the ozone hole will bring further warming⁷. The Antarctic seas are also at higher risk of acidification and the associated impacts on the parts of the food chain dependent on pteropods, plankton that make their skeletons from the calcium carbonate mineral "aragonite"¹³. Experimental temperature manipulation of the limpet *Nacella concinna* and other benthic organisms (Peck, L., in Turner *et al.*, 2009⁷) shows that small temperature changes can have major implications on the survival of some Antarctic species. However, jumping to conclusions would be unwise, as some of those same species thrive in the sub-Antarctic islands where the waters may be 3°C warmer.

Much increased monitoring is needed in the polar regions, to map poorly known terrestrial and marine biodiversity and to sustain observations to monitor the impacts of climate change over the long term as the basis for making sensible plans for conservation¹⁴.

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02

FUTURE
CLIMATE
IMPLICATIONS
FOR WILDLIFE
AND PEOPLE

Issues on the Horizon – beyond our current knowledge

Professor William Sutherland, University of Cambridge

Climate change often involves new science, developing new approaches and moving into new areas of activity. Failure to understand the consequences of change, and of developing responses, may have unforeseen and harmful implications. Horizon scanning can help to identify potential problems and so guide development into new areas with a much-reduced risk of unintended consequences, such as the rush to biofuels has produced.

There are three main areas for horizon scanning in the area of climate change: new sources of climate change, new consequences of climate change and new consequences resulting from adaptation or mitigation.

Climate change may produce positive feedback loops that escalate the situation. As examples, it is well known that large volumes of methane are trapped in high-latitude sediments in both terrestrial and marine environments and their release, linked to melting of surface layers of permafrost and of deeper ocean marine hydrates, could be a potential driver of greater changes in climate. There is recent evidence that methane trapped by permafrost under relatively shallow water is being vented from beneath the sea, as a result of increases in global temperature. Burning of arctic tundra, highly anomalous in the historic record, is becoming more common with warmer, drier summers. This release of nutrients may encourage shrub growth and so provide more fuel for further fires. Large areas of volcanic activity are covered by ice in high latitudes. With thinning ice, there is evidence both that the reduced pressure makes eruptions more likely and that eruptions are more likely to reach the atmosphere rather than be smothered by ice.

To illustrate the range of possible consequences that may affect a group we have reviewed the possible changes that may impact on shorebirds resulting both directly from, and as a response to, climate change.

- ▶ Rice farmers are increasingly delaying planting to avoid reduced quality of rice from high temperatures during midsummer ripening. Flooded rice fields are an important habitat for migrant shorebirds and further changes to flooding dates may not coincide with the timing of the birds' arrival.
- ▶ Warming in the tundra region has been faster than predicted and linked to insect pest outbreaks, drying of wetland habitat and the northward movement of the treeline into shorebirds' tundra breeding habitat.
- ▶ Algal blooms are increasing, due to warmer temperatures and eutrophication. Blooms are harmful to birds through both direct poisoning and bio-accumulation in filter-feeding invertebrate food, and appear to have caused several shorebird mass mortality events. Some shorebirds appear to avoid previously suitable, contaminated sites, reducing potential habitat.
- ▶ In New Zealand, Japan and Australia, mangroves have colonised salt marsh habitat or tidal mudflats, leading to the loss of large areas of open intertidal zones critical to waders during the austral summer.
- ▶ Advancing springtime and higher temperatures, along with increased fertilisation, combine to bring earlier cutting of grasslands, leading to nest destruction of ground-nesting waders and shortening the available nesting season.
- ▶ Rapid changes in ocean current circulation and/or on-shore winds could change the distribution of intertidal sites with high levels of near-shore primary productivity, at which shorebirds are usually concentrated and upon which long-distance migrant, Arctic-breeding shorebird species are especially reliant as staging sites for fattening.
- ▶ The world's oceans store up to 50% of anthropogenically-produced CO₂, lowering pH. Continued ocean acidification could reduce nitrification rates by up to 44%. Certain calciform organisms have some capacity to compensate for acidification by accelerating their metabolism and calcification rates, although these are likely to be unsustainable for extended periods of time. More commonly, calcification has been found to decline linearly with increasing concentration of CO₂, changing shorebird food supply.
- ▶ Changes in nutrient cycling in high-latitude estuaries may impact the food supply of shorebirds. These estuaries tend to be oligotrophic and nitrogen limited and they tend to divert nitrogen from the ocean shelf, reducing the effect of anthropogenic nitrogen loading. There is recent evidence of high-latitude estuaries switching from denitrification to nitrogen fixation, leading to a reduction in phytoplankton biomass due to reduced nitrogen availability and shifting the peak grazing pressure on phytoplankton to the summer, which is the main season for cyanobacterial nitrogen fixation.
- ▶ Changes in atmospheric circulation patterns are likely to change wind directions, which will affect shorebirds whose migration routes use these winds.

