MIGRATORY SPECIES AND CLIMATE CHANGE

Impacts of a Changing Environment on Wild Animals

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Commerson´s Dolphin (Cephalorhynchus commersonii),© Miguel Iniguez

"One of the greatest environmental and development challenges in the twenty-first century will be that of controlling and coping with climate change. The overwhelming majority of scientists now agree that human activity is having a significant impact on the climate ."

Kofi Annan, In Larger Freedom.
Towards Development, Security and Human Rights for All, 2005.

FOREWORDS

The impacts of Climate Change on biodiversity are already visible. Studies show clearly that changes in distribution and behaviour of a large number of species are the consequence of shifts in local or regional climate, weather patterns and resulting changes of vegetation and habitat quality. The work of the Intergovernmental Panel on Climate Change has also made us all aware that Climate Change is likely to be the main driver of biodiversity loss in future. The impacts of Climate Change cause additional pressures on ecosystems that are already stressed by overuse, degradation, fragmentation and loss of total area. In combination, these factors reduce not only ecosystem resilience, but also human options for coping with a changing environment.

It is evident that some species and geographic areas are found to be at greater risk than others and there is reason to expect migratory animals to be badly affected. Animals and their migration patterns already suffer, and are likely to do so even more in the future from changes in their critical habitats and shifts in their geographic coverage. Replacement of tundra by forest in the Arctic, habitat loss in Europe, desertification in Northern Africa, sea level rise in Asia and the Pacific, hurricanes in the Caribbean, and rising temperatures in polar regions are just a few of the most problematic changes which we are expecting already.

Most of these effects cannot be prevented or reversed in a short time. It is necessary, therefore, to improve the ability of species to adapt to the changes in their environment. Ecosystem resilience needs to be enhanced and the connectivity of habitats improved to allow for necessary shifts in ranges and unhindered migration. This publication is an aid in raising awareness by highlighting some case studies, assessing impacts and identifying possible solutions and mitigation measures. It will give decision makers and environmental experts an excellent overview of the links between Climate Change impacts and migratory species.

Achim Steiner

Achim Steiner
Executive Director of UNEP

Our climate is changing and this change is affecting wild birds and animals. Disrupted breeding, barriers to migration and increased disease transmission are just some of the threats migratory species face from Climate Change. In line with the leading role the UK has long taken in conservation and research, my ministry commissioned a study into the links between Climate Change and the abundance, distribution and behaviour of migratory species. Published in late 2005, the report makes for some alarming reading.

Even the limited knowledge available suggests that projected changes in climate during the twenty-first century, coupled with land-use change and the spread of alien or exotic species will hinder not only migration and successful breeding, but will also limit the availability of suitable habitats for some species and could, ultimately, lead to their extinction. The report points out that migratory species are already changing their behaviour, some no longer migrate south from the UK in the winter, and others are arriving in their breeding areas 2-3 weeks earlier than 30 years ago. As for the future, up to ⅓ of turtle breeding sites in the Caribbean could be lost with a predicted sea-level rise of ½ metres and the birth rate of whales is expected to fall as sea temperatures rise.

DEFRA is committed to continue addressing the adverse consequences of Climate Change with even stronger resolve, working with other countries and partner organisations, such as the Convention on Migratory Species. We believe that only international and cross-sectoral cooperation can provide the solutions which will allow migratory species to adapt to a changing environment. I trust this publication will increase awareness of the effects of a changing climate on migratory species, and trigger policy and conservation actions to mitigate them. DEFRA stands ready to assist these efforts both at the national and the international level.

Barry Gardiner

Barry Gardiner MP
Parliamentary Under-Secretary, Department for Environment Food and Rural Affairs, UK

The impacts of a steadily changing climate, such as rising global average temperatures and increases in frequency and severity of extreme events, droughts and floods, are already affecting human well-being, biodiversity and ecosystems, economies and societies worldwide. The scientific evidence on Climate Change and its impacts is rapidly becoming clearer and more precise.

Aware of the seriousness of this global problem, governments around the world are engaged in tackling the challenges posed by Climate Change. In 1992 they adopted the United Nations Framework Convention on Climate Change, followed by the Kyoto Protocol in 1997. While the Convention provides a broad platform for governments to join efforts in striving to stabilize concentrations of greenhouse gases in the atmosphere and to prepare for the inevitable impacts of Climate Change, the Kyoto Protocol sets out specific emission reduction commitments for industrialized countries that are Party to it.

Climate change is a highly complex problem, closely interlinked with many environmental challenges. The impacts of Climate Change pose additional pressures on ecosystems and biodiversity, in particular on highly vulnerable migratory species. At the same time, the underlying causes of many environmental problems, including Climate Change and loss of biodiversity, and the solutions to these problems, are often interlinked and mutually reinforcing. They concern the patterns of industrial activities, use of energy, agricultural production, and land use.

This publication illustrates the inter-linkages between Climate Change and migratory species by providing numerous examples and outlining possible solutions. I trust it will help raise awareness of the consequences of a changing climate on this unique group of animals whose survival depends on a large number of different habitats and climate conditions around the globe.

Ivo de Boer
Executive Secretary, UNFCCC

The unique way of life of migratory animals, be it birds, marine or terrestrial mammals, fish, marine turtles, or insects, illustrates like no other phenomenon the connectivity of ecosystems across the globe. While Climate Change has very different faces in different regions, these animals need to adjust their migration patterns accordingly if they are to survive. Migratory species are especially at risk due to Climate Change because they require separate breeding, wintering, and migration habitats of high quality and in suitable locations. Often, one or more of these habitats could be at risk because of changing temperature ranges, hydrological patterns and habitat loss due to increasing human pressures.

The Convention on Migratory Species has long been taking an interest in the impacts of Climate Change on wildlife. The Scientific Council formed a working group in 1997 to assess the relevance of studies conducted by other bodies for the work of CMS. Since then, results of such assessments show more and more clearly that Climate Change places yet another severe pressure on many species. Often, decreasing population sizes can be attributed to habitat conversion, pollution, migration barriers or unsustainable use. In many cases, shifts in range and habitats are not possible due to fragmented landscapes, very specific needs or limited genetic variability caused by sharp population declines. Also, competition systems are being altered, favouring for example regional migrants over long-distance travellers. Upset ecological balances, along with milder winters in many parts of the world, increase problems with invasive alien species.

These complex issues cannot easily be addressed. We urge decision makers around the world therefore to strive to enhance ecosystem resilience and promote ecological connectivity to allow migration, genetic exchange as well as range shifts in reaction to changing environmental conditions. The papers in this brochure identify the need for coordinated research, monitoring and conservation throughout a species' range – something for which CMS provides the ideal framework.

R G Hepworth

Robert Hepworth,
Executive Secretary of the UNEP
Convention on Migratory Species

CONTENTS

1 INTERLINKAGES BETWEEN BIODIVERSITY AND

Manuel Guariguata
Secretariat of the Convention on Biological Diversity (CBD)

Biodiversity and Climate Change are intimately linked

Biodiversity is defined as the variability among living organisms from all sources including diversity within species, between species and of ecosystems. There is strong evidence that biodiversity influences the rate, magnitude, direction, and delivery of essential ecosystem processes such as pollination, agricultural pest and disease control, nutrient conservation in soils, and water purification.

In addition, biodiversity plays a direct role in climate regulation. Biodiversity affects the ability of terrestrial ecosystems to capture atmospheric carbon, their rates of evapotranspiration and temperature, all of which affect climate at local and global levels. Biodiversity affects atmospheric carbon sequestration primarily through its effects on species' characteristics, which determine how much carbon is taken up from the atmosphere, how much will be retained or fixed, and how much of this carbon will be released back into the atmosphere over time. The appropriate choice of species is potentially critical for maximizing carbon sequestration in the design and implementation of Climate Change mitigation activities.

The loss of biodiversity as a result of the clearing and burning of vegetation also contributes to global warming through the release of greenhouse gases to the atmosphere. Furthermore, as biodiversity is degraded or lost through human activities, options for coping with global Climate Change may be diminished. There is evidence that reductions in biodiversity limit ecosystem resilience, or its ability to recover to its original state after natural or human-induced disturbances.

Sandstorm in the desert, © Kevin Lane/UNEP/Still Pictures

Current and Expected Impacts of Climate Change on Biodiversity

In its third assessment report, the Intergovernmental Panel on Climate Change (IPCC) determined that the global mean surface temperature has increased by 0.6 degrees Celsius over the last century, and that the decade of the 1990s was the warmest on record so far. Precipitation patterns also changed spatially and temporally, and global sea level has risen 0.1-0.2 m. It is forecasted that, by the end of the century, Climate Change and its impacts may be the dominant direct driver of biodiversity loss and changes in ecosystem services at the global level. The scenarios developed by the IPCC project a further increase in global mean surface temperature of two to six degrees Celsius above pre-industrial levels by 2100, increased incidence of floods and droughts, and further rises in sea level of several centimetres.

All of these changes are already having significant impacts on biodiversity and ecosystems, including changes in species distribution, population sizes, the timing of reproduction or migration events, and increases in the frequency of pest and disease outbreaks. On average, the spatial distributions of a substantial set of studied species over different taxa has shifted 6.1 km per decade towards the poles or 1 m in elevation per decade. Spring events such as flowering and leaf flushing are occurring on average 2.3 days earlier per decade thus affecting the seasonal movement of species. Unique and highly productive ecosystems such as coral reefs have undergone major, although sometimes partially reversible, bleaching episodes caused where local sea surface temperatures have increased above the average for the warmest months.

Global Climate Change has been directly blamed for the extinction of at least one endemic vertebrate species, the golden toad, from the cloud forests of Costa Rica. It is projected that by 2050, Climate Change will cause the extinction of a substantial number of the subset of 1000 endemic species currently being analysed globally. Climate change is projected to hit hardest those species with intrinsically low population numbers, those inhabiting restricted or patchy areas, and those circumscribed to limited climatic ranges, such as coral reefs, mangrove forests, cloud forests, inland water ecosystems, and ecosystems overlying permafrost. Projected changes in climate are very likely to be without precedent during at least the last 10,000 years and will affect biodiversity both directly through changes in temperature and precipitation, and indirectly through changes in the frequency of disturbances such as fires, hurricanes, and storms.

In addition to changes in the global climate, human activities are exerting additional pressure on biodiversity and are expected to exacerbate climate-mediated biodiversity loss through land use change, soil and water pollution, diversion of water to managed ecosystems and urban systems, habitat fragmentation, selective exploitation of species, and the spread of invasive alien species. These pressures, which usually act in a concerted manner, will also limit the capacity of species to migrate, and of entire ecosystems to shift in extent in response to changes in temperature.

Burning forest, Thailand. Flock of egrets flying past burning trees, © D.Juntawonsup/UNEP/Still Picture

Biodiversity Considerations in Mitigation and Adaptation Activities

There are significant opportunities for both mitigating and adapting to Climate Change while enhancing the conservation and sustainable use of biodiversity. Carbon mitigation and adaptation options that take into account environmental, social, and economic considerations offer the greatest potential for synergistic impacts. Forests, agricultural lands, and other terrestrial ecosystems offer significant mitigation potential through afforestation and reforestation, as well as through agriculture, grazing land, and forest management. Yet, since mitigation activities represent long-term endeavours, reducing other pressures on biodiversity, such as habitat conversion, overharvesting, and introduction of invasive alien species, constitutes important adaptation measures. Other measures include protection, restoration, and maintenance of ecosystem structure and function in order to maximize local species diversity and enhance ecosystem resilience.

In particular, mitigation of Climate Change through afforestation and reforestation activities, where appropriate management and adequate site selection and design criteria are in place, can enhance the conservation and use of biodiversity. The value of a planted forest to biodiversity, however, will depend to a large degree on what was previously on the site and also on the landscape context in which it occurs. As a concrete example, a reforestation and/or afforestation activity that includes planting a variety of native tree species or mixtures of single species stands, rather than a vast monoculture is highly likely, while fixing atmospheric carbon, to also (i) reduce the probability of pest incidence; (ii) restore key watershed functions; and (iii) promote ecological connectivity between forest fragments and allow migration across altitudinal gradients.

Challenges and the 2010 Biodiversity Target

Although past changes in the global climate resulted in extensive species migration and ecosystem reorganization, these changes occurred in landscapes that were not as fragmented nor as degraded as those found today. Therefore, the adaptive capacity of species and ecosystems in the face of contemporary Climate Change may be more limited, and underscores the need for managing existing protected areas or other habitats of high biological importance in a dynamic way.

The need to promote both ecological connectivity and integrated land and water management outside protected areas, while reducing present threats to biodiversity, should be explicitly taken into account when managing for biodiversity in the face of Climate Change. In intensively managed ecosystems such as farmlands, biophysical adaptations to Climate Change can be relatively straightforward, such as switching plant varieties. In less intensively managed ecosystems, decisions will have to be made as to whether to minimize or facilitate their change in order to maintain the supply of ecosystem services — in other words, planning for adaptation. In particular, lands set aside for conservation pose special challenges. The management of biodiversity outside reserves will need an "off reserve" approach to ensure species dispersal across a habitat matrix that may not always be favourable and that may cross political boundaries.

To this end, an important determinant of success for managing biodiversity in the face of Climate Change is that managers have available in a timely fashion information about likely trends in climate, and a deeper understanding of species adaptations to the present climate. Likewise, the development of models of plant and animal migration that take into account current patterns of land cover/land use type may be essential for predicting pathways of climate-induced species dispersal across habitats fragmented and/or degraded by human actions.

Since biodiversity is essential to human well-being and survival, by regulating climate and maintaining ecosystem resilience, among other services, its loss has to be controlled in the long term. In 2002, the Conference of the Parties to the Convention on Biological Diversity adopted the target "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level as a contribution to poverty alleviation and to the benefit of all life on Earth" and, in 2004 adopted a framework that includes a number of global subtargets and a set of associated indicators aimed at assessing progress in achieving this 2010 target.

Specifically, one global sub-target, to "maintain and enhance resilience of the components of biodiversity to adapt to Climate Change", responds to the fact that even if all anthropogenic greenhouse gas emissions would be stopped today, the effects of global Climate Change would be expected to continue for decades. Many of the necessary actions to achieve the 2010 target and this particular global sub-target are incorporated into the programmes of work of the Convention. Specifically, this subtarget can be achieved if areas of high importance for biodiversity and functioning ecological networks are maintained within protected areas or by other conservation mechanisms, and if proactive measures are taken both to protect endangered species and facilitate their movement. The rate of climate-induced biodiversity loss of targeted habitats and species could then be reduced.

Presented at the Roundtable on Climate Change and Migratory Species, Nairobi, 19 November 2005

Glacier, Alaska, Prince William Sound, USA, © P.L. Sherman/UNEP/Still Pictures

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A German Perspective

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Introduction

Climate Change is a phenomenon which currently can be recognized by many indicators in Germany. The impacts of Climate Change affect not only species and ecosystems but also the economy and the people of Germany. Nature conservation is faced with new challenges and thoughts on appropriate strategies and measures to cope with the most likely developments are essential.
The following text deals with the status and perspectives of German nature conservation under Climate Change, taking the country as an example for Central Europe.

European Bee-Eater (Merops apiaster), © NABU/Pollin

Characters and Impacts of Climate Change in Germany

In Germany weather conditions have been monitored throughout the country for more than a century. Data indicates that the mean temperatures are increasing continuously (LEUSCHNER & SCHIPKA 2004). Since 1870 the annual mean temperatures have been recorded in Karlsruhe in southwest Germany. During this period it has been shown that the mean annual temperatures fluctuated but with a rising trend. The lowest mean temperature was 8.2°C in 1876, and the highest in 1994 and 2000 at 12.2°C.

The pattern of the seasonal weather conditions is more extreme. Recently not only hot summers and frosty winter periods occurred more frequently, but also intense storms and heavy rainfall were observed. The River Elbe in Saxony flooded in 2002, when the historic city centre of Dresden was damaged by the run off of water into the river from the mountains of Saxony and the northern Czech Republic.

Responding to changes in the seasons' timing and mean temperatures, plants and animals have changed their specific phenologies (MENZEL & FABIAN 2001). In springtime many plant species flower earlier than they did a century ago. In migratory birds, which breed in Germany and stay in southern Europe or Africa during the winter, impacts of Climate Change can clearly be observed. Migrants travelling over short or medium distances arrive earlier and stay longer in their breeding areas. Such species may benefit from a higher rate of reproduction from early occupation of breeding sites, consecutive broods or other effects (DUNN 2004, HÜPPOP & HÜPPOP 2005). However, long distance migrants crossing the Sahara desert are less adaptable and often keep their traditional timing of spring arrivals and autumn departures in Germany (LEHIKOINEN et al. 2004).

Higher mean temperatures support the extension of the distribution ranges of species occurring in the south of Germany. Some Mediterranean species indicate this clearly: The Praying Mantis (*Mantis religiosa*), formerly restricted to the southernmost valley of the River Rhine is spreading northward; European Bee-Eaters (*Merops apiaster*), which were infrequent in Germany are now regular breeders in many regions of the country; and Kuhl's Pipistrelle Bat (*Pipistrellus kuhlii*) has been observed north of the Alps for a couple of years.

The opposite effect also occurs from Climate Change impacts: Species lose their central European habitats and move their range northwards, as documented in the Ruff (*Philomachus pugnax*) (Zöckler 2002).

Warmer conditions not only open the way for northward extension of natural ranges but the survival of introduced species is also higher. So Climate Change is connected with increasing problems of invasive alien species in central Europe. A prominent example is the Pacific oyster (*Crassostrea gigas*), introduced to the North Sea in 1964 for economic reasons. This species needs a certain water temperature for reproduction and for this reason was unable to leave aquaculture. However, as water temperatures changed, Pacific oysters have reproduced in the North Sea since 1990 and are currently displacing native oyster species in the Wadden Sea (Nehring 1999; Nehring & Klingenstein 2005).

