UN environment
United Nations Environment Programme

# Convention on the Conservation of Migratory Species of Wild Animals

CMS

## Workshop on Climate Change and Migratory Species: Regional Approach, Practical Measures and Examples (CCWS2017)

*Bonn, Germany, 20 - 21 February 2017*

UNEP/CMS/CCWS2017/Inf.6

## LITERATURE RELEVANT FOR THE WORKSHOP – A PRELIMINARY COMPILATION

**(***prepared by the CMS Secretariat***)**

This document is a compilation of literature relevant to sessions two (collation of key examples of climate change impacts on species and the detail of their response), three (identification and promotion of practical measures) and four (development of a Regional approach) of the workshop programme as well as of more general reports on climate change and migratory species. The compilation has no pretention of being exhaustive, and rather tries to identify significant examples focusing on species listed in the CMS appendices. The majority of the publications selected are highly cited and published in high impact journals, thus setting future trends. For each paper mentioned, a brief summary and the abstract are provided.

Most papers are associated to one of the three sessions, and further clustered by theme. This was done with the purpose of providing some structure to the compilation. However, The Secretariat acknowledges that the proposed association and clustering can appear arbitrary in a number of cases, and the same paper could be equally associated to different sessions and themes.

This meeting has been kindly funded by the Government of the Federal Republic of Germany, through the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit

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# Examples of climate change impact on migratory species and their response (session 2)

## Climate change impact on Polar bears

Polar bears (*Ursus maritimus*) are generally referred to as a best example for the impacts of climate change on species. To date, global warming has been most pronounced in the Arctic, and this trend is projected to continue. There are suggestions that before mid-century we could have a nearly ice-free Arctic in the summer. The highly citied article “Effects of climate warming on polar bears: a review of the evidence” (2012) authored by two experts in the field of polar bear conservation, forecasts that “If the climate continues to warm and eliminate sea ice as predicted, polar bears will largely disappear from the southern portions of their range by mid-century”. However, Crockford (2017) has recently challenged this hypothesis based on the fact that sea ice decline is already happening and has not had the expected impact on polar bear populations.

### a) *Expected climate change impact on polar bears*

*Title*
Effects of climate warming on polar bears: a review of the evidence

*Summary*
A thorough analysis of all the possible direct and indirect effects of sea ice loss on polar bears and the threat to their long-term survival.

*Abstract*
Climate warming is causing unidirectional changes to annual patterns of sea ice distribution, structure, and freeze-up. We summarize evidence that documents how loss of sea ice, the primary habitat of polar bears (*Ursus maritimus*), negatively affects their long-term survival. To maintain viable subpopulations, polar bears depend on sea ice as a platform from which to hunt seals for long enough each year to accumulate sufficient energy (fat) to survive periods when seals are unavailable. Less time to access to prey, because of progressively earlier breakup in spring, when newly weaned ringed seal (*Pusa hispida*) young are available, results in longer periods of fasting, lower body condition, decreased access to denning areas, fewer and smaller cubs, lower survival of cubs as well as bears of other age classes and, finally, subpopulation decline toward eventual extirpation. The chronology of climate-driven changes will vary between subpopulations, with quantifiable negative effects being documented first in the more southerly subpopulations, such as those in Hudson Bay or the southern Beaufort Sea. As the bears' body condition declines, more seek alternate food resources so the frequency of conflicts between bears and humans increases. In the most northerly areas, thick multiyear ice, through which little light penetrates to stimulate biological growth on the underside, will be replaced by annual ice, which facilitates greater productivity and may create habitat more favorable to polar bears over continental shelf areas in the short term. If the climate continues to warm and eliminate sea ice as predicted, polar bears will largely disappear from the southern portions of their range by mid-century. They may persist in the northern Canadian Arctic Islands and northern Greenland for the foreseeable future, but their long-term viability, with a much reduced global population size in a remnant of their former range, is uncertain.

*Reference*
Stirling, I. and Derocher, A.E., 2012. Effects of climate warming on polar bears: a review of the evidence. *Global Change Biology*, *18*(9), pp.2694-2706.
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2012.02753.x/full

### *b) A rejected hypothesis: “sea ice decline = polar bear population decline”*

*Title*

Testing the hypothesis that routine sea ice coverage of 3-5 $mkm^2$ results in a greater than 30% decline in population size of polar bears.

*Summary*

This publication finds that predictions of polar bear population crashes due to summer sea ice loss are based on a scientifically unfounded assumption. Sea ice conditions predicted to occur by 2050, occurred regularly since 2007 giving the opportunity to test the hypothesis “sea ice decline = polar bear population decline”. The hypothesis that repeated summer sea ice levels of below 5 $mkm^2$ will cause significant population declines in polar bears was rejected. The author criticizes the process of listing a species, with tens of thousands of individuals, as endangered based only on predictions. The authors suggest that similar predictions made for the Arctic ringed seals, bearded seals and walrus may also be incorrect.

*Abstract*

The polar bear (*Ursus maritimus*) was the first species to be classified as threatened with extinction based on predictions of future conditions rather than current status. These predictions were made using expert-opinion forecasts of population declines linked to modeled habitat loss – first by the International Union for the Conservation of Nature (IUCN)’s Red List in 2006, and then by the United States Fish and Wildlife Service (USFWS) in 2008 under the Endangered Species Act (ESA), based on data collected to 2005 and 2006, respectively. Both assessments predicted significant population declines of polar bears would result by mid-century as a consequence of summer sea ice extent reaching 3-5 $mkm^2$ on a regular basis: the IUCN predicted a >30% decline in total population, while the USFWS predicted the global population would decline by 67% (including total extirpation of ten subpopulations within two vulnerable ecoregions). Biologists involved in these conservation assessments had to make several critical assumptions about how polar bears might be affected by future habitat loss, since sea ice conditions predicted to occur by 2050 had not occurred prior to 2006. However, summer sea ice declines have been much faster than expected: low ice levels not expected until mid-century (about 3-5 $mkm^2$) have occurred regularly since 2007. Realization of predicted sea ice levels allows the ‘sea ice decline = population decline’ assumption for polar bears to be treated as a testable hypothesis. Data collected between 2007 and 2015 reveal that polar bear numbers have not declined as predicted and no subpopulation has been extirpated. Several subpopulations expected to be at high risk of decline have remained stable and at least one showed a marked increase in population size over the entire period. Another at-risk subpopulation was not counted but showed marked improvement in reproductive parameters and body condition with less summer ice. As a consequence, the hypothesis that repeated summer sea ice levels of below 5 $mkm^2$ will cause significant population declines in polar bears is rejected. This result indicates that the ESA and IUCN judgments to list polar bears as threatened based on future risks of habitat loss were hasty generalizations that were scientifically unfounded, which suggests that similar predictions for Arctic seals and walrus may be likewise flawed, while the lack of a demonstrable ‘sea ice decline = population decline’ relationship for polar bears invalidates updated survival model outputs that predict catastrophic population declines should the Arctic become ice-free in summer.

*Reference*

Crockford, SJ. (2017). Testing the hypothesis that routine sea ice coverage of 3-5 $mkm^2$ results in a greater than 30% decline in population size of polar bears (*Ursus maritimus). PeerJ Preprints* 5:e2737v1 (not peer reviewed publication)
https://doi.org/10.7287/peerj.preprints.2737v1

### *c) Increased frequency and distance of polar bear swims*

*Title*
Migratory response of polar bears to sea ice loss: to swim or not to swim.

*Summary*
Spatial habitat heterogeneity can vary the impact of climate change on species' response. Variation in movement dynamics during migration, and therefore energy expenditure, may alter the rate at which climate change affects polar bear populations.

*Abstract*
Migratory responses to climate change may vary across and within populations, particularly for species with large geographic ranges. An increase in the frequency of long-distance swims (> 50 km) is one predicted consequence of climate change for polar bears *Ursus maritimus*. We examined GPS satellite-linked telemetry records of 58 adult females and 18 subadults from the Beaufort Sea (BS), and 59 adult females from Hudson Bay (HB), for evidence of long-distance swimming during seasonal migrations in 2007–2012. We identified 115 swims across both populations. Median swim duration was 3.4 d (range 1.3–9.3 d) and median swim distance was 92 km (range 51–404 km). Swims were significantly more frequent in the BS (n = 100) than HB (n = 15). In the BS, subadults swam as frequently as lone adult females, but more frequently than adult females with offspring. We modelled the likelihood of a polar bear engaging in swims using collar data from the BS. Swims were more likely for polar bears without offspring, with the distance of the pack ice edge from land, the rate at which the pack ice edge retreated, and the mean daily rate of open water gain between June–August. Coupled with an earlier study, the yearly proportions of BS adult females swimming in 2004–2012 were positively associated with the rate of open water gain. Results corroborate the hypothesis that long-distance swimming by polar bears is likely to occur more frequently as sea ice conditions change due to climate warming. However, results also suggest that the magnitude of the effect likely varies within and between populations.

*Reference*
Pilfold, N.W., McCall, A., Derocher, A.E., Lunn, N.J. and Richardson, E., (2017). Migratory response of polar bears to sea ice loss: to swim or not to swim. *Ecography*, *40*(1), 189-199.
http://onlinelibrary.wiley.com/doi/10.1111/ecog.02109/full

## <u>Observed climate change impact on migratory species</u>

### 1. General observations

### *a) Decline of migratory bird species with no phenological response to climate change*

*Title*
Populations of migratory bird species that did not show a phenological response to climate change are declining.

*Summary*
An association between bird population trend and change in migration phenology (considerable advancement of optimal timing of reproduction in the northern hemisphere) was found.