Of course other groups or habitats would face a comparable list of issues. There is a very complicated, inter-related set of ecological and other factors that has to be considered for understanding the impact climate change is likely to have on a species, which include, a great many unquantified or unknown linkages.

There are consequences, too, to consider of novel mitigation solutions. Geo-engineering is attracting increasing interest, with ideas to both reduce the amount of incident sunlight and to remove CO₂ from the atmosphere. Yet there is little science to predict the consequences of these options to tackle climate change. Some measures could have major ecological impacts, eg fertilisation of the sea with iron could cause algal blooms. Dry-tolerant rice would reduce water demand and methane emissions, but it is likely to have major impact on paddy-dependent biodiversity.

New sources of energy need more research into their impacts. Hydraulic fracturing, or fracking, has large potential for water pollution. Impacts on aquatic fauna from in-stream and marine turbines are still little-known – yet there are 8,000 proposed in-stream sites in British Columbia. Biochar has potential for locking carbon in soil and also improving soil quality, but there are serious questions about type and source of feedstock required. There is also large-scale land acquisition (eg by countries) for biofuel growth with little information about the loss of natural habitats.

Biofuels gained political support with a very poor appreciation of their environmental impact. Horizon scanning helps understand the wider implications of climate change impacts and potential solutions and should help reduce the likelihood of being so unprepared.

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Nature Conservation at +4°C

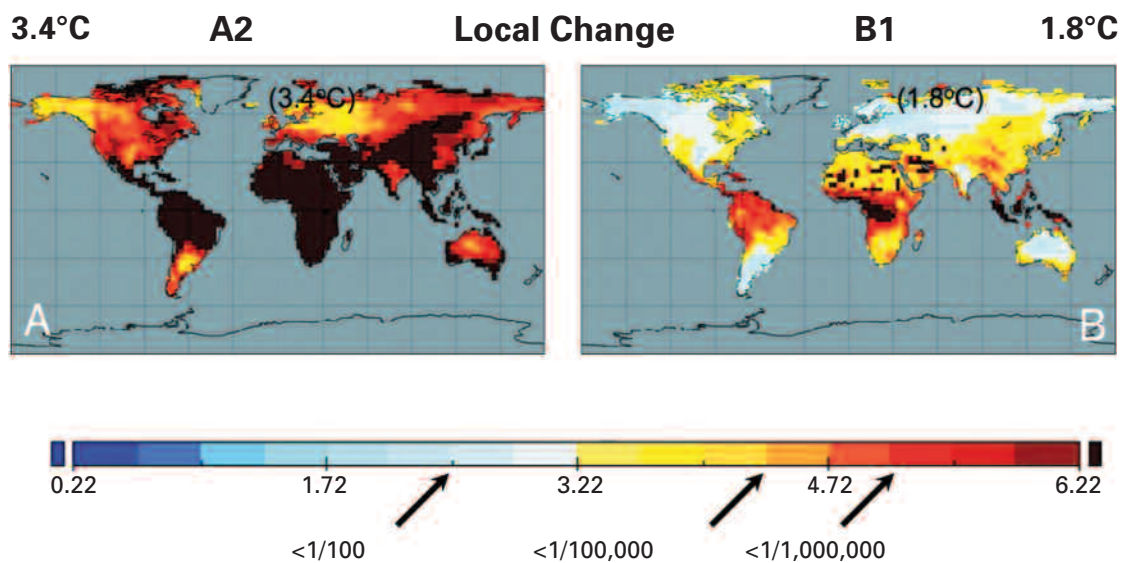
Professor Chris Thomas, University of York

Our current approach to nature conservation will not work effectively for a world of 4°C global average temperature rise.

The changing conditions on Earth pose major challenges for biodiversity. The current rate of climate change is extremely fast, although change has also been fast in other eras. Equally or more significant is that, by the end of this century, average temperatures on Earth are liable to be greater than those experienced for the last 2 million years and perhaps warmer than those for the last 5–10 million years.

We are facing CO₂ concentrations in the atmosphere not experienced for over 20 million years. Most of the planet will, within coming decades, have conditions outside those experienced by most of the species that occur in those locations. Moreover, the overall climate-CO₂ conditions on Earth will fall outside the conditions under which most current species evolved. This presents some key questions: how many species will survive and how will people respond through nature conservation?