Kuhl's Pipistrelle Bat (Pipistrellus kuhlii), © Markus Nolf, http://markus.nolf.org

Future Expectations and Predictions

As the ecological processes connected to Climate Change continue, one can predict that vegetation composition in Germany will be altered, too. Plants typically growing under Atlantic climate conditions with mild winters will expand their range eastwards as the continental climate influence weakens. This may especially be the case for many winter green species like the English holly (*Ilex aquifolium*) which could double its range by the year 2050, thus changing significantly the understorey vegetation of beech forests in eastern Germany (Walther et al. 2005a).

With changes in the vegetation composition of habitats the altitudinal zoning of plant and animal species will be altered. Arctic-alpine specialists on mountaintops will face competition with other species which did not previously grow in higher altitudes. This development can already be observed on mountaintops of the Alps (Walther et al. 2005b). As one result mountain specialist species may become threatened or even become extinct. As a second result characteristic vegetation types and zones, as they were known biologically and geographically, may vanish.

It can also be expected that the alteration of flora and fauna will continue as species from regions with another climate become successful invaders in Germany. A special problem for nature conservation will come from an increasing rate of alien species being introduced unintentionally through trade and tourism.

Migratory species will be heavily affected by future climate developments. The conservation of these species will have multiple problems as a result of changes in habitats used for breeding, stop over rests or wintering of migrants, changes in the compe titive systems among species, e.g. predators and their prey, and adaptive changes of the migration routes used by the animals (Bairlein & Hüppop 2004). These conservation problems will be added to those already encountered by migratory species, e.g. population decrease, habitat fragmentation and poor monitoring data.

Challenges for Nature Conservation

More research and monitoring of Climate Change impacts on plant and animal species is essential. Bird ringing has proved to be the most important method in observing ongoing developments and adaptations among migratory species. For this reason the distribution and occurrence of populations should be surveyed and the migratory and reproductive behaviour of individuals has to be observed and recorded.

For the implementation of appropriate conservation measures it is important to develop regional scenarios for the coming centuries. Such scenarios should be based on today's knowledge of the ecology and habitat preference of species as well as general climate and circulation models. They may be used to assess the vulnerability of species and ecosystems to Climate Change with awareness of their limitations (Goodess & Palutikof 1992). There are good examples for regional scenarios available, e.g. for waders, geese and polar bears in the Arctic, cetaceans in Scottish waters, and marine turtles in the Caribbean Sea (Fish et al. 2005, Lindström & Agrell 1999, MacLeod et al. 2005, Zöckler & Lysenko 2000).

Species conservation should focus on the protection of vital populations, consisting of many individuals and showing successful reproduction. Another problem is establishing large enough areas under conservation management in order to allow viable populations of the different animal species. In Germany, such areas with suitable habitats are few as the development of settlements, industries and traffic lines caused intensive fragmentation of habitats and landscape (Bundesamt für Naturschutz 2004). As insufficient connectivity of habitats can limit the movement and migration in many species, these large-scale landscape developments hinder range shifts as an adaptation to Climate Change.

To conserve migration routes of animals it is important to protect and improve the connectivity of habitats. On a small scale there are many possible measures to enable animal movement across human structures like roads, railways and canals. However, on a large scale it is very difficult to save a network of connected habitats in Europe. The Natura 2000 network of the European Community, the Emerald Network of the Council of Europe and the Pan European Biological and Landscape Diversity Strategy are ambitious programmes for habitat conservation, but with limited options in habitat connectivity (Ssymank et al. 1998, van Opstal 2000). More successful is the idea of The Green Belt, which means the conversion of the former borderlines between NATO and communist countries into a belt of habitats. Last century's "strip of death" shall become a "life line" across Europe (Bundesamt für Naturschutz 2004).

The Green Belt – a life line across Europe,
© BUND-Projektbüro Grünes Band/Klaus Leidorf

Although the instruments of nature conservation to face the effects of Climate Change will be the same as those used to deal with "traditional" conservation problems, targets and strategies have to be reviewed. Some aims and ideas may prove to be unrealistic in a changing climate. Conservation strategies must consider the international or even global situation. In a country like Germany it is essential to set priorities, e.g. for the conservation of species with a higher percentage of the population living in or migrating through our country.

Educating future generations, © T. Martin / DeWiSt

Beech forest, © NABU / Christoph Heinrich

Another challenge is the education of future conservationists who will have to deal with ever changing ecosystems. They should know about dynamic processes in nature and learn the way of "dynamic thinking". Good knowledge of vegetation development or population dynamics would be essential. This could encourage biologists out of their modern laboratories and into the field again to study nature *in situ* – which would probably be the only positive effect of Climate Change.

Finally, to slow down Climate Change processes nature conservation policies must support the work on national and international levels to improve the use of renewable energy sources and to protect natural CO_2 sinks such as swamps, bogs and forests (King 2005).

The ecological effects of Climate Change especially on species should be communicated among ecologists and to the public more intensively (Vitousek 1994). The main messages should be:

- Migratory species are among the organisms most affected by Climate Change. Their problems are very diverse in different regions of the earth, e.g. replacement of tundra by forest in the Arctic, habitat loss in Europe, desertification in northern Africa, sea level rise in the Asian Pacific, hurricanes in the Caribbean, and rising temperatures in Antarctic waters.
- Current methods and instruments of nature conservation are appropriate to face the challenges connected to Climate Change. There is no need to call for innovations or wait for them.
- Climate change is one element of global change, which is additionally characterized by human population growth, habitat degradation, habitat fragmentation, urbanisation, desertification, pollution, alteration of the global nitrogen cycle and loss of biodiversity.
- It is fundamental to protect nature in a changing world. There is no reason to lose hope or stop conservation actions.

Conclusion

Climate change is a process which impacts species and ecosystems that can be observed in Germany. It is a global challenge for nature conservation to face the development which is foreseeable by future climate models and relevant for biodiversity. The impact of Climate Change can only be managed through international cooperation, especially in the case of migratory species. The Convention on Migratory Species of Wild Animals CMS is the best international body to cope with Climate Change and its impact on migratory species.

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Examples from Eastern Asia and Northern Australia

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Introduction

Many wetlands in eastern Asia and northern Australia have been degraded and are under increasing pressure from the introduction of alien species, water pollution, urban encroachment, reclamation and infilling, and hydrological disruption (Revenga et al. 2000; Storrs and Finlayson, 1997; Finlayson and D'Cruz 2005; Dudgeon et al. 2005).The inventory information base for addressing these issues is uneven and in places absent (Finlayson et al. 1999). At the same time these wetlands are under threat from Climate Change and sea level rise, as shown by analyses undertaken almost a decade ago in Kakadu National Park, northern Australia (Bayliss et al. 1998; Eliot et al. 1999), Olango Island, the Philippines (Mapalo 1999), and the Yellow River delta, China (Li et al. 1999).

Not only do these analyses provide a striking example of the potential loss or change that could occur at individual sites, but as they are linked with each other along the East Asian-Australasian Flyway (www.wetlands.org/IWC/awc/waterbirdstrategy/Netwirk.htm) they also illustrate the interconnectedness of wetland sites and the necessity to manage within the wider context. Thus, the value and management of the wetlands in Kakadu National Park are not separable from the value and management of the networks of wetlands that support migratory birds across much of eastern Asia. Management of the network of important sites that occur within the flyway (Fig. 1) is encouraged through the Asia-Pacific Waterbird Strategy. With this background the implications of Climate Change for wetlands in northern Australia and eastern Asia are discussed with particular reference to the analyses undertaken at particular sites. Reference is also made to the recent initiative by the Ramsar Convention on Wetlands to provide guidance on vulnerability assessment of wetlands.

Methods

The assessments in northern Australia and eastern Asia were based on a model provided by Kay and Waterman (1993) and included the following steps:

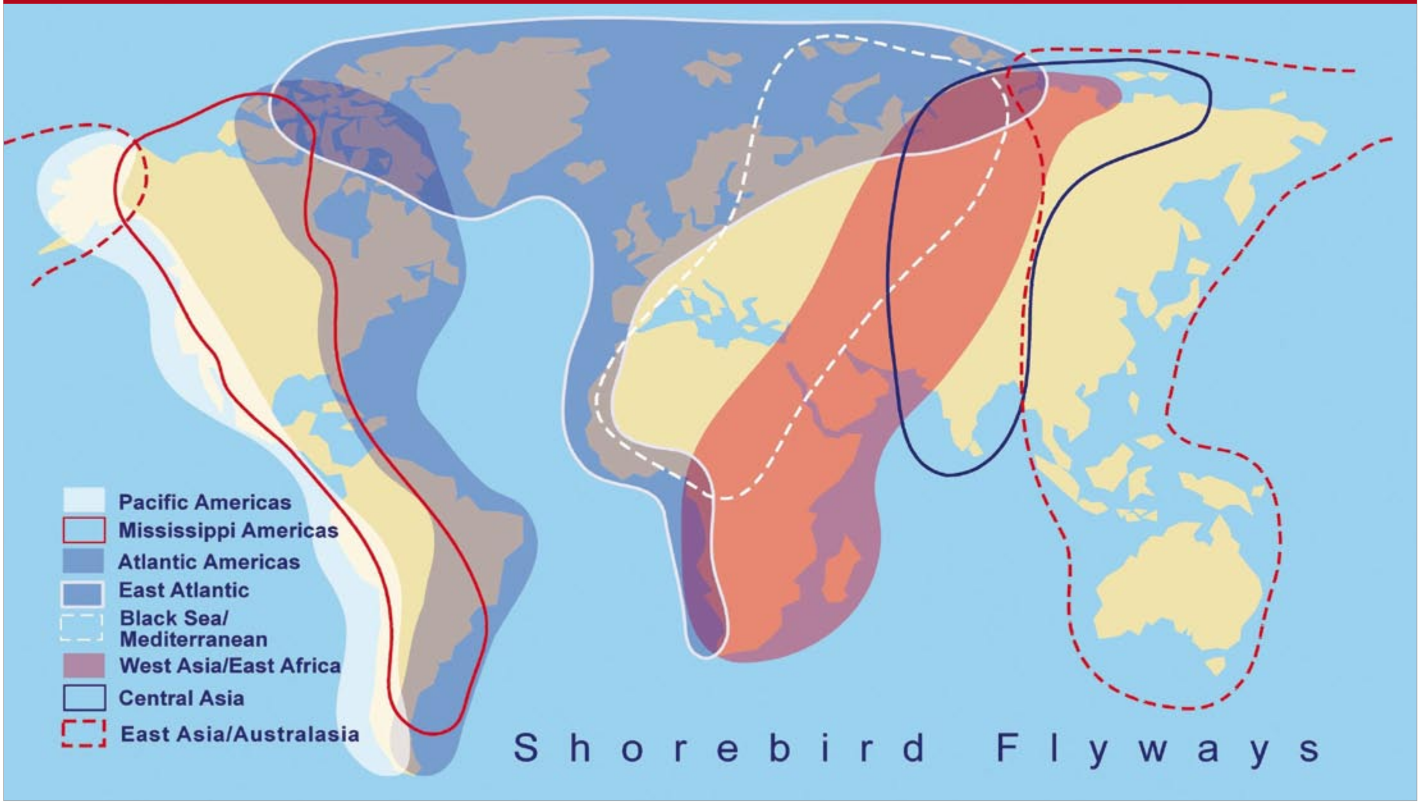
- Description of the sites, including physical, biological and socio-economic attributes;
- Identification of natural and anthropogenic 'forcing factors', including predicted Climate Change and sea level rise, and their impacts;
- Assessment of the vulnerability to existing forcing factors;
- Assessment of the vulnerability to Climate Change and sea level rise;
- Documentation of current responses to coastal hazards;
- Recommendations for future monitoring and management strategies;
- Identification of information gaps and research priorities.

This included collation of information on major land uses, conservation values and management threats and issues; analysis of the major values and benefits derived from the wetland; analysis of sea level rise; identification of possible management responses; and identification of necessary training for local conservation personnel. The assessments at all sites were undertaken in collaboration with relevant conservation management authorities and local communities.

Regional Climate Change scenarios were adopted for each site with adjustments based on local data. The key factors in the scenarios for each site were:

- Kakadu National Park: 1 - 2°C increase in temperature by 2030; average rainfall increase of 0 - 20 % with a more intense monsoon; sea level is expected to rise with a best estimate for Australia of 20 cm ± 10 cm by 2030.
- Olango Island: rise in mean sea level of 30 cm by 2030, and 95 cm by 2100; increase in mean global sea surface temperature of 0.5°C by 2010 and 3°C by 2030; 20% increase in typhoon intensity; and a tendency for increased rainfall, intensity and frequency.

Figure 1: Outline of global shorebird flyways (from International Wader Study Group, map drawn by Rodney West).



- Yellow River delta: rise in relative sea level of 48 cm by 2050; increase in mean air temperature of 1.4°C by 2050 and 3°C by 2100; and increase in annual precipitation of 2 - 4.5% by 2050.

It is important to note that the scenarios are not the same due to geographic differences and to differences in the data resources. It is anticipated that some of the outcomes of these assessments may change as more site-specific scenarios are developed and feedback from climate-related events are considered.

Wetlands and Climate Change

Based on the scenarios and available information on the bio-physical features of the sites and information derived from a variety of other investigations the following responses to Climate Change and sea level rise were projected. The confidence in the components of the site projections varied enormously between and within sites due to vast differences in the data resources and knowledge about biophysical responses. The extent of the information available at each site for an assessment of this nature varied greatly.

In terms of the projections the mapping of areas potentially affected by changes in rainfall and runoff or sea level rise was fraught with uncertainty, especially in relation to vertical scales of change given the absence of sufficiently accurate digital elevation mapping and by the lack of precision in the climate scenarios. However, the confidence in these projections was, on the whole, greater than that for the ecological responses which were also confounded by the uncertainties with the spatial analyses of physical changes. The ecological analyses were weak due to the absence of basic data on population sizes and dynamics as well as the inter-relationships with the physical environment. General projections are possible at all sites, but the certainty of these is greatly affected by the information sources. The projections are considered important as they provide managers and scientists with a base for seeking further information in order to better inform management actions. With this note of caution the general projections for each site are given below.

Kakadu National Park, © C. Max Finlayson

Kakadu National Park: Changes to the wetlands due to sea level rise, shoreline erosion and saltwater intrusion were considered important and would combine to change both the salt and freshwater wetlands. Change to the wetlands from Climate Change would likely include reduction or loss of some components of the mangrove fringe along the coast line, colonisation of mangrove species along creek lines as an accompaniment to salt water intrusion, replacement of freshwater wetlands with saline mudflats; and extensive loss of *Melaleuca* (paperbark) trees in freshwater wetlands. With changes in the wetland vegetation and habitats there would also be changes in animal populations, particularly noticeable would be changes to the community composition and distribution of bird species and fish in the freshwater wetlands. It is also expected that changes in the biotic resources may have cultural, social and economic consequences for the Aboriginal and non-Aboriginal people living in or visiting the area.

Olango Island: Climate change and sea level rise are expected to place considerable additional stress on Olango Island. Given its low elevation and topographical relief, more than 10% of the current land mass would be lost in the event of a 95 cm rise in sea level. In addition, more severe typhoons and storm surges would result in an even greater portion of the island being subjected to inundation and flooding. Given that the majority of human settlements on the island occur in close proximity to the shoreline, this represents a major problem. An increase in sea level would also facilitate saltwater intrusion into the underground freshwater lens, although this could be offset by an increase in rainfall. Potential effects on the biological attributes include loss of mangrove stands due to an inability to re-colonise inland, bleaching and death of corals due to increased sea surface temperature, and loss of feeding grounds and roosting habitat for resident and migratory shorebirds. Potential effects on socio-economic attributes include the displacement of people, loss of infrastructure and loss of livelihood options.

Yellow River Delta: The delta is vulnerable to predicted Climate Change and sea level rise. Salt marshes and other coastal wetlands are thought to be particularly vulnerable to permanent inundation and erosion as a result of sea level rise and increased storm surge. This would have flow-on effects to tourism, fresh-

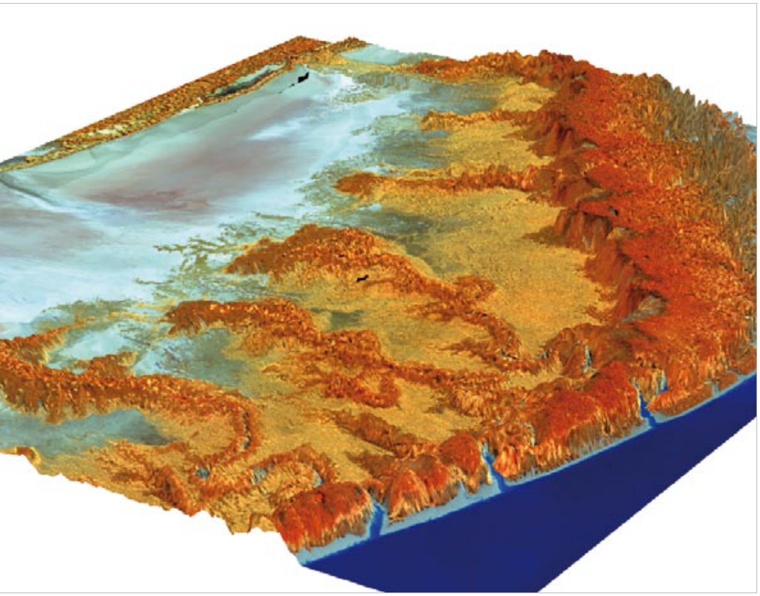
Tidal wetlands in Kakadu National Park, © C. Max Finlayson

water supplies, fisheries and biodiversity. Sea level rise will also result in a number of other impacts including a reduction in the protective capacity of the dyke systems. Assuming a 1 m sea level rise and 2 - 3 m storm surge, approximately 40% of the delta could be inundated. Saltwater intrusion will also be a major issue, further reducing already limited freshwater resources. The above impacts will have major consequences for both the socio-economic and biological attributes of the delta.