*Abstract*
Recent rapid climatic changes are associated with dramatic changes in phenology of plants and animals, with optimal timing of reproduction advancing considerably in the northern

hemisphere. However, some species may not have advanced their timing of breeding sufficiently to continue reproducing optimally relative to the occurrence of peak food availability, thus becoming mismatched compared with their food sources. The degree of mismatch may differ among species, and species with greater mismatch may be characterized by declining populations. Here we relate changes in spring migration timing by 100 European bird species since 1960, considered as an index of the phenological response of bird species to recent climate change, to their population trends. Species that declined in the period 1990–2000 did not advance their spring migration, whereas those with stable or increasing populations advanced their migration considerably. On the other hand, population trends during 1970–1990 were predicted by breeding habitat type, northernmost breeding latitude, and winter range (with species of agricultural habitat, breeding at northern latitudes, and wintering in Africa showing an unfavorable conservation status), but not by change in migration timing. The association between population trend in 1990–2000 and change in migration phenology was not confounded by any of the previously identified predictors of population trends in birds, or by similarity in phenotype among taxa due to common descent. Our findings imply that ecological factors affecting population trends can change over time and suggest that ongoing climatic changes will increasingly threaten vulnerable migratory bird species, augmenting their extinction risk.

*Reference*
Møller, A.P., Rubolini, D., Lehikoinen, E. (2008). Populations of migratory bird species that did not show a phenological response to climate change are declining. *Proceedings of the National Academy of Sciences of the United States of America* 105: 16195–16200.
http://www.pnas.org/content/105/42/16195.abstract

## 2. Changes in species range due to climate change

The change in ranges has various knock on effects such as the need to re-consider the location of current and future protected areas for the affected species as well as the possible changes in trophic networks and thus in ecosystem stability.

### *a) Balearic shearwater*

*Title*
Climate change impact on Balearic shearwater through a trophic cascade.

*Summary*
A change in the range of the Balearic shearwater was observed. The hypothesis of a link between the biogeographic shift and temperature and that the shift occurred through the food web was tested. The hypothesis of a direct and an indirect effect of climate change on the spatial distribution of post-breeding Balearic shearwater through a trophic cascade was supported.

*Abstract*
A recent study showed that a critically endangered migratory predator species, the Balearic shearwater *Puffinus mauretanicus*, rapidly expanded northwards in northeast Atlantic waters after the mid-1990s. As a significant positive correlation was found between the long-term changes in the abundance of this seabird and sea temperature around the British Isles, it was hypothesized that the link between the biogeographic shift and temperature occurred through the food web. Here, we test this conjecture and reveal concomitant changes in a regional index of sea temperature, plankton (total calanoid copepod), fish prey (anchovy and sardine) and the Balearic shearwater for the period 1980–2003. All three trophic levels exhibit a significant shift detected between 1994 and 1996. Our findings therefore support the assertion of both a direct and an indirect effect of climate change on the spatial distribution of post-breeding Balearic shearwater through a trophic cascade.

*Reference*
Luczak, C., Beaugrand, G., Jaffre, M., Lenoir, S. (2011). Climate change impact on Balearic shearwater through a trophic cascade. *Biology Letters*, *7*(5), 702-705.
http://rsbl.royalsocietypublishing.org/content/7/5/702.short

### b) Cetaceans

*Title*
Climate change and the cetacean community of north-west Scotland.

*Summary*
Changes in cetacean community composition around north-west Scotland attributed to increase in sea temperature. Emphasis on the potential need to adjust the protected areas to these changes.

*Abstract*
Climate change is thought to affect the composition and structure of local ecological communities. We investigate whether ocean warming around north-west Scotland since 1981 has been associated with changes in the local cetacean community. Analysis of strandings from 1948 to 2003 found that no new species per decade were recorded in north-west Scotland between 1965 and 1981. This rose to 2.0 new species per decade from 1988 onwards. The new species recorded since 1988 are generally restricted to warmer waters, while those recorded prior to 1981 regularly occur in colder waters. In the period 1992 to 2003, the relative frequency of stranding of white-beaked dolphin, a colder water species, has declined while strandings of common dolphin, a warmer water species, have increased. Similarly, sightings surveys conducted in May–September 2002 and 2003 show that the relative occurrence and abundance of white-beaked dolphins have declined and common dolphins increased in comparison to previous studies. These observations are consistent with changes in the local cetacean community being driven by increases in local water temperature. If such temperature changes continue, some formerly abundant cold-water species, such as white-beaked dolphins, may be lost from this cetacean community. In a wider context, such changes may lead to populations of cetaceans moving out of areas specifically designated for their protection as they respond to changes in local oceanic conditions.

*Reference*
MacLeod, C.D., Bannon, S.M., Pierce, G.J., Schweder, C., Learmonth, J.A., Herman, J.S., Reid, R.J. (2005). Climate change and the cetacean community of north-west Scotland. *Biological Conservation* 124: 477-483.
http://www.abdn.ac.uk/marfish/pdfs/MacLeod2005.pdf

## 3. Earlier migration and/or earlier nesting

### a) Fin and humpback whales

*Title*
Adapting to a warmer ocean—seasonal shift of baleen whale movements over three decades.

*Summary*
Earlier Summer migration of fin and humpback whales. Whales have high phenotypic plasticity and thus should be able to survive climate change, however there are concerns about the rate of climate change.

*Abstract*

Global warming poses particular challenges to migratory species, which face changes to the multiple environments occupied during migration. For many species, the timing of migration between summer and winter grounds and also within-season movements are crucial to maximise exploitation of temporarily abundant prey resources in feeding areas, themselves adapting to the warming planet. We investigated the temporal variation in the occurrence of fin (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*) in a North Atlantic summer feeding ground, the Gulf of St. Lawrence (Canada), from 1984 to 2010 using a long-term study of individually identifiable animals. These two sympatric species both shifted their date of arrival at a previously undocumented rate of more than 1day per year earlier over the study period thus maintaining the approximate 2-week difference in arrival of the two species and enabling the maintenance of temporal niche separation. However, the departure date of both species also shifted earlier but at different rates resulting in increasing temporal overlap over the study period indicating that this separation may be starting to erode. Our analysis revealed that the trend in arrival was strongly related to earlier ice break-up and rising sea surface temperature, likely triggering earlier primary production. The observed changes in phenology in response to ocean warming are a remarkable example of phenotypic plasticity and may partly explain how baleen whales were able to survive a number of changes in climate over the last several million years. However, it is questionable whether the observed rate of change in timing can be maintained. Substantial modification to the distribution or annual life cycle of these species might be required to keep up with the ongoing warming of the oceans.

*Reference*

Ramp, C., Delarue, J., Palsbøll, P.J., Sears, R., Hammond, P.S. (2015). Adapting to a warmer ocean—seasonal shift of baleen whale movements over three decades. *PloS one*, *10*(3), e0121374.
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0121374

### *b) Loggerhead sea turtles*

*Title*

Earlier nesting by loggerhead sea turtles following sea surface warming.

*Summary*

The authors examined 15 years of loggerhead sea turtle nesting patterns on Florida's Atlantic coast and concluded that the median nesting date was at the time of the study 10 days earlier.

*Abstract*

The onset of spring, noted by the timing of wildlife migratory and breeding behaviors, has been occurring earlier over the past few decades. Here, we examine 15 years of loggerhead sea turtle, *Caretta caretta*, nesting patterns along a 40.5 km beach on Florida's Atlantic coast. This small section of beach is considered to be the most important nesting area for this threatened species in the western hemisphere. From 1989 to 2003, the annual number of nests fluctuated between 13 000 and 25 000 without a conspicuous trend; however, based on a regression analysis, the median nesting date became earlier by roughly 10 days. The Julian day of median nesting was significantly correlated with near-shore, May sea surface temperatures that warmed an average of 0.8°C over this period. This marine example from warm temperate/subtropical waters represents another response of nature to recent climate trends.

*Reference*

Weishampel, J.F., Bagley, D.A., Ehrhart, L.M. (2004). Earlier nesting by loggerhead sea turtles following sea surface warming. *Global Change Biology*, *10*(8), 1424-1427.
http://onlinelibrary.wiley.com/doi/10.1111/j.1529-8817.2003.00817.x/full

### *c) Climate change effect on the seasonal cycle of plants and animals in Europe*

*Title*
Phenology of plant and animal species

*Summary*
The timing of seasonal events has changed across Europe. A general trend towards earlier spring phenological stages (spring advancement) has been shown in many plant and animal species, mainly due to changes in climate conditions. As a consequence of climate-induced changes in plant phenology, the pollen season starts on average 10 days earlier than it did and is longer than it was in the 1960s. The life cycles of many animal groups have advanced in recent decades, with events occurring earlier in the year, including frogs spawning, birds nesting and the arrival of migrant birds and butterflies. This advancement is attributed primarily to a warming climate. The breeding season of many thermophilic insects (such as butterflies, dragonflies and bark beetles) has been lengthening, allowing, in principle, more generations to be produced per year. The observed trends are expected to continue into the future. However, simple extrapolations of current phenological trends may be misleading because the observed relationship between temperature and phenological events may change in the future.

*Reference*
2016. Phenology of plant and animal species. European Environment Agency CLIM 023.
http://www.eea.europa.eu/data-and-maps/indicators/plant-phenology-2/assessment

## 4. Impact on reproductive success

Climate change is altering the frequency of extreme weather events. Impacts of such events include the increased mortality rate of chicks, thus increasing the reproductive failure of birds breeding in the affected areas. The increased sea temperature reduces the marine turtle reproductive success by: reducing the length of the nesting period, temperature related altered sex ratio of hatchlings and decreased hatching success.

### *a) Increased reproductive failure in Magellanic Penguins*

*Title*
Climate change Increases Reproductive Failure in Magellanic Penguins

*Summary*
Climate change that increases the frequency and intensity of storms results in more reproductive failure of Magellanic penguins, a pattern likely to apply to many species breeding in the region.

