Climate Change Vulnerability of Migratory Species

Species Assessments

PRELIMINARY REVIEW

A PROJECT REPORT FOR CMS SCIENTIFIC COUNCIL 16, BONN, 28-30 JUNE, 2010

The Zoological Society of London (ZSL) has conducted research for the UNEP Convention on Migratory Species (CMS) into the effects of climate change on species protected under the convention.

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TABLE OF CONTENTS

1. Executive Summary

"The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response."
Stern Review, 2006

We can no longer afford to delay our response to the threat of climate change. IPCC predictions are clear and observed impacts are already affecting species and ecosystems. Indications of the scale of threat to biodiversity and urgency for a swift and effective global response are demonstrated by the imminent collapse of species interactions and even entire ecosystems. Coral reefs will be the first major ecosystems likely to collapse as a direct result of exponential increases in atmospheric CO_2 from anthropogenic activities. If atmospheric CO_2 is not brought back down to safe levels they are unlikely to be the last, with major impacts predicted for many species both migratory and non migratory that depend on these key habitats.

There is still time to avoid the worst impacts of climate change, if strong action is taken now

Biodiversity underpins a major mechanism by which we can build resilience into global systems, assisting adaptation to climate change whilst also providing vital carbon sinks and stores to aid mitigation. This is increasingly being acknowledged within the texts of the United Nations Framework Convention on Climate Change (UNFCCC) and negotiations are now laying plans for 'Reducing Emissions from Deforestation and Forest Degradation' as well as 'Ecosystem Adaptation'. Climate change models are also becoming more sophisticated as appreciation and understanding grows of the interlinkages between ecosystem dynamics and climate dynamics, as well as the destabilising influence ecosystem degradation has on climate systems and the potential for feedback loops that escalate the impacts felt on both systems. Alongside this is an increased awareness that urgent action must be taken to address climate change impacts on biodiversity. This is being picked up at an international level with a growing number of decisions ratified within treaties, including the Convention on Biodiversity, the Ramsar Convention on Wetlands and the Convention on Migratory Species.

International cooperation is essential if actions are to be most effective

The Convention on Migratory Species (CMS) provides an unparalleled opportunity to develop strategies at the international level and foster cooperation between countries to tackle the impacts of climate change on specific species. As climatic changes become more apparent, and the rate of change potentially increases, habitats and species ranges will shift significantly, often crossing national borders in the process. The current protected area network may not match critical sites in future as it does today. Development of an international framework through which countries can cooperate to protect species is an essential step under such dynamic and changing conditions and one in which CMS and its multiple agreements can play a key role.

Numerous challenges lie ahead for migratory species

Without mitigation the IPCC predicts that temperatures will be 3.4°C warmer by the end of the century. However, more recently the UK Met Office has indicated that temperatures are likely to increase by more than 5.5°C within the same time period. Mitigation efforts will be able to reduce this level of warming if action is taken immediately. However even with mid range scenarios of warming migratory species will still have to contend with some major challenges.

Some of the most immediate threats caused by increased temperatures to migratory species will be the loss of vital habitat as sea ice and tundra permafrost melts, as well as the collapse of food webs in the oceans linked to changing zooplankton abundance. Species exhibiting temperature dependent sex determination, including all reptile species listed on Appendix I, are likely to be impacted by increased feminisation of populations. Changes in precipitation will impact migratory species, for example, through a reduction of wetland habitats required for breeding and feeding and the reduction of grazing habitats for terrestrial mammals. Increased variation in rainfall will also affect the breeding success of species. Extreme weather events will become more frequent with migratory species identified as vulnerable to extremes in temperature, increases in storm frequency and intensity and extremes in precipitation causing flooding and drought. Sea level rise will have a major impact on many migratory species reducing availability of nesting sites and low lying coastal habitats. Ocean acidification will have wide ranging consequences for species, impacting on food webs, most prominently in Arctic Regions, as well as accelerating the loss of vital coral habitats. Changes in ocean circulations will change food distribution and abundance patterns, making predictable migrations difficult for many species dependent on these currents for blooms of prey or dependent on them for as a mechanism to aid migration.

In response to these changes biomes will shift, potentially lengthening the migrations necessary for species to reach optimal feeding and breeding locations. Phenological shifts will have implications of potential mis-match between species migration and optimal food abundance. Where certain biomes are unable to shift to track climatic changes, for example due to geographical barriers, migratory species will be impacted as suitable habitat is lost. Existing anthropogenic threats will further exacerbate the challenges faced by migratory species under changing climate regimes. These will act synergistically with climate change impacts, reducing their populations resilience to cope with such changes and most importantly reducing their ability to adapt.

The increased threats identified within this study to migratory species from climate change should act to clarify and highlight the urgency for immediate mitigation action to prevent such levels of increased pressures on species survival. Although climate change is inevitable to a certain degree, due to committed levels of warming from historical emissions, the more that emission levels can be reduced in the future the less severe climate change will be in terms of peak temperature and the slower the rate of change. This is a vitally important factor for species survival. If the rate of change and peak temperatures can be reduced, the more chance species have to adapt to these changes. Migratory species, which are highly mobile in nature and therefore potentially able to disperse to track changes, offer great opportunities for conservation success if adaptation can be facilitated.

Identifying and developing effective conservation measures is vital

To enable identification and development of effective conservation measures CMS urgently requires a standardised process by which species can be prioritised for further action. This study has piloted a methodology to grade migratory species on their vulnerability to climate change that allows for identification of main limiting factors for species resilience and ability to adapt to climate change. Conservation measures will be most effective if they focus efforts on main limiting factors to species survival. However, in light of the increasing urgency for CMS to review the large number of migratory species, both listed within its appendices and those currently not listed, a phased methodological approach has been recommended and details of potential steps forward outlined. This will allow CMS to take full advantage of both a low level review that can cover more species, identifying those of *concern* and *likely concern* for further attention, whilst also providing a foundation for higher levels of review that will output gradings of vulnerability for selected species. A standardised approach is required throughout every phase that will increase beneficial outputs for CMS and reduce inefficiencies. Changing methodologies from one year to the next will limit the ability for comparative reviews to be made. A standardised phased approach will also allow for an iterative process of reviews and long term monitoring of research findings that could immediately identify species requiring elevation to a status of concern for further attention, making policy more responsive to the latest information. Currently species-level climate change information is often very limited and data deficient. However, this is an expanding field of research and even within the last 2 years the level of information has grown rapidly, highlighting the potential importance of a mechanism through which relevant information can be rapidly incorporated by CMS. Key research gaps can also be highlighted with a lower level review and communicated to the scientific community, facilitating wider engagement.