FIGURE 11 MAPPED INDICES OF CLIMATE CHANGE RISK FOR END OF 21ST CENTURY CLIMATES¹



"Once in a million" year becomes the norm in red/dark areas

The home advantage of many native species, which are suited to and potentially locally adapted to the conditions historically found in a particular region, will be lost as conditions change and strengthen the advantage of invasive species that are adapted to the new climatic conditions. Cinnamon and palm trees are colonising in the foothills of the Alps, replacing a deciduous biome with broadleaf evergreens. However, predicting future vegetation change is complicated by the potential impacts of high CO₂ concentrations.

Some ecosystems are already in transition and a 4°C world will see major ecosystem transitions in most regions, including ecosystem die-back and extinctions. Can we intervene to prevent ecosystems from collapsing? Is there anything that can be done to reduce the likelihood that large areas of the Amazon, and the species therein, will disappear under future droughts? We will need to develop large-scale solutions and major ecosystem engineering projects. But what might these look like? Rather than blocking individual drainage ditches, will we have to build walls around peatlands to maintain their carbon- and water-regulating functions? Might we cool coral reefs by constructing huge tents to provide shade, or by pumping cold water up from the deep to cool them?

It is hard to predict the fate of individual species and many will be in serious trouble. Modelling studies in Queensland, Australia, suggest that the montane lemuroid ringtail possum will lose 46% of its population at 1.5°C warming and become extinct at greater than 3.5°C, as it is not possible for it to migrate or evolve within the time frame of anthropogenic climate warming. Overall, a 1°C increase will cause minor losses of Queensland's endemic vertebrate species, 50% will be lost at 3°C and, at over 5°C, nearly all of the endemic species will disappear. Some species have no chance of survival unless we

translocate them, possibly hundreds or thousands of miles, to new suitable locations. Overall, a 10% level of extinction is estimated for each additional 1°C warming; and some 25–50% of species are expected to have no overlap between their existing range and locations where the types of climate they need will occur in future.

For a 4°C world there will be an increased need for our current primary conservation approach of *in-situ* conservation measures. We will need more, bigger and better places for biodiversity, which are more heterogeneous and increasingly engineered. Conservation will need to extend *ex-situ* conservation measures, such as zoos and botanic gardens, although their capacity to contribute to the future re-establishment of species in the wild may be compromised by a lack of suitable areas. Currently a relatively trivial conservation measure, *trans-situ* conservation will become important – the process by which individuals are moved from climatically-deteriorating donor locations to climatically-improving areas. For this to work, we will require robust methods to identify climatically threatened species and rules to govern the importation of species into regions where they are not historically native. We will also need a coherent approach to the importation of species to facilitate ecosystem transitions and prevent ecosystem collapse. More conservation land will be needed to support these new measures, for example moving species from the Mediterranean and around the Black Sea to northern Europe, and will require significant areas of land. Perhaps the UK could be a large scale bio-park, devoted predominantly to the conservation of these climate-threatened species? We will need to review what conservation areas and refugia are required in a 4°C world, and what other measures are required to conserve the biodiversity at risk.

FIGURE 12 CONSERVATION STRATEGIES

Broad strategy	Recent	+4°C
► <i>in situ</i> (reserves, protection, etc. in existing range)	primary	increased (more, bigger, better, heterogeneous, engineered)
► <i>ex situ</i> (zoos, botanic gardens, gene/seed banks)	secondary	increased (gene banks, for <i>trans situ</i>)
► <i>trans situ</i> (moved to <i>new</i> locations)	trivial	increased (joined up, moved)

Our consideration of native species will need to develop as the climate changes. Evidence from previous eras indicates that there were very different ecosystems and species assemblages. Fossil evidence demonstrates a wider native biodiversity and illustrates that the current distributions of species are not “natural” in the sense that they are unchanging. We need to forget about returning to a past era of mediaeval or Victorian conditions, and radically re-evaluate our approach for future conservation and non-native species. For example, discussions about reintroducing once-present species in the UK should perhaps consider introducing the critically endangered Iberian lynx to the downlands of England rather than the Eurasian lynx to the highlands of Scotland. The Iberian lynx is under the very real threat of extinction, is smaller than the Eurasian lynx and the food source to support it is available.

Eight key conclusions for nature conservation in a 4°C world are:

- ▶ Maintaining the *status quo*, or reverting to the past, is not feasible
- ▶ Our current philosophy about “natural” and “native” will be blown out of the water – a “keep things as they are” conservation ideology will have to be replaced
- ▶ Ecosystems and biological communities will be fundamentally different – but we will still like them!
- ▶ A major programme of establishing refugia for species and ecosystems will need to be developed
- ▶ Conservation strategies for perhaps one-third of species will involve moving them around the planet; most translocations will be of plants and invertebrates
- ▶ Mega wildlife parks and countries (eg Britain) will need to focus on receiving biological refugees
- ▶ Mass species transfer and major engineering solutions will have to be underway to prevent ecosystem collapse
- ▶ And it is likely that, if the global temperature rises by 4°C, we will end up being reviled as the generation that failed to act, that let nature die, even when we knew broadly what would happen.