*Abstract*
Climate change is causing more frequent and intense storms, and climate models predict this trend will continue, potentially affecting wildlife populations. Since 1960 the number of days with >20 mm of rain increased near Punta Tombo, Argentina. Between 1983 and 2010 we followed 3496 known-age Magellanic penguin (*Spheniscus magellanicus*) chicks at Punta Tombo to determine how weather impacted their survival. In two years, rain was the most common cause of death killing 50% and 43% of chicks. In 26 years starvation killed the most chicks. Starvation and predation were present in all years. Chicks died in storms in 13 of 28 years and in 16 of 233 storms. Storm mortality was additive; there was no relationship between the number of chicks killed in storms and the numbers that starved ($P=0.75$) or that were eaten ($P=0.39$). However, when more chicks died in storms, fewer chicks fledged ($P=0.05$, $R^2=0.14$). More chicks died when rainfall was higher and air temperature lower. Most chicks died from storms when they were 9–23 days old; the oldest chick killed in a

storm was 41 days old. Storms with heavier rainfall killed older chicks as well as more chicks. Chicks up to 70 days old were killed by heat. Burrow nests mitigated storm mortality (*N*=1063). The age span of chicks in the colony at any given time increased because the synchrony of egg laying decreased since 1983, lengthening the time when chicks are vulnerable to storms. Climate change that increases the frequency and intensity of storms results in more reproductive failure of Magellanic penguins, a pattern likely to apply to many species breeding in the region. Climate variability has already lowered reproductive success of Magellanic penguins and is likely undermining the resilience of many other species.

*Reference*

Boersma, P.D., Rebstock, G.A. (2014). Climate Change Increases Reproductive Failure in Magellanic Penguins. *PLoS ONE* 9(1): e85602.
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0085602

### b) Shorter nesting seasons for the Loggerhead Seaturtle

*Title*

Earlier nesting contributes to shorter nesting seasons for the loggerhead seaturtle*, Caretta caretta*.

*Summary*

The authors demonstrate that warmer sea surface temperatures are related to earlier nesting in the Loggerhead Seaturtle, and that this response actually decreases, rather than increases, the length of the nesting season.

*Abstract*

Evidence is mounting that warming air and sea temperatures are affecting nesting patterns in oviparous species by causing earlier nesting within seasons. The potential fitness consequences of nesting earlier include extended periods of offspring growth and larger clutch sizes. Additionally, the potential for nesting seasons to last longer exists, possibly allowing species that lay multiple clutches within a season to increase the number of clutches produced. To date, no studies have examined consequences of earlier nesting on duration of nesting season in oviparous vertebrates. We demonstrate that warmer sea surface temperatures are related to earlier nesting in the Loggerhead Seaturtle *Caretta caretta*, and that this response actually decreases, rather than increases, the length of the nesting season. In recent years (1995–2003), nesting became more evenly distributed throughout the season than in earlier years (1989–1994), and the nesting season decreased by approximately 43 days. Female turtles are unlikely to produce additional clutches within a reproductive season in response to this effect because of physiological constraints, and we cannot rule out the hypothesis that female turtles will lay fewer clutches because of a shortened nesting season, leading to reduced fecundity within seasons.

*Reference*

Pike, D.A., Antworth, R.L., Stiner, J.C. (2006). Earlier nesting contributes to shorter nesting seasons for the loggerhead seaturtle*, Caretta caretta*. *Journal of Herpetology*, *40*(1), 91-94.
http://www.bioone.org/doi/abs/10.1670/100-05N.1

### c) Increased breeding success of Reed warblers

*Title*

Climate change affects breeding of Reed warblers *Acrocephalus scirpaceus*

*Summary*

Climate change had a positive impact on reed warblers by extending their breeding season and the decrease of nest losses due to warmer weather.

*Abstract*
Between 1970 and 2006 reed warblers *Acrocephalus scirpaceus* started breeding progressively earlier; both the initiation of breeding (the earliest first egg dates) and peak of breeding (median first egg dates) advanced. Median first egg dates correlated significantly with increasing May–July mean temperatures. However, in contrast to other studies showing the advancement in laying dates, the end of the season did not shift. As a result, the breeding season is now longer increasing re-nesting opportunities. Individuals are able to re-nest 4–5 times, which might have important implications for the species. It was also found that in warmer seasons the population suffered fewer nest losses. Both factors, higher re-nesting potential and a trend toward fewer losses, should lead to increased fitness of individuals in the studied population.

*Reference*
Halupka, L., Dyrcz, A., Borowiec, M. (2008). Climate change affects breeding of reed warblers Acrocephalus scirpaceus. *Journal of Avian Biology*, *39*(1), 95-100.
https://www.jstor.org/stable/30243848?seq=1#page_scan_tab_contents

## Expected climate change impact on migratory species

Climate change impact is studied in relation to changes in species distribution, phenology and abundance, changes in community synthesis and demography and change of calcification rate. The level of climate change impact on the conservation status of species can vary greatly, and at the moment is still more presumed and based on projections and model than on absolute scientific evidence. Vulnerability assessments have now been undertaken for a good number of species, including a many species listed in CMS appendices. For those assessed as highly vulnerable, climate change effects are considered to have the potential to lead them to extinction in a rather short time frame.

### 1. Terrestrial mammals: range loss for the African Antelopes

*Title*
Disproportionate Climate-Induced Range Loss Forecast for the Most Threatened African Antelopes.

*Summary*
The hypothesis that small range size is directly linked to large climate-induced range reduction was tested using antelopes as a model. Gap analysis shows high priorities for antelope conservation to include creation of new protected areas, as well as improved connectivity between existing protected areas. The potentially important role for ex situ conservation is also highlighted.

*Abstract*
According to the “small-range climate-hypersensitivity hypothesis,” we predict small range size to be directly linked to large climate-induced range reduction. Antelopes, an exemplary macroecological model due to their striking ecological diversity and species richness, present an ideal opportunity to test this. Here we provide the first empirical evidence that climate change will cause a disproportionate decline in African antelopes with small geographic ranges, which places the most threatened taxa in double jeopardy. This substantiates our theoretical expectation that the link between small range size and large climate-induced range reduction is a general phenomenon. Our empirically based models also allow specific recommendations for mitigating climate-induced species declines. Gap analysis shows high priorities for antelope conservation to include creation of new protected areas in the horn of Africa and Liberia, as well as improved connectivity between existing protected areas. Predicted extinction of four species unable to reach areas with suitable climatic conditions by

2080 moreover highlights a potentially important role for ex situ conservation. The study emphasizes the urgent need to incorporate climate change into the IUCN threat assessment by extending the timeframe over which population trends are assessed.

*Reference*

Payne, B.J., Bro-Jørgensen, J. (2016). Disproportionate Climate-Induced Range Loss Forecast for the Most Threatened African Antelopes. Current biology 26(9): 1200–1205. https://www.ncbi.nlm.nih.gov/pubmed/27133868

## 2. Marine mammals

### *a) Swift of migration routes and decreased reproductive success in marine mammals*

*Title*

Climate change and migratory species.

*Summary*

This report examines the potential effects of climate change across taxa, with focus on the following species: Sperm whale (*Physeter microcephalus*), Green turtle (*Chelonia mydas*), Atlantic cod (*Gadus morhua*), Sooty shearwater (*Puffinus griseus*), Siberian crane (*Grus leucogeranus*), Red knot (*Calidris canutus*), Common redshank (*Tringa tetanus*), Aqautic Waebler (*Acrocephalus paludicola*), Pied flycatcher (*Ficedula hypoleuca*), Saiga antelope (*Saiga tatarica*), Caribou (*Rangifer taurandus*), Pond bat (*Myotis dasycneme*), Brazilian free-tail bat (*Tadarida brasiliensis*), Straw-coloured fruit bat (*Eidolon helvum*), Monarch butterfly (*Danaus plexippus*).

For the Sperm whale:

Climate change will affect Sperm Whale distribution and migration as a result of changes in prey abundance and distribution throughout their range and in regional areas. For example, long-term interannual variation in the number of Sperm Whale strandings on the North Sea coast may be related to ocean climate, with a weak but statistically significant positive association between North Sea strandings (1563-1999) and the (three-year lagged) winter North Atlantic Oscillation (NAO) index. It appears that a link could operate through changes in the distribution of the whales' main squid prey and consequent shift in Sperm Whale migration routes. Climate change could affect the reproductive success of Sperm Whales through changes in prey availability. For example, a decrease in reproductive success of female Sperm Whales near the Galápagos Islands was associated with periods of warm sea surface temperature, usually caused by El Niño Southern Oscillation events, probably linked to poor foraging success (Whitehead 1997). Therefore, any increase in temperature as a result of global warming and/or the frequency and duration of El Niño events could have serious implications for Sperm Whale populations such as those found around the Galápagos Islands (Whitehead 1997).

*Reference*

Robinson, R.A., Learmonth, J.A., Hutson, A.M., Macleod, C.D., Sparks, T.H., Leech, D.I., Pierce, G.J., Rehfisch, M.M., Crick, H.Q.P. (2005). Climate change and migratory species. *Department for Environment, Food and Rural Affairs, London.* http://www.abdn.ac.uk/marfish/pdfs/Robinson2005.pdf

### *b) Projected climate change impact on marine mammals*

*Title*

The impacts of climate change on marine mammals: early signs of significant problems.

*Summary*
A review that highlights the need to take projected impacts into account in future conservation and management plans, including species assessments. It emphasizes the need for cooperation between ecosystem modellers and marine mammal experts.