Management Issues

Given the potential changes to wetlands along the flyway, environmental management issues that may assist in developing effective responses for dealing with change have been identified. As the broad scenario includes large-scale modification of wetland habitats and environmental changes that may extend across land uses and jurisdictional bounds, it is anticipated that existing management structures will be severely challenged and possibly unable to implement radical actions that sufficiently address concerns of the broader community. Responses that may be necessary are introduced below while accepting that not all will apply equally at all sites.

1. **Systematic examination of perceptions and values with respect to management of the wetlands and surrounding areas.** Raising awareness of the implications of Climate Change is an important step in changing governmental and community perceptions.
2. **Responsibility and accountability for increased natural hazards.** Across the flyway natural hazards include extreme weather events (e.g. tropical cyclones, monsoonal depressions, and heavy rainfall) that could disrupt orderly use of coastal and wetland resources for habitation, industry and commerce, and necessitate change to planning and financial mechanisms.
3. **Broader and transparent governance structures and processes.** Current governance and jurisdiction may not be well equipped to deal with environmental change across broad



3D image of the mangroves on the West Alligator River, Kakadu National Park, Aust. © Anthea Mitchell

areas in a multi-sectoral manner. Broader and community-based management mechanisms that can provide consistent and appropriate responses irrespective of jurisdictional boundaries are needed.

4. **Balance between economic imperatives and ecological conditions.** Strategic management should include the inter-related components of regional development and conservation. There is a need for the broad community to accept mechanisms that can resolve conflict within the context of a regional development strategy that encompasses adequate conservation of resources.
5. **Acquisition and custodianship of information.** Access to existing data and information should be improved and reports made readily available and unconfined to the grey literature. Much data and information is currently difficult to access.
6. **Environmental investigation, including research and monitoring to support further vulnerability assessment.** Data and information on the processes and extent of environmental change, development of management strategies, implementation and auditing of management actions, and assessing performance of the overall management processes, is required.

Vulnerability Assessment – Issues and Pitfalls

The above cases illustrate some of the difficulties faced by wetland managers and scientists in undertaking and responding to assessments of the vulnerability of important wetlands to Climate Change and sea level rise. In many cases we know which wetlands are the most important for migratory and sedentary species, especially where there are large populations of species. However, we often do not have sufficient information for projecting change and establishing management scenarios that can be used to inform decision makers; a problem that is compounded when considering the network of sites distributed along the flyway. The challenge is to provide managers and decision makers with sufficient information – the issue is clear – we are seeking informed and more enlightened decisions that transparently consider the trade-offs between the various values and uses of important wetlands. Making assessments on inadequate data can result in major mistakes being made, but on the other hand, managers and decision makers require data and information – they need to manage now.

Vulnerability assessment is proposed as one way in which some of the shortcomings in data and information can be addressed, but this becomes a pitfall for the unwary if it is done without due analysis of the uncertainties and gaps introduced by inadequacies in the data. The following information on vulnerability assessment is drawn mainly from Ramsar CoP9 Doc.24 Information Paper (Assessment tools within the Integrated Framework for Wetland Inventory, Assessment and Monitoring (IF-WIAM)).

Vulnerability assessment has been used to determine the extent to which a wetland is susceptible to, or unable to cope with, adverse effects of Climate Change and variability and other pres-

Figure 2: Framework for wetland vulnerability assessment (based on information provided by Habiba Gitay).

Vulnerability Assessment - Method

Vulnerability Assessment = Risk Assessment x Risk Perception

1. Risk Assessment – based on *present status* and *recent trends*

Excellent | Good | Poor

2. Risk Perception – based on *sensitivity* and *adaptive capacity*

Sensitivity	Low	Moderate	High
Adaptive capacity	High	Moderate to Low	

Involve stakeholders – develop scenarios for drivers of change

No responses | Develop responses

Underpinned by adaptive management – monitoring & learning

sures, such as changes in land use and cover, water regime, or over-harvesting and overexploitation and invasion by alien species. Vulnerability incorporates risk assessment (i.e., the extent of and exposure to a hazard) and is linked to the stability or resilience and sensitivity of a wetland, as well as the capacity to cope with one or more hazard. It is a forward-looking process that is used to assess the probability of a change in the condition of a wetland in the future relative to some benchmark (or baseline). In this respect it is time dependent and assesses the likelihood of change to the wetland caused by some risky event given the sensitivity and resiliency of the wetland. The framework for vulnerability assessment (Fig. 2) is drawn from the OECD state-pressure-response model and the Millennium Ecosystem Assessment conceptual framework, as well as the case studies mentioned above. Thorough attention should be given to each step in the framework and the extent of uncertainty in each assessed before confirming the projections – the purpose of the framework is to encourage careful analysis of the information and the gaps.

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4 CLIMATE CHANGE AND MARINE APEX PREDAT

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Introduction

Our global climate is changing and human activities, including greenhouse gas emissions, deforestation and ozone depletion are at least in part responsible (Würsig et al., 2002). Trying to predict the precise consequences for life on the planet is difficult and this is especially true for highly mobile marine mammal predators. These are inherently difficult to study and adequately long term data sets defining marine predators' normal biology, ranges and habitats are typically rare. Indeed, we are now at the point when the links between global climatic change and predator responses are 'only just being explored' (Forcada et al., 2005). In addition, the effects of Climate Change on higher trophic levels can be difficult to understand because they involve various relationships that may be non-trivial and nonlinear and, possibly, affected by significant time-lags (Lusseau et al., 2004). The constraints of existing climate models also severely limit predictive ability for particular species (IWC, 1996) and, in addition, patterns and trends in species diversity and in the open oceans are enigmatic (Worms et al., 2005).

Here we review what is known of the impacts of Climate Change on marine predators and in addition consider the effects caused by 'normal' marine circulation fluctuations, including the El Niño/ Southern Oscillation of the Pacific Ocean. Whilst this phenomenon creates an average surface temperature anomaly of only 1.6°C, it still has an important negative influence on coastal upwelling systems that bring nutrients to the surface and fuel highly productive marine ecosystems and fisheries.

Marine mammals may prove to be important indicators of Climate Change: many species are highly visible (especially when compared with other marine predators) and, as we shall see below, the species that breed out of water provide an opportunity to monitor both their productivity and that of the ecosystem that they inhabit. Marine mammal ranges are generally related to species temperature tolerances (Robinson et al., 2005); hence, temperature is an important defining component of habitat for many species. Some are exclusively found in warm tropical waters, some in the temperate zones and some only at the poles. Whilst quite a few species can move between different temperatures zones during regular migrations, they may be adapted to particular temperature regimes at particular parts of their annual cycles. For example, young animals may require warmer waters for their early growth and development. Marine mammals typically exploit patchy prey species that they require in dense concentrations. Hence their distributions tend to reflect both static features (such as depth and slope) and more mobile ones (such as fronts and upwellings) where productivity is high.

Sousa chinensis, © Nicola Hodgins

Several authors have considered the likely impacts of Climate Change on cetaceans[1], including MacGarvin and Simmonds (1996) and Burns (2002), and the International Whaling Commission has held a special workshop on this theme, concluding that "concerns about the ability of at least some cetacean populations to adapt to future conditions are justified" (IWC, 1996). Würsig et al. (2002) also reviewed this issue, emphasising the vulnerability of species that are dependent on limited patches of particular types of habitat, such as certain land-breeding pinnipeds, the coastal and freshwater cetaceans, and the sirenians[2].

Würsig et al. (2002) also suggested that Climate Change effects can be divided into three types:

- primary effects – those experienced by the individual;
- secondary effects – those that affect a population or species; and
- tertiary effects – those created as a response to Climate Change by our own species (for example, Climate Change-driven fisheries failures may cause human fishers to move their attentions to marine mammals).

They also noted the potential for a shift in the Gulf Stream in the North Atlantic and the possibility that the Northwest Passage across North America will become more easily navigable. This, in turn, could increase boat traffic in this region, increasing the risks of oil spills and other pollution, worsening acoustic pollution and, generally, degrading what is regarded as a still relatively pristine area.

Observations and Evidence

i. Changes in Water Bodies

Burns (2002) emphasised the importance of Antarctica, where 90 percent of the world's great whales feed, and that temperatures in some areas have already risen by 4-5°C in only 50 years. He also noted the importance of the zooplankton species krill (*Euphausiacea*) and its relationship to the extent of sea-ice and the algae associated with it which are a critical food resource for krill[3]. In areas where the sea-ice has receded, salps (tunicates of the species *Salpa thompsoni*) tend to dominate and may outcompete the krill. Salps are more tolerant of warmer and lower nutrient water than krill and there is evidence that their range is expanding with profound implications for the Southern Ocean food web, including penguins, albatrosses, seals and whales, which despite their wide foraging ranges, are all susceptible to krill shortages (Atkinson et al., 2004).

Areas of open water in the polar ice-pack, known as polynyas or leads, are important for some species of marine mammals[4] and their extent may be affected by Climate Change (Burns, 2002). In the Arctic, no one species of plankton dominates but a diminution of the phytoplankton populations, with knock-on effects throughout the Arctic food chains, is predicted. Burns (2002) suggests

Common Dolphin (Delphinus delphis), © Cornwall BND Colin Wood

that several key prey species for cetaceans may be affected but adds "some cetacean species in the region, such as fin whales (*Balaeonoptera physalus*) and bowhead whales (*Balaena mysticetus*) have demonstrated adaptability in feeding behaviour and may be able to switch to other species". With this statement, he introduces an important theme for further consideration, the issue of the adaptability of marine apex predators.

Burns (2002) also noted that global warming may foster poisonous algal blooms and contribute to epizootics and it appears that there has been a significant increase in mass die-offs in marine mammal populations in the last few years (Simmonds and Mayer, 1997; Robinson et al., 2005). Whilst, in many cases, viruses (notably of the typically highly pathogenic morbillivirus family) have been identified as the proximate cause, environmental factors may have exacerbated or even predicated these epizootics (Simmonds and Mayer, 1997). For example, in the case of the die-off of striped dolphins (*Stenella coeruleoalba*), which spread across the entire Mediterranean in the 1990s resulting in the loss of thousands of animals, the poor nutritional state of the dolphins resulting from low nutrient input to the eastern Mediterranean – caused originally by abnormally low rainfall – may have been a precipitating feature (Simmonds and Mayer, 1997).

In addition to Climate Change, another by-product of increasing atmospheric CO_2 concentrations is the acidification of seawater. It has been suggested that squid – which are key prey species for many deep-diving marine mammal species – may be especially vulnerable to this change. The high energy swimming method of squid and their high metabolism requires a good supply of oxygen from the blood and increasing CO_2 concentration lowers blood pH and its capacity to carry oxygen (TRS, 2005).

ii. Distributions Shifts

The importance of temperature in species distribution in the oceans has recently been investigated by Worms et al. (2005) who found what appears to be a general rule: that diversity is positively correlated with thermal fronts, dissolved oxygen and a non-linear function of temperature (with an optimum of about 23° C).

Predator demographics can of course be expected to be affected by prey, so changes in prey distribution or abundance may precede shifts or negative outcomes in predator populations. Würsig et al. (2002) stressed the importance of the El Niño events as a proxy for Climate Change (although a change in the incidence of these events could also be a feature of Climate Change itself). They noted that recent events have prompted reproductive failure (especially in the form of high juvenile mortality) in colonies of seabirds and seals. For example, in the major El Niño year of 1982, all female Galapagos fur seals (*Arctocephalus galapagoensis*) lost their pups. Several distributional shifts also occurred in other marine species at this time. For example, near-bottom spawning market squid (*Loligo opalescens*) left the southern California area, followed by the short-finned pilot whales (*Globicephala macrorhynchus*) that normally prey on them. Whether this loss of prey and apparently climate-induced shift caused deaths or health-impairment is not known. A few years later, an influx of Risso's dolphins (*Grampus griseus*) into the same region occurred and they fed on the by now returned market squid. Würsig et al. (2002) suggest that the dolphins may be taking advantage of the niche left by the pilot whales. During the same event there was also an expansion of bottlenose dolphins (*Tursiops truncatus*) from southern to central California and they remained there after the El Niño event ended (Würsig et al., 2002).

On a large scale, it is predicted that species will shift towards the poles and, ultimately, this is likely to result in a reduced global range for those that are most cold water adapted. Perry et al. (2005) examined long-term, climate-related changes in demersal fish in the North Sea. They found that both exploited and non-exploited fish responded markedly to recent increases in sea temperature, with nearly two thirds of species shifting their mean latitude or depth (or both) over a 25 year period. There is some evidence that predators are following suit. MacLeod et al. (2005) considered cetacean strandings and sighting frequency and relative abundance in north-west Scotland. The data suggested a range expansion of common dolphins (*Delphinus delphis* – a warmer water species) and a decrease in range of White-Beaked Dolphins (*Lagenorhynchus albirostris*). Their data 'may be the first direct evidence that this [pole-ward shift] is indeed happening in a cetacean species'. Changes in sperm whale (*Physeter macrocephalus*) distribution in the North East Atlantic, based on strandings data, has recently been related to shifts in the North Atlantic Oscillacion (NAO) which probably affects their squid prey species (Robinson et al., 2005).

Population level responses apart from distribution shifts are also possible and Lusseau et al. (2004) using two unusually long-term and detailed data sets, found that the group size of bottlenose dolphins in the Moray Firth, Scotland, and orcas (*Orcinus orca*) in Johnstone Strait, Canada, varied from year to year in relation to large scale ocean climate variation. Local indices of prey abundance also varied with climate and the cetaceans tended to live in smaller groups when there were less salmon around, which seemed to occur two years after a 'lower phase' of the North Atlantic and Pacific Decadal Oscilliations (NAO and PDO). This changing of group size is another illustration of the adaptability of these predators.

iii. Sea Ice Changes

The breeding assemblages of Antarctic fur seals (*Arctocephalus gazella*) at South Georgia provide an unusual opportunity to monitor an apex marine predator species, especially as good quality data exists from several decades (i.e. from summer 1984/5 onwards). Forcada et al. (2005) studied this situation and their analysis indicated that positive sea surface temperature (SST) anomalies at South Georgia, preceded by, and cross-correlated with, frequent El Niño-La Niña events between 1987 and 1988, explained extreme reductions in Antarctic fur seal pup production for the 20 years of the study. The authors believe that these anomalies were likely to be associated with low availability of prey, mainly krill.

Humpback Whales (Megaptera novangeliae), © Duncan Morrel

Another relatively highly visible marine predator is the polar bear (*Ursus maritimus*), which lives throughout the ice-covered waters of the Arctic and particularly on near-shore annual ice cover above the continental shelf where productivity is at its highest (Derocher et al., 2004)[5]. Climate change models predict changes to the sea ice with reduced seal prey availability for the bears. Derocher et al. (2004) have suggested that at first the bears might be favoured by more annual ice with more leads in it — making more suitable seal habitat available, but as the ice thins further they will have to travel more — using up energy to keep in contact with favoured habitat. Derocher et al. (2004) emphasise the 'behavioural plasticity' of all ursids but also note that "given the rapid pace of ecological change in the Arctic, the long generation time, and the highly specialised nature of polar bears, it is unlikely that polar bears will survive as a species if the ice disappears completely as has been predicted by some". WWF (2002) describe the polar bear as an ideal species through which to monitor human-caused impacts in the ecosystem including Climate Change. They note that in the Hudson and James Bays of Canada, sea ice is now melting early in the spring and forming later in the autumn and, therefore, the time that the bears have on the ice, storing up energy for the summer and autumn when there is little available food, is becoming shorter. In Hudson Bay, the main cause of death for cubs is either an absence of food or lack of fat on nursing mothers.

It should be stressed that Climate Change can — and probably already does — cause different effects in different regions. In Baffin Bay and the Davis Strait, strong increasing trends in winter sea-ice concentrations have been reported between 1979 and 1996; Baffin Bay also happens to host the largest concentrations of wintering narwhals (*Monodon monocerus*) and these animals are entirely dependent on leads and cracks in the ice so that they can breathe. Many major mortality events have been recorded when the narwhals have become trapped in the ice. Given their high site-fidelity and the decrease in open water areas for them, these polar specialists seem very vulnerable to Climate Change (Laidre and Heide-Jorgensen, 2005).

iv. Impact on Breeding Success

We have already mentioned the Climate Change-driven effects seen in Arctic pinnipeds and, despite the difficulties involved in identifying such matters with animals that breed in the sea, there are some signals from cetaceans that breeding is, or will be, affected. Sperm whale populations were heavily impacted by commercial whaling and recovery for these slow breeding animals is taking a very long time. It has been noted that Climate Change may further impair this and the poor reproductive success of this species in waters near the Galápagos Islands has been associated with periods of warm sea surface temperature, usually caused by El Niño events (Whitehead, 1997).

For one critically endangered whale population at least, a recent analysis indicates that Climate Change may be the agent that prevents its recovery and pushes it to its final extinction. Following the ending of commercial whaling, the North Atlantic Right Whale (*Eubalaena glacialis*) was expected to slowly recover. However, population growth slowed in the 1990s – with collisions with shipping and entanglement in nets identified as the chief culprits (Greene and Pershing, 2004). Greene and Pershing (2004) note that the planktonic copepod (*Calanus finmarchicus*) is the principal source of nutrition for right whales and its relatively high abundance in the 1980s explains the stable calving rate at this time. A decline in *Calanus* in the early 1990s has been associated with a drop in calving and the "most troubling observations" have occurred since 1995. Indeed, in 1996, the NAO Index exhibited its largest single year drop of the 20th century and this had effects on the North Atlantic's physical and biological oceanography. Effects in the Gulf of Maine/Scotian Shelf region were not seen until 1997/8, including a dramatic decline in calving rates.