Case study assessments of CMS Appendix I species have revealed a high level of vulnerability for many species

Previous studies have suggested that migratory species are particularly sensitive to climatic disturbances and corresponding impacts. Their vulnerability stems from the large investments they make to migrate to high quality habitats, often timing their arrival to coincide with the optimum abundance of resources at their destination. With this in mind, and considering the urgent need for CMS to identify species with high vulnerability for further policy attention, species within CMS Appendix I were prioritised for review that showed indications of being the most biologically migrant species, including those with long distance or cyclic migration patterns. Assessment results of 45 case study species are presented within this report. 44 Appendix I species and one example species from Appendix II, the Narwhal, have been graded against ranges of high, medium or low vulnerability. All species studied exhibited either high or medium vulnerabilities to climate change. No species studied were found to have a low vulnerability to climate change.

Each species has been evaluated on the basis of in-depth literature reviews and, where possible, expert opinion and graded against 4 main factors to identify their overall vulnerability to climate change:

1. **Vulnerability of habitat/s:** to identify whether species will be affected by climate change impacts on key dependent habitats.

2. **Ecological flexibility:** to identify the adaptation potential and resilience of species to climate change by reviewing key life history traits and characteristics. These include species degree of specialisation and ability to disperse to new suitable ranges as well as the degree to which climate change will impact on reproductive success and important environmental triggers or phenological cues.
3. **Species interactions:** to identify whether species will be affected by climate change due to impacts on predator, prey, competitor species as well as impacts on key mutualistic and symbiotic relationships.
4. **Synergistic threat processes:** to identify whether further threats, including those directly anthropogenic driven as well as diseases and invasive species, will reduce species ability to adapt and reduce their resilience to climate change impacts alongside any potential interactions between these threat processes and climate change.

Recommendations have been made for any future studies to use a phased methodological approach, as outlined in this report, to increase outputs at each stage for policy use and allow for a standardised review of remaining migratory species. Main case study results are outlined below:

REPTILES

- 7 out of the total 8 reptile species listed on CMS Appendix I have been included in case study assessments
- All species of reptiles included in this study have been identified as having a HIGH VULNERABILITY to climate change

  Green Turtle, Hawksbill Turtle, Kemp's Ridley Turtle, Gharial, Loggerhead Turtle, Olive Ridley, Leatherback Turtle

MAMMALS

- 16 species (42%) out of the total 38 species of mammals on CMS Appendix I have been included in case study assessments
- 9 species of mammals studied have been identified as having a HIGH VULNERABILITY to climate change

  North Pacific Right Whale, Northern Atlantic Right Whale, West African Manatee, Bowhead Whale, Dama Gazelle, Southern Right Whale, Addax, Blue Whale, Snow Leopard

- 7 species of mammals studied have been identified as having a MEDIUM VULNERABILITY to climate change

  Cuvier's Gazelle, Sei Whale, Short-beaked Common Dolphin, Humpback Whale, Mexican Free-tailed Bat, Sperm Whale, Marine Otter

- One mammal species assessed from Appendix II and has been identified as having a HIGH VULNERABILITY to climate change

  Narwhal

FISH

- All 4 species of fish on CMS Appendix I have been included in this study and fully assessed.
- 2 species of fish assessed have been identified as having a HIGH VULNERABILITY to climate change

  Giant Catfish, Common Sturgeon

- 2 species of fish assessed have been identified as having a MEDIUM VULNERABILITY to climate change

  Basking Shark, Great White Shark

BIRDS

- 17 species (23%) out of the total 75 species of birds on CMS Appendix I have been included in case study assessments
- 10 species of birds assessed have been identified as having a HIGH VULNERABILITY to climate change

  Balearic Shearwater, Relict Gull, Short-tailed Albatross, Sociable Plover, Steller's Eider, White-naped Crane, Red-breasted Goose, Siberian Crane, Basra Reed-warbler, Bermuda Petrel

- 7 species of birds assessed have been identified as having a MEDIUM VULNERABILITY to climate change

  Aquatic Warbler, Swan Goose, Andean Flamingo, Humboldt Penguin, Pallas Fish Eagle, Puna Flamingo, White-tailed Eagle

Within CMS Appendix I the species most vulnerable to climate change impacts have been identified as the Green Turtle and the Hawksbill Turtle.

The top twelve species most vulnerable to climate change impacts (which rank 1-4) within CMS Appendix I have been identified as the Green Turtle, Hawksbill Turtle, Balearic Shearwater, Kemp's Ridley Turtle, North Pacific Right Whale, Northern Atlantic Right Whale, Relict Gull, Loggerhead Turtle, Gharial, Bowhead Whale, West African Manatee and the Short-tailed Albatross.

It is recommended that immediate action be taken to develop climate change conservation strategies for species identified as highly vulnerable to these impacts. Suggested effective responses have been outlined within the conclusions of this report.

Important results to note:

- All marine turtle species listed within CMS Appendix I are highly vulnerable to climate change due to the combined impacts of sea level rise, increased temperatures and extreme weather events alongside synergistic impacts of current anthropogenic threats.

- All plankton and krill feeding whales are highly vulnerable to climate change due to combined impacts of ocean acidification, changes in ocean circulations and polar ice melt.

- The Narwhal has been identified as one of the most highly vulnerable species, of those included in this study, to climate change. However this species is currently only listed on CMS Appendix II.

- All species studied listed by IUCN Red List as Critically Endangered are highly vulnerable to climate change

Further detailed results are outlined in the case study analysis and concluding comments sections of this report.

Some species studied will have little hope of a future if strong and immediate action is not taken to mitigate climate change

This study has identified highly vulnerable species within CMS Appendix I that will not respond to conservation measures in the long term if action is not taken to mitigate climate change. Many of these are marine species. For these species the threat of climate change is so severe and the potential for conservation to effectively increase their resilience and ability to adapt so limited that the **only** available option for their future survival is to mitigate climate change. This is not to say that other conservation measures should be stopped for these species, but that climate change mitigation needs to be acknowledged as an essential part of their long term conservation strategy. Other conservation measure will only be effective if mitigation is also achieved. These species include:

Hawksbill Turtle, Green Turtle, Balearic Shearwater, Kemp's Ridley Turtle, Narwhal, North Pacific Right Whale, Northern Atlantic Right Whale, Relict Gull, Gharial, Loggerhead Turtle, Short-tailed Albatross, Bowhead Whale, Leatherback Turtle, Southern Right Whale, Siberian Crane and Blue Whale.