*Abstract*
Climate change is now known to be affecting the oceans. It is widely anticipated that impacts on marine mammals will be mediated primarily via changes in prey distribution and abundance and that the more mobile (or otherwise adaptable) species may be able to respond to this to some extent. However, the extent of this adaptability is largely unknown. Meanwhile, within the last few years direct observations have been made of several marine mammal populations that illustrate reactions to climate change. These observations indicate that certain species and populations may be especially vulnerable, including those with a limited habitat range, such as the vaquita *Phocoena sinus*, or those for which sea ice provides an important part of their habitat, such as narwhals Monodon monoceros, bowhead *Balaena mysticetus* and beluga *Delphinapterus leucas* whales and polar bears *Ursus maritimus*. Similarly, there are concerns about those species that migrate to feeding grounds in polar regions because of rapidly changing conditions there, and this includes many baleen whale populations. This review highlights the need to take projected impacts into account in future conservation and management plans, including species assessments. How this should be done in an adequately precautionary manner offers a significant challenge to those involved in such processes, although it is possible to identify at this time at least some species and populations that may be regarded as especially vulnerable. Marine ecosystems modellers and marine mammal experts will need to work together to make such assessments and conservation plans as robust as possible.

*Reference*
Simmonds, M.P. and Isaac, S.J. (2007). The impacts of climate change on marine mammals: early signs of significant problems. *Oryx*, *41*(01), 19-26.
https://www.cambridge.org/core/journals/oryx/article/div-classtitlethe-impacts-of-climate-change-on-marine-mammals-early-signs-of-significant-problemsdiv/B105EB0556C8CD009845D3350C7E7B8A

## 3. Marine turtles

### *a) Hatching success*

*Title*
Climate change implications for the nest site selection process and subsequent hatching success of a green turtle (listed in CMS Appendix 1) population.

*Summary*
The authors concluded that Green turtles use a combination of cues to find nest sites, mainly higher elevations and lower sand surface temperatures. It was found that hatching success was significantly and negatively correlated to sand temperature at cloaca depth. Rising air temperatures could alter sand temperature cues for suitable nest sites, and produce uneven sex ratios or lethal incubating temperatures. Elevation cues and preferred ranges may also be affected by sea level rise, risking inundation of nests.

*Abstract*
Sandy beach habitat where sea turtles nest will be affected by multiple climate change impacts. Before these impacts occur, knowledge of how nest site selection and hatching success vary with beach microhabitats is needed to inform managers on how to protect suitable habitats and prepare for scientifically valid mitigation measures at beaches around the world. At a highly successful green turtle (*Chelonia mydas*) rookery at Akumal, Quintana

Roo, Mexico, we measured microhabitat characteristics along the beach crawl (rejected sites) and related nest site conditions (selected sites) to subsequent hatching success rates for 64 nesting events. To our knowledge, this is the first study to report environmental data along the nesting crawl for a green turtle population and the first to use natural breaks in the data to describe their preferred habitat ranges. Our results indicate that turtles were likely using a combination of cues to find nest sites, mainly higher elevations and lower sand surface temperatures (Kruskal-Wallis test, $H = 19.84$, $p < 0.001$; $H = 10.78$, $p < 0.001$). Hatching success was significantly and negatively correlated to sand temperature at cloaca depth (Spearman's $\rho = -0.27$, $p = 0.04$). Indeed, the preferred range for cloaca sand temperatures at the nest site (26.3–27.5 °C) had significantly higher hatching success rates compared to the highest temperature range (Tukey HSD = 0.47, $p = 0.05$). Sand temperatures at various depths were intercorrelated, and surface and cloaca depth sand temperatures were correlated to air temperature ($\rho = 0.70$, $p = 0.00$; $\rho = 0.26$, $p = 0.04$). Therefore, rising air temperatures could alter sand temperature cues for suitable nest sites, preferred nest site ranges, and produce uneven sex ratios or lethal incubating temperatures. Elevation cues and preferred ranges (1.4–2.5 m) may also be affected by sea level rise, risking inundation of nests.

*Reference*

Santos, K.C., Livesey, M., Fish, M., Lorences, A.C. (2017). Climate change implications for the nest site selection process and subsequent hatching success of a green turtle population. Mitigation and Adaptation Strategies for Global Change 22(1): 121-135.
http://link.springer.com/article/10.1007/s11027-015-9668-6

### *b) Conservation status of the loggerhead turtle in the Indian Ocean and South-East Asia*

Predictions for loggerhead turtles. Increased sea surface temperatures could negatively influence the numbers of females breeding each year, and shifts in the nesting season or impact of threats could change with a warming climate. Key research gaps: conversion of global/ocean-scale climate models down to smaller scales so they are relevant to local scale (e.g. for nesting beaches or foraging areas), understanding sensitivity and thresholds of concern (e.g. pivotal temperatures and sand temperature ranges) and understanding adaptive capacity.

*Reference*

Hamann M., Kamrowski, R. L., and Bodine, T. (2013). Assessment of the conservation status of the loggerhead turtle in the Indian Ocean and South-East Asia. IOSEA Marine Turtle MoU Secretariat, Bangkok.
http://www.ioseaturtles.org/UserFiles/File/Loggerhead_Assessment_LQ-FINAL-Sept2013.pdf

## 4. General impact of ocean warming on different animal groups

*Title*

Explaining ocean warming: Causes, scale, effects and consequences

*Summary*

This report analyses the impacts of ocean warming on marine fish, seabirds, marine turtles and marine mammals as well as on marine ecosystems.

*Reference*

Laffoley, D., Baxter, J.M. (2016). Explaining ocean warming: Causes, scale, effects and consequences. *Full report. Gland, Switzerland: IUCN*, *27*.
https://portals.iucn.org/library/sites/library/files/documents/2016-046_0.pdf

**Are the projected climate change impacts in agreement with the observed?**

*Title*
Global imprint of climate change on marine life

*Summary*
This publication is an analysis of the consistency of marine ecological observations with expectations under climate change. The authors showed that from the 1,735 observed responses of marine organisms to climate change from 208 single- and multi-species studies 1,092 responses are consistent with climate change, 225 are opposite to expected and 418 are equivocal.

*Abstract*
Past meta-analyses of the response of marine organisms to climate change have examined a limited range of locations, taxonomic groups and/or biological responses. This has precluded a robust overview of the effect of climate change in the global ocean. Here, we synthesized all available studies of the consistency of marine ecological observations with expectations under climate change. This yielded a meta-database of 1,735 marine biological responses for which either regional or global climate change was considered as a driver. Included were instances of marine taxa responding as expected, in a manner inconsistent with expectations, and taxa demonstrating no response. From this database, 81–83% of all observations for distribution, phenology, community composition, abundance, demography and calcification across taxa and ocean basins were consistent with the expected impacts of climate change. Of the species responding to climate change, rates of distribution shifts were, on average, consistent with those required to track ocean surface temperature changes. Conversely, we did not find a relationship between regional shifts in spring phenology and the seasonality of temperature. Rates of observed shifts in species' distributions and phenology are comparable to, or greater, than those for terrestrial systems.

*Reference*
Poloczanska, E.S., Brown, C.J., Sydeman, W.J., Kiessling, W., Schoeman, D.S., Moore, P.J., Brander, K., Bruno, J.F., Buckley, L.B., Burrows, M.T. and Duarte, C.M., 2013. Global imprint of climate change on marine life. *Nature Climate Change*, *3*(10), 919-925.
http://marinepalaeoecology.org/wp-content/uploads/2011/09/nclimate1958.pdf

## "Good practice" examples/ success stories (session 3)

The 2014 UNEP/CMS Workshop Report "towards a CMS programme of work on climate change" provides a detailed list of suggestions on:

- measures to facilitate adaptation in response to climate change
- vulnerability assessments
- monitoring and research
- climate change mitigation, human adaptation and land use planning
- knowledge exchange and capacity building
- cooperation and implementation

### Practical measures

### 1. Nestling translocation

#### *a) Bermuda Petrel*

*Title*
Establishment of a new, secure colony of Endangered Bermuda Petrel by translocation of near-fledged nestlings.

*Summary*
Successful translocation of near-fledged hatchling and establishment of a new colony of the Bermuda petrel.

*Abstract*
Until recently, Bermuda Petrel *Pterodroma cahow* (IUCN Category: 'Endangered') bred only in sub-optimal habitat on four small islets in north-east Bermuda. Although intensive management of the population since 1962 has led to a substantial increase in population size (now approaching 100 pairs), the nesting habitat on these four islets is being increasingly inundated, eroded and destroyed by high seas associated with hurricanes and storms. To ensure the long-term conservation of the species a decision was made to establish a new colony at a more secure site on nearby Nonsuch Island, where they once bred in large numbers. Between 2004 and 2008, 104 near-fledged nestlings were translocated to artificial burrows on Nonsuch Island, where they were hand-fed meals of fish and squid. All but three translocated birds fledged successfully, with the first returning to Nonsuch Island in February 2008. The first Bermuda Petrel egg on Nonsuch Island in more than 300 years was laid in January 2009, and the resultant fledgling departed in June of the same year. By the end of the 2009/10 breeding season, a total of 18 Bermuda Petrels have been recorded on Nonsuch Island, 17 were translocated as near-fledged nestlings, and one bird came from the existing colonies. A total of five eggs have been produced, resulting in two fledglings. The establishment of this new colony, at a site that is much more secure than the existing nesting sites, greatly enhances the conservation prospects of the species and demonstrates the importance of translocation as a tool for the conservation of threatened seabirds.

