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CLIMATE CHANGE AND MIGRATORY SPECIES

(Document submitted by the United Kingdom)

Below are reproduced the executive summary and the extended summary of the report submitted by the United Kingdom on Climate Change and Migratory Species. The full text of the report, in english only, is contained in document UNEP/CMS/Inf. 8.19.

EXECUTIVE SUMMARY

Background

Our climate is changing and there is already compelling evidence that animals and plants have been affected. We conducted a literature review and consulted experts through a specially organised international workshop to identify the range of climate change impacts and to consider how migrant populations could be affected by these changes. The primary instrument for migratory species conservation is the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and its daughter Agreements and Memoranda of Understanding. Several other international policy instruments cover some migratory species, but only the Ramsar Convention (an agreement concerning wetland site protection) explicitly mentions climate change.

Knowledge of the likely impacts of future climate change varies greatly between taxonomic groups, being best for birds. Of the bird species listed on the CMS, 84% face some threat from climate change, almost half because of changes in water regime; this is equivalent to the (summed) threats due to all other anthropogenic causes. Further understanding of how populations will respond, through knowledge of climate impacts on breeding performance and survival, will be necessary for successful predictions of impacts. However, understanding of this is poor for all groups of wildlife, particularly because breeding performance and survival often vary with population density to an unknown extent. Although it is thought that no species has yet become extinct solely because of climate change (Golden Toad is a possible exception), many extinctions (of both migratory and non-migratory species) are predicted in the future.

Climate Change Impacts on Migratory Species

Changes in range are widely documented in all taxa, with distributions of most shifting polewards. The incidence of 'southern' species, such as the Little Egret (a bird), Loggerhead Turtle and Red Mullet (a fish) is increasing in the UK. The wintering areas of bird populations are changing as a result of climate-driven changes in migratory behaviour. In response to warmer temperatures, many waders, such as the Ringed Plover, are now wintering on the east of Britain (closer to their breeding grounds) rather than the west coast. Increasing numbers of European Blackcaps are now migrating west to Britain rather than south, and Chiffchaffs are remaining in the UK over winter (rather than migrating south). Climate change will alter the probability of invasive and alien species establishing, which may have important effects on local biodiversity.

Barriers to migration may become more severe in response to climate change. Many migratory birds use the Sahel region of Africa to refuel before crossing the Sahara Desert. Decreased precipitation and over-grazing is causing increased desertification and reduced vegetation quality; breeding numbers of species such as Whitethroat are substantially lower in drier years, so further declines in trans-Saharan migrants might be expected with climate change. Interactions between climate change and human exploitation are widespread, though poorly quantified. For example, changes in migratory journeys of Wildebeest in Africa are hampered by the presence of park fences; changes in rainfall patterns in Southern America are leading to the construction of dams that are proving a major barrier to the migration of the Tucuxi (a river dolphin). Many waterbirds are reliant on a network of a few, widely separated wetland sites for migration, which are at risk from rising sea-levels. Many sites also face development and increasing water abstraction (due to climate change), exacerbating direct climate-driven threats.

A major conservation concern is for arctic and montane species (most of which are migratory), the distributions of which cannot shift further north in warmer climates. Many migratory waders, such as the Red Knot, face large population declines and some, such as the endangered Spoon-billed Sandpiper, face extinction. Among mammals, Polar Bear and northern seals are of key concern through the loss of Arctic sea ice. Sea-level rise is leading to loss of beaches used by nesting turtles (32% of beaches used by nesting turtles in the Caribbean could be lost with 0.5m sea-level rise) and seals (e.g. the endangered Mediterranean Monk Seal) and loss of shallow coastal areas used by whales, dolphins, dugongs and manatees (e.g. White-beaked Dolphins require cold water less than 200 m deep).

A major effect of climate on migratory (and other) species will be changes in prey distribution, some of which are already well documented. Such changes are a major threat in marine ecosystems. Large shifts in distribution (as much as 10° latitude) and abundance (with declines to a hundredth or a thousandth of former values) of plankton communities in response to changes in sea surface temperature have already been demonstrated (particularly for Krill, a key component of marine foodwebs). These changes have resulted in changes in the distribution and abundance of many marine species, such as Cod, Salmon, Long-finned Pilot Whale, Kittiwake and a number of penguin species. Breeding seals are particularly vulnerable to such climate change effects as they are dependent on access to relatively undisturbed haul-out sites that are within access of abundant prey.