Other species have not been included in this selection if they have potentially viable conservation options available to them to reduce the impacts of climate change. However it is very likely that climate change will further stretch limited conservation resources and capacities and species will not be able to have all available conservation options applied to them effectively to ensure there survival. Therefore for these species it is also vital to take a dual approach to climate change whereby proactive adaptation measures are applied to species alongside considerable and rapid emissions abatement to limit further impacts that threaten their future.

Reduction of greenhouse gas emissions is vital if we are to avoid unmanageable levels of climate change.

2. Overview of Threats

CMS aims to conserve terrestrial, aquatic and avian migratory species throughout their range. Due to the urgent need to address climate change, the number of decisions responding to this threat has markedly increased within biodiversity-related treaties including the Convention on Biodiversity, the Ramsar Convention on Wetlands and CMS. CMS Parties have made several decisions that prioritise actions to reduce climate change impacts on migratory species. Most recently in 2008, Resolution 9.7 called upon Parties to mitigate climate change and aid adaptation of species to these changes. Section 2 of the resolution requests that research be undertaken to identify which Appendix I species are most vulnerable to climate change, with further research into Appendix II species to follow. Working towards fulfilment of this part of Resolution 9.7 forms the basis of this study.

Investigations to date show that migratory species are particularly sensitive to climatic disturbances and corresponding impacts, including habitat loss/alteration and changes to the composition of biological communities[1,2]. Their vulnerability stems from the large energy investment they make to migrate to high quality habitats, often timing their arrival to coincide with the optimum abundance of resources at their destination.

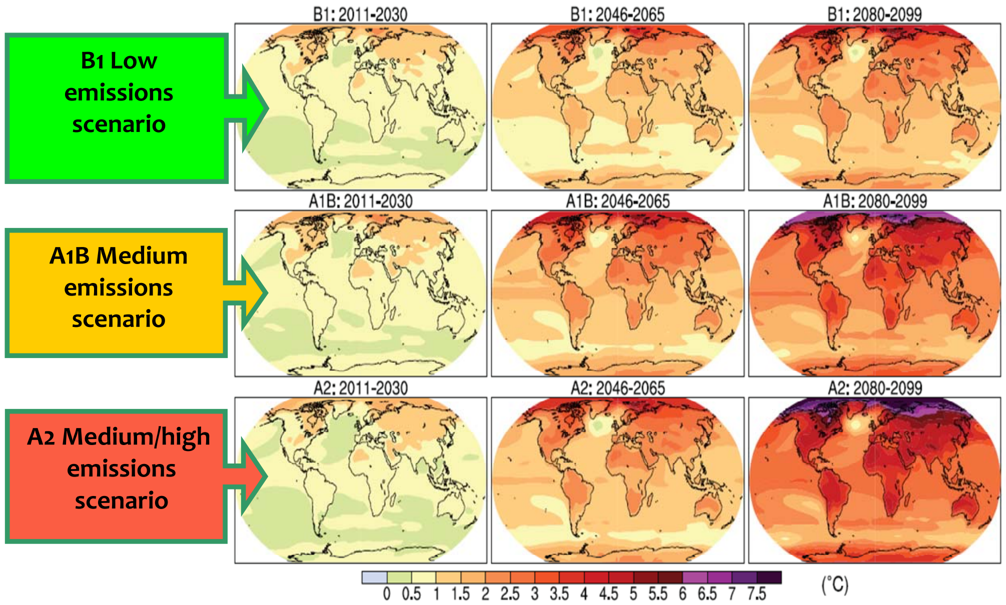
Mexican-free tailed bats

With carbon dioxide emissions already reaching 387ppm (2009 average annual concentration) and causing significant and irreversible ecosystem change, it is evident that emphasis needs to be placed not only upon mitigation of greenhouse gas emissions, but also on maximising the adaptive potential of migratory species populations.

A broad range of climate change processes will affect migratory species populations. These have been outlined within this chapter, with examples of significant impacts on CMS Appendix I species studied.

INCREASING TEMPERATURES

Without mitigation, the IPCC predicts that temperatures will be 3.4°C warmer by the end of the century[3]. However, more recently the UK Met Office has indicated that temperatures are likely to increase by more than 5.5°C within the same time period[4]. Mitigation efforts will be able to reduce this predicted warming. However, due to inertia in the system, even if emissions were halted immediately the climate would continue to warm[5].



Annual mean surface warming (°C) for three emissions scenarios (A1, A1B, A2) and three time periods. Temperatures are relative to the average of the period 1980 to 1999. *Source: IPCC 2007 WGI*

Reducing Vital Habitats Due to Melting of Sea Ice: Polar marine mammals will suffer due to a decline in protective and breeding habitats. The **bowhead whale**[6] and the **narwhal**[7] (Appendix II) require the Arctic sea ice to provide them with protection, whilst other species such as the **ringed seal** (not yet listed by CMS) rely upon this habitat to breed[8]. Intense warming is projected for the Arctic[3] with air temperatures rising between 5°C - 7°C by 2100, two times higher then the predicted global average. Ice free summers are expected by 2025-2040[9,10].

Collapsing Food Webs Linked to Changes in Zooplankton Abundance: Baleen whales, a number of fish (e.g. **basking shark**)[11] and bird species (e.g. **Humboldt penguin, Balearic shearwater, Bermuda petrel, short-tailed albatross**) are reliant on abundant zooplankton either directly, or to nourish their prey: krill, fish and cephalopod populations. These species will be negatively affected by changes in marine ecosystems and food-webs as increasing sea temperatures cause zooplankton abundance to decline[12]. Algae, a vital nutrient within the Arctic ecosystem, is also predicted to decline as this grows beneath the sea ice. Numerous cetaceans that feed in the Arctic such as the **bowhead whale**[13] and three **right whale** species will be affected as krill abundances decline.

Changing Sex Ratios: Many reptiles are reliant on temperature sex determination[14], as are some birds[15] and fish[16]. Temperatures of 29.2°C produce a 50:50 sex ratio in sea turtle populations; including the **green turtle, hawksbill turtle, leatherback turtle, loggerhead turtle and the olive ridley turtle**. Higher temperatures will lead to the feminisation of populations[17], which will affect breeding success.

CHANGES IN PRECIPITATION

An increase in temperature will intensify the hydrological regime whilst increasing the spatial variability of precipitation. The overall projected patterns show a reduction of rainfall in the subtropics and an increase in rainfall near the equator and at high latitudes[3].