Reference

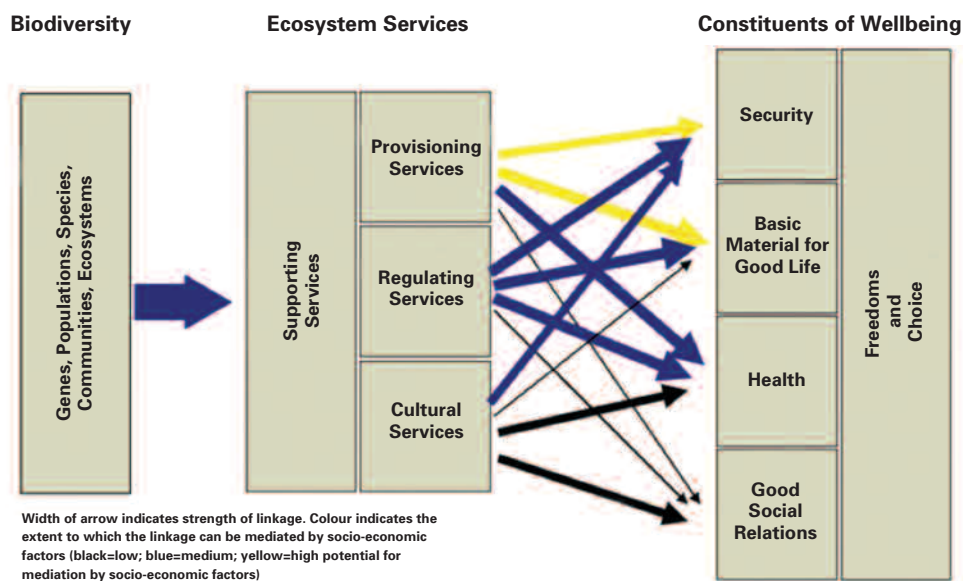
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Climate Change and the Interdependence of People and Biodiversity

Joanna Phillips, WWF-UK

The 2005 Millennium Ecosystem Assessment (MA) showed clearly that biodiversity is essential for ecosystem services, which are in turn essential for human wellbeing¹ (Figure 13).

FIGURE 13 LINKAGES BETWEEN BIODIVERSITY, ECOSYSTEM SERVICES AND HUMAN WELLBEING



Overwhelming evidence, including from the MA, clearly demonstrates that humans have changed ecosystems more rapidly and extensively in the last 50 years than in any other period in history. This has contributed to substantial net gains in human wellbeing and economic development for some, but has exacerbated poverty for others and has been at the cost of considerable and increasing degradation of the majority of ecosystem services. The MA found that 60% of the 24 ecosystem service groups it examined were being degraded or used unsustainably².

WWF-UK's Living Planet Report shows that when trends in global Ecological Footprint are broken down by income group, it is very clear that the footprint of high-

income countries has not only significantly increased, but dwarfs that of low- and middle-income countries. Meanwhile the Living Planet Index – a measure of the world's biodiversity – is declining much faster in low-income countries than in middle- or high-income countries, a 58% decline since 1961³.

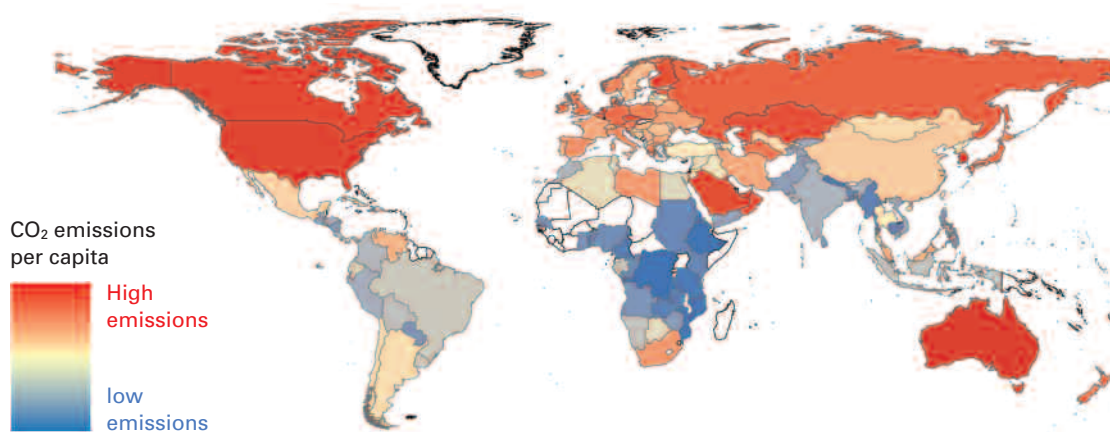
This trend in low-income countries is particularly alarming, not just for biodiversity, but also for the people living in these countries. Without access to clean water, food and other natural resources, vulnerable people cannot break out of the poverty trap and prosper, and their ability to cope with shocks and surprises or adapt to climate change is likely to be reduced.