In the North Atlantic, the NAO Index has been mainly positive over the last 25 years; this should provide favourable conditions for right whale feeding and, therefore, breeding. However, one of the IPCC conclusions is that there will be an increase in climate variability, and Greene and Pershing (2004) question whether the situation in 1996 was unusual or a sign of the future likely swings in climate. The worst scenario would be a prolonged period of negative NAO conditions. If right whale calving rates were depressed for a significant period of time, then the time to extinction would even become shorter than the 200 years previously predicted. Climate change and variability need, therefore, to now be taken into account in the management of the recovery of this population (Greene and Pershing, 2004).

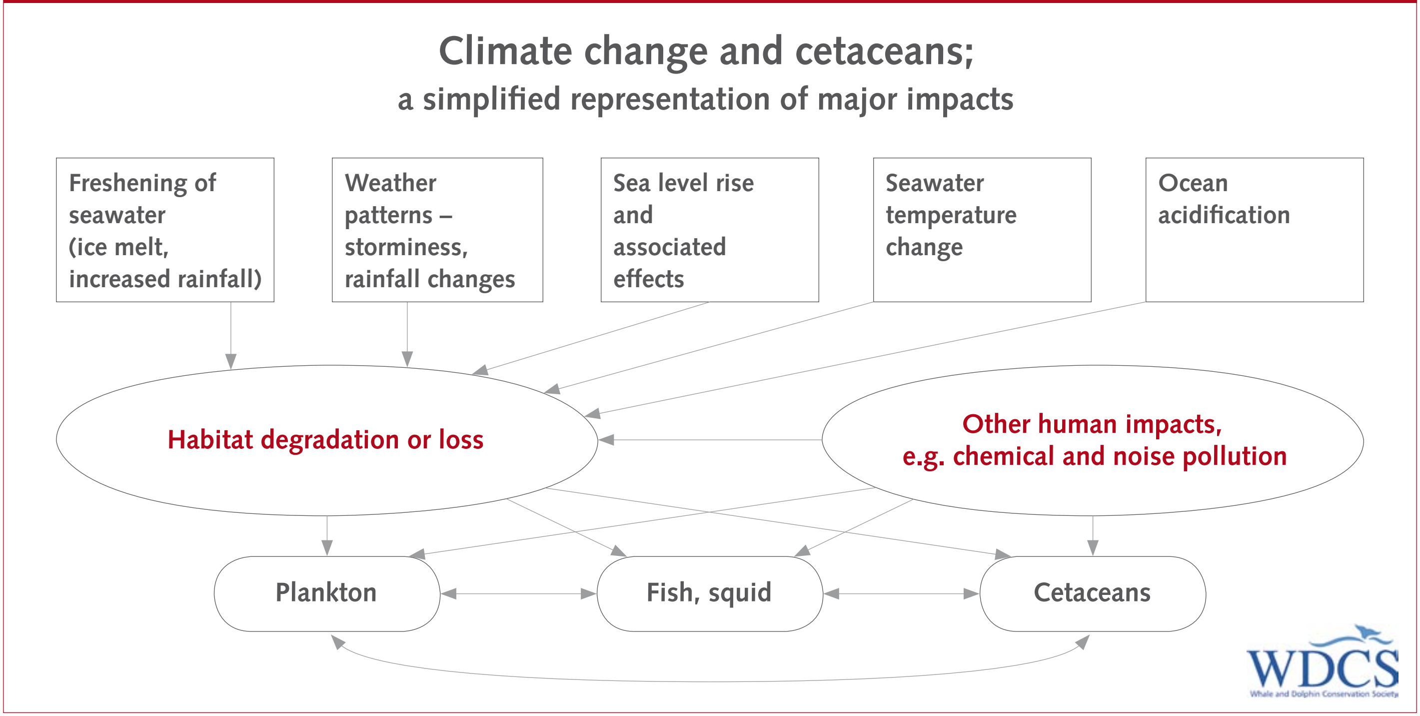
Conclusions

Perhaps the most obvious conclusion is that monitoring marine systems and linking observed changes to effects is far from easy. However, despite this, concerns for marine species are increasingly underpinned by observed effects. The ways in which Climate Change may affect marine predators are summarised in figure 1. This review also highlights the likely negative consequences and particular vulnerability of species that are dependent on the extent of sea ice. Similarly highlighted is the vulnerability of small and isolated populations, such as that of the northern right whale, where Climate Change is set to become a determining factor in its survival.

More generally, for all species, the key question concerns how quickly they can adapt to changes in their habitats and prey. It can be expected that at least some of the wider ranging predators – such as oceanic dolphins – are likely to be able to adapt to some extent to movements in their resource base. Indeed, even Bowhead Whales (*Balaena mysticetus*) (which are spectacularly long-lived and slow breeding ice-edge specialists) have been able to change their patterns of habitat use several times in the last 11,000, or so, years, apparently in response to changes in ice conditions, currents or marine productivity (Würsig et al., 2002). However, the current rates of change may be too great for many species to keep up with them.

Monitoring for changes in marine species and systems, including identifying vulnerabilities will be difficult and expensive but is also important and necessary for our understanding of global processes, including within ecosystems where we directly ex-

Figure 1: Ways in which Climate Change may affect marine predators



ploit resources. The international fora that deal with species conservation have a major role in providing co-ordination and direction. The IWC, for example, has recognised over the last ten years the need to address environmental change issues, including the possible impacts of Climate Change. However, the contribution of the IWC has been criticised for lack of adequate funding (Burns, 2002)[6] and it is unclear if there will still be will in the Commission to look at these important matters in the future. Fortunately, the Convention for Migratory Species has also recognised the importance of this issue (for example via an international workshop at its 2005 Conference of Parties where this paper was presented) and it will hopefully embrace a major role in related research and monitoring – in particular of the species on its appendices – in the future.

Finally, in closing, we would like to echo the words of Würsig et al. (2002) who further to their review of concerns for marine mammals, concluded that *"for such a pervasive problem as global Climate Change, we need strong political leadership that cares about the environment. Such leadership can emerge from any part of the globe, but a special responsibility falls on those of us in over-developed countries who can most afford to curb our huge, disproportionate per capita consumption of energy and output of toxins and other environmental degraders"*. We agree; energy policies urgently need to change worldwide.

In addition, in the face of the overwhelming changes that may result – and indeed already seem to be resulting – from 'global warming', conservation strategies should be expanded to encompass predicted changes resulting from climatic impacts;

failure to do so may mean that many strategies rapidly become redundant as they are overwhelmed by the consequences of a rapidly changing climate. This is the time for a fundamental revision in our thinking about conservation and resource management; and this new approach needs to be both adequately precautionary and significantly far-seeing.

Bottlenose dolphin (Tursiops truncatus), © Charlie Phillips

Acknowledgement

Climate Change and Migratory Species (Robinson et al., 2005) provided a very helpful yardstick to measure this short review against and in particular allowed us to confirm that we had identified the relevant key studies.

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Footnotes

[1] The mammalian Order Cetacea includes all the whales, dolphins and porpoises.

[2] Animals in the marine mammalian order Sirenia – more commonly called sea cows.

[3] Sea ice may also shelter krill from predators.

[4] Polynyas are important spring feeding and breeding grounds for some marine mammals in the Arctic and overwintering sites for white whales and possibly bowheads (Burns, 2002).

[5] Polar bears can be considered a 'marine mammal'; the sea ice is where they spend most of their lives. In summer, the sea ice melts in all, or part, of their range and only then are the bears forced to spend several months on land. Otherwise they are usually only on land when moving between sea-ice feeding areas or when searching for a mate or having cubs.

[6] Burns (2002) concluded that if the IWC failed to develop its environmental work then its "ultimate legacy may be that it saved whales from extinction by commercial harvesting but failed them in their time of greatest need".

5 IMPACTS OF CLIMATE CHANGE ON MARINE

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Consider the Australasian region at the end of the last Ice Age when Australia and New Guinea formed one large land mass. With a warming earth accompanied by melting ice caps and glaciers, the sea level rose and the Indian Ocean flooded into the Gulf of Carpentaria about 8,000 years BP, the Pacific Ocean breached the Torres Strait land bridge about 7,000 years BP and the coral islands of the Great Barrier Reef formed about 5,000 years BP. Turtle nesting beaches of 10,000 years BP are now totally submerged and most of the present day major marine turtle rookeries are located at sites that were inaccessible across dry land less than 150 turtle generations ago. The present major migratory route for adult green turtles feeding in eastern Indonesia, Arnhem Land and the Gulf of Carpentaria through Torres Strait to the Great Barrier Reef nesting beaches is a geologically recent phenomenon.

Marine turtles have been among the great survivors of dramatic Climate Changes and fluctuating sea levels spanning tens of millions of years since the age of the dinosaurs. Modern marine turtle populations developed new migratory routes and redistributed their breeding sites in response to changing climate and elevated sea levels since the last ice ages. In general terms, responding to Climate Change should not be a threat to marine turtle survival. Our concerns regarding their response to present day Climate Change should centre on their capacity to respond satisfactorily to an elevated rate of Climate Change while simultaneously being impacted by a wide range of significant threatening processes from human origins.

Increasing Temperatures on Nesting Beaches

Marine turtles of both families, Dermochelyidae and Cheloniidae, lay eggs that require nest temperatures in the 25-32°C for successful incubation. Both families are characterised by temperature dependent sex determination. Cool beaches produce predominantly male hatchlings; warm beaches produce mostly female hatchlings.

Green Turtle (Chelonia mydas) digging nest,
© Nicholas Pilcher

With increasing temperatures there is likely to be a feminising of marine turtle populations. Over the last 50 years or so, some critical nesting beaches like those in eastern mainland peninsula Malaysia have already shifted into a totally female producing temperature range presumably as a result of man-made changes to the nesting habitat and the more subtle global increases in temperature. While turtle populations appear to function successfully with an excess of females (male:female = 1:2 to 1:3), there probably should be concerns if the regional sex ratio for the species (stock) approaches 1:4 male to female.

Even without the current trend to warmer summers, sand temperatures at nest depth during mid summer in the tropics at some beaches approach or exceed the upper lethal limit for egg incubation (34°C). At such tropical beaches in northern Australia, marine turtles nest in winter while the same species (but different genetic stocks) in eastern and western Australia nests in the mid summer but on cooler beaches.

In contrast, within the southern Great Barrier Reef, in the first decades after our marine turtle studies commenced in 1968, we never recorded sand temperatures at nest depth reaching the 34°C lethal temperature at any nesting beach. Since the extraordinarily hot summer of December 1997 – January 1998, sand temperatures at nest depth at Mon Repos are now reaching as high as 36°C for weeks at a time during hatching season. In response to these excessively high nest temperatures, there has been increased debilitation and even death of eggs and hatchlings. It can be predicted that with further increases in summer temperatures, significant decreases in hatching success and hatchling emergence from nests can be expected on beaches that until recently were good turtle egg incubators.

A commonly held hypothesis is that marine turtles return to breed at the beach at which they were born – such a behaviour implies a static breeding association with specific locations. However, the loggerhead turtles, *Caretta caretta*, tagged as hatchlings at Mon Repos beach decades ago are now returning to breed at about 30 years of age but not just at Mon Repos. They are returning to breed at many beaches in the region. When these results are linked to the observations of past changes in nesting distribution in response to the end of the ice ages, we need to consider an alternate hypothesis regarding fidelity to ancestral breeding sites: Marine turtle populations may return to the same breeding area while environmental conditions remain stable but they may shift to new breeding sites in response to changing environmental cues such as sea temperature, beach stability and proximity to suitable ocean current for dispersing hatchlings to pelagic foraging areas. There is a range of temperature variables that will exert selective pressure on marine turtle nesting biology: white sand beaches are cooler than dark sand beaches; temperate beaches are cooler than tropical beaches; beaches are cooler in winter than in summer.

I present the hypothesis that marine turtles will respond to Climate Change as they have done in the past through changes in the distribution of nesting and changes in the associated migratory routes or through shifts their nesting to cooler months. I suggest that these changes will not occur primarily through changes in behaviour of the existing adult population but rather through changes occurring as new adults recruit to join the breeding population over future generations. Because of the long generation time of marine turtles, this response to Climate Change will be slow and occur over decades or more likely hundreds of years.

Green turtle (Chelonia mydas) surfacing to breath,
© Alejandro Fallabrino

Sea Level Rise and Impacts on Nesting Beaches

At nesting beaches with elevated sand dunes, turtles are expected to be little affected by sea level rise. Their nesting should occur above the new tide levels. The situation will be very different with low elevation sand islands such as occurs widely in the Pacific Island nations, the Caribbean, the Maldives and the Great Barrier Reef. At these low elevation sand beaches, the combined impact of erosion and flooding of the nesting habitat is expected to cause increases in egg mortality and eventually loss of some nesting beaches. It is uncertain whether reef building processes will keep pace with sea level rise to renourish the beaches naturally. Turtles that lose their nesting beaches, are expected to seek out new nesting sites. How turtles from very remote/isolated sites will cope will loss of nesting habitat is conjecture.

Management Response to Climate Change at Nesting Beaches

Knowledge gap: We do not understand how a turtle selects her nesting beach as she commences her breeding life. Research needs:

- Investigation of cues used by turtles during nesting beach selection.
- Investigation of the potential for turtles to change their breeding behaviour through shifts in timing of the breeding season, through shifts to use cooler beaches or through selection of new breeding sites following the loss of a rookery.

Knowledge gap: Incubation success, hatchling emergence success and temperature profiles of the nesting habitats are not documented at most rookeries. Research needs:

- Establish temperature profiles throughout the range of nesting beaches for the species (stock).
- Census annual turtle breeding (nesting and hatchling production) at beaches that represent the full spectrum of temperature profiles, including marginal nesting beaches as well as core index beaches. This monitoring should include the monitoring of interchange of turtles between breeding sites.
- Investigate the possibility for remote sensing to quantify sand temperatures at nest depth.

Leatherback Turtle on the beach (Dermochely coriacea), © Jacques Fretey

Managers should:

- Explore options for modifying temperature on the nesting beaches through the use of vegetation cover and artificial shading. These are particularly applicable with highly managed nesting areas where hatcheries are in use. With hatcheries, it is even possible to reduce the "beach" temperature by choosing lighter coloured sand.
- Explore options for beach renourishment and restoration of the sand mass at low sand islands.
- Increase habitat protection of cooler nesting beaches which have the potential for remaining functional rookeries as Climate Change progresses (even if they are minor rookeries at present).

Green Turtle at „Turtle Rock," Sipadan, Malaysia (Chelonia mydas), © Jason Isley / Scubazoo

Hawksbill Turtle (Eretmochelys imbricata), © Robert Yin / UNEP / Still Pictures

Climate Change and the Pelagic Environment

Post-hatchling turtles feed on plankton in open ocean but plankton is not uniformly distributed in the oceans. It is aggregated along convergence zones and upwellings. This oceanic pelagic life history phase is the most poorly understood aspect of marine turtle life history. This is where our greatest uncertainty in understanding the potential impacts of Climate Change on the turtles occurs. The locations of these plankton rich zones of the open ocean are expected to vary in location between years in response to Climate Change and, with continued global warming, post-hatchling migrations should change in response to changes in distribution of water masses and plankton. The positive/negative aspects are difficult to predict at present.

Climate Change Impacts on Coastal Foraging Habitat

Changing sea temperature will change rates of physiological function for poikilothermic species such as marine turtles. Increased metabolic rates in response to warmer habitat have the potential to increase growth rates of immature turtles and to hasten vitellogenesis (with resulting shorter intervals between breeding seasons) in adults. If this does happen, the age to maturity could shorten. Fecundity may increase. These could positively benefit the population dynamics of the species but there will be other negative impacts operating in parallel.

For green turtles, the size of the annual nesting population is controlled by climate. In the Australasian region, it is regulated by the El Niño Southern Oscillation: mass nesting occurs 18 months following an major El Niño event and depleted nesting occurs 18 months after a major La Niña event. This short term variation in nesting numbers is not the result of births and deaths but the result of whether or not a turtle prepares for breeding back

Leatherback Turtle hatchling (Dermochely coriacea), © George R. Hughes

Green Turtle in Cerro de la Verde (Chelonia mydas), © Alejandro Fallabrino

in her home foraging area. This is being regulated by food availability (quality and abundance). With continued global warming, any change in the "El Niño Southern Oscillation" climate pattern or intensity will change the frequency of green turtle breeding migrations.

With current Climate Change trends, it is expected that the unusually hot summers that have occurred in recent years will become more frequent. These very hot years are causing coral bleaching and negatively impacting coral reefs. These same hot years are also having a negative impact on intertidal seagrass pastures in eastern Australia. 35°C is a lethal temperature for a number of seagrass species. This temperature is being regularly exceeding on the intertidal seagrass flats during recent hot summer – with associated reduction in pasture quality and abundance for the foraging green turtles.

Within the tropical areas, the Climate Change prediction is for more intense storms (cyclones and hurricanes), though their frequency may decrease. Intense storms cause structural damage to coral reefs and erosion of seagrass pastures. It takes 5-10 years for badly damaged coral reefs and seagrass pastures to renew following major storm damage. While the food resources are depleted over these years, there will be reduced growth rates of immature turtles and reduced levels of adult turtles that prepare for breeding migrations. Similarly the prediction for areas like tropical Australia is for less rain and for more intense rainfall when it occurs. The intense rainfall events are likely to cause flooding and associated run-off of sediments. Our experience in recent years in south Queensland is for the flooding events and associated sediment run-off to cause the death of coastal seagrass pasture. As well as the impacts noted above for reduced growth and breeding rates for green turtles, we are detecting elevated increases in mortality of green turtles in the months that follow such an event.

Collectively, the combined impact of increased frequency of hot summers, increased intensity of storms and flooding events is expected to be seriously damaging to coastal ecosystems, especially coral reefs and seagrass pasture. These coastal waters encompass the primary foraging habitats for most of the Cheloniidae species but not for the Dermochelyidae. While our understanding of the foraging ecology and associated population dynamics is best understood for green turtles, it is expected that these negative impacts will apply to all species inhabiting coastal waters.