Addax

Reducing Wetland Habitats for Breeding and Feeding: Many bird species are particularly dependent on wetland habitats during vital stages of their life cycles. Reduced precipitation in these areas will negatively impact many species including the **Andean flamingo**, **aquatic warbler** and **red-knot.** Decreased precipitation coupled with increased evaporation rates has been identified as a key threat that will cause a reduction in the number of wetland stop-over habitats available to the **swan goose** and the **white-naped crane**[18]. To breed, the **Basra reed warbler** requires aquatic vegetation in or around shallow water, on marshlands and in river basins across Mesopotamia[19]. This habitat is under threat from drought, alongside increased human pressures from water extraction. Water resources for this region are already in decline, and models show a stark decrease in the availability of water from the moderate to the high warming scenarios[20], highlighting the importance of climate change mitigation.

Reducing Grazing Habitat for Terrestrial Mammals: Terrestrial mammals such as the **addax**, **Cuvier's gazelle** and **dama gazelle** are already adapted to very dry climates. However, a number of models are predicting prolonged periods of drought in the North African region[21] which will further increase pressures on both wild and domestic animals through declines in grazing habitats.

Variation in Rainfall Affecting Breeding Success: More variable rainfall is likely to affect the breeding success of birds, especially those nesting in close proximity to water. **Relict gulls** for instance, are is very sensitive to changes in water levels as they require low-lying islands on freshwater lakes for nesting[22]. Precipitation across much of this breeding habitat is expected to increase in variability[3], further reducing the low breeding success of the species. Aquatic reptiles such as the **Kemp's ridley turtle** utilise freshwater beaches for egg-laying. Heavy rainfall from storms has the potential to rapidly cool the sand and nest temperature, increasing mortality in hatchlings[23]. The crocodile-like **gharial** is also vulnerable to variations in rainfall. High water levels and faster river flows can destroy nest sites and cause higher mortality, particularly in hatchlings[24]. In 2008, early monsoon flooding destroyed all nests in Katerniaghat, India, a primary reserve for this species.

EXTREME WEATHER

More erratic weather regimes, which increase the incidence of phenomena such as hurricanes, droughts and floods, are predicted to become more frequent[25]. This is likely to increase the vulnerability of many species in the future. Half of the CMS Appendix I species studied to date have been identified as vulnerable to increased incidences of extreme weather, mainly through direct impacts on mortality rates.

Extremes in Temperature: Species which utilise freshwater habitats appear to be much more vulnerable to extreme weather events when compared with marine species, as they are more restricted in their movement and the smaller water bodies they inhabit heat up more rapidly. Extreme temperatures have been known to cause mortality in the **West African manatee** as sections of river can become isolated from the main flow, leaving pools or channels vulnerable to intense heating[26]. Other species such as the **Ganges River dolphin** are also vulnerable to these changes.

Increased Storm Frequency and Intensity: The diet of marine mammals has been shown to be impacted by increased incidence and intensity of storms. Storms can affect zooplankton concentration, thereby disrupting the diet of many marine species. Krill, upon which the **blue whale** depends, have been documented to be affected by tropical cyclones and increased surface turbulence[27] and it is likely that this will also negatively affect other baleen whales and the **basking shark.** The nesting beaches of marine turtles are expected to be damaged by the increased occurrence and intensity of hurricanes and tropical cyclones[28], with **green turtles** being particularly vulnerable as they use beaches prone to storms during peak hurricane season. The storm surges generated have the potential to destroy large numbers of nests[29]. The **Mexican-free tailed bat** is also expected to suffer because the availability of its insect prey is reduced in poor weather[30].

Precipitation Extremes: The **West African manatee** is vulnerable to both high and low extremes in river flow[31]. Precipitation in West Africa is expected to become more extreme with more infrequent, heavy rainfall[3]. Optimum habitat for the manatee is deep, slow moving river waters[31]. Drought leaves them vulnerable to isolation in channels and to the loss of navigable habitat. Flooding events cause fast flowing water, and can lead to entrapment when the waters recede.

SEA LEVEL RISE

By 2100, the IPCC predict sea levels will rise by 0.18m-0.59m compared to 1980-1999[32] levels. However, other models indicate a much greater magnitude of sea level rise by the end of the century[10], with some predicting it to be in the range of 0.5m - 1.4m[33]. This will have an impact on numerous migratory species utilising coastal habitats.

Loss of Low-Lying Coastal Habitats: The **swan goose** for instance, will lose large amounts of its important wintering grounds located on coastal mudflats and estuaries. This will greatly reduce the winter feeding capacity of the species, as there will be less prey available, reducing the amount of energy available for their annual migration[34].

Loss of Nesting Sites: Of species listed on CMS Appendix I, sea turtle populations are likely suffer the most from sea level rise. The IPCC predicts that a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds[35]. If sea levels rise significantly higher than this over the next century, which is expected, many more vital nesting sites will be threatened.