Behind these global trends are real people and real lives, often directly dependent on natural systems and processes that are being affected by human activity, including climate change. The poorest people are often affected most directly and most severely; however, in an interconnected world, no one escapes. Economies, security, and our “shopping baskets” are intimately connected through global trade and global markets.

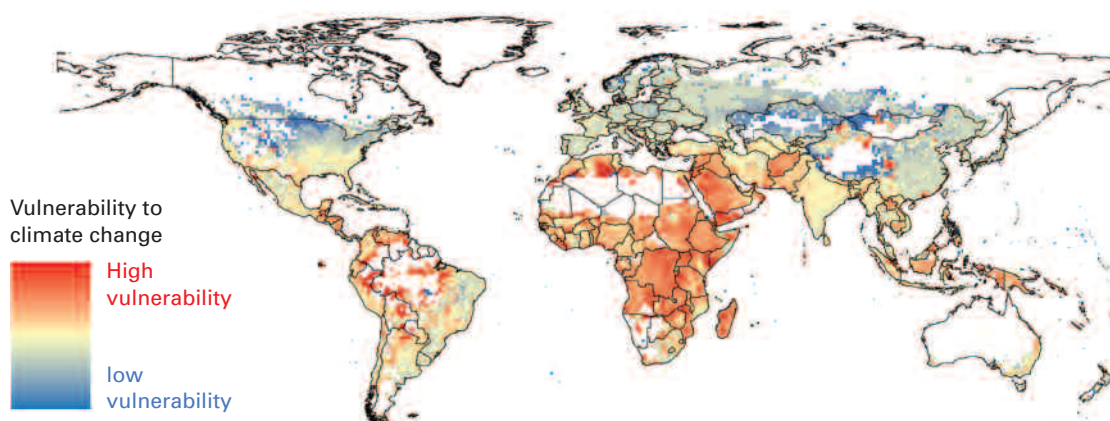
Humankind’s global footprint has doubled in the last 40 years, and is on course to double again in the next 40 – with our carbon footprint being the largest component

of that increase. Existing stresses linked to both poverty and environmental degradation are being compounded by increasing climate variability⁴. This is affecting people and communities now, particularly in developing countries. People already experiencing poverty are generally least responsible for global greenhouse gas emissions and yet are often most vulnerable to risks associated with climate change such as droughts, floods, coastal storms, changes in agricultural productivity and changes in ecosystems (that provide ecosystem services).

FIGURE 14 CLIMATE CHANGE AND HUMAN POPULATIONS: CO₂ SOURCES AND PREDICTED IMPACTS⁵



Those who contribute the least greenhouse gases will be most impacted by climate change



Climate change is a direct threat to both ecosystems and their services and it also compounds existing threats. Climate change has the potential to rearrange species, assembling new communities of plants and animals as they shift their ranges and adjust their phenology, as well as cause extinctions. The IPCC in its Fourth Assessment said that “For increases in global average temperature exceeding 1.5–2.5°C, there are projected to be major changes in ecosystem structure and function, species’ ecological interactions, and species’ geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, such as water and food supply.”⁶

If global greenhouse gas emissions do not peak and decline well before 2020, the UK Met Office’s worst-case scenario suggests a 4°C average global temperature rise is possible by 2060–70. Kevin Anderson, Deputy Director of the Tyndall Centre, recently warned the Department for International Development: “There is a widespread view that a 4°C future is incompatible with an organised global community, is likely to be beyond adaptation, is devastating for the majority of ecosystems, and has a high probability of not being stable (4°C would be on the way to much higher equilibrium levels/warming).”⁷

In such a world, safeguarding biodiversity becomes essential; species redundancy becomes a thing of the past. In a rapidly changing world any species may become a “keystone”, critical for the current functioning of a system, or providing resilience and resistance to environmental change, as species move in or out over time. “Whole ecosystem” biodiversity conservation could be seen as part of a security or insurance mechanism for providing ecosystem services into the future⁸.