*Reference*
Carlile, N., Priddel, D. and Madeiros, J., 2012. Establishment of a new, secure colony of Endangered Bermuda Petrel Pterodroma cahow by translocation of near-fledged nestlings. *Bird Conservation International*, *22*(01), pp.46-58.
https://www.cambridge.org/core/journals/bird-conservation-international/article/div-classtitleestablishment-of-a-new-secure-colony-of-endangered-bermuda-petrel-span-

classitalicpterodroma-cahowspan-by-translocation-of-near-fledged-nestlingsdiv/3C5619DE30E739CCAA420D4360524AFD

### *b) Short-tailed Albatross*

*Title*
Translocation and hand-rearing techniques for establishing a colony of threatened albatross

*Summary*
Successful translocation of the Short-tailed Albatross, with detailed analysis of translocation techniques.

*Abstract*
Many breeding colonies of Procellariiformes have been threatened with extinction. Chick translocation has been shown to be an effective method for establishing new "safer" colonies of burrow-nesting species, but techniques for surface-nesting species have not been fully developed. The entire breeding population of the threatened Short-tailed Albatross *Phoebastoria albatrus* is restricted to two sites, Torishima Island and the Senkaku Islands, and neither site is secure due to volcanic activity or political instability. The Short-tailed Albatross Recovery Team has recommended facilitating the recovery of this species by establishing at least one additional colony through the translocation and hand-rearing of chicks at a safe historical breeding site. To evaluate the feasibility of this approach, we hand-reared 10 post-guard phase chicks of two related species in 2006–2007: Laysan Albatross *P. immutabilis* translocated from Midway Atoll to Kaua'i Island, Hawai'i and Black-footed Albatross *P. nigripes* translocated from a nearby islet in the Ogasawara (Bonin) Islands to Mukojima Island, Japan. In these pilot studies, 40% of Laysan Albatross chicks and 90% of Black-footed Albatross chicks fledged successfully. Following this groundwork, 40 post-guard phase Short-tailed Albatross chicks were translocated from Torishima Island to Mukojima Island in February 2008–2010 and hand-reared to fledging. Their fledging success has been 100% in all three years. Fledging body sizes were similar or greater in hand-reared chicks at the release site than parent-reared chicks on Torishima Island. There were significant differences in levels of some blood chemistry parameters between pre-fledging hand-reared and parent-reared chicks. The techniques developed in our studies have broad-reaching implications for the future conservation of threatened populations of other surface-nesting seabirds.

*Reference*
Deguchi, T., Jacobs, J., Harada, T., Perriman, L., Watanabe, Y., Sato, F., Nakamura, N., Ozaki, K. and Balogh, G., 2012. Translocation and hand-rearing techniques for establishing a colony of threatened albatross. *Bird Conservation International*, *22*(01), pp.66-81. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S0959270911000438

## 2. Site connectivity

### *a) Migratory connectivity using stable isotopes*

*Title*
Using stable isotopes to investigate migratory connectivity of the globally threatened aquatic warbler *Acrocephalus paludicola*

*Summary*
Stable isotopes were used for providing insights into migratory connectivity and migration of the aquatic warbler.

*Abstract*
Understanding the links between breeding and wintering areas of migratory species has important ecological and conservation implications. Recently, stable isotope technology has been used to further our understanding. Stable isotope ratios vary geographically with a range of biogeochemical factors and isotope profiles in organisms reflect those in their food and environment. For inert tissues like feathers, isotope profiles reflect the environment in which they were formed. Following large-scale habitat destruction, the globally threatened aquatic warbler *Acrocephalus paludicola* has a fragmented breeding population across central Europe, largely in Belarus, Poland and Ukraine. The species' sub-Saharan African wintering grounds have not yet been discovered, and this significantly hampers conservation efforts. Aquatic warblers grow their flight feathers on their wintering grounds, and we analysed stable isotope ratios ($\delta^{15}N$, $\delta^{13}C$, $\delta D$) in rectrices of adults from six main breeding sites (subpopulations) across Europe to determine whether different breeding subpopulations formed a single mixed population on the wintering grounds. $\delta^{15}N$ varies considerably with dietary trophic level and environmental factors, and $\delta D$ with the $\delta D$ in rainfall; neither varied between aquatic warbler subpopulations. Uniform feather $\delta^{15}N$ signatures suggest no major variation in dietary trophic level during feather formation. High variance and inter-annual differences in mean $\delta D$ values hinder interpretation of these data. Significant differences in mean $\delta^{13}C$ ratios existed between subpopulations. We discuss possible interpretations of this result, and consider differences in moulting latitude of different subpopulations to be the most parsimonious. $\delta^{13}C$ in plants and animals decreases with latitude, along a steep gradient in sub-Saharan Africa. Birds from the most north-westerly breeding subpopulation (Karsibor, Poland) had significantly lower variance in $\delta^{13}C$ and $\delta^{15}N$ than birds from all other sites, suggesting either that birds from Karsibor are less geographically dispersed during moult, or moult in an area with less isotopic heterogeneity. Mean $\delta^{13}C$ signatures from winter-grown feathers of different subpopulations were positively correlated with the latitude and longitude of breeding sites, suggesting a strong relationship between European breeding and African winter moulting latitudes. The use of stable isotopes provides novel insights into migratory connectivity and migration patterns in this little-known threatened species.

*Reference*
Pain, D.J., Green, R.E., Gieβing, B., Kozulin, A., Poluda, A., Ottosson, U., Flade, M., Hilton, G.M. (2004). Using stable isotopes to investigate migratory connectivity of the globally threatened aquatic warbler Acrocephalus paludicola. *Oecologia*, *138*(2), 168-174.
http://link.springer.com/article/10.1007/s00442-003-1416-z

### *b) Consistent foraging areas and commuting corridors of the Balearic shearwater*

*Title*
Consistent foraging areas and commuting corridors of the critically endangered Balearic shearwater *Puffinus mauretanicus* in the northwestern Mediterranean.

*Summary*
Spatial and temporal patterns of marine space use by the Balearic shearwater. Such a method can be used for developing area-based management approaches. Preferred foraging areas showed strong overlap with recently declared Special Protection Areas, strengthening the evidence base for targeted management at these sites.

*Abstract*
Unprecedented changes to the marine environment and growth of bio-logging science make detailed study of the movement ecology of threatened marine species timely. Here, we study spatial and temporal patterns of marine space use by a critically endangered seabird: the Balearic shearwater *Puffinus mauretanicus*. Using a suite of bio-logging systems, 67 foraging trips were recorded during incubation periods between 2011 and 2014 from one of the species' largest colonies (Sa Cella, Mallorca). Most birds followed narrow flight corridors to restricted neritic foraging grounds on the Iberian continental shelf. Productive foraging areas

along the Catalan coast (NE Spain) were consistent across multiple years and between sexes, indicating extensive use of predictable resources. While our study emphasises the vulnerability of this species to anthropogenic activity in nearshore waters, consistent commuting corridors and foraging grounds represent tractable habitat for protection and offer hope for developing area-based management approaches. Preferred foraging areas showed strong overlap with recently declared Special Protection Areas, strengthening the evidence base for targeted management at these sites.

*Reference*
Meier, R.E., Wynn, R.B., Votier, S.C., Grivé, M.M., Rodríguez, A., Maurice, L. et al. (2015). Consistent foraging areas and commuting corridors of the critically endangered Balearic shearwater *Puffinus mauretanicus* in the northwestern Mediterranean. *Biological Conservation*, *190*, 87-97.
http://www.sciencedirect.com/science/article/pii/S0006320715002074

### *c) Review of Migratory Bird Flyways and Priorities for Management*

To facilitate migratory movements, it is vital to find ways to improve the connectivity of habitats critical to population survival. Need for: monitoring and research into the impacts of climate change on migratory species, the ability of species and populations to adapt. Identify: key limiting factors, the ‘weakest link’, upon which each species’ survival hinges, and to provide essential building blocks for policy guidance. Need: to further develop the analytical and modelling tools to describe connectivity between breeding and wintering areas and within the network of sites along the main flyways. Large sets of available data (e.g. the EURING Data Bank in Europe) can offer unique opportunities for modelling the best analytical approach. CMS is already involved in developing critical site networks, but there is an urgent need to identify and protect further critical site networks with species range shifts in mind. Analysis of the impact of climate change on migratory birds. The habitat of stop-over sites will change and thus alternative sites need to be available in future to ensure the connectivity of the flyways.

*References*
UNEP/CMS (2014). Technical Series: A Review of Migratory Bird Flyways and Priorities for Management.
http://www.cms.int/sites/default/files/publication/CMS_Flyways_Reviews_Web.pdf
and
A bird’s EYE VIEW on flyways. A brief tour by the Convention on the Conservation of Migratory Species of Wild Animals UNEP/ CMS Secretariat, Bonn, Germany. 2012.
http://www.cms.int/sites/default/files/publication/cms_pub_pop-series_bird-eye-view-flyways_2ed_web.pdf

### *d) Impacts of habitat fragmentation and patch size upon migration rates*

A spatially explicit model (MIGRATE) was used to investigate the effects of habitat loss and fragmentation on the ability of species to migrate in response to climate change.

*Reference*
Collingham, Y.C. and Huntley, B. (2000). Impacts of habitat fragmentation and patch size upon migration rates. *Ecological Applications*, 10: 131–144.
http://onlinelibrary.wiley.com/doi/10.1890/1051-0761(2000)010[0131:IOHFAP]2.0.CO;2/full

### *e) Understanding migratory connectivity*

*Title*
Links between worlds: unraveling migratory connectivity

*Summary*
Review of new approaches in determining the population and geographical origin of individual birds (using advances in satellite telemetry, genetic analyses and stable isotope chemistry). Considers the relevance of understanding migratory connectivity to ecological, evolutionary and conservation issues.