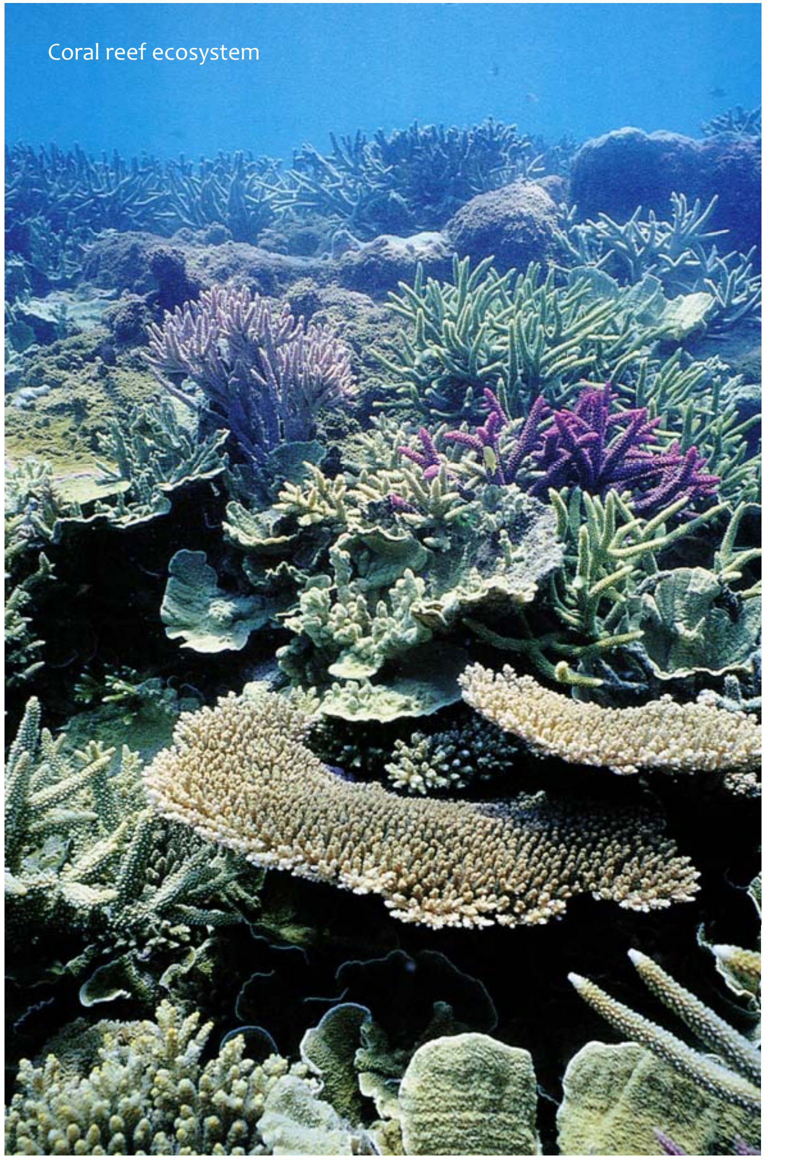
Loggerhead turtle hatching

OCEAN ACIDIFICATION

CO_2 is the primary molecule influencing the pH of oceans[36]. Since the 1800's, oceans have absorbed 1/3 of anthropogenic CO_2 emissions[37] and the average oceanic pH has dropped by 0.10 units, equivalent to a 30% decrease. If unmitigated, oceanic pH is likely to decrease by a further 0.4 units[36] by 2100. Increases in atmospheric CO_2 are currently more rapid than at any point in the last 650,000 years[38]. A reduction in pH will have impacts on the entire oceanic system, with high latitude cold water oceans affected earlier and more severely than warm water oceans.

Impacts on Food-Webs: Many species including corals, snails and krill are dependent on aragonite and calcite concentrations in the water. As oceans acidify, these minerals will become less abundant and species will struggle to mineralise their exoskeletons. Severe impacts will be felt within polar regions, with aragonite undersaturation expected to occur as early as 2016[40] and both calcite and aragonite concentrations expected to be insufficient for mineralisation in Arctic waters by 2060[41]. This will have serious consequences for the entire ecosystem, as species dependent on these minerals form the basis of food webs in these regions. As zooplankton composition and abundance is expected to change[39,42,43,44], species directly or indirectly dependent on these (e.g. whales, dolphins) are likely to suffer[25].

Habitat Loss: **Hawksbill turtles** depend upon coral reef ecosystems at various stages of their life-cycle[45]. The shelves and caves formed by coral reefs provide resting and sheltering areas for this species[46], whilst adult hawksbills feed almost exclusively upon reef fauna[45]. By 2030-2050, reefs globally will be facing severe acidification stress[25]. Coral reef formation depends upon aragonite, which has decreased considerably in tropical seawaters[47]. When atmospheric CO_2 levels reach approximately 450ppm, the ability of coral reefs to withstand erosion and grow will be severely impeded[48]. This combined with increased temperature stress and storm frequency will cause the collapse of coral reef ecosystems globally, possibly within the next 30 years. Considering that coral reefs are the most biodiverse marine ecosystems harbouring up to 3 million species, with more than 1/4 of all marine fish species, the **"Coral Reef Crisis"** is currently proving to be the most urgent threat to biodiversity from climate change. Further degradation could precipitate a 'domino-effect' across marine ecosystems[49], which is likely to have severe implications for many CMS species.



Coral reef ecosystem

OCEAN CIRCULATION

Humpback whale

Marine primary production is the basis of ocean ecosystems and a key component of the carbon cycle[50]. By increasing water temperatures and freshwater discharge from melting ice sheets, climate change will affect nutrient supplies and is likely to change the ocean circulation system[32]. All marine species assessed were found to be vulnerable to these changes; however there is currently still a high spatial and temporal uncertainty as to the extent and magnitude of these impacts[51].

Changes in Food Distribution and Abundance: Ocean circulation affects species abundances, through nutrient upwellings and more directly by transporting species and providing resources for specific oceanic habitats. Numerous species (e.g. **humpback whale**[13], **basking shark**[11]) are likely to be affected by changing ocean circulations as these will affect prey distribution. Migration routes will have to adapt[52] if species are to survive.

Altering Migrations: Many species depend upon ocean currents to aid movement, with a number of turtle species using ocean currents to migrate. During their juvenile phase, **hawksbill turtles**[54] and **loggerhead turtles**[55] float on ocean currents until they mature. Turtle hatchlings instinctively swim towards local surface currents to help transport them across ocean basins[53]. Changes in ocean circulation are likely to change the distributions and migration patterns of such species[54].

SPATIAL AND TEMPORAL RESPONSES

Species have varied responses to climate change. Some species are already adapting the timings of their annual cycles due to a changing climate, whilst others are altering the locations of their migration or foraging habitats. Such individual and dynamic responses will inevitably interfere with species interactions.

Biome Shifts: Migratory species rely on a number of isolated high quality habitats during their annual cycle. Any disturbance or alteration to a required habitat can leave a species vulnerable[1]. As temperatures rise, the distances between suitable habitats can increase. This threat is particularly pronounced when geological features or human developments limit suitable habitats, when there are barriers to migration, or when food abundances occur in different locations to traditional migratory routes. The distance between the breeding and feeding sites of the **Balearic shearwater** is increasing due to shifts in prey abundances, linked to changing sea surface temperatures[56,57,58,59]. The extra energy required for this migration increases the species vulnerability.

Phenological Shifts: Species display varying phenological responses to climate change, which can lead to mismatches in predator prey interactions. For example, due to increasing sea surface temperatures, changes in **loggerhead turtle** nesting times are occurring[60] which could alter predation on hatchlings. Mismatches also occur when food requirements and abundances do not coincide[52,61]. Energy-intensive migrations are timed with critical life stages, including reproduction cycles and growth of individuals, linking them to periods of peak resource availability. Mistiming of these events could have severe consequences for many species.