Climate change needs urgent action. We know largely what has to be done: rapid and transformational change in energy and land use and in our economic systems, and accompanying behaviour change to support this.

However successful our mitigation effort, we are already locked into some degree of climate change, and adaptation for people and nature is vital. This provides further opportunity for transformational change, pioneering integrated trans-disciplinary systems approaches: new and innovative partnerships, working at different scales and with multiple stakeholders to assess trade-offs and make informed “climate smart” decisions that build the resilience and adaptive capacity of people and ecosystems, and that embed and share learning.

As emissions continue to rise, thinking “beyond adaptation” becomes an even more critical issue, including an international mechanism for addressing “loss and damage”⁹. Key components of this include the scaling-up of disaster risk reduction and risk management, the establishment of an international climate risk insurance mechanism and a rehabilitation mechanism to deal with long-term climate loss and damage and slow onset events¹⁰.

We all need to take responsibility for addressing the transformational change necessary, as individuals, as employees or employers, as voters and as global citizens. People in the developed world, and the rich in developing countries, must reduce their consumption and change their lifestyles to live fairly, equitably and sustainably. We need to empower governments to make climate-smart decisions that will often be difficult and unpopular in the short term – but are crucial for the long term. Election cycles and short-termism must not condemn us to a race to the bottom. We need to help decision makers understand trade-offs and make informed decisions that recognise planetary boundaries, and build the resilience and adaptive capacity of ecosystems and people now, and into the future.

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Development, Environment and Climate Change – an African perspective

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Africa is one of the most vulnerable continents to climate change: the IPCC warns that agricultural yields could fall by up to 50% by 2050 in some countries and, by 2020, up to 250 million people are projected to face increased water stress due to climate change¹.

Africa is considered to be one of the most vulnerable areas, mainly because of its very low development level. This is why Africa's slogan for the Durban UNFCCC meeting was "Development first!". This was also the key focus at the United Nations' Commission for Africa climate change and development conference in Addis in October 2011.

Adaptation is urgent for Africa to build the resilience of its natural resource-based populations threatened by food insecurity. The food shortages and malnutrition affecting more than 10 million people in the Horn of Africa in 2011, following the worst drought for 60 years², could happen in any other part of Africa and we need to avoid it.

In Maradi, stretching across southern Niger and the border with Nigeria, the Maradi River used to be permanent, flowing from Nigeria into Niger. The ecosystem created by this river was a source of food and income for Maradi people and a source of permanent water for irrigation to complement the rain-fed agriculture, which became uncertain because of climate variability and changes. But, to address the food security challenges posed by the 1970s climate variability and change, authorities in Nigeria built a dam on the Maradi River. Since the settlement of this dam, irrigation in Maradi has been seriously undermined, creating impacts on ecosystems and the livelihoods of people. Policy makers from Niger and Nigeria are talking to each other to find a compromise, but up to now, the problem is still to be solved.

The Maradi case shows an interaction between climate, environment, ecosystem services and governance.

But worryingly, this entanglement of climate change and governance on ecosystem services is now moving from an environmental and development issue to a security issue. There are conflicts between farmers and herders, and difficult high-level consultations between Niger and Nigeria on the share of Maradi Goulbi water for irrigation in both countries, to

compensate for the food deficit caused by climate change.

In Africa climate change has become a really serious issue. Amazingly, the *Guardian* reported on Wednesday 12 October 2011 that, opening Climate Week in New York, former UK prime minister Tony Blair quipped that: "It's a relief after the weeks I've spent deep in the entrails of the Middle East peace process to now talk about something that is relatively easy to solve." Yet in some respects he is right, because the solutions to climate change are relatively straightforward and can be solved with co-operation.

Some are saying climate change is a justice issue. But another perspective, widely shared in Africa, is that climate change is a solidarity issue. Indeed Africa has shown "solidarity" in the past with many developed countries to help achieve their current development levels: we have suffered colonisation and slavery. It is this development which is causing climate change.

Africa is growing and the quality of this growth matters³. It's a chance for Africa to climate-proof its development and resolutely engage in climate-compatible development paths that are also more widely sustainable, and may protect our natural environment and the services it provides for us.

It is time for developed countries to show, in turn, their solidarity with Africa in its efforts to address climate change and achieve climate-compatible development goals. Developed countries will be acknowledged by history and indeed time will tell.

Kyoto should not die! The world needs to agree on a second commitment period and a legally binding treaty that will result in the action required to avoid dangerous climate change, in Africa and elsewhere. We cannot afford wasting all the efforts made so far.