Changes in the timing of many life history events are well documented. For example, migratory British birds are arriving in breeding areas two to three weeks earlier than thirty years ago. Laying dates have also advanced for both birds and turtles. However, changes in laying date of migratory birds (typically 2d/1^{o}C) appear to be less than changes in vegetation and invertebrate phenology (typically 6d/1^{o}C) which may lead to a mismatch between the birds and their prey. There is good evidence for this in some populations of birds, particularly Pied Flycatcher, but these effects can be regionally specific. In consequence, there is evidence that long-distance migrant birds, such as the Swallow, may be less able to adapt their phenology than short-distance migrants, such as the Chiffchaff. Warmer winters are encouraging the earlier emergence of bats from hibernacula but the population impacts of this are unknown.

Fecundity in bird species is positively related to temperature, and long-term increases have been reported in many species, such as the Pied Flycatcher, while cetaceans have lower fecundity in warmer waters (reduced fecundity of Sperm Whales during warm water El Niño events, gives some indication of future trends). To what extent populations will be able to adapt to these changes by shifting distribution is unknown. Sex ratios of hatchling turtles are dependent on temperature and increased warmth could potentially lead to all-female populations. Survival of individuals is also strongly related to climatic conditions. Amongst birds, warmer winter temperatures are likely to increase survival in those that winter in northern latitudes, as has been seen for some wader species, while those that winter in southern latitudes are likely to suffer from reduced precipitation. There is also the potential for changes in patterns of disease transmission as a result of climate change effects on the distribution of vectors and the growth of pathogens – but this is an area of great uncertainty due to lack of knowledge; potential examples include large-scale mortality of cetaceans and seals in the Mediterranean and North Sea over the last decade and increases in Fibropapilloma tumours in Green Turtles.

Changes in population size are a combination of changes in survival and breeding performance and the impact of climate change will depend on the relative balance of these two factors. For example, in one colony, increased sea surface temperatures meant that Emperor Penguins had to forage further from the breeding colony (reducing survival), but the penguins benefited from increased hatching success; the effects on survival were greater and colony size declined. In general, changes in survival and fecundity will interact with population density, and thus quantitative scenarios of changes in population size will require further development.

Future Priorities

In terrestrial systems, changes to water regime (e.g. increased water abstraction and drought frequency) and loss of vulnerable habitat (particularly Arctic tundra) are likely to affect the greatest number of migratory species. While adaptation (through habitat management) to climate change may bring benefits in terrestrial ecosystems and to some extent in marine systems, but mitigation of emissions will be required to achieve significant benefits in the marine environment. In many cases, a reduction in anthropogenic impacts (such as over-exploitation or habitat loss) will help taxa to adapt. More generally, maintenance of large population sizes to provide sufficient variation will allow populations the greatest chance of adapting. In terrestrial taxa, some migratory species require a coherent network of discrete sites and hence appropriately flexible site management in response to changing conditions. Others will require continuous habitat corridors and broad-scale land-use planning. Changing patterns of human exploitation in response to climate change are a major threat and conservation measures need to take these into account, both as threats and as opportunities for providing benefits through multi-functional ecosystem management.

A commitment to long-term support of monitoring schemes is critical to ensure best value, by utilising existing data collection networks (with standardised protocols), both in detecting long-term climate change impacts and monitoring the success of adaptation measures. There is also a need to collate information on migratory stopover sites to identify coherent migratory networks and target site conservation action. Targeted implementation and enforcement of existing measures should provide much of the protection needed, as would the broader use of existing guidance codes. 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.

EXTENDED SUMMARY

1. Introduction

1.1. Climate change is one of the major factors likely to affect the earth's ecosystems in the coming decades[43,35]. 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.

1.2. There is already compelling evidence that animals and plants have been affected by recent climate change[79,53,35]. 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.