Habitat Loss: Biome shifts will result in the reduction of certain habitats. For example, tundra habitat cannot advance polewards as temperatures rise due to its position at the northern extent of the Eurasian landmass. These higher temperatures are causing forests to invade areas which were originally treeless tundra[62,63], greatly reducing suitable habitat area for some species. The **Siberian crane** for example is currently affected by these changes as the open tundra that it requires to nest disappears[64,65].

Siberian Cranes

EXACERBATION OF EXISTING THREATS

The majority of the species assessed by this study are already at high risk from anthropogenic pressures. There is evidence that past climatic change increased overexploitation of certain species[66]. The negative socio-economic impacts of current climate change on humans will ultimately result in increased anthropogenic pressures on species and natural systems. For example, harvested species are likely to be even more heavily exploited. Wetland habitats will be starved of water as it becomes increasingly diverted for human use, threatening species such as the **Basra reed warbler**[67]. Sea level rise will encourage the construction of coastal defences, which are likely to negatively impact species reliant on coastal habitats, including sea turtle species and the **West African manatee**[68].

Climate change has the capacity to act synergistically with current anthropogenic threats, so that species are not only dealing with the direct impacts of climate change, but also consequences of climate change impacts on humans. Current anthropogenic threats also weaken a species ability to cope with climate change. Building resilience into species populations, and the habitats on which they depend by reducing conventional threats such as pollution, habitat fragmentation and overexploitation will improve species ability to adapt.

Policy Considerations

Monitoring and Further Research Needs: Little is known about migratory species capacity for adaptation to climate change. If we are to gain a solid understanding of the impacts of climate change on migratory species, intensive monitoring and research is needed. Thorough assessment is not only required for species already protected by CMS, but also for those not currently listed in the Appendices. This knowledge is vital to identify key limiting factors, the 'weakest link', upon which each species survival hinges, and to provide essential building blocks for policy guidance. Further literature on the interactions between climate change and migratory species populations is being gathered and made available online to inform policy and management decisions: www.bioclimate.org

Managing Changing Environments: The advantage that migratory species have in comparison with most non-migratory taxa is their ability to move over large distances. To facilitate this movement, it is vital to improve the connectivity of habitats critical to population survival currently and in the future. CMS is already involved in developing critical site networks and tools such as the African-Eurasian Waterbird Agreement's Wings Over Wetlands Project (www.wingsoverwetlands.org). There is an urgent need to identify and protect further critical site networks with species range shifts in mind. By maintaining viable habitats and reducing current threats, stakeholders may be able to improve the resilience of some species to cope and adapt to climate change.

Difficulty of Adaptation and Importance of Mitigation: The large extent of many migratory species ranges will make the design of adaptation strategies, aimed at minimising climate change impacts, very challenging. For instance, the **Siberian crane's** global population consists of roughly 3000 individuals, which nest over an area of 26,000km². Even if adaptation is facilitated, such as by shifting migratory routes with imprinting and microlight plane guidance (e.g. Flight of Hope project), these measures require a large investment both in terms of time and money.

Unfortunately, even high levels of investment will not ensure viable populations if emissions surpass critical thresholds, as many of the threats highlighted in this study will be difficult to control and adapt to once levels are breached. Furthermore, populations currently dependent on habitats located on the most northerly or southerly ends of landmasses, as well as those close to mountain tops, are particularly vulnerable since migration to follow their climatic niche is not an option. There is potential for the translocation of species to new areas through assisted colonisation/migration, but this again is costly and should only be used as a last resort once adequate research has been done on the long term affects of such drastic intervention.

On a species by species basis, provisions to aid adaptation could be feasible in the short to medium term, but it is clear that for a multitude of species such actions will be too costly and ultimately not sufficient to ensure their survival, especially if rapid levels of climate change are allowed to occur. It is therefore vital that a **dual approach** be taken where; **proactive adaptation measures** are applied to species already threatened by committed levels of climate change alongside **considerable and rapid emissions abatement** to limit further impacts. This is the only cost effective and practical way to safeguard migratory species into the future.

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3. Objectives of Current Study

- Development and piloting of an assessment process for CMS to review migratory species vulnerability to climate change

The current study represents an initial investigation into potential steps that CMS can take to review migratory species vulnerability to climate change impacts. From this review a set of recommendations on future actions has been developed for CMS consideration.

- Preliminary review of CMS Appendix I migratory species for climate change vulnerability

Each step of the recommended assessment methodology has been developed and sections trialled through a review of selected species within Appendix I of CMS. This has provided an output of vulnerability gradings for a case study number of species to inform policy decisions.

4. Recommendations for a Phased Methodology to Assess Migratory Species

PHASE 1:	**REVIEW OF CURRENT RESEARCH FINDINGS**
PHASE 2:	**CLIMATE CHANGE VULNERABILITY ASSESSMENTS - EXPERT SCOPING REVIEWS**
PHASE 3:	**CLIMATE CHANGE VULNERABILITY ASSESSMENTS – IN DEPTH REVIEWS**
PHASE 4:	**INDIVIDUAL SPECIES REPORTS**

Taking into account the issue of time restraints and the urgent need for outputs for policy use a staged assessment process is proposed if further assessments on CMS species are carried out. Each stage will have an output that will be useful for policy decisions. Funding will be required for each phase of the assessment process and each should be seen as a separate project.

4.1. PHASE 1: REVIEW OF CURRENT RESEARCH FINDINGS

Stage 1: Overview of research directly relating species with climate change impacts and vulnerabilities

Objectives:	Gather and sort all published literature directly referring to climate change impacts and vulnerabilities for (1) each subject species and (2) related taxon or group type. Identify research gaps: Identify species which have had little or no direct research into their climate change vulnerabilities. Identify species with large amount of research indicating vulnerability to climate change. Identify species where observed changes have been directly related to climate change
Methods:	Table of species listed under groupings and taxon alongside related literature directly referring to climate change impacts on each (see appendix 2 for example). A direct reference to climate change, global warming or synonym must be made in the literature otherwise the reference can not be included. No inferences can be made at this stage of review. Each reference will be hyperlinked to original document. References showing observed changes tagged Species with no direct references identified *This methodology is being proposed for follow on work and has been tested within this study.*
Results:	Each species will have a list of peer reviewed references that directly relates this species to climate change vulnerability All references identifying observed changes will be tagged
Outputs:	Organised list of relevant references for CMS and further research use. Overview of species where there are research gaps and where there are disproportionately high levels of research. References can be made available online for all CMS Parties and public to access through BioClimate (www.bioclimate.org) if follow up work is requested. List of migratory species flagged as "concern" due to climate change impacts already being felt.