Coastal Management Response to Climate Change

While the global community is collectively working to reduce the impacts of Climate Change, it is imperative that marine turtle foraging habitat is managed to reduce stress on our already stressed turtle populations. In particular, we need to manage for healthy and functional coral reefs and seagrass pastures. Actions can include:

- Improved catchment management to reduce sediment run-off during floods;
- Reduced chemical pollution through fertiliser, herbicide and industrial chemical out-flow;
- Reduced dispersal of synthetic waste for land sources.
- Management of fisheries and boating activity to minimise habitat damage.

Conclusion

Without positive action to improve their conservation prospects:

threatened marine turtles

+

climate change

=

threatened marine turtles under greater threat

After Climate Change, there will still be suitable turtle habitat but not necessarily where it is today and it may take decades to centuries to re-establish and stabilise.

As we look to the future, we should have confidence that today's threatened turtle populations will respond to the new Climate Change stresses and that they have the biological potential to survive, but only if we allow them the opportunity.

Our success in conservation management of migratory marine turtles with their dependence on multiple habitats will be a good indicator of our success in maintaining biodiversity throughout our oceans and coastal waters.

6 MIGRATORY WILDLIFE IN A CHANGING CLIMA

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Abstract

The world's climate is changing rapidly, especially in certain parts of the world where evidence of its impacts is particularly apparent. There is already substantial evidence that wildlife has been affected by Climate Change and as a group, migratory wildlife appears to be particularly vulnerable to the impacts of Climate Change because it uses multiple habitats and sites and use a wide range of resources at different points of their migratory cycle. I provide a brief review of the potential and actual impacts of Climate Change on migratory wildlife. The Convention for the Conservation of Migratory Species provides a valuable framework for facilitating the adaptation of migratory wildlife to Climate Change, as well as providing a mechanism for the exchange of knowledge between parties and the development of multinational strategies.

Harbour seal on ice-berg, USA (Prince Willian Sound),
© Richard Reid - UNEP/Still Pictures

Introduction

The world's climate is changing rapidly, especially in certain parts of the world where evidence of its impacts is particularly apparent. Thus, for example, Mount Kilimanjaro in Tanzania has all but lost its snow for the first time in 10,000 years and there have been substantial losses from parts of the Antarctic ice-shelves. The Reports of the Intergovernmental Panel on Climate Change show that global temperatures have risen by 0.6°C over the past 150 years and that such a rise is unprecedented over the past 1000 years.

There is already substantial evidence that wildlife has been affected by Climate Change and there is the strong expectation that it will be increasingly affected in the future. As a group, migratory wildlife appears to be particularly vulnerable to the impacts of Climate Change because it uses multiple habitats and sites and use a wide range of resources at different points of their migratory cycle. They are also subject to a wide range of physical conditions and often rely on predictable weather patterns, such as winds and ocean currents, which might change under the influence of Climate Change. Finally, they face a wide range of biological influences, such as predators, competitors and diseases that could be affected by Climate Change. While some of this is also true for more sedentary species, migrants have the potential to be affected by Climate Change not only on their breeding and non-breeding grounds but also while on migration.

Apart from such direct impacts, factors that affect the migratory journey itself may affect other parts of a species' life cycle. Changes in the timing of migration may affect breeding or hibernation, for example if a species has to take longer than normal on migration, due to changes in conditions *en route*, then it may arrive late, obtain poorer quality breeding resources (such as territory) and be less productive as a result. If migration consumes more resources than normal, then individuals may have fewer resources to put into breeding — the large baleen whales may suffer from this, as they do not feed while on migration.

General Patterns

The degree of knowledge about the potential and actual impacts of Climate Change varies considerably between different taxonomic groups — best studied are birds, then mammals; fish and turtles are relatively poorly understood, but very little is known about the invertebrates. Species have three possible responses to Climate Change:

- They can change geographical distribution to track environmental changes.
- They can remain in the same place but change to match the new environment, through either a behavioural response (such as a shift in the timing of breeding) or a genetic response (such as an increase in the proportion of heat tolerant individuals).
- They can go extinct. No species has unambiguously become extinct due to Climate Change yet, although the Golden Toad of the montane cloud forests of Costa Rica may be one such case.

Key factors that are likely to affect all species, regardless of migratory tendency, are changes in prey distributions and changes or loss of habitat. Changes in prey may occur in terms of their distributions or in timing. The latter may occur though differential changes in developmental rates and can lead to a mismatch in timing between predators and prey ("phenological disjunction"). Changes in habitat quality (leading ultimately to habitat loss) may be important for migratory species that need a coherent network of sites to facilitate their migratory journeys. Habitat quality is especially important on staging or stop-over sites, as individuals need to consume large amounts of resource rapidly to continue their onward journey. Such high quality sites may crucial to allow migrants to cross large ecological barriers, such as oceans or deserts.

However, it should be noted that migration itself is a response to ecological conditions, and in many species is a flexible and adaptable trait. Thus, changes in length, timing and location of migratory routes in response to changing climatic conditions have been documented. These are leading to changes in the patterns of occurrence in a wide range of taxa.

Typical localized rainfall in Chad, © John Newby/SSIG

Impacts of Climate Change on Different Taxonomic Groups

Marine Invertebrates, Fish and Turtles

The distributions, abundance and communities of marine invertebrates and fish are very temperature-dependent, as these species are ectothermic, i.e. unable to regulate their own body temperature internally. Thus, for example the distributions of copepod plankton in the North Sea have changed considerably since the 1960s: southern edge shelf species and "pseudo-oceanic" temperate species have tended to move northwards. The migration of Herring in the North Sea, which feed on *Calanus finmarchius*, is affected by temperatures and ocean currents leading them to move further north in warmer years. There is evidence for the increasing occurrence of exotic southern species into the North Sea, such as Red Mullet, Anchovy, Sardine, and Poor Cod since the mid-1990s, which is correlated with warmer sea temperatures. There have been similar changes recorded in the abundance of squid, both in the North Sea, but also in the Southern Atlantic Ocean.

Changes in ocean mixing, deep water production and coastal upwellings will have profound effects on the status, sustainability, productivity and biodiversity of coastal zone and marine ecosystems. Very little is known about the physical determinants of upwellings zones, but these are crucial zones of productivity for marine communities.

Elevated levels of CO_2 in the atmosphere will tend to result in increased concentrations in sea-water, leading to decreases in pH (i.e. acidity). This has the potential to affect calcification rates by marine plankton as part of their exoskeletons and could ultimately affect coral formation. Squid have extremely pH-sensitive blood oxygen transport which may be detrimentally affected by even small changes in oceanic pH. The potential significance of such effects needs further research.

Marine turtles face a number of problems that are specific to their life cycles. Sex determination is dependent on the temperature during incubation of the eggs, with warmer temperatures resulting in the production of more females. For example, on Ascension Island the pivotal temperature at which Green Turtle eggs produce a sex ratio of 50% males and females is 28.8 °C and current sex ratios are approximately 75% female after approximately 0.4 °C warming over the past 100 years. Thus there is the possibility of global warming altering sex ratios substantially in the future. In addition warmer temperatures on nesting beaches may exceed the maximum for successful development, leading to heat stress, smaller body size and increased embryo mortality. Climate warming may also increase the incidence of disease: for example Fibropapilloma tumours in Green Turtles are hypothesised to grow faster in warmer waters and the prevalence of this disease has increased since the 1980s. Finally, there are direct effects that may arise from sea-level rise. Under a scenario of a 0.5 m sea-level rise, GIS-based elevation models indicate that up to 32% of beaches used by nesting sea turtles in the Caribbean could be lost via “coastal squeeze“ – the loss of coastal habitat between the high-water mark and hard coastal defences, such as sea-walls.

Marine Mammals

Most cetaceans (whales and dolphins) are highly migratory. For example the larger baleen whales, such as Blue Whale, undertake long seasonal migrations between tropical calving grounds in winter and high latitude feeding grounds in summer. Changes in the distribution, abundance and community compositions of their food supplies, plankton, fish and squid, are strongly related to climatic factors, particularly sea temperatures. Such changes are already affecting cetacean communities, for example in the North Sea there has been an increase in the representation of southern-water species further north. Warm waters also affect cetacean reproduction, as reductions in food supplies in warmer waters decrease the physical condition of females and increases the intervals between reproduction events.

There may be similar impacts on seal populations, but these are also potentially affected by the loss of undisturbed haul-out sites, due to sea-level rise, which are used for breeding, nurseries and resting. Endangered species, such as the Mediterranean Monk Seal (listed on CMS Appendix I), which use a limited number of (often cave) sites are particularly threatened. Similarly, pinnipeds, such as Ringed Seal, Bearded Seal and Walruses, that use ice flows for resting, pupping and moulting, may be particularly vulnerable to changes in sea ice extent. Thus, declines in Ringed Seal pup survival in the western Hudson Bay is associated with earlier spring break-up of ice and lower snow cover.

The Polar Bear is another migratory species that requires solid ice as a substrate on which to hunt and rear its offspring. The condition of adult Polar Bears in the western Hudson Bay has declined significantly since the 1980s, as has the proportion of independent yearling cubs. This is associated with a period that has seen the earlier break-up of sea ice and its later re-formation.

Migratory Birds

Migratory birds form the best studied group of wildlife and can act as an indicator of the types of effects and impacts that may affect other, less well studied groups. Most species (84%) listed on the Appendices of the CMS have the potential to be affected by Climate Change in some way: 53% from changes to water regime (droughts, lowered water tables, etc.), 24% from mismatches with food supplies, 18% from sea-level rise, 17% from habitat shifts, 17% from changes in prey range and 7% from increased storm frequency. These are estimates based on expert opinion, but the total proportion thought to be threatened by Climate Change impacts is greater than that threatened from all other man-induced impacts.

Changes in the distribution, abundance and timing of prey have already been demonstrated to have impacts on migratory birds. For example, changes in the relative timing of caterpillar food supplies for woodland birds, such as (resident) Great Tit and (migratory) Pied Flycatcher in Europe, are already having impacts on the reproductive success of those species that are not able to adjust their timing in synchrony ("phenological disjunction"). This provides evidence for natural selection already occurring in response to Climate Change, as early breeding birds are being disproportionately favoured compared to later nesting individuals. In North Scotland, internationally important populations of seabirds have suffered massive breeding failures (near 100%) in recent years, which appears to be due to warmer waters leading to a loss of plankton and thus the fish that they feed on. Migratory birds often require highly productive areas in which to fatten prior to migration and when these fail, catastrophic declines can take decades to recover. For example the Sahel drought in 1968 - 69 led to a massive decline (ca. 80%) in Whitethroat Warblers returning to the UK and their numbers are still only 25% of their former abundance.

One of the biggest threats to a significant number of highly migratory birds is the consequence of warming in polar regions, if this leads to a loss of tundra habitats due to sea-level rise and encroachment of taller-growing vegetation with increased warmth. There is already evidence that decreased snow cover is leading to accelerated thawing in these areas. The lack of land further north means that the area available for the large populations of migratory birds that breed in these regions may shrink significantly, with important consequences for the viability of their populations.

Bats

While it is probable that many species of bats are migratory, the scale and extent of such movements are largely unknown, though females are usually more migratory than males. The reproductive cycle of temperate zone bats is closely linked to their pattern of hibernation. Bats mate in the autumn and winter and spermatozoa are stored in the female reproductive tract until spring. If bats experience warm conditions in the second half of winter, they will arouse from hibernation prematurely, ovulate and become pregnant, thus the timing of their reproductive cycles is likely to be significantly affected by Climate Change, although not necessarily to their detriment. However, a key period is lactation, and a loss of 2 - 3 days of feeding due to inclement weather could lead to major productivity declines.

Bats are likely to feed continuously *en route*, and require corridors of suitable habitat, especially moist woodlands, wetlands and waterways. Thus the maintenance of suitable migration corridors is important and changes in water regimes, combined with habitat fragmentation, may have serious consequences for their successful migration. There is also the need to protect key roost sites and in some areas, particularly Caribbean islands, loss of coastal cave roosts through sea-level rise could be important.

Terrestrial Mammals

Migratory journeys are less common in terrestrial mammals than other groups, but there some spectacular and well-known migrations undertaken by large herbivorous mammals that feed on seasonal grasses, such as Wildebeest and Caribou. (The CMS also covers a number of species, such as Mountain Gorilla, that are termed technical migrants because they cross state boundaries in the course of their movements, but do not have regular seasonal migrations in the traditional sense).

Climate is important for their reproduction and survival, through impacts on the quality and quantity of their food supplies, and can influence calving success and juvenile survival. Changes in the migrations of these large herding species will have major impacts on their ecosystems. Increased grazing in an area will affect the vegetation and may lead to erosion, decreased grazing may lead to ecological succession and the encroachment of woody plants into the grassland. Changes in timing and routes are also likely to have major impacts on the communities of predators and scavengers that rely on them.

As many of these migrations track seasonal changes in vegetation, there is the potential to come into conflict with human populations. For example, elephants may move into cultivated areas with damaging impacts for local farmers. However, land-use patterns may also prevent animals from adapting their migratory routes, for example park boundary fences have been demonstrated to disrupt major migratory journeys, leading to population decline in Wildebeest.

Conservation Priorities

The Convention for the Conservation on Migratory Species (CMS) has the potential to provide a framework that will allow parties to work together to help overcome the developing problems that are likely to arise out of Climate Change. In particular, the sharing of information and expertise will be very important means of speeding up the responses of different nations to these issues.

Within terrestrial systems, two issues potentially affect a large number of migratory species: changes in water resources and the loss of vulnerable habitats. 'Leap' migrants, those that take large long distance migrations without refuelling, require a coherent network of stopover sites, and 'broad-front' migrants require extensive habitat provision along their routes and may benefit from initiatives such as the development of agri-environment schemes in Europe and the Meso-American Corridor in Central America. The maintenance of wetland quality is of key importance, but there are a number of habitats that are particularly threatened by Climate Change: tundra, cloud forest, sea-ice and low-lying coastal areas. Many of these areas also face severe anthropogenic threats and it would help them to adapt to Climate Change if these pressures were reduced.

In the marine environment, the priority for adapting to Climate Change will be to manage the human impacts on the resources required by migratory species through ecosystem based management. The designation of marine protected areas (or 'no-take zones') for the prey of marine mammals at key sites could be valuable. However the locations of such areas are likely to change over time and protective legislation will require a degree of flexibility to be effective.

In both terrestrial and marine environments, the maintenance of large population sizes will be important to facilitate successful adaptation to changed climatic factors. Populations will require sufficient genetic variation within them to provide the basis for adapting to new conditions.

Khulan herd (Equus hemionus) running, © Richard Reading

The maintenance of long-term monitoring schemes is vital for the identification of conservation priorities and in providing base-line data against which to measure the impacts of Climate Change. In addition, such monitoring schemes are the only means by which it will be possible to detect unexpected or unpredictable impacts of Climate Change at their early stages. Many of these schemes are threatened by lack of resources, and a commitment to long-term support of these schemes is critical to ensure their existence and to ensure best value by utilising existing data collection networks. There is also a need to identify new monitoring requirements, such as in the marine environment, and to identify potentially useful indicator species or suites of species, that might indicate site condition and the condition of migration routes. Such indicators have proved useful in driving policy when considering the impacts of agricultural land-use change in Europe.

The CMS has already had many conservation successes, particularly through the development of regionally and taxonomically based agreements that aim to promote the conservation of certain groups of migratory wildlife throughout their range states. The incorporation of Climate Change considerations within specific Agreements and Memoranda of Understanding will provide flexibility to address particular threats to migratory wildlife. Exploiting synergies between treaties and conventions, for example through joint work programmes, would provide increased value, better coordination and improved focus, as well as facilitating the development of key priorities.

Conclusions and other Issues

Migratory wildlife is especially vulnerable to the impacts of Climate Change, because the changing pressures can be felt at different points throughout their life cycle. The world's climate is moving into a period of change that is unprecedented since the ice ages and we will be moving outside the boundaries of the data on wildlife responses that we currently have, as a result there may be changes that are effectively unpredictable in scale, timing and consequences. Another aspect that is difficult to assess is the consequences of the potential for the increased prevalence of more extreme climate events – an increased frequency of such events could be particularly damaging for migratory wildlife as they will have reduced time for population recovery between events. Interactions with man are very important, particularly the anthropogenic responses to Climate Change that may lead to large changes in land-use, and it is possible that changes in the distributions of migratory species are likely to affect man economically and provide increased conflict with his interests.

Adaptation policies are likely to be very helpful in terrestrial habitats, but such responses are more difficult to implement in the marine environment. However, the CMS provides an excellent mechanism for the development of suitable strategies to improve the capacity of migratory wildlife to adapt to Climate Change.

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7 CLIMATE CHANGE AND MIGRATORY SPECIES

The following is a reprint of the Extended Summary of the report on "Climate Change and Migratory Species", commissioned by the UK Department for Environment, Food and Rural Affairs, published in August 2005 (© Crown copyright 2005). The full report is available from http://www.defra.gov.uk/wildlife-countryside/resprog/findings/climatechange-migratory/index.htm. Update from UNEP/CMS Secretariat in square brackets.

1. Introduction

Climate change is one of the major factors likely to affect the earth's ecosystems in the coming decades. The increase in global temperature in the 20th century was the largest in any century during the past 1,000 years and this has been associated with changes in weather patterns, precipitation, snow cover, sea-temperatures and sea-level.

There is already compelling evidence that animals and plants have been affected by recent climate change. Migratory species, by travelling large distances, being subject to a wide range of environmental influences and relying on a wide range of natural resources, are particularly likely to be affected by climate change at some point in their life cycles. These may be effects that apply to all species in that area, or effects that are specific to migrants

This review aims to (i) assess the strength of current scientific evidence of links between climate change and migratory species' behaviour, abundance and distribution, (ii) identify what effects climate change has had, and may have in the future, on migratory species (iii) identify which species are threatened by climate change and comment on the measures proposed to tackle such threats and (iv) comment on the reliability or uncertainty of predicted effects.