*Abstract*
Migration is the regular seasonal movement of animals from one place to another, often from a breeding site to a nonbreeding site and back. Because the act of migration makes it difficult to follow individuals and populations year round, our understanding of the ecology and evolution of migrating organisms, particularly birds, has been severely impeded. Exciting new advances in satellite telemetry, genetic analyses and stable isotope chemistry are now making it possible to determine the population and geographical origin of individual birds. Here, we review these new approaches and consider the relevance of understanding migratory connectivity to ecological, evolutionary and conservation issues.

*Reference*
Michael S. Webster, Peter P. Marra, Susan M. Haig, Staffan Bensch, Richard T. Holmes (2002). Links between worlds: unraveling migratory connectivity. *Trends in Ecology & Evolution*: 17, (2): 76-83.
http://www.sciencedirect.com/science/article/pii/S0169534701023801

## 3. Marine turtle and climate change

### *a) Comparison of 58 marine turtle RMUS's*

*Title*
Resilience of marine turtle regional management units to climate change.

*Summary*
The resilience of 58 marine turtle regional management units (RMUs) to climate change was analyzed and a Resilience Index was developed.

*Abstract*
Enhancing species resilience to changing environmental conditions is often suggested as a climate change adaptation strategy. To effectively achieve this, it is necessary first to understand the factors that determine species resilience, and their relative importance in shaping the ability of species to adjust to the complexities of environmental change. This is an extremely challenging task because it requires comprehensive information on species traits. We explored the resilience of 58 marine turtle regional management units (RMUs) to climate change, encompassing all seven species of marine turtles worldwide. We used expert opinion from the IUCN-SSC Marine Turtle Specialist Group (n=33 respondents) to develop a Resilience Index, which considered qualitative characteristics of each RMU (relative population size, rookery vulnerability, and genetic diversity) and non climate-related threats (fisheries, take, coastal development, and pollution/pathogens). Our expert panel perceived rookery vulnerability (the likelihood of functional rookeries becoming extirpated) and non climate-related threats as having the greatest influence on resilience of RMUs to climate change. We identified the world's 13 least resilient marine turtle RMUs to climate change, which are distributed within all three major ocean basins and include six of the world's seven species of marine turtle. Our study provides the first look at inter- and intra-species variation in resilience to climate change and highlights the need to devise metrics that measure resilience directly. We suggest that this approach can be widely used to help prioritize future actions that increase species resilience to climate change.

*Reference*

Fuentes, M.M., Pike, D.A., Dimatteo, A., Wallace, B.P. (2013). Resilience of marine turtle regional management units to climate change. *Global change biology*, *19*(5), 1399-1406. http://onlinelibrary.wiley.com/doi/10.1111/gcb.12138/full

### *b) Importance of RMU's for turtle conservation*

*Title*
Regional management units for marine turtles: a novel framework for prioritizing conservation and research across multiple scales

*Summary*
Importance of RMU's for turtle conservation.

*Abstract*
The RMU framework is a solution to the challenge of how to organize marine turtles into units of protection above the level of nesting populations, but below the level of species, within regional entities that might be on independent evolutionary trajectories. Among many potential applications, RMUs provide a framework for identifying data gaps, assessing high diversity areas for multiple species and genetic stocks, and evaluating conservation status of marine turtles. Furthermore, RMUs allow for identification of geographic barriers to gene flow, and can provide valuable guidance to marine spatial planning initiatives that integrate spatial distributions of protected species and human activities. In addition, the RMU framework — including maps and supporting metadata — will be an iterative, user-driven tool made publicly available in an online application for comments, improvements, download and analysis.

*Reference*
Wallace, B.P., DiMatteo, A.D., Hurley, B.J., Finkbeiner, E.M., Bolten, A.B., Chaloupka, M.Y., et al. (2010). Regional management units for marine turtles: a novel framework for prioritizing conservation and research across multiple scales. *PLoS One*, *5*(12), e15465. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0015465

### *c) Conservation recommendations to increase the capacity of marine turtle populations to adapt to climate change*

*Title*
Vulnerability of Marine Turtles to Climate Change

*Summary*
This book chapter analyzes all the climate change impacts on marine turtles and presents various adaptation, resilience strategies and recommendations.

*Abstract*
Marine turtles are generally viewed as vulnerable to climate change because of the role that temperature plays in the sex determination of embryos, their long life history, long age-to-maturity and their highly migratory nature. Extant species of marine turtles probably arose during the mid–late Jurassic period (180–150 Mya) so have survived past shifts in climate, including glacial periods and warm events and therefore have some capacity for adaptation. The present day rates of increase of atmospheric greenhouse gas concentrations, and associated temperature changes, are very rapid; the capacity of marine turtles to adapt to this rapid change may be compromised by their relatively long generation times. We consider the evidence and likely consequences of present-day trends of climate change on marine turtles. Impacts are likely to be complex and may be positive as well as negative. For example, rising sea levels and increased storm intensity will negatively impact turtle nesting beaches; however, extreme storms can also lead to coastal accretion. Alteration of wind patterns and ocean currents will have implications for juveniles and adults in the open ocean.

Warming temperatures are likely to impact directly all turtle life stages, such as the sex determination of embryos in the nest and growth rates. Warming of 2°C could potentially result in a large shift in sex ratios towards females at many rookeries, although some populations may be resilient to warming if female biases remain within levels where population success is not impaired. Indirectly, climate change is likely to impact turtles through changes in food availability. The highly migratory nature of turtles and their ability to move considerable distances in short periods of time should increase their resilience to climate change. However, any such resilience of marine turtles to climate change is likely to be severely compromised by other anthropogenic influences. Development of coastlines may threaten nesting beaches and reproductive success, and pollution and eutrophication is threatening important coastal foraging habitats for turtles worldwide. Exploitation and bycatch in other fisheries has seriously reduced marine turtle populations. The synergistic effects of other human-induced stressors may seriously reduce the capacity of some turtle populations to adapt to the current rates of climate change. Conservation recommendations to increase the capacity of marine turtle populations to adapt to climate change include increasing population resilience, for example by the use of turtle exclusion devices in fisheries, protection of nesting beaches from the viewpoints of both conservation and coastal management, and increased international conservation efforts to protect turtles in regions where there is high unregulated or illegal fisheries (including turtle harvesting). Increasing research efforts on the critical knowledge gaps of processes influencing population numbers, such as identifying ocean foraging hotspots or the processes that underlie the initiation of nesting migrations and selection of breeding areas, will inform adaptive management in a changing climate.

*Reference*

*Elvira S. Poloczanska, Colin J. Limpus, and Graeme C. Hays, Vulnerability of Marine Turtles to Climate Change. In D. W. Sims, editor: Advances in Marine Biology, Vol. 56, Burlington: Academic Press, 2009, pp. 151-211.*

## 4. Example techniques and measures

### *a) Satellite imagery for tracking Arctic wildlife*

*Title*

Polar Bears from Space: Assessing Satellite Imagery as a Tool to Track Arctic Wildlife

*Summary*

Satellite imagery as a tool for monitoring polar bears on land, with implications for use with other Arctic wildlife.

*Abstract*

Development of efficient techniques for monitoring wildlife is a priority in the Arctic, where the impacts of climate change are acute and remoteness and logistical constraints hinder access. We evaluated high resolution satellite imagery as a tool to track the distribution and abundance of polar bears. We examined satellite images of a small island in Foxe Basin, Canada, occupied by a high density of bears during the summer ice-free season. Bears were distinguished from other light-colored spots by comparing images collected on different dates. A sample of ground-truthed points demonstrated that we accurately classified bears. Independent observers reviewed images and a population estimate was obtained using mark–recapture models. This estimate ($\hat{N}$: 94; 95% Confidence Interval: 92–105) was remarkably similar to an abundance estimate derived from a line transect aerial survey conducted a few days earlier ($\hat{N}$: 102; 95% CI: 69–152). Our findings suggest that satellite imagery is a promising tool for monitoring polar bears on land, with implications for use with other Arctic wildlife. Large scale applications may require development of automated

detection processes to expedite review and analysis. Future research should assess the utility of multi-spectral imagery and examine sites with different environmental characteristics.

*Reference*

Stapleton, S., LaRue, M., Lecomte, N., Atkinson, S., Garshelis, D., Porter, C. and Atwood, T., 2014. Polar bears from space: assessing satellite imagery as a tool to track Arctic wildlife. PloS one, 9(7), p.e101513.
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0101513

### b) Modelling sea turtle nesting habitat loss

*Title*

Predicting the impact of sea-level rise on Caribbean sea turtle nesting habitat.

*Summary*

Development of models that calculate the vulnerability of different beaches to flooding and thus the potential loss of nesting habitat.

*Abstract*

The projected rise in sea level is likely to increase the vulnerability of coastal zones in the Caribbean, which are already under pressure from a combination of anthropogenic activities and natural processes. One of the major effects will be a loss of beach habitat, which provides nesting sites for endangered sea turtles. To assess the potential impacts of sea-level rise on sea turtle nesting habitat, we used beach profile measurements of turtle nesting beaches on Bonaire, Netherlands Antilles, to develop elevation models of individual beaches in a geographic information system. These models were then used to quantify areas of beach vulnerable to three different scenarios of a rise in sea level. Physical characteristics of the beaches were also recorded and related to beach vulnerability, flooding, and nesting frequency. Beaches varied in physical characteristics and therefore in their vulnerability to flooding. Up to 32% of the total current beach area could be lost with a 0.5-m rise in sea level, with lower, narrower beaches being the most vulnerable. Vulnerability varied with land use adjacent to the beach. These predictions about loss of nesting habitat have important implications for turtle populations in the region.