Scope: An initial overview of literature is recommended for all migratory species and species listed on the CMS appendices.

Stage 2: Review of research directly relating species with climate change impacts and vulnerabilities

Objectives: Identify trends in literature directly relating species with climate change impacts and vulnerabilities; separating those observed, predicted and potential (inferred).
Identify key areas of concern for each species highlighted in current literature
Identify areas for further research requirements highlighted in current literature

Methods: Each direct reference relating to species will have main points extracted and tabulated next to species.
Climate change vulnerability factors (as identified in table 1, p48) will be listed and species literature reviewed in relation to each of these points with results formulated into a table (see table 2, p49) allowing for detailed analysis.
Impacts on populations in terms of positive, negative or neutral for observed, predicted and potential (inferred) affects will be identified for each factor.
This methodology is being proposed for follow on work and has been tested within this study.

Results: Identification of number of species affected by different climate change processes (including temperature changes, ocean acidification, desertification etc).
Identification of number of species affected by different climate change biological response processes (including changes in reproductive success, phenological shifts, interspecific interactions etc.).
Identification of number of species affected by interactions of climate change with other threat processes (including invasive species, disease risk, habitat fragmentation etc).
Further analysis can be carried out grouping species under taxa, habitat type, region, IUCN category, CMS appendices to show trend data for each factor.

Outputs: Format favourable to report and policy informing documents which provide further clarification of migratory species vulnerabilities to climate change impact factors outlined.
Provides a mechanism for identifying species for further pick up in follow on phases of assessments and provides a basis for filtering a select number of species as required.

Scope: All migratory species and species listed on CMS. Initial stages should focus on Appendix I species and species identified as significant for review, due to time constraints.

OPTIONAL Stage 3: Review of research indirectly relating species with climate change impacts and vulnerabilities.

Can be carried out in conjunction with Phase 3 of assessments to provide further scoping of potential linkages between known factors of species vulnerability related to climate change but not directly referenced as such in current literature. Also has the potential to act as a stand alone review to inform policy.

Objectives: Gather and sort published literature indirectly related to climate change vulnerabilities of each subject species. This includes literature on climate change impacts and vulnerabilities of i.e. key prey species, key habitats, key phenological factors and key environmental factors influencing species survival.
Identify research gaps:
- Identify where key factors for species survival have been highlighted as vulnerable to climate change but no direct references are available linking this to subject species.
- Identify where observed changes are occurring to key factors for species survival but no research is present recording effects on species.

Methods: Initial review to list key factors and dependencies influencing survival of species including traits and characteristics of species that may be affected by climate change.
List keywords (i.e. prey species name) under relevant factors (see Appendix I for list of recommended factors for review). These include factors affected by (1) climate change processes i.e. precipitation, (2) climate change biological response processes i.e. interspecific interactions and (3) climate change interactions with other threat processes i.e. habitat fragmentation.
Review literature for any observed or predicted impacts on factors outlined.
List references under species name and factors outlined.
List key findings of concern from literature for each factor identified
Key factors and dependencies influencing survival of subject species that have currently no linked climate change research will be identified
This methodology is being proposed for follow on work and has been tested within this study.

Results: Each species will have a secondary list of peer reviewed references that indirectly relates this species to climate change vulnerability
All references identifying observed changes will be tagged

Outputs: Combine with Phase 1 stage 2 assessment findings to increase depth of review.
Supports and contributes further information to Phase 3 assessment findings.
Identifies more areas where further research is required.

Identifies key factors and dependencies of "likely concern" for ongoing species survival.
Provides organised list of relevant references for CMS and further research use.

Scope: Recommended action for key species identified as being data deficient in terms of climate change vulnerability information.

4.2. PHASE 2: CLIMATE CHANGE VULNERABILITY ASSESSMENTS – EXPERT SCOPING REVIEWS

Objectives:
Identify initial indicator of climate change vulnerability gradings for each species
Provide an index suitable for prioritising species for policy attention
Provide quick methodology for rapid review of large number of species that identifies a grading for each species.
Engage species specialists with climate change vulnerability assessments for migratory species
Facilitate long term relationships with species specialists to review migratory species vulnerabilities
Capture enhanced knowledge of species vulnerabilities to climate change not currently available in literature.

Methods:
Engage network of CMS relevant species specialists
Develop list of species specialists currently engaged with climate change research to support CMS network of specialists and fill any gaps.
Provide species specialist with expert assessment for completion (see appendix 3). Experts are asked to identify scenarios most relevant to their subject species for each criteria within the assessment. Rational, evidence and related references is requested for each selection.
Compile feedback and refer to second round of expert reviewers where necessary
Review assessments and gradings given.
This methodology is being proposed for follow on work.

Results: Initial climate change vulnerability gradings for each species assessed.

Outputs:
Ranking of each species climate change vulnerability (initial gradings) for policy consideration.
Identification of migratory species most and least threatened by climate change

Scope:
First wave of reviews cover CMS Appendix I species
Second wave of reviews cover CMS Appendix II species
Third wave of reviews cover all remaining migratory species.

4.3. PHASE 3: CLIMATE CHANGE VULNERABILITY ASSESSMENTS – IN DEPTH REVIEWS

Objectives:	Identify climate change vulnerability gradings for each species
Methods:	Using climate change vulnerability assessment format assess each species on categories of climate change vulnerability as outlined. Use expert scoping climate change vulnerability assessments, where available, to increase speed of assessment process. Review and assign gradings to species identifying climate change vulnerability. *This methodology has been applied to case study species presented within this report.*
Results:	See example In Depth Climate Change Vulnerability Assessments provided in current review
Outputs:	Provides written assessments for each species. Provides important information for inclusion into management and policy recommendations. Provides an index suitable for prioritising species for policy attention. Grades of high / medium / low climate change vulnerability assigned to each species
Scope:	Key species, as identified by CMS as priorities. A prioritisation process will have to be carried out that identifies species for further review. This can take into account (1) political factors that influence ability to act on information, (2) biological factors that provide species with ability to be resilient to climate change if management and policy actions are taken and (3) indications of climate change vulnerability from previous assessment phases. Both Phase 1 and Phase 2 assessments can be used to inform selection and help identify species requiring further attention and detail in reporting.

4.4. PHASE 4: INDIVIDUAL SPECIES REPORTS

Objectives:	Provide detailed reports for key species in liaison with species specialists
Methods:	Review latest information and research directly relating to species and the vulnerability of dependent factors such as habitat, prey, phenological events etc.