The UK Government is party to a number of international treaties and agreements that seek to promote and maintain the conservation status of migrant species of wildlife and Defra takes a lead role for the Government in these areas, with the Convention on the Conservation of Migratory Species of Wild Animals (CMS) being the primary instrument of interest. In this review, we focus on migratory species which occur in the U.K. or its Overseas Territories (UKOTs).

For the purposes of this review, we follow the CMS in defining a migratory species as one in which 'a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries'.

Although climate change may have effects on individual patterns of behaviour and physiology, from a conservation perspective impacts on population size and dynamics are of most interest. Thus changing climatic factors are most relevant if they impact on an organism's capacity to survive or to reproduce. We use the term 'impact' where a consequence for population size is likely, an effect where species biology is altered, but not population size directly.

2. Legislative Framework

The primary instrument for migratory species conservation is the Convention on the Conservation of Migratory Species of Wild Animals, signed in Bonn, Germany in December 1979, and since ratified by 91 parties (as at 1 July 2005; www.cms.int), [101 parties by 1 January 2007]. Indeed, it is the only global intergovernmental convention that is established exclusively for the conservation and management of migratory species. It is a framework document supported by a Secretariat under the auspices of the United Nations Environment Programme and progressed through a triennial Conference of Parties.

The CMS recognises that states have a duty to protect migratory species that live within or pass through their jurisdictional boundaries and that their effective management requires concerted action from all states in which a species spends any part of its life-cycle (the 'Range States'). It provides for the protection of endangered species (listed on Appendix I) and for those that would benefit from internationally co-ordinated efforts (Appendix II).

The strength of the CMS is in its framework nature, under which daughter agreements can be concluded to provide specific coverage for particular groups. To date, six legally binding Agreements and seven [eight] formal (but non-binding) Memoranda of Understanding (MoU) between appropriate Range States have been concluded.

The Agreements cover European species of bats and cetaceans, seals in the Wadden Sea and two groups of birds, the oceanic albatrosses and petrels and migratory waterbirds that use the African-Eurasian flyway.

The MoU cover marine turtles (in African waters and the Indian Ocean), four species of birds (Siberian Crane *Grus leucogeranus*, Slender-billed Curlew *Numenius tenuirostris*, Great Bustard *Otis tarda* and Aquatic Warbler *Acrocephalus paludicola*) and one terrestrial mammal (Bukhara Deer *Cervus elaphus bactrianus*) [two terrestrial mammals (Bukhara Deer *Cervus elaphus bactrianus* and Saiga Antelope *Tatarica tatarica*) and cetaceans in the Pacific.].

The Convention on Biological Diversity (CBD, www.biodiv.org) drawn up at the Earth Summit in Rio de Janeiro in 1992 has been ratified by 188 states and endorsed the aim of achieving 'by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth'. The UK has been successful in agreeing Action Plans (www.ukbap.org.uk) for 391 species, some covered by CMS and some habitats used by migratory species. Progress in the UK Overseas Territories (UKOTs) has been slower (and the British Antarctic and Indian Ocean Territories are excluded), but should be enhanced through the launch, in 2003, of the Overseas Territories Environment Programme to support the implementation of the Environment Charters within each Territory as well as Multilateral Environment Agreements.

Other instruments that affect migratory species include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, www.cites.org), the United Nations Convention on the Law of the Sea (fish and cetaceans), the Migratory Bird Treaty Act (North America only, http://migratorybirds.fws.gov) and the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar, www.ramsar.org). This latter is particularly important for migratory birds, as most waterfowl are migratory. Also relevant, particularly for conserving habitat used by migratory species are the European Wild Birds (79/409/EEC) and Habitats (92/43/EEC) Directives, the Bern Convention on the Conservation of European Wildlife and Natural Habitats and Antarctic treaties, such as the Commission for the Conservation of Antarctic Marine Living Resources.

The Ramsar Convention is the only international instrument protecting migratory species that makes explicit reference to climate change calling upon parties, *inter alia*, to 'manage wetlands to increase their resilience to climate change and extreme climatic events, and to reduce the risk of flooding and drought in vulnerable countries, through promoting wetland and watershed and protections' and to 'make every effort when implementing the Kyoto protocol, including re-vegetation and afforestation, that this implementation does not lead to serious damage to the ecological character of their wetlands'. Wetlands provide critical stopover areas for many bird species listed on the CMS.

3. Projected Climate Change

Our climate is changing. The global average surface temperature has increased over the 20th Century by around 0.6°C and precipitation has increased over the same period, particularly over mid- and high-latitudes. These have had secondary impacts, for instance the extent of ice cover has decreased and global sea-level is rising. Such changes are demonstrable.

The climate system comprises of a number of components: the atmosphere, oceans, land surface, cryosphere (ice areas) and biosphere (including human influences). Each of these systems is the result of a large array of drivers, and climate is a result of complex interactions between each of the components. Global Climate Models (GCM), which simulate the physical processes involved, are used to predict future changes under given scenarios of possible changes in greenhouse gas and other aerosol emissions. Regional Circulation Models, which build detail onto a GCM framework, have been used in certain areas, such as the UK, to provide more detailed inference of future climate changes.

The Intergovernmental Panel on Climate Change (IPCC) was formed by the World Meteorological Organisation and the United Nations Environment Programme, to provide a co-ordinated and broadly agreed consensus view on global climate processes. As part of its Third Assessment Report, it developed a series of marker scenarios (or alternative futures), which capture the broad range of variability of all scenarios that have been presented in the literature, for use as a basis in predicting the amount of greenhouse emissions and subsequent climate change. These scenarios describe broad dichotomies between development of economic and environmental objectives and between global and regional development. Each narrative assumes a distinctly different direction for future developments, but together they encompass the range of underlying uncertainty in the development of the main driving forces behind climate change. No likelihood of occurrence can be assigned to each of these narratives, so each is considered equally plausible.

In climate change models, to avoid the effects of annual fluctuation, model results are usually averaged over a period of years. Thus, simulations usually run from the 'present' (1961 - 1990) until the period 2070 - 2099, referred to as the 2080s. Globally, temperatures are expected to increase over the next century, with the projected increase expected to be somewhere in the region of 1.4 to 5.8 °C. This projected rate of warming is much larger than the observed changes during the 20th century. Warming is likely to be greatest over land areas, particularly at northern high latitudes in winter and lowest in southeast Asia (summer) and southern South America (winter). Global average precipitation is also likely to increase during the 21st century, however, there is likely to be much regional and seasonal variation and there is also more uncertainty in the magnitude of change.

Predictions for small island territories (such as the UKOTs) from large-scale GCMs are uncertain. The projected degree of warming is similar across UKOTs (in the order of 1 to 3 °C, but possibly higher), with the two territories in the Mediterranean region (Gibraltar and the Cyprus SAFB) likely to experience a greater degree of warming; the South Atlantic Islands show least projected warming. Precipitation levels are likely to decrease generally in the two Mediterranean territories. Amongst the Caribbean territories, projections are mixed, but there is a tendency towards an increase in precipitation in the autumn and winter months (September through February) and a decrease in the summer months.

The Caribbean territories will be influenced by changes in the El Niño Southern Oscillation (ENSO), influences that will occur more broadly. Warm episodes of ENSO have been more frequent, persistent and intense since the mid-1970s, leading to greater extremes of drying and heavy rainfall and increasing the risk of droughts and floods. It is uncertain whether there will be an increase in the frequency of tropical cyclones, but it is likely these will become more intense, with greater peak wind speeds, more intense rainfall and greater storm surges.

Climate change scenarios also suggest the North Atlantic Oscillation (NAO) will become more positive in the future, resulting in more wet, windy, mild winters along the north eastern Atlantic seaboard. Associated with these shifts in large-scale climate patterns there is likely to be a greater frequency in the formation of storms; wind speeds and wave size have increased over the North Sea.

There is consensus on the broad pattern of climatic changes in the UK and Europe. Temperatures are likely to increase (see below), precipitation will decrease in summer and increase in winter and the frequency and severity of extreme events (e.g. floods, storms) will increase. The UK climate is already beginning to alter in these directions, though these changes may still be within the 'normal' range of variability.

As the UK is home to many migratory birds from Scandinavia and the Arctic (that spend their winter in the UK) and some UK breeders spend the winter in southern Europe or Africa, the climate in these areas also needs to be considered. Temperatures are likely to increase markedly in northern latitudes and in Africa. Precipitation in Africa, upon which vegetation is particularly dependent, is likely to decrease, particularly in western and southern Africa, where most of the UK bird populations spend the boreal winter.

Global ocean heat content has increased significantly since the late 1950s, with more than half of this increase in the upper 300 m of the ocean. The North Sea is also warming, with an increase in annually averaged temperature of about 0.6°C over the past 70 to 100 years, most occurring in the last 20 years. The temperature of UK coastal waters will continue to rise, although not as rapidly as over land.

There has been a retreat of sea-ice extent in the Arctic spring and summer by about 10 to 15% and a 40% decline in sea-ice thickness. In the Arctic more freshwater from melting snow and ice will be released into the North Atlantic, through the Fram Strait between north-eastern Greenland and Svalbard, which may exert a strong influence on salinity in the North Atlantic and alter large-scale currents and circulation. Most models show a weakening of the thermohaline circulation in the North Atlantic leading to a reduction of heat transport into high latitudes of the

Northern Hemisphere; scenarios predict a weakening of the Gulf Stream, perhaps by as much as 25% by the 2080s; it is unlikely to stop completely.

Changes in seawater salinity are expected, but these will be regionally variable, and dependent on circulation patterns. For example, the salinity of Scottish oceanic waters has generally increased, indicating the arrival of warmer, saltier waters from further south in the Atlantic, however in the southern North Sea fishing areas there is an apparent trend of decreasing salinity linked to increasing freshwater inputs from coastal rivers.

Tide gauge data show that global average sea level rose between 0.1 and 0.2 m during the 20th century; in the UK sea level has risen by 0.1 m. Global mean sea level is projected to rise by 0.09 to 0.88 m by the 2080s, through, for example, the geographical variation in thermal expansion and changes in salinity, winds and ocean circulation; regionally, there is much variation. Sea-level rise will be an important consideration for low-lying coastal states (such as many of the UKOTs).

4. Impacts of Climate Change – General Patterns

The knowledge of the likely impacts of climate change varies greatly between taxonomic groups. There is much knowledge, and some degree of confidence about the impacts on bird populations, less so for all other groups. The general patterns noted here are expanded in the next section.

Many of the impacts of a changing climate will apply to species irrespective of their migratory status, thus consideration of migratory species cannot be done in isolation from non-migratory taxa. However, migratory species face additional constraints relating to the length of the migratory journey and conditions *en route*, particularly the location and quality of stopover areas, where sufficient food must be available for the next leg of the journey.

A useful distinction is between 'broad-front' migrants, which migrate in short hops, stopping frequently on route, and often have geographically diffuse migration routes (most bats, insects, passerine birds and marine animals) and 'leap' migrants, which migrate in long-haul journeys stopping at only a few, usually discrete, sites, such as wetlands, often in large numbers; the primary example of these would be migrating shorebirds and waterfowl.

Species have three possible responses to climate change: (i) change geographical distribution to track environmental changes; (ii) remain in the same place but change to match the new environment, through either a behavioural response, such as shifts in phenology (for example timing of growth, breeding etc.) or a genetic response, such as an increase in the proportion of heat tolerant individuals; or (iii) extinction. Examples of geographical shifts and behavioural changes as a response to changing climates have been documented, but no species has unambiguously become extinct because of a changing climate yet, although the Golden Toad *Bufo periglenes* may be one such case and many are predicted.

Many of the impacts of a changing climate are likely to be species-specific and related to particular ecological aspects of individual taxa, necessitating a species-based approach. However, some impacts will be important across all, or some, species groups.

Changes in range are perhaps the most widely documented effect of climate change and have been demonstrated in a number of groups. Such changes are relatively easy to measure and because climate is a fundamental determinant of whether an area is suitable for occupancy.

Further changes in distribution are predicted, often using an 'envelope' approach, i.e. defining current bioclimatic habitats occupied and modelling how these shift however, habitat occupancy (and other) relationships may change in future, particularly if future conditions are outside the currently observed range. Understanding the actual mechanisms and population processes behind the observed patterns will be the only way to understand how these relationships will operate in future.

Changes in prey distribution are equally common (though sometimes less well documented because of poorer data) and will have widespread effects on the distribution and survival of species at higher trophic levels (i.e. predators). These changes might be spatial (through changes in range), or temporal (through differential changes in development rates), and lead to a mismatch between prey abundance and the need for resources.

Habitat loss and, importantly, changes in habitat quality will affect all species, but are likely to be particularly important for migratory species that need a coherent network of sites to facilitate their migratory journeys. Habitat quality is particularly important on staging (stopover) sites, as individuals may need to consume a large amount of resource rapidly to continue their onward journey, particularly if this involves crossing an ecological barrier. In some cases migratory species will be better able to cope than others if their increased mobility enables them to exploit new situations.

Migration itself is a response to ecological conditions, and in many species is a flexible and adaptable trait. Changes in the length, timing and location of migratory routes in response to changing climatic conditions have been documented. These are leading to changes in patterns of occurrence in a wide range of taxa, including birds, turtles, cetaceans and insects.

The timing of migration occurs in the context of other life-history activities, such as breeding, moult or hibernation (depending on group). Changes in the timing of breeding are widely documented and migratory species face additional constraints in adapting to this. Equally, changes in the nature of the migratory journey (particularly if it lengthens or becomes more difficult because of fewer resources) will have consequences for successful breeding, moult etc. These effects are poorly understood at present.

By altering distributions, climate change will bring some species into conflict with human activities, particularly amongst migratory species, which use a network of sites, and may constrain their ability to adapt to changes. Conversely, anthropogenic responses to climate change are likely to exacerbate the impacts on wildlife caused by changing climatic conditions, e.g. through increased water abstraction, changes in agri- or silviculture, or changes in fishing patterns.

Changing climatic distributions will extend the range of many species, but it will also increase the probability of introduced ('alien') establishing. These may have significant impacts on local communities and biodiversity.

Although the scenarios of climate change are generally within the known range of historical conditions, the rate at which they are changing is unprecedented, so organisms may be unable to adapt sufficiently rapidly.

Few measures specifically targeted at adapting to climate change impacts have been undertaken at present, though many undertaken for other reasons, such as the creation of habitat corridors have been shown to be beneficial. 'Managed Realignment' of coastal defences in the face of rising sea-levels has been undertaken in the U.K. In the short-term these have not been very successful at re-creating bird inter-tidal communities, but properly designed programmes hold much potential for the longer term.

5. Impacts of Climate Change on Migratory Species

a. Marine Invertebrates, Fish and Turtles

Changes in distribution, abundance and community composition of fish and marine invertebrates, such as squid, are strongly related to sea temperature, as these species are ectothermic (i.e. unable to regulate their body temperature internally) and changes in temperature have caused changes in distribution of both exploited and non-exploited species and in the recruitment of Atlantic Cod *Gadus morhua* in the North Sea.

Recruitment of Herring *Clupea harengus* and Squid are linked to climatic conditions (through temperature impacts on the plankton ecosystem), with higher recruitment in warmer years, when migratory movements of Herring are also shorter. Increasing temperatures can therefore be expected to increase recruitment of at least some marine species.

The distributions of many marine species are associated with fronts between waters masses, and shifts in the location of these can have impacts on patterns of recruitment, which may impact on population size. However, increased temperatures will affect ocean circulation and the strength of marine upwellings, which is predicted to decrease global fish production.

The only fish listed on the CMS Appendices are the anadromous (migrating between freshwater and marine systems) sturgeons (Acipenseridae), the impacts of climate change on which are unstudied; their main relevance to CMS listed species is as prey to marine mammals.

Nesting biology of sea turtles is strongly affected by temperature, both in timing and in the sex-ratio of hatchlings, but the impacts of this on overall population size are unknown at present, though population structure is likely to be impacted with an increase in the relative number of females.

The range of many migratory turtles is shifting (or at least expanding) northwards, with an increasing number of records from UK waters. These include five species listed on CMS Appendix I (Loggerhead *Caretta carreta*, Green *Chelonia mydas*, Leatherback *Dermochelys coriacea*, Hawksbill *Eretmochelys imbricata* and Kemps' Ridley *Lepidochelys kempii* turtles). While the population impacts of this increased movement are unclear, the number of Range States with a conservation interest in these species will increase.

Sea turtles are likely to be directly impacted by an increase in sea levels and the loss of egg laying beaches. Under a predicted sea-level rise of 0.5 metres this will amount to up to 32% of nesting beaches in the Caribbean.

b. Marine Mammals

Most cetaceans (whales and dolphins) are highly migratory, the larger baleen whales e.g. Blue Whale *Balaenoptera musculus*, undertake long seasonal migrations between tropical calving grounds in winter and high latitude feeding grounds in summer, as a response to the need to feed in colder waters and reproduce in warmer waters. Movements of toothed whales (such as the Sperm Whale *Physeter macrocephalus*, Killer Whale *Orcinus orca* and dolphins) have different scales depending on geographic areas and species, with both north-south and inshore-offshore seasonal movements observed, probably in response to prey availability. Dispersal and migration is also common in several pinniped (seal) species. However, migratory journeys are poorly known.

Changes in plankton, fish and squid (which are prey for cetaceans and pinnipeds) distribution, abundance and community composition are strongly related to climatic factors, particularly sea temperature (see above). Shifts in plankton and fish community composition in the North Sea have been observed in plankton and fish communities and reflected in changes in the cetacean community, with a greater representation of southern-water species further north. Similar shifts have been shown elsewhere and such shifts in prey distribution are likely to be the greatest threat from changing climates to marine mammal populations. Conservation of these, particularly in preferred areas would be important for conserving marine mammals.

Changing water temperature also has an effect on the reproduction of cetaceans and pinnipeds, indirectly through prey abundance, either through extending the time between individual breeding attempts, or by reducing breeding condition of the mother. The growth and survival of Antarctic Seal *Artocephalus gazelle* pups is influenced by krill *Euphausia* abundance.