1.3. 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.

1.4. 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).

1.5. 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'.

1.6. 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

2.1. 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). 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.

2.2. 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).

2.3. 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 formal (but non-binding) Memoranda of Understanding (MoU) between appropriate Range States have been concluded.

2.4. 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.

2.5. 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*).

2.6. 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.

2.7. 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.

2.8. 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'[4]. Wetlands provide critical stopover areas for many bird species listed on the CMS.

3. Projected Climate Change

3.1. Our climate is changing[1]. 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.

3.2. 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.

3.3. 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[52]. 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.

3.4. 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[43]. 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[43].

3.5. 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[50,65]), 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[50,65], 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.

3.6. The Caribbean territories will be influenced by changes in the El Niño Southern Oscillation (ENSO), influences that will occur more broadly[7]. 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.

3.7. 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[43]. 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.

3.8. There is consensus on the broad pattern of climatic changes in the UK[42] and Europe[25,54],summarised in Table 1. Temperatures are likely to increase (but see 3.11), 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.

3.9. 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[11]. Temperatures are likely to increase markedly in northern latitudes and in Africa[43,50]. 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[43,50].

3.10. 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[43]. The North Sea is also warming, with an increase in annually averaged temperature of about 0.6^{o}C over the past 70 to 100 years, most occurring in the last 20 years[42]. The temperature of UK coastal waters will continue to rise, although not as rapidly as over land.

3.11. 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[43]. 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[43]; it is unlikely to stop completely[42].

3.12. 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[75], 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.

3.13. Tide gauge data show that global average sea level rose between 0.1 and 0.2 m during the 20th century[43]; in the UK sea level has risen by 0.1 m[42]. 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)[65,34].

4. Impacts of Climate Change – General Patterns

4.1. The knowledge of the likely impacts of climate change varies greatly between taxonomic groups (Table 2). 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.

4.2. 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.

4.3. 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.

4.4. 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[53,63] and behavioural changes[53,22] 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[58] and many are predicted[74].

4.5. 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 (Table 3).

4.6. Changes in range are perhaps the most widely documented effect of climate change and have been demonstrated in a number of groups[53,62]. Such changes are relatively easy to measure and because climate is a fundamental determinant of whether an area is suitable for occupancy.

4.7. Further changes in distribution are predicted, often using an 'envelope' approach, i.e. defining current bioclimatic habitats occupied and modelling how these shift[11,37], 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.

4.8. 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.

4.9. 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[57]. 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.

4.10. Migration itself is a response to ecological conditions, and in many species is a flexible and adaptable trait[75]. Changes in the length, timing and location of migratory routes in response to changing climatic conditions have been documented[12]. These are leading to changes in patterns of occurrence in a wide range of taxa, including birds, turtles, cetaceans and insects[53].

4.11. 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[22,29], 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[20].

4.12. 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.

4.13. 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.

4.14. 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[35].

4.15. 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 (6.5) 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.[5]. 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[5,83].

5. Impacts of Climate Change on Migratory Species

a. Marine Invertebrates, Fish and Turtles

5.1. 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[55] and in the recruitment of Atlantic Cod *Gadus morhua* in the North Sea[68].

5.2. Recruitment of Herring *Clupea harengus* and Squid are linked to climatic conditions[10,56] (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.

5.3. 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[79].

5.4. 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.

5.5. Nesting biology of sea turtles is strongly affected by temperature, both in timing and in the sex-ratio of hatchlings[39], 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.

5.6. The range of many migratory turtles is shifting (or at least expanding) northwards, with an increasing number of records from UK waters[2]. 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.

5.7. 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[34].

b. Marine Mammals

5.8. 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[49]. 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[49]. Dispersal and migration is also common in several pinniped (seal) species[49]. However, migratory journeys are poorly known (see Sperm Whale Case Study).

5.9. 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 5.1 to 5.3 above). Shifts in plankton and fish community composition in the North Sea have been observed in plankton and fish communities[55,10], and reflected in changes in the cetacean community, with a greater representation of southern-water species further north[49]. Similar shifts have been shown elsewhere[13,17] 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[38].