*Reference*

Fish, M.R., Côté, I.M., Gill, J.A., Jones, A.P., Renshoff, S., Watkinson, A.R. (2005). Predicting the impact of sea-level rise on Caribbean sea turtle nesting habitat. *Conservation Biology* 19: 482-491.
http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2005.00146.x/abstract

### c) Vulnerability of sea turtle nesting grounds to climate change

*Title*

Vulnerability of sea turtle nesting grounds to climate change

*Summary*

A vulnerability assessment framework is used for assessing the cumulative impact of various climatic processes on sea turtle nesting grounds.

*Abstract*

Given the potential vulnerability of sea turtles to climate change, a growing number of studies are predicting how various climatic processes will affect their nesting grounds. However, these studies are limited by scale, because they predict how a single climatic process will affect sea turtles but processes are likely to occur simultaneously and cause cumulative effects. This study addresses the need for a structured approach to investigate how multiple climatic processes may affect a turtle population. Here, we use a vulnerability assessment framework to assess the cumulative impact of various climatic processes on the nesting grounds used by the northern Great Barrier Reef (nGBR) green turtle population. Further, we manipulate the variables from this framework to allow users to investigate how mitigating different climatic processes individually or simultaneously can influence the vulnerability of the nesting grounds. Our assessment indicates that nesting grounds closer to the equator, such as Bramble Cay and Milman Island, are the most vulnerable to climate change. In the short-term (by 2030), sea level rise will cause the most impact on the nesting grounds used by the nGBR green turtle population. However, in the longer term, by 2070 sand temperatures will reach levels above the upper transient range and the upper thermal threshold and cause relatively more impact on the nGBR green turtle population. Thus, in the long term, a reduction of impacts from sea-level rise may not be sufficient, as rookeries will start to experience high vulnerability values from increased temperature. Thus, in the long term, reducing the threats from increased temperature may provide a greater return in conservation investment than mitigating the impacts from other climatic processes. Indeed, our results indicate that if the impacts from increased temperature are mitigated, the vulnerability values of almost all rookeries will be reduced to low levels.

*Reference*

Fuentes, M.M.P.B., Limpus, C.J. and Hamann, M., 2011. Vulnerability of sea turtle nesting grounds to climate change. *Global Change Biology*, *17*(1), pp.140-153.
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2010.02192.x/full

### *d) Measures to facilitate species adaptation*

Measures to facilitate species adaptation in response to climate change e.g. prepare species action plans for species listed in Appendix 1 considered to be most vulnerable to climate change.

*Reference*

UNEP/CMS (2014). Workshop Report: towards a CMS programme of work on climate change.
http://www.cms.int/sites/default/files/document/Costa%20Rica%20CLIMATECHANGE%20Workshop%20report%2012%20May%20clean.pdf

### *e) Indicator species and data collection protocols*

Indicator species whose attributes can act as indicators of likely climate change impacts on the range of migratory species. Protocols for data collection for indicator species.

*Reference*

UNEP/CMS (2007). 14th Scientific Council Meeting document on climate change and migratory species: indicator species and protocols for data collection (submitted by the UK).
http://www.cms.int/sites/default/files/document/Sclimate change14_Doc_11_ClimateChangeMigratorySpecies_Eonly_0.pdf

### *f) Biodiversity Early Warning Systems*

The use of integrated early warning systems for biodiversity. The key features of the early warning systems are: An explicit science/ policy/ planning/ implementation interface; Scientifically grounded, simple and robust methods (protocols) for data collection; Statistically robust trends analysis and uncertainty assessment; The combination of citizen science and academic science for detailed analysis of large-scale or long-term datasets, such as species atlases.

*Reference*

Barnard, P. 2017. Climate Change effects in Africa. African Conservation Telegraph. https://conbio.org/groups/sections/africa/act/climate-change-biodiversity-early-warning-systems-and-africas-futur

### *g) The safe operating space concept*

*Title*

Creating a safe operating space for wetlands in a changing climate

*Summary*

The concept of a "safe operating space" focuses on respecting nine boundaries in order to keep the Earth system in a desired state. A central element of the concept is that many of the Earth system's processes act in a nonlinear way and are sensitive around threshold levels of key variables. If these thresholds are crossed, severe and sometimes irreversible change can occur (eg melting of ice sheets or collapse of monsoon circulations). Climate change exacerbates the anthropogenic degradation. These synergetic effects can be avoided by reducing existing local impacts and keeping the system within a "safe operating space" where it remains resilient to climate change.

*Abstract*

Many of the world's wetlands may be profoundly affected by climate change over the coming decades. Although wetland managers may have little control over the causes of climate change, they can help to counteract its effects through local measures. This is because direct anthropogenic impacts, such as water extraction and nutrient loading, work in concert with climate change to damage wetlands. Control of these local stressors may therefore ameliorate undesired effects of climate change, such as a shift towards dominance by invasive floating plants, increasingly frequent cyanobacteria blooms, or extinction of key species. Using the iconic Doñana wetlands in Spain as a case study, we illustrate how the concept of creating a "safe operating space" may be implemented to better ensure that ecosystems do not surpass thresholds for collapse during an era of global change.

*Reference*

Green, A.J., Alcorlo, P., Peeters, E.T.H.M., Morris, E.P., Espinar, J.L., Bravo, M.A., Bustamante, J., Díaz-Delgado, R., Koelmans, A.A., Mateo, R., Mooij, W.M., Rodríguez-Rodríguez, M., van Nes, E.H., Scheffer, M. 2017. Creating a safe operating space for wetlands in a changing climate. *Frontiers in Ecology and the Environment*. DOI**:** 10.1002/fee.1459
http://onlinelibrary.wiley.com/doi/10.1002/fee.1459/full

## <u>**General wildlife conservation literature**</u>

### *a) Prioritizing threat management for biodiversity conservation*

*Title*

Prioritizing threat management for biodiversity conservation.

*Summary*

Cost-effectiveness approach for prioritizing threat management to maximize the *in situ* protection of biodiversity per dollar spent.

*Abstract*
Calls for threat management actions to protect biodiversity and restore ecosystem function are rarely coupled with costed and prioritized sets of management actions for use in decision making. We present a cost-effectiveness approach for prioritizing threat management to maximize the *in situ* protection of biodiversity per dollar spent. The approach draws on empirical data and expert knowledge of major threats to biodiversity, feasible threat management actions, and likely responses of biodiversity to a set of costed management scenarios. An application assessing 637 vertebrate wildlife species in the Kimberley region of north-western Australia suggests that the likely functional loss of 45 mammals, birds, and reptiles over the next 20 years can be averted by effectively managing fire, grazing, and invasive species for approximately AU$40 million per year. Our approach is flexible and may be useful for delivering transparent guidance for conserving species and ecosystems in other regions, including those where data is limited.

*Reference*
Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H.P. and Martin, T.G., 2012. Prioritizing threat management for biodiversity conservation. *Conservation Letters*, *5*(3), pp.196-204.
http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2012.00228.x/full

## Climate change and conservation

### *a) Seabird conservation in a changing world*

*Title*
Seabirds and climate change: roadmap for the future.

*Summary*
Literature review on the effect of climate change on seabirds with emphasis on the need for modelling studies to enhance our understanding of the relationship between climate and population dynamics.

*Abstract*
Based in part on a symposium held at the first World Seabird Conference in September, 2010 in Victoria, BC, Canada, we present a Theme Section (TS) on the topic of seabirds and climate change. We introduce this TS with a meta-analysis of key attributes of the current seabird−climate literature, based on 108 publications representing almost 3000 seabird−climate associations (mostly correlations) published up to 2011. Using the papers in this TS and our meta-analysis, a brief roadmap for the future of seabird−climate change research is presented. Seabird studies have contributed substantially to the literature on marine climate effects. To improve our understanding of climate change effects on seabirds at the global scale, however, additional low-latitude, mechanistic, and 'end-to-end' modeling studies, including integration of climatic, oceanographic, food web, and population dynamics models, should be conducted. This approach will enhance our understanding of the relationship between climate and population dynamics, and facilitate seabird conservation in a changing world.

*Reference*
Sydeman, W.J., Thompson, S.A., Kitaysky, A. (2012). Seabirds and climate change: roadmap for the future. *Marine Ecology Progress Series*, *454*, 107-117.
http://www.int-res.com/abstracts/meps/v454/p107-117/

### *b) Climate change adaptation planning for biodiversity conservation*

*Title*
Climate change adaptation planning for biodiversity conservation

*Summary*
Approaches for integrating climate change adaptation into conservation planning.

*Abstract*
Climate change has been linked to well-documented changes in physiology, phenology, species distributions, and in some cases, extinction. Projections of future change point to dramatic shifts in the states of many ecosystems. Accommodating these shifts to effectively conserve biodiversity in the context of uncertain climate regimes represents one of the most difficult challenges faced by conservation planners. A number of adaptation strategies have been proposed for managing species and ecosystems in a changing climate. However, there has been little guidance available on integrating climate change adaptation strategies into contemporary conservation planning frameworks. The paper reviews the different approaches being used to integrate climate change adaptation into conservation planning, broadly categorizing strategies as continuing and extending on “best practice” principles and those that integrate species vulnerability assessments into conservation planning. We describe the characteristics of a good adaptation strategy emphasizing the importance of incorporating clear principles of flexibility and efficiency, accounting for uncertainty, integrating human response to climate change and understanding trade-offs. The authors argue that the planning activities that have been labelled in some form as “climate change adaptation" can be placed into three broad strategies: 1) continuing “best practice"; 2) extending on “best practice" principles in consideration of species and ecosystems response to past climate change; and 3) integrating assessments on species vulnerability to climate change into a conservation planning framework. They also state that the characteristics of a good adaptation strategy are: clear planning principles (flexibility, efficiency), account for uncertainty, understand trade-offs, manage for both climate variability and long-term climate change, integrate human response and clarity of adaptation goal: Resilience vs. resistance.