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03

PLENARY
DISCUSSION
SESSION

Questions and Answers

The conference panel

This section summarises the responses of an expert panel to questions delegates raised from the floor. It is intended to give a flavour of discussion on the day, rather than present a verbatim account or the views of the organisers. Ruth Davis (Greenpeace), Tony Juniper (independent environmentalist), William Sutherland (Cambridge University), Chris Thomas (York University) and Robert Watson (Defra) comprised the panel, which was chaired by Martin Harper (RSPB).

ARE THERE REASONS FOR OPTIMISM?

The conference demonstrated the severity of the risk that climate change poses to biodiversity and people. The panel did not however feel that the situation was hopeless: we can still avoid the worst effects if we act quickly.

Ideas that address a need, gain political support and bring on board partners for delivery can be got off the ground very quickly. Nature Improvement Areas in the UK are a good example, getting underway in a relatively short period of time. So, if the right ideas are there, then we can get implementation.

Many people want to promote a fairer and better-cared-for world and are optimistic about the prospects of this. This may not necessarily develop through traditional economic systems and there is increasing talk about what “good capitalism” could be. There is growing concern that our current version of capitalism and our present economic systems are not working as they need to, and that economics needs to be driven less by what institutions, individuals and politics can get away with and more by what it can provide for wider society and the common “goods” we all share. This should embrace environment and sustainability, including climate change adaptation and mitigation, as well as more equitable social concerns.

Consideration of longer term thinking and solutions to the current economic crisis may actually provide opportunities for such change. The response to the Occupy movement and related demonstrations revealed a willingness to consider radical ideas amongst wider society and institutions, for example in the Church of England.

We need to bring ordinary people into conversations about climate change and biodiversity loss, and find ways to share information that attract and connect people. Sharing common problems brings solidarity and, ultimately, a common language towards solving them. We need to find new communications that take account of psychology and sociology as well as

science and climate change, so that more people become involved and understand these issues.

The development of Reducing Emissions from Deforestation and Forest Degradation (REDD+) gives real hope, acknowledging the developed world’s historical responsibility for greenhouse gas emissions and directing money from rich to poor countries. There does not need to be a dichotomy between biodiversity and economics, as the growing influence of green economics and the growth of green industry indicate. There are nonetheless concerns about where the promised £250 billion funding for climate change, biodiversity and food security will actually come from.

HOW CAN WE LIVE IN A 3–5°C WORLD?

A 3–5°C average global temperature rise will mean a 4–7°C rise on land. This prospect ought to frighten people into action! For biodiversity, we will need a new way of thinking about conservation that accepts and integrates change, and most likely develop a new paradigm.

Taking a forward look and building knowledge about biodiversity in these new climates is the first step towards generating a vision for both biodiversity and conservation which is compatible with climate change. Then we need to develop ideas about how to get there, and find ways to build co-ordinated action and resources.

Achieving a successful response to climate change also depends on changing how society addresses the challenge. Awareness and concern about climate change has slipped over the last two years, largely lost from the front news pages and from the top of heads of states’ priorities. Alongside biodiversity loss, global consumption per capita is increasing, as is human population. New thinking and action is needed to bring climate change and biodiversity loss to be among the top important issues for country leaders and world agendas. More than just a good evidence base is needed, as the failure of the Common Fisheries Policy demonstrates that decades of good science advice can be constantly ignored – and maybe suggests that appealing to self-interest is important to finding solutions.

Different politics and a different economic model are also needed. A new kind of capitalism, encompassing civil society responsibilities, is not only possible but can be welcomed by big corporations. Unilever provides an example of this.

SHOULD SCIENTISTS BE DOING SOMETHING DIFFERENT TO WHAT THEY ARE DOING NOW?