5.10. Changing water temperature also has an effect on the reproduction of cetaceans (see Sperm Whale case study) and pinnipeds, indirectly through prey abundance, either through extending the time between individual breeding attempts, or by reducing breeding condition of the mother[81]. The growth and survival of Antarctic Seal *Artocephalus gazelle* pups is influenced by krill *Euphausia* abundance[16].

5.11. 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[81].

5.12. 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[63]. The population consequences of this are unknown, but maybe locally severe

5.13. 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[60]. This vulnerability is increased as the location of feeding areas is changing simultaneously, meaning new, undisturbed haul-out sites will be required.

5.14. Melting ice-sheets in the Arctic will reduce ocean salinities[43], 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[45].

c. Birds

5.15. 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[43], 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[84].

5.16. 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.

5.17. The most widespread threat (53% of species, Table 4) faced is changes in water regime (Table 4), 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.

5.18. 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[47]. 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.

5.19. The timing of migration is changing[29,20]. 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*, see Case Study), though this pattern is not universal[77]. 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[47]. 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[36].

5.20. 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[20,76], though the effects are regionally variable[77]. 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.

5.21. 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 (see Case Study)[14].

5.22. 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[29,20,23]. There is evidence that such increases in productivity are occurring amongst temperate breeding species[22,15], though change will often be a complex function of weather variables[82]. Such changes may be beneficial, unless the breeding season becomes disjunct from the timing of peak prey abundance[21,14]. Studies of polar (particularly Antarctic) species show that increased temperatures are reducing breeding success (probably because of changes in prey distribution)[1].

5.23. 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)[46].

5.24. 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)[61]. 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[80]. Such changes are likely to be beneficial to populations, though the presence of density-dependence in population processes may reduce these impacts[36].

5.25. 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[73] and southern species are colonising Britain[18], though attributing this solely to climate change is difficult in many cases. Similar range shifts have been demonstrated elsewhere[79,53], as have altitudinal shifts in montane species[58] and further changes are predicted[37].

5.26. 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[80,6,69]. 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).

5.27. 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[21]; 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* (see Case Study) 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[5]. In the UKOTs, the available habitat for breeding seabirds may be reduced, both from rising sea-levels and increased erosion[65].

5.28 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[30] and elsewhere, particularly the Antarctic[1], but probably also applies to other groups of birds[21]. 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[9].

5.29 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[8]. Droughts in this region have significantly reduced population size previously, from which populations may take a long time to recover their former size[7].

5.30. 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.

5.31. 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[26]. 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).

5.32. 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[23]. 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

5.33. 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[64]. The distance and routes of migration in some tropical or subtropical species depend on variations in fruiting or flowering success of food plants.

5.34. 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.

5.35. 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.

5.36. 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.

5.37. 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[59]. (This may also have implications for the use of roost counts to monitoring populations.)

5.38. 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[4]. 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.

5.39. 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[4]. 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.

5.40. 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.

5.41. 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[28]. 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.

5.42. 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.

5.43. 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)[65]. Studies of bat populations after historical events have shown mixed patterns[32,44]. 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.

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

e. Terrestrial Mammals

5.45. 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*[31]. 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.

5.46. 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[31,27]. 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.

5.47. 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[72]. 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[82].

5.48. Changed migratory routes may also have effects throughout the ecosystem[31]. 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[67].

5.49. 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[24]. 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.

5.50. 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[40], and in range changes in European shrew *Sorex* species[78]. However, generalisations are unlikely to be possible as these will be dependent on species-specific ecological factors.

f. Insects

5.51. 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*[19], or the Lepidoptera (butterflies and moths), such as the Monarch *Danaus plexippus* (the only insect listed by the CMS (see Case Study), although most groups, particularly of the larger insects, have representatives that can be considered migratory.

5.52. 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.

5.53. 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.

5.54. Almost by definition, pest species tend to be highly adaptable and occur in large populations[19]. Climate change is unlikely to adversely affect them, although it may shift their distributional range, which may have an impact on human activities.

5.55. There is growing evidence of distributional shifts in invertebrates, for example amongst butterflies and dragonflies (Odonata) in the UK[41,70]. 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.