*Reference*
Watson, J.E.M., Rao, M., Kang, A.L. et al., (2012): Climate change adaptation planning for biodiversity conservation: A review. *Advances in Climate Change Research,* 3(1): 1-11.
http://www.sciencedirect.com/science/article/pii/S1674927812500018

### *c) Adaptation of conservation efforts to climate change*

*Title*
Biodiversity management in the face of climate change: a review of 22 years of recommendations*.*

*Summary*
Literature review on the adaptation of conservation efforts to climate change.

*Abstract*
Climate change creates new challenges for biodiversity conservation. Species ranges and ecological dynamics are already responding to recent climate shifts, and current reserves will not continue to support all species they were designed to protect. These problems are exacerbated by other global changes. Scholarly articles recommending measures to adapt conservation to climate change have proliferated over the last 22 years. We systematically reviewed this literature to explore what potential solutions it has identified and what consensus and direction it provides to cope with climate change. Several consistent recommendations emerge for action at diverse spatial scales, requiring leadership by diverse actors. Broadly, adaptation requires improved regional institutional coordination, expanded

spatial and temporal perspective, incorporation of climate change scenarios into all planning and action, and greater effort to address multiple threats and global change drivers simultaneously in ways that are responsive to and inclusive of human communities. However, in the case of many recommendations the how, by whom, and under what conditions they can be implemented is not specified. We synthesize recommendations with respect to three likely conservation pathways: regional planning; site-scale management; and modification of existing conservation plans. We identify major gaps, including the need for (1) more specific, operational examples of adaptation principles that are consistent with unavoidable uncertainty about the future; (2) a practical adaptation planning process to guide selection and integration of recommendations into existing policies and programs; and (3) greater integration of social science into an endeavor that, although dominated by ecology, increasingly recommends extension beyond reserves and into human-occupied landscapes.

*Reference*
Heller N.E., Zavaleta E.S. *(2009)* Biodiversity management in the face of climate change: a review of 22 years of recommendations*. Biol. Conserv. 142:14–32*.
http://www.sciencedirect.com/science/article/pii/S000632070800387X

### *d) Role of models, monitoring, and adaptation in reducing uncertainty*

*Title*
Conservation in the face of climate change: the roles of alternative models, monitoring, and adaptation in confronting and reducing uncertainty.

*Summary*
The authors suggest to overcome the problem of uncertainty in relation to the impact of climate change with a method where decisions are guided by predictions under multiple, plausible hypotheses about climate impacts. Monitoring could be used to evaluate the response of the system to climate drivers, and management actions to confront testable predictions with data.

*Abstract*
The broad physical and biological principles behind climate change and its potential large scale ecological impacts on biota are fairly well understood, although likely responses of biotic communities at fine spatio-temporal scales are not, limiting the ability of conservation programs to respond effectively to climate change outside the range of human experience. Much of the climate debate has focused on attempts to resolve key uncertainties in a hypothesis-testing framework. However, conservation decisions cannot await resolution of these scientific issues and instead must proceed in the face of uncertainty. We suggest that conservation should precede in an adaptive management framework, in which decisions are guided by predictions under multiple, plausible hypotheses about climate impacts. Under this plan, monitoring is used to evaluate the response of the system to climate drivers, and management actions (perhaps experimental) are used to confront testable predictions with data, in turn providing feedback for future decision making. We illustrate these principles with the problem of mitigating the effects of climate change on terrestrial bird communities in the southern Appalachian Mountains, USA.

*Reference*
Conroy, M.J., Runge, M.C., Nichols, J.D., Stodola, K.W., Cooper, R.J. (2011) Conservation in the face of climate change: the roles of alternative models, monitoring, and adaptation in confronting and reducing uncertainty. *Biol Conserv* **144,** 1204–1213.
http://www.sciencedirect.com/science/article/pii/S0006320710004623

## Key regional examples (session 4)

### *a) Polar bear conservation in Canada*

*Title*
Conservation and management of Canada’s polar bears in a changing Arctic.

*Summary*
Polar bear conservation in Canada.

*Abstract*
Canada has an important responsibility for the research, conservation, and management of polar bears (*Ursus maritimus* Phipps, 1774) because the majority of polar bears in the world occur within the nation’s borders. Two fundamental and recent changes for polar bears and their conservation have arisen: (1) the ongoing and projected further decline of sea-ice habitat as a result of climate change and (2) the implementation of aboriginal land claims and treaties in Canada’s North. Science has documented empirical links between productivity of polar bear population and sea-ice change. Predictive modeling based on these data has forecast significant declines in polar bear abundance and distribution of polar bears. With the signing of northern land claims and treaties, polar bear management in Canada has integrated local aboriginal participation, values, and knowledge. The interaction of scientific and local perspectives on polar bears as they relate to harvest, climate change, and declining habitat has recently caused controversy. Some conservation, management, and research decisions have been contentious because of gaps in scientific knowledge and the polarization and politicization of the roles of the various stakeholders. With these ecological and governance transitions, there is a need to re-focus and re-direct polar bear conservation in Canada.

*Reference*
Peacock, E., Derocher, A.E., Thiemann, G.W., Stirling, I. (2011). Conservation and management of Canada’s polar bears (*Ursus maritimus*) in a changing Arctic 1 1 This review is part of the virtual symposium “Flagship Species–Flagship Problems” that deals with ecology, biodiversity and management issues, and climate impacts on species at risk and of Canadian importance, including the polar bear (*Ursus maritimus*), Atlantic cod (*Gadus morhua*), Piping Plover (*Charadrius melodus*), and caribou (*Rangifer tarandus*). *Canadian Journal of Zoology*, *89*(5), 371-385.
http://www.nrcresearchpress.com/doi/abs/10.1139/z11-021#.WIiloH2znLg

# Other reports on migratory species and climate change

## a) *Migratory species and climate change: impacts of a changing environment on animals*

Introduction on the impact of climate change on migratory species. Section on adaptation methods for reducing the loss of biodiversity due to climate change. Identifies knowledge gaps. Example of vulnerability assessment in northern Australia and eastern Asia (example of good practice). Marine turtle case study with knowledge gaps and examples of good practice. Mentions the need for a coherent network of sites that take into account climate change.

*Reference*
UNEP/CMS (2006). 14th Scientific Council Publication on migratory species and climate change: impacts of a Changing Environment on Wild Animals
http://www.cms.int/sites/default/files/document/ScC14_Inf_09_Migratory_Species%26Climate_Change_E_0.pdf

## b) *Climate change and migratory species*

Climate change impacts adaptations and knowledge gaps for each migratory animal group. Case studies on the impacts of climate change for many species listed in the Appendices. Waterbirds loosing stop over sites due to sea level rise, need for habitat connectivity. Emphasis on the need to collate information on migratory stopover sites to identify coherent migratory networks.

*Reference*
UNEP/CMS (2005). Information document 8.19 on climate change and migratory species (submitted by the UK)
http://www.cms.int/sites/default/files/document/Inf_19_Climate_Change_Migratory_Species_0.pdf

## c) *Climate Change impact on Migratory Species: the Current Status and Avenues for Action*

The potential of migratory species to adjust to climate change. Adaptive management and ecological networks as tools for migratory species conservation.

*Reference*
UNEP/CMS (2011). 17th Scientific Council Workshop Technical Proceedings on the impact of Climate Change on Migratory Species: the Current Status and Avenues for Action.
http://www.cms.int/sites/default/files/document/Inf_12_Rpt_Tech_Workshop_on_Climate_Change_Eonly_0.pdf

## d) *Transboundary wildlife conservation in a changing climate*

Analysis of the present and potential future role, in respect of climate adaptation, of the main intergovernmental regime for migratory species conservation.

*Reference*

Trouwborst, A. (2012). Transboundary Wildlife Conservation in A Changing Climate: Adaptation of the Bonn Convention on Migratory Species and Its Daughter Instruments to Climate Change. *Diversity*, 4: 258-300.
http://www.cms.int/en/publication/transboundary-wildlife-conservation-changing-climate-adaptation-bonn-convention

### e) Travelling through a warming world: climate change and migratory species

Long-distance migrations are among the wonders of the natural world, but this multi-taxon review shows that the characteristics of species that undertake such movements appear to make them particularly vulnerable to detrimental impacts of climate change. Migrants are key components of biological systems in high latitude regions, where the speed and magnitude of climate change impacts are greatest. They also rely on highly productive seasonal habitats, including wetlands and ocean upwellings that, with climate change, may become less food-rich and predictable in space and time. While migrants are adapted to adjust their behaviour with annual changes in the weather, the decoupling of climatic variables between geographically separate breeding and non-breeding grounds is beginning to result in mistimed migration. Furthermore, human land-use and activity patterns will constrain the ability of many species to modify their migratory routes and may increase the stress induced by climate change. Adapting conservation strategies for migrants in the light of climate change will require substantial shifts in site designation policies, flexibility of management strategies and the integration of forward planning for both people and wildlife. While adaptation to changes may be feasible for some terrestrial systems, wildlife in the marine ecosystem may be more dependent on the degree of climate change mitigation that is achievable.

*Reference*

Robinson, Robert A., Crick, Humphrey Q.P., Learmonth, Jennifer A., Maclean, Ilya M.D., Thomas, Chris D., Bairlein, Franz, Forchhammer, Mads C., Francis, Charles M., Gill, Jennifer A., Godley, Brendan J., Harwood, John, Hays, Graeme C., Huntley, Brian, Hutson, Anthony M., Pierce, Graham J., Rehfisch, Mark M., Sims, David W., Santos, M. Begoña, Sparks, Timothy H., Stroud, David A. and Visser, Marcel E. (2009). Travelling through a warming world: climate change and migratory species*, Endangered species research*, 7(2): 87-99.
http://dro.deakin.edu.au/view/DU:30058331