An indication of potential effects can be gained through currently extreme climatic events, which may reflect more typical conditions in the future (though species will have the chance of adaptation in the interim). For example, the warm water phase of the ENSO (which is becoming increasingly frequent) is associated with large-scale changes in movements, mortality and reproductive success of marine mammals, at least in part, through changes in prey abundance, there may thus be serious negative population impacts in future.

If prey abundance is low, there will be increased use of blubber reserves and the associated mobilisation of any accumulated anthropogenic contaminants, such as organochlorines, organobromines and polyaromatic hydrocarbons, can have marked effects on an individual's health. The population consequences of this are unknown, but maybe locally severe

A major impact of sea level rise is likely to be as a reduction in the number of seal haul-out sites used for breeding, nurseries and resting. Endangered species, such as the Mediterranean Monk Seal *Monachus monachus* (listed on CMS Appendix I), which use a limited number of sites, may be especially vulnerable; disturbance and killing of individuals may be greater threats though. This vulnerability is increased as the location of feeding areas is changing simultaneously, meaning new, undisturbed haul-out sites will be required.

Melting ice-sheets in the Arctic will reduce ocean salinities, which in turn will cause shifts in the distribution and biomass of major constituents of Arctic food webs (differing between species according to their ecology), with a tendency for poleward shifts in species assemblages and the potential loss of some polar species (such as Narwhal *Monodon monoceros*). Migratory whales, such as the Grey Whale *Eschrichtius robustus*, that use the Arctic for summer feeding grounds are likely to experience disruptions in the timing and distribution of their food sources.

c. Birds

The number of bird species that migrates varies with latitude. In the northern hemisphere, less than 10% of species living in tropical areas undertake migratory journeys, this proportion increases with distance away from the equator and more than 80% of species living within the Arctic Circle migrate south. Climate induced changes in habitat are predicted to be greatest in the Arctic, where the importance of migratory species is highest, these species have limited options for range shift due to limited availability of land at high latitudes and altitudes.

Most species listed by the CMS have the potential to be affected by climate change in some way. Of the bird species listed in the Appendices (excluding non-European Muscicapidae), 84% rely on vulnerable habitats (coastal, wetland, montane or tundra) at some point in their life cycle; many species use more than one habitat. In virtually all cases, the extent of the threat has not been quantified.

The most widespread threat (53% of species) faced is changes in water regime, reflecting the importance of wetland sites to migratory birds. Lowered mean water tables and an increased frequency of droughts will reduce habitat availability for aquatic species, such as Baikal Teal *Anas formosa* and reduce food availability for terrestrial species that forage in such areas, particularly on migration, such as Aquatic Warbler *Acrocephalus paludicola*. Habitat loss may compromise migrants' ability to complete their migratory journeys by reducing the coherence of the stopover site network.

Changes in wind patterns (and increases in storm frequency) have the potential to affect migratory journeys adversely. There is some evidence that a higher spring storm frequency in the Caribbean can cause problems for migrating passerine birds, and lead to reduced numbers reaching the breeding grounds. The journeys of some of the longest distance-migrants, such as Red Knot *Calidris canutus* (see Case Study) and Bar-tailed Godwit *Limosa lapponica*, push individuals to the physiological limit, so any perturbations are likely to have adverse consequences; maintaining high quality stopover habitat will be important in this regard.

The timing of migration is changing. The results of several studies investigating the spring arrival times of migrant species in temperate latitudes suggest that birds are reaching their breeding grounds progressively earlier in the season as the climate becomes warmer (e.g. Pied Flycatcher *Ficedula hypoleuca*), though this pattern is not universal. Where no (significant) change has been observed in local temperatures, no advancement in arrival date has been observed and where local temperatures have become cooler, there has been a tendency for later arrival. Evidence for later departure of migratory birds from their breeding grounds, and earlier arrival on their wintering grounds is sparser; some changes appear to be occurring, but these are inconsistent. Although these effects (and the role of climate change in them) are well demonstrated, the impacts on population size are unclear, mostly because of the presence of density-dependence.

Timing of arrival on the breeding grounds is important, as the breeding season should be synchronised with the availability of prey, the peak timing in abundance of which is, in many cases, shifting earlier in response to warmer temperatures though the effects are regionally variable. The timing of available food supply may be particularly critical in stopover areas, which are used for a fixed period of time, though no evidence demonstrating this exists as yet. Although populations will be able to adapt somewhat to these changes, it is unclear to what extent.

There is currently debate as to whether long-distance migrants may be more vulnerable to phenological changes, since the cues they use to time onset of spring migration may no longer be good measures of conditions on the breeding grounds, thus creating a mismatch between arrival date and optimal breeding date, as has been demonstrated for the Pied Flycatcher.

Breeding output is known to vary with temperature and time in the season, being greater earlier in the season and at (not too) warmer temperatures. There is evidence that such increases in productivity are occurring amongst temperate breeding species though change will often be a complex function of weather variables. Such changes may be beneficial, unless the breeding season becomes disjunct from the timing of peak prey abundance. Studies of polar (particularly Antarctic) species show that increased temperatures are reducing breeding success (probably because of changes in prey distribution).

Heavy precipitation can adversely affect breeding success, particularly during the period when fledglings are in the nest (and vulnerable to chilling). Overall, increased precipitation levels are predicted so impacts on productivity are predicted, though the timing of such rainfall will be critical, and it is possible that birds may be able to compensate by increased productivity in years of better weather, or by relaying if seasons become extended (though migratory species may be more constrained in this regard).

For many temperate bird species, survival during the winter months is very important in determining population trend, and is strongly related to winter severity (usually some proxy of temperature). Increased winter temperatures appear to be leading to higher survival and to an increasing tendency for migratory species to winter in the UK, rather than at more southerly latitudes. Such changes are likely to be beneficial to populations, though the presence of density-dependence in population processes may reduce these impacts.

Overall, breeding bird species (including migratory taxa) in the UK have extended their breeding ranges northwards by an average of around 9 km per decade and southern species are colonising Britain, though attributing this solely to climate change is difficult in many cases. Similar range shifts have been demonstrated elsewhere, as have altitudinal shifts in montane species and further changes are predicted.

The distribution of migratory species is also changing because of changes in migratory behaviour; migratory journeys are generally becoming shorter as has been demonstrated for Chiffchaffs *Phylloscopus collybita* and Blackcap *Sylvia atricapilla*, resulting in changes in wintering distributions. While, these changes generally yield increases in fitness for the individuals concerned, the population impacts are unclear, though they are likely to be positive (however, such populations may be more vulnerable to, increasingly, occasional severe weather events).

The available habitat for coastal species is being influenced by sea-level rise, increased erosion from a higher frequency of storm events and greater wave action; nearly 20% of bird species listed by the CMS have the potential to be impacted in such a fashion. Waders, such as Spoon-billed Sandpiper *Eurynorhynchus pygmeus*, and waterfowl, such as Lesser White-fronted Goose *Anser erythropus*, may be particularly vulnerable in this regard as many important stopover areas are in such coastal habitat, often at a relatively limited number of discrete sites. The UK hosts internationally important numbers of several wader and waterfowl species, such as the Redshank *Tringa totanus* both in winter and on passage and sea-level rise is affecting both breeding and wintering distributions, although habitat creation by 'managed retreat' from the sea has the potential to mitigate these impacts to some extent. In the UKOTs, the available habitat for breeding seabirds may be reduced, both from rising sea-levels and increased erosion.

A major impact of climate change will be indirect through altering abundance, distribution and quality of prey (in addition to temporal effects described above). This has been shown to be important for a number of species of seabird, both in UK waters and elsewhere, particularly the Antarctic, but probably also applies to other groups of birds. Extrapolation from published relationships suggests around 25% of species listed on the CMS Appendices may be impacted by changes in prey distribution, though this should probably be considered a conservative guess; the true number is likely to be higher, though particular species may show considerable population buffering.

Prey abundance and quality is particularly important on stopover sites, especially those that are used for fuel preparatory to crossing an ecological barrier, such as the Sahara desert. Increased desertification in this area would adversely affect the ability of many Afro-European migrants to fatten sufficiently prior to crossing the desert. Droughts in this region have significantly reduced population size previously, from which populations may take a long time to recover their former size.

Climatic impacts on migration are likely to be most important for the spring (northward) migration (because timing of arrival on the breeding grounds is critical, e.g. for mate and territory choice, and also because a reduction in numbers has a direct effect on breeding population size). Increased desertification of the Sahel region of Africa is of particular concern, since it is a key fuelling area for many migratory species.

Increased temperatures are thought to favour the spread of various diseases and parasites, which are an important source of mortality and can limit population growth in some cases. However, it is not known to what extent climate change will increase the impact on bird populations (relatively little is known about bird-parasite/disease interactions).

A further poorly understood area is the degree to which effects carry over between seasons. For example, alterations in the timing of breeding will have consequences for the timing of moult, and hence migration and individuals that experience poor conditions in winter may start the breeding period at a disadvantage, and have a lowered reproductive potential. These effects are beginning to be shown to be important and are likely to provide some of the mechanisms by which changing climatic conditions will impact on population size.

d. Bats

While it is probable that many species of bats are migratory, the scale and extent of such movements are largely unknown, though females are usually more migratory than males. The distance and routes of migration in some tropical or subtropical species depend on variations in fruiting or flowering success of food plants.

In temperate areas, where all bats are insectivorous, migration is usually between warm sites suitable for pregnancy and lactation and with adequate food supplies in summer, and cool sites for hibernation in winter (this migration need not be North/South). Within the tropical or subtropical latitudes, migrations depend on variations in fruiting or flowering success of food plants and to allow the formation of large communal maternity colonies. In some cases, movements may be associated with retreat from seasonally arid areas to concentrate in moister areas where food supply may be more persistent.

There have been almost no studies of bats directly in relation to climate change in Europe, but the most significant impacts (in terms of population size) are likely to be indirect, influencing the availability of their food supply or roost sites.

Changes in the composition of bat communities are likely as species alter their distribution northwards, possibly through range expansion rather than a simple shift in range, but the impacts of this are largely unknown. Species dependent on caves (as roost sites for maternity colonies) which shift their range northwards may be constrained by a lack of suitable caves (or other appropriate underground habitats) in their potential new locations. This is unlikely to be a serious issue in the UK, but could be significant in parts of mainland Europe and may lead to longer migratory journeys.

The predicted decrease, or even the disappearance of extreme cold winters in the UK may result in a reduced period of hibernation, increased winter activity (when there may be limited food supply) and reduced reliance on the relatively stable temperatures of underground hibernation sites. (This may also have implications for the use of roost counts to monitoring populations.)

An earlier advent of spring (by 1-3 weeks) would predicate a shorter hibernation period and hence an earlier appearance of most bats on the wing and this will require sufficient food to be available and may influence the timing of breeding. Cold weather events later in the winter (after the 'premature' emergence of individuals) may inflict increased mortality on populations, but the incidence of these is expected to decrease.

The reproductive cycle of temperate zone bats is closely linked to their pattern of hibernation. Bats mate in autumn and winter, and spermatozoa are stored in the female reproductive tract until spring. If bats experience warm conditions and a supply of food in the second half of winter, they will arouse from hibernation prematurely, ovulate and become pregnant. Conversely, if bats experience periods of inclement weather associated with food shortages during pregnancy, they will become torpid and the gestation period is extended. Experimentally, timing of births can be altered by up to three months by manipulating environmental conditions. Given this extreme dependence on external temperatures and food supply, the timing of reproductive cycles of temperate bats is likely to be significantly affected by climate change, although possibly not to their detriment.

For a large number of bat species, wetlands, waterways and water bodies and woodland provide key resources of insect biomass and diversity used by bats. Thus a decline in wet or moist areas is likely to affect bat populations and cause declines or behavioural changes; these changes will be particularly pronounced for Mediterranean populations.

The available evidence suggests that most bats do not undertake long continuous movements; rather the journey is interrupted at frequent intervals (perhaps daily) at 'stopover' points, with the bats resting and feeding to replenish energy requirements. Thus, the maintenance of suitable migration corridors, and sufficient prey at stopover points, may be an important conservation requirement for migrating bats. These requirements may be threatened by other factors, such as land-use patterns, and climate change has the potential to exacerbate these problems.

A total of 22 bat species occur in the Caribbean UKOTs, but information on the status and populations of these species on most small islands is incomplete. Many of the Caribbean island populations have been recognised as separate (sedentary) subspecies, though their validity requires verification. Migratory individuals of other subspecies may also occur contemporaneously for part of the year.

The predicted increase in incidence and, particularly, intensity of storms in the Caribbean is likely to result in damage to roost sites (e.g. trees, buildings, etc) and foraging habitats (especially fruit and flower feeders through stripping of flowers and seeds/fruit). Studies of bat populations after historical events have shown mixed patterns. Populations of some species do recover in the short to medium term, but given the generally slow reproductive rate of many species, an increased frequency of storms is likely to be of concern.

Sea-level rise may affect the suitability of some foraging habitats and coastal roost caves.

e. Terrestrial Mammals

Migratory journeys are less common in terrestrial mammals than other groups. The most familiar and well studied migrations are those undertaken by large herbivorous mammals that feed on seasonal grasses, such as Wildebeest *Connochaetes taurinus* and Caribou (Reindeer) *Rangifer taurandus*. The CMS covers a number of 'technical' migrants. These are species such as the Mountain Gorilla *Gorilla gorilla beringei*, which cross range state boundaries in the course of their movements, but which do not have regular seasonal migrations in the more traditional sense.

The reasons for migration are not always clear but may include movements between areas of seasonal food abundance, changes in availability of drinking water, avoidance of predators or access to food with essential minerals. A particular journey may be undertaken for a combination of these factors, and different factors may stimulate different phases of the annual migratory cycle. Consequently, many of the potential impacts of climate need to be assessed on a species by species basis.

As many migrations, particularly of herbivores, track seasonal changes in vegetation, climate change has the potential to alter migratory routes (and timings), which may increase conflicts with humans, particularly in areas where rainfall is low. Land-use patterns in Africa can prevent animals adapting their migratory routes, for example, park boundary fences have been demonstrated to disrupt migratory journeys, leading to a population decline in Wildebeest.

Changed migratory routes may also have effects throughout the ecosystem. Predator populations may experience a reduction in the number of available prey. Grassland ecosystems may require periods when grazing pressure is relatively low to recover from the effects of grazing and increase above-ground biomass to counter higher grazing pressure at other times of the year. As migration temporarily reduces local grazing pressure, local ecosystems may not be able to cope with high levels of grazing throughout the year if formerly migratory populations become resident.

Timing of reproduction in mammals is influenced by temperature, at least for northern populations; advancement in breeding season has been demonstrated in a few cases, though not in migratory species. It is unknown how this might be affected by changes in migratory patterns, consequent on changes in food supplies in relation to climate change. Growth rates, particularly of juveniles, have been demonstrated to be dependent on climatic factors in ungulate species and relate to the availability and, importantly, quality of the food supply. The impacts of climate change on food supplies and migratory behaviour may have important consequences for the growth of migratory ungulates, but these are largely unexplored at the moment.

If mammal communities change in response to climatic shifts, inter-specific relationships (e.g. competition) are likely to alter. Such effects may be important in some instances and have been demonstrated in two cases: small rodent communities in Australian tropical forest, and in range changes in European shrew *Sorex* species. However, generalisations are unlikely to be possible as these will be dependent on species-specific ecological factors.

f. Insects

Very little is known about the migratory behaviour of insects; virtually all the work that has been done concerns pest species, such as the desert locust *Schistocerca gregaria*, or the Lepidoptera (butterflies and moths), such as the Monarch *Danaus plexippus* (the only insect listed by the CMS, although most groups, particularly of the larger insects, have representatives that can be considered migratory.

The definition of a migratory species, as used by the CMS, is less applicable in insect taxa, as in relatively few species do particular individuals make a complete return journey. For invertebrates, the annual cycle of migration may consist of several successive generations rather than the same individuals; only in some situations can this be considered to be migration with a predictable trajectory and return phase. Few insects cross range state boundaries in their journeys; in many cases, this is a consequence of the scale of their journeys relative to territorial areas.

In broad terms, invertebrate migration occurs because the destination provides better potential opportunities for breeding and feeding resources than the current location. The location of suitable resources may vary from year-to-year, even from month-to-month, so migration destinations can be quite dynamic and unpredictable, as can range limits.

Almost by definition, pest species tend to be highly adaptable and occur in large populations. Climate change is unlikely to adversely affect them, although it may shift their distributional range, which may have an impact on human activities.

There is growing evidence of distributional shifts in invertebrates, for example amongst butterflies and dragonflies (Odonata) in the UK. A northwards shift in distribution has been witnessed as climate warming makes more northerly areas more suitable for colonisation, for example two species of butterfly Clouded Yellow *Colias croceus* and Red Admiral *Vanessa atalanta* are now over-wintering in the UK.

Changes in the timing of appearance of adult butterflies (which is dependent primarily on temperature) are well documented. This may lead to mismatches between the appearance of populations and the abundance of food plants at an appropriate growth stage. Migratory species, being more mobile, will have a greater capacity to adapt to these changes than sedentary species (which often rely on highly specialised habitats), so are less at risk than other species.

6. Migratory Species – Conservation Priorities

In terrestrial ecosystems, two issues potentially affect a large range of migratory species: (i) **changes in water resources** – particularly wetland quality, site maintenance and increased desertification; (ii) **loss of vulnerable habitats** – particularly tundra, cloud forest, sea ice and low-lying coastal areas, especially in small island states. Many of these areas also face severe anthropogenic threats.