5.56. Changes in the timing of appearance of adult butterflies (which is dependent primarily on temperature) are well documented[64,71]. 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

6.1. 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.

6.2. Different conservation approaches are required for 'broad-front' and 'leap' migrants (see 4.3). 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.**

6.3. **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.

6.4. **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.

6.5. **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.

6.6. **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.

6.7. **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

7.1. 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).

7.2. **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.

7.3. 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.

7.4. 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.**

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

7.6. 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.

7.7. 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.**

7.8. 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

8.1. 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.

8.2. **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.

8.3. 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.**

8.4. 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.**

8.5. **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.**

Table 1. Summary of changing climate from the present until the 2080s from two climate scenario models covering the UK (UKCIP) or Europe (ACACIA).

Variable	UKCIP	ACACIA
Temperature		
Mean Temperature	+2˚C to +5˚C	+0.8˚C to +3.2˚C
Spring Timing	1-3 wks earlier	-
Extreme Summer Temperatures	Increase	9-10x Increase
Extreme cold Winters	-	Disappear
Precipitation		
Mean Precipitation	0% to –15%	Variable
Summer Precipitation	Decreased	0% to +8% (N) 0% to –15% (S)
Soil Summer Moisture	-40%	Decrease
Winter Precipitation	Increased	Increased
Extreme Winter Precipitation	Increase	-
Snowfall	-30% to –90%	-
Other		
Sea-level Rise	-2 to +58 cm (NW) +26 to +86 cm (SE)	+5 to +90cm (NW) +35 to +140cm (SE)
Extreme Sea Levels	Increase	-
Gales	-	Increase

Table 2. Summary the extent of knowledge about climate change impacts on migratory species across taxonomic groups. Based on a consensus opinion of experts attending a workshop in Cambridge, March 2005.

Climate Change Factors	Birds	Bats	Terrestrial and marine Mammals	Fish	Turtles	Insects
Migration Patterns	***	*	**	*	*	*
Abundance & Distributions	***	**	**	**	**	*
Habitat use of each species to allow future modelling	***	**	*	*	*	*

*** = good information for some species; ** = some knowledge; * = little or no knowledge

Table 3. Summary of likely climate change impacts on the population dynamics migratory species across taxonomic groups. Dashes indicate the factor is not generally relevant for that group, particularly important effects that are well (relatively) well documented are highlighted. Almost nothing is known about climate change impacts on insects. Based on a consensus opinion of experts attending a workshop in Cambridge, March 2005, and the review in the main report.

Factors	Birds	Bats	Mammals	Fish	Turtles
Loss of Stopover Sites	Important	Yes	--	--	--
Temperature	Indirect	--	Yes (esp. Arctic, marine spp.)	Important	Yes
Loss of Breeding Habitat	Yes (Important for some)	Yes	Yes	Yes	Important
Longer Migratory Pathways	Yes	Yes ?	Yes (esp. terrestrial)	?	--
Mismatch in Timing	Yes	?	?	Yes	--
Changes in prey availability	Yes	Yes	Important (marine only?)	Yes	Yes
Inter-species Competition	Debated	Roosting sites ?	?	?	No
Non-breeding habitat/ wintering sites	Yes	Yes	?	?	Important

Table 4 Summary of threats faced by migratory species listed on the CMS. In each case the number of species affected is given; in many cases a species faces multiple threats. Based on Information in Appendix 1, Table 11.

Climate Change Impacts		**Anthropogenic Impacts**	
Lowered Water Tables	127	Hunting or Persecution	137
Increased Drought Frequency	84	Habitat Loss	132
(Water Tables and Drought)	(160)	Human Disturbance	76
Mismatch with Prey Abundance	73	Overgrazing	63
Sea Level Rises	55	Agricultural Intensification	22
Habitat Shifts	52	(Overgrazing and Intensification)	(70)
Changes in Prey Range	50	Direct Mortality	49
Increased Storm Frequency	20	Over-fishing / Long-lining	42
		Introduced Species	30
No Threats	35	No Threats	59
Total Number of Species	300		300

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