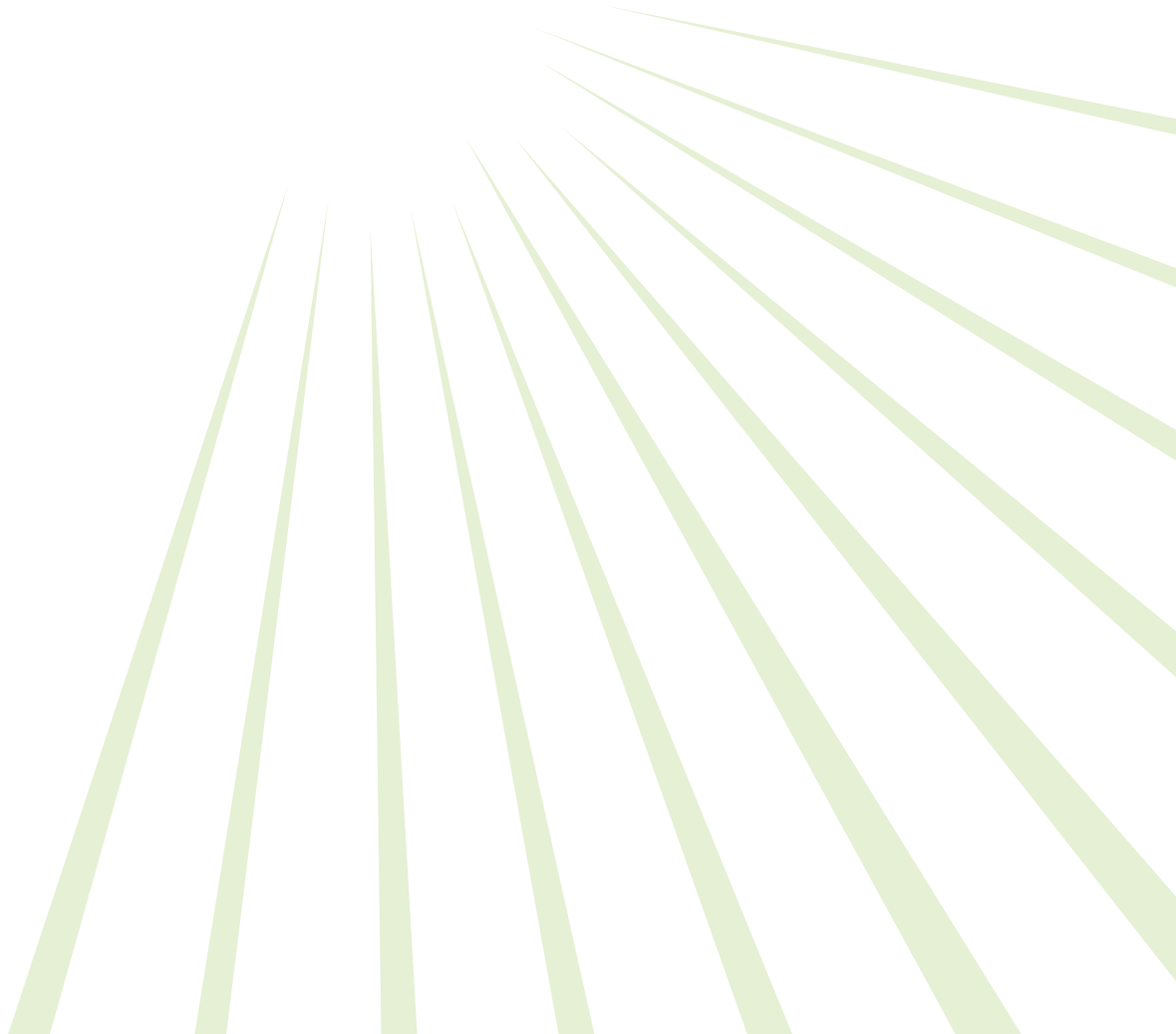
Most people don't see or understand climate change happening. How can we change this, how can scientists play their part and are they trusted by the public?

There is a fine line between being advocates and impartial scientists. Science needs to retain scientific independence and integrity. Yet it also needs its messages to be heard clearly and effectively among the public and those with the position and power to act upon its information. This takes scientific information into the realms of politics and of vested interests, where scientists may need to defend and justify their evidence. The scientific community should raise its voice when science is ignored or unjustly attacked. Scientists should engage in debate, but in scientific ways and not through engagement in the "poisonous theatre" of those with fixed opposing views and private or ulterior motives. Scientific bodies such as the Union of Concerned Scientists could be more active and outspoken in these situations. The speed of the climate change denier response to scientific reports, news and events is astonishing and the science and environment communities should aspire to a similar speed of communications.

The science community needs to defend science-based policy making, yet should act as a knowledge broker rather than advocate, to maintain trust through impartiality. Lessons can be drawn from other processes such as the Montreal Protocol. In this case self-interest was a key driver – the ozone hole causes skin cancer in white people and scared people into action. Greater awareness of the impacts and dangers of increasing global temperature may lead to a similar response for climate change.

DISCUSSION CLOSING SUMMARY

We need to develop new ways of working and communicating one of the greatest threats to people and biodiversity. There is a real urgency that we address this challenge now. Working together we have a strong community that can bring a powerful focus to support policy makers to take the tough decisions that are needed. To build this support, we need to simplify our messages, whilst retaining scientific accuracy, and develop ways to trigger effective political responses to address climate change, biodiversity loss and the continuing provision of the ecosystems services upon which people ultimately depend.





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