Different conservation approaches are required for 'broad-front' and 'leap' migrants (see above). Broad-front migrants will benefit from modifications to extensive land-use along the migratory route, whereas, leap migrants require a coherent site network, with the quality of individual sites being of critical importance. **In most cases, the impacts of climate change need to be integrated with other economic, social and conservation objectives.**

For leap migrants, maintenance of a coherent network of stopover sites will be required. Currently there is a lack of even some of the most basic syntheses of information that are required for conservation action. **There is an urgent need to collate information on migratory stopover sites to identify coherent migratory networks.** This would provide a strategic, international overview and enable clear identification of site protection priorities for leap migrants. Much of this information is available for birds, so this could be achieved relatively straightforwardly for the key flyways. The same consideration may also apply to other taxonomic groups.

For broad-front terrestrial migrants, the creation of suitable migratory habitat, such as wildlife-friendly field margins, hedgerows, small copses and ponds have potential to allow migrants to adapt to climate change. Where these are absent, populations may not be able to adapt sufficiently and hence will suffer negative impacts. The UK's Entry Level Scheme for farmers provides an excellent model for encouraging such features.

In areas with remaining pristine habitat, the creation of protected trans-boundary habitat corridors is likely to be a great benefit. This will help broad-front migrants as well as migrants at the end of their migrations. Currently it is an approach applied particularly in the Americas, e.g. the Meso-American Corridor, through Central America.

The priority for adapting to change in the marine environment will be to manage human impacts on the resources required by migratory species through ecosystem-based management. One way to achieve this would be to designate marine protected areas (a.k.a. 'no-take zones') for the prey of marine mammals at key sites. However, the locations of such areas are likely to change over time, and protection will require very different legislation than anything that has been developed to date. There will need to be a degree of flexibility in the establishment of protected areas for marine mammals, such as Special Areas of Conservation (SAC) to take account of the potential for shifts in the range of species with climate change.

Maintain large population sizes. Successful adaptation to changed climatic factors (and consequently habitat) will require sufficient genetic variation present in the population, which will be related to population size.

7. Migratory Species – Monitoring and Research Priorities

Many long-term monitoring programs exist, which have been successful in identifying conservation priorities and providing base-line data against which to measure the impacts of climate change. **A commitment to long-term support of these schemes is critical to ensure their existence, and to ensure best value by utilising existing data collection networks.** Better use also needs to be made of existing data, for example in using populations on temperate non-breeding grounds to provide indices of arctic breeding populations (where large-scale data collection is impractical).

Develop standardised protocols for monitoring populations. Climate change is a global phenomenon and migratory species may cross many range boundaries. Standardised data collection is required if monitoring is to be effective. A unified system of alerts, to identify future problems, and thresholds to identify when environmental management is successful should be developed.

Although the importance of such monitoring is explicitly recognised by ASCOBANS, current knowledge of **cetacean population status, movements and habitat requirements is patchy and good baseline data are urgently needed for many species.** Although many European countries have cetacean strandings networks, which provide valuable data, the majority are run by the voluntary sector and both co-ordination of their work and the provision of core funding are needed to secure this source of information.

Information on occurrence, abundance and ecology of migratory species in the UKOT and on intra-tropical migrants (where anthropogenic threats are greatest) is limited, **structured programmes of survey and monitoring are needed to inform the setting of conservation priorities.**

Identify indicator species, including those that might indicate site condition and the condition of migration routes.

Populations using migratory staging do not do so synchronously, i.e. there can be a considerable turnover of individuals so the peak count may not relate to the total numbers using a site. This may affect the identification of designated sites, the importance of which is often determined by the peak number of individuals counted in the site. **There is a need to develop software for practitioners to accurately assess the total number of individuals using the site,** to ensure site importance is properly evaluated.

Quantitative predictions on the impacts of climate change on populations are extremely difficult as population processes are often density-dependent, resulting in a buffering of population size. **Research into assessing the strength and effect of density-dependent processes on population size is needed, though fraught with difficulties.**

In adapting to climate change, interactions with socio-economic factors, such as prevailing land-use are likely to be paramount, both as a constraint on the extent to which adaptation can occur and as an exacerbating factor. In general, anthropogenic factors, e.g. habitat loss and overexploitation of resources, are the most critical issues in the conservation of endangered species.

The interaction of socio-economic factors with climate change is poorly understood and predictions of climatic impacts currently take relatively little account of them.

8. Migratory Species – Legislative Requirements

The CMS has already had many conservation successes, particularly through the development of regionally and taxonomically based agreements that aim to promote the conservation of certain groups of migratory wildlife throughout their range states. **Given the species specific nature of the climate change threats faced by migratory species, the explicit incorporation of climate change considerations within specific Agreements and Memoranda of Understanding will provide flexibility to address particular threats to migratory wildlife.** In many cases minimising other threats to populations to allow populations to adapt to a changing climate may be the most useful way forward.

In terrestrial systems adaptation measures may be successful in maintaining or restoring a secure conservation status for many species. In marine systems, however, mitigation of climate change may be the only solution (i.e. reduction in anthropogenic greenhouse gas emissions), as habitat management at a sufficient scale will be virtually impossible.

In addressing the conservation challenges of climate change, a multi-functional approach is likely to be most successful. This approach entails considering the benefits of ecosystem preservation from a holistic viewpoint, considering both the anthropogenic and wildlife benefits. It is much more likely that conservation goals will be achieved if they are part of ecosystem management with wider aims such as floodplain management, coastal protection or preventing deforestation to reduce soil erosion. **Frameworks for integrated land-use planning exist in a number of different parts of the world, and they could valuably be developed and implemented more widely elsewhere.**

Climate change may be the 'last straw' for many marine species, which are already under severe anthropogenic pressure. **Strengthening protection for marine species and ecosystems should improve their ability to adapt to changing climatic conditions.**

Exploiting synergies between treaties and conventions, e.g. joint work programmes, would provide increased value, better co-ordination and improved focus, as well as facilitating the development of key priorities.

8 CMS RESOLUTION 8.13 –

CLIMATE CHANGE AND MIGRATORY SPECIES

Adopted by the Conference of the Parties at its Eighth Meeting (Nairobi, 20 - 25 November 2005)

Conscious of the findings of the Inter-governmental Panel on Climate Change's *Third Assessment Report - Climate Change 2001*, especially in relation to the vulnerability of habitats and species to the direct and indirect consequences of unprecedented changes to the global climate;

Further conscious of the role that the Convention has in facilitating achievement of the 2010 biodiversity target under the Convention on Biological Diversity (CBD) and the need to work collaboratively with the United Nations Framework Convention on Climate Change (UNFCCC);

Also aware of the findings of the CBD Technical Report on interlinkages between biological diversity and Climate Change and that this Report is to be followed up by one issued in 2006 on the integration of biodiversity considerations in the implementation of Climate Change adaptation activities at the local level through to the international level;

Recognizing that Climate Change may significantly affect the behaviour, distribution and abundance of migratory species and may change the ecological character of their habitats;

Aware that Climate Change issues were considered at the 5th Conference of the Parties which resulted in a request that the Scientific Council establish a small working group to review, amongst other things, the scientific work done by other bodies on Climate Change;

Further aware that the Convention considers it important to base its decisions on the best and most recent scientific data available;

Noting that the desk study[1] into the effects of Climate Change on migratory species commissioned by the UK Government earlier this year found that:

1. migratory species have been, and will continue to be, adversely affected by Climate Change;
2. knowledge of the likely impacts of future Climate Change varies greatly between taxonomic groups, and confident predictions on breeding performance and survival need to be underpinned by more research; and
3. changes to water regimes and loss of vulnerable habitats are likely to affect the greatest number of migratory species, and in many cases a reduction in human impacts will help species adapt to these changes;

Further noting that the 13th Meeting of the Scientific Council considered the issue of the effects of Climate Change upon migratory species and supported Resolution 8.13 Climate Change and Migratory Species; in addition, a round table, convened after the Scientific Council to discuss these effects of Climate Change, heard detailed evidence of the extent of the likely impacts and the significant implications for conserving migratory species; and

Conscious that the possible effects of Climate Change with relevance to some migratory species and their habitats have also been recognized by other MEAs, notably the Convention on Wetlands of International Importance and the desirability for CMS to take account of the work done by them;

The Conference of the Parties to the Convention on the Conservation of Migratory Species of Wild Animals

1. *Requests* the Scientific Council to afford Climate Change high priority in its future programme of activities, and to:
   (a) Identify priorities for future research;
   (b) Identify which migratory species, based on best available evidence, are particularly threatened by Climate Change;
   (c) Review the range states list for CMS species as changes in distribution are seen as a consequence of Climate Change; and
   (d) Strengthen links with other MEAs, including UNFCCC, that have undertaken research into the impacts of Climate Change on biodiversity and to take account of that research;

2. *Instructs* the Secretariat to work with the Scientific Council and secretariats of the CMS daughter agreements and their scientific advisory bodies on producing guidance that would help CMS Parties introduce adaptation measures to help counteract the effects of Climate Change on migratory species;
3. *Calls* on Parties and non-Party range states to implement, as appropriate, adaptation measures that would help reduce the foreseeable adverse effects of Climate Change on Appendix I species; and
4. *Encourages* the initiation of collaborative international research projects into the effects of Climate Change on migratory species and their habitats so as to better understand implications and appropriate policy responses.

9 AEWA RESOLUTION 3.17 –

CLIMATE CHANGE AND MIGRATORY WATERBIRDS

Sponsored by the United Kingdom

Conscious of the findings of the Inter-governmental Panel on Climate Change's *Third Assessment Report – Climate Change 2001*, especially in relation to the vulnerability of habitats and species to the direct and indirect consequences of unprecedented changes to the global climate,

Further conscious of the role that AEWA has in facilitating achievement of the 2010 biodiversity target under the Convention on Biological Diversity (CBD),

Also aware of the findings of the CBD Technical Report on interlinkages between biological diversity and Climate Change and that this Report is to be followed-up by one issued in 2006 on the integration of biodiversity considerations in the implementation of Climate Change adaptation activities at the local level through to the international level,

Recognizing that Climate Change may significantly change the ecological character of the habitats of migratory waterbirds, *inter alia*, through changed patterns of land-use, the loss of intertidal habitats through rising sea-levels, the loss or degradation of wetlands, possible increases in mortality caused by potential changes in harvest regimes, and changes in distribution of waterbird diseases and their vectors; and that such changes operating at different scales will have consequences for the status and trends of waterbird populations,

Recognizing also that Climate Change may significantly affect the behaviour of migratory waterbirds, bringing about changes in the timing of reproduction and migration, and in spatial patterns of habitat use, *inter alia*, through changes in the ecological character of habitats,

Noting that the regulation of harvesting, to remain in accordance with the principle of sustainable use as envisaged by the Action Plan, should be responsive to significant changes in pressures on waterbirds caused by Climate Change,

Aware that strategies for the conservation of protected areas for waterbirds, developed according to the ecosystem approach, need to take into account the potential effects of Climate Change and be adapted to ensure the maintenance of the ecological functions of the individual areas within the framework of flyway-scale networks,

Noting also that such changes will significantly influence measures to achieve AEWA's fundamental objective, which is to maintain migratory waterbird species in a favourable conservation status, or restore them to such status, and yet aware that the Agreement's Action Plan makes no reference to the complex issues rose by climatic change and its direct and indirect consequences,

Conscious that the possible effects of Climate Change on ecosystems and biological diversity have been noted by the Convention on Migratory Species (CMS), and that in particular CMS has recognized the need to ensure that its decisions are based on the best and most recent scientific data available,

Aware that the Scientific Council of CMS has established a working group to review scientific work being undertaken on Climate Change, to assess the relevance of this to migratory species and the aims of CMS, and to strengthen links with other bodies working on this issue,

Noting the desk study into the effects of Climate Change on migratory species commissioned by the UK Government earlier this year found:

- migratory species have, and will continue to be, adversely affected by Climate Change – over 80% of CMS listed bird species face some threat from it, almost half because of changes in water regimes,
- migratory waders, such as the Red Knot *Calidris canutus*, are expected to face large population declines and the Spoon-billed Sandpiper *Eurynorhynchus pygmeus* faces extinction,

- that knowledge of the likely impacts of future Climate Change varies greatly between taxonomic groups, but the best knowledge exists for birds,
- that confident predictions on breeding performance and survival need to be underpinned by more research, and
- that changes to water regimes and loss of vulnerable habitats are likely to affect the greatest number of migratory species, and in many cases a reduction in human impacts will help species adapt.

Conscious that the possible effects of Climate Change with relevance to waterbirds and their habitats have also been recognized by other MEAs, notably the Convention on Wetlands of International Importance and for the desirability for AEWA to consider these issues and the work done by them given the scale and nature of likely impacts on migratory waterbirds.

The Meeting of the Parties:

1. *Instructs* the Technical Committee, working with the Agreement Secretariat, and taking into consideration the work of the CMS Scientific Council and others as appropriate, to give priority, resources permitting, to an assessment of current evidence of the effects of changing climate on migratory waterbirds, a review of the implications of modelled future patterns of Climate Change on waterbirds, and an outline of possible means of adapting to these changes, and to report conclusions to a future Meeting of the Parties;
2. *Requests* that the Technical Committee's review seeks to identify those species listed in Table 1 of the Agreement's Action Plan that current knowledge suggests are especially vulnerable to the consequences of a changing climate, and to identify measures that may help to maintain such populations;
3. *Requests also* that the Technical Committee's review identifies relevant actions that might be undertaken as part of the international implementation of the Agreement;
4. *Urges* the Secretariat, drawing on the results of the Technical Committee's review, to give priority, resources permitting, to the development of Conservation Guidelines on possible adaptation measures, and requests that these be brought to a future Meeting of the Parties following review by the Technical Committee;
5. *Urges* Parties to address Climate Change in so far as it is regarded as likely to bring about significant change in the ecological character of wetlands and affect the behaviour of migrating waterbirds;
6. *Stresses* the importance of including potentially beneficial adaptation measures in the development and implementation of single and multi-species action plans at both national and international scales;
7. *Highlights* the need to include relevant actions related to Climate Change impacts and adaptation in the Agreement's Action Plan, and requests that the Standing Committee, following review by the Technical Committee, communicates any relevant amendments to the Secretariat for consideration by a future Meeting of the Parties; and
8. *Encourages* the Technical Committee to identify international research needs into the effects of Climate Change on migratory waterbirds and their habitats, so as to better understand implications and appropriate policy responses, that could be taken forward collaboratively with other stakeholders, as resources permit.

10 A MESSAGE FROM AEWA

By Bert Lenten, Executive Secretary of the UNEP/AEWA Secretariat

AEWA, like any other multilateral environmental agreement committed to biodiversity, plays a key role in facilitating achievement of the target under the Convention on Biological Diversity (CBD) to significantly reduce the loss of biodiversity by 2010. Making Climate Change and its impact on migratory waterbirds a priority issue for the development of future conservation activities is important. The member states to AEWA thereby acknowledged that effective species conservation as a result of the 2010 target can only be reached by taking into account the various long term impacts Climate Change could have on migratory waterbirds.

Although there is no evidence that any species has been extinct solely due to Climate Change, the predictions for the future are alarming and we cannot afford to ignore them. The discussions on the impact of Climate Change make clear that species conservation is one important aspect of nature conservation, and that close cooperation between all relevant conventions, agreements and key partners is urgently needed.

It is now up to the key international organizations and decision makers on national levels to cooperate in order to share knowledge and expertise. We must develop policies, both on the national as well as on the international level, which adapt the current nature conservation efforts to the expected impact of Climate Change on habitats and species. In particular, the responses of migratory waterbirds to Climate Change needs to be understood and managed in the context of other threats. Human exploitation e.g. may increase in the Arctic region due to rising temperatures, which make the access to the region easier. Increasing desertification may cause barriers to migration and reduce the number of existing stop-over sites used by waterbirds during their migration. Conversely, some impacts could be positive for certain species. The reproductive success of bird species e.g. is positively related to temperature. These examples make clear that migratory species are particularly affected by Climate Change because of the variety of sites and habitats they use during their annual cycle and the different changes in conditions they are exposed to throughout the year. These examples make also clear that further research and understanding is vital in order to predict and address the impact of Climate Change in the future. To assess the different impacts Climate Change will have on single species and in the different regions, to understand their interdependency and to adapt the conservation measures accordingly is the most important challenge for the international community. The ecological effects of Climate Change will be very diverse from region to region and a global understanding is imperative.

Migratory birds represent the group of wildlife, for which the impacts of Climate Change are best studied. This is a good starting point for bird conservationists to deal with this issue in order to overcome the problems migratory birds are likely to face, but at the same time it implies much responsibility as migratory birds can act as an indicator of effects that may affect less well studied groups.

In this spirit, the Third Meeting of the Parties to AEWA has included a desk study into the International Implementation Priorities for 2006 - 2008, which shall summarize understanding of the current and future responses of migratory waterbirds to actual and predicted Climate Change, and practical means of adaptation. At the same time research and monitoring work has to be continued and intensified, as much knowledge on the migration patterns of migratory waterbirds and their habitats is still lacking. It is important to collate information on migratory stopover sites in order to identify coherent migratory networks and target site conservation action.

A lot has to be done, provided that the necessary funds could be allocated. However, with its strong network and highly pragmatic focus on the flyways, AEWA is prepared to face the challenge of Climate Change and its implications for migratory waterbird conservation.

MIGRATORY SPECIES AND CLIMATE CHANGE

Impacts of a Changing Environment on Wild Animals

Our climate is changing – the global mean surface temperature is rising, regional precipitation patterns are being altered, sea levels rise, floods, droughts and storms occur more often. Animals, ecosystems, economic systems and people are affected and nature conservation has to cope with new challenges, which add to other well-known pressures.

There is substantial evidence that wildlife is being affected by Climate Change already, and as a group, migratory wildlife appears to be particularly vulnerable because it uses multiple habitats and sites and uses a wide range of resources at different points of its migratory cycle.

The UNEP Convention on Migratory Species is the only global agreement specifically dealing with the needs of animals on the move. Climate change and its direct and indirect effects are becoming an ever more important aspect of the Convention's work. This brochure, containing contributions from experts around the world, explores the current state of knowledge and identifies ways forward that allow migratory species to continue fulfilling their unique role in the global web of life.

UNEP CMS AEWA

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