Compile information into a report identifying all potential threats, vulnerabilities as well as uncertainties and discussion of points raised.
Provide graphical information where available.
Liaise with species specialists and, where available, climate change specialists during production of report.
This methodology has been applied to case study species presented within this report.

Results: See example Species Reports provided in current review

Outputs: Species reports often 4 - 10 pages each.
Reports can be published as stand alone documents, part of a series or a number of reports collated as case studies in a larger document.
Potential to feed into conservation management planning processes

Scope: Key species, as identified by CMS, requiring further investigation and reporting of climate change vulnerabilities and threats

4.5. Piloting the Assessment Methodology for use by CMS

An objective for CMS currently is to "*identify which migratory species are most likely to be directly or indirectly threatened or impacted by climate change*" CMS Resolution 9.7 (2)

In this round of assessments the focus has been to develop and test a mechanism by which each species can be assessed to a degree of confidence that allows for a high, medium or low comparative gradings of vulnerability to be assigned. The objective of identifying differential gradings of vulnerability for each species is to provide a basis by which decision makers can prioritise action for species.

However it may be that a different approach would be more productive in terms of being able to cover the number of migratory species both listed under CMS and those not currently listed. With a potential 5000 migratory species worldwide (Riede K, 2004) it may be that a process by which species can first be reviewed and those of "concern" and "likely concern" due to direct and indirect affects of climate change can be identified. These species can then be prioritised for further attention through more detailed reviews that assign gradings of vulnerability to each species.

Proposal for a Phased Approach

With this in mind a phased approach has been recommended and a mechanism by which this can be applied identified and outlined. Each step will provide useful policy outputs to the level of detail required at each phase of assessment. The objective is that as you move up to the next phase of assessment the detail in information and novel information that is outputted increases but the number of species reviewed decreases as species are selected and prioritised for further review. Species can be prioritised on the basis of results of prior phases in the assessment process alongside input from more political rational which would select species according to those having beneficial output and outreach potential in terms of relevant CMS agreements, MoU's, action plans and initiatives.

The current study has focused on the development of an assessment that delivers gradings of climate change vulnerability for each species assessed. This has provided a useful insight into what should be an end point objective of such species level assessments, identifying both the benefits and limitations of carrying out such detailed studies. This preliminary review process has been an essential step to inform and feed into the development of other phases of assessments which although less detailed have the potential to be more productive in terms of species coverage.

A major limitation to the speed at which species can be assessed is a lack of current information at the species level of both observed and predicted vulnerabilities to, and impacts from, climate change. Most prominent is a lack of information that directly links individual species to climate change. More information is available that is currently not directly linked to species but would be of great value in identifying potential impacts and key vulnerabilities. For example, the current study has found that there to be a lack of information at the species level for many species within CMS Appendix I. This has necessitated a much higher level of detailed research and analysis to be carried out for each species to ascertain their climate change vulnerabilities and draw upon these indirect information sources. Increasing the detail of research carried out increases confidence in the studies findings, making them of more value to inform policy. However this also causes a major problem, as this project has clearly identified, that due to a lack of direct information such assessments take considerable time to complete, especially if aiming for a high standard of review which is felt necessary to provide accurate species gradings for CMS purposes. Such a lack of information will likely be the case for many other migratory species CMS wishes to review further studies.

However information and new research findings are being produced at an accelerated rate within the climate change and biodiversity linked disciplines. Accuracy and reliability of predictions of climate change impacts are also increasing. The complexity of modelling both climate change and species responses is developing further as knowledge and understanding of the Earth's systems grows and technological capacity to represent this complexity increases. This means there are continual improvements in the confidence and accuracy of such predictions and studies findings. The inclusion of biological feedbacks into climate system models has become possible as there is a growing awareness and understanding of the importance these will have in the final climatic outcomes. It may therefore be preferable that a lower level of review be carried out at first on species, identifying where information is available and where there are current knowledge gaps. However this needs to be done in a systematic manner that allows for information gaps to be filled, updating the assessments as and when new information becomes available, making such a process responsive.

Proposal of Phase 1 Assessments

With this in mind the Phase 1 section of the assessment process has been proposed. Although an extensive literature review has been carried out for this study and others like it, this assessment phase outlines a standardised approach where results of such reviews can be logged so that they can be analysed with the objective of providing policy informing outputs. The option to also log all references gathered onto the online reference tool 'www.bioclimate.org' is available that would also provide a means to fulfil Resolution 9.7 (2) which "*Encourages Parties to assist the Secretariat to establish an open-access database on scientific literature of relevance to climate change and migratory species.*"

Phase 1 assessments would be able to identify species that show an indication of climate change impact and vulnerability "concern" and "likely concern". Although it would not be able to grade species on their climate change vulnerability to give a high, medium and low ranking it would provide a good basis as a warning system to policy makers. Such initial species overviews would not necessarily have to go into such detail on each species to gather the latest information on those that are currently being viewed as vulnerable and flag these for further priority and attention. This level of assessment could not claim to be able to identify all species that are vulnerable to climate change out of the number assessed, but instead it would just provide a means to flag those that have currently been identified as such. However as more information becomes available and further species level research is carried out such gaps will shrink if this process allows for continual updating. The benefit of such a surface level overview of the current knowledge of species level impacts is that that it would be less resource intensive in terms of funding and time required to cover a large number of species. We also have to consider the fact that we are currently potentially very time limited, with impending climatic changes being predicted at increasing intensities. Species which do have information available currently, identifying their climate change vulnerability and threat, need to be incorporated into policy as soon as possible to increase the effectiveness of any subsequent actions in what may become a rapidly changing world.

Proposal of Phase 2 Assessments

The requirement to rapidly identify climate change vulnerability gradings for species has instigated the development of a streamline fast track assessment process as outlined in Phase 2 of the assessment methodology. Phase 2 assessments have the benefits of being less resource intensive, both in time and funding. The outputs of these will be the grading and ranking of species, in terms of high, medium and low vulnerability, however these will not be able to provide any further information, although rational for gradings will be recorded to clarify any confidence issues. Further work would have to be carried out on assessments to present more detailed findings and discussion of each species reviewed, that would bring these up to a Phase 3 level of assessment. Phase 2 assessments use species experts to identify the most applicable criteria and grading of species vulnerability factors using a selection of scenarios.

The aim in the development of Phase 2 assessments is to provide a streamlined system by which species can be graded on their vulnerability to climate change without impacting on the confidence levels of gradings given. It also increases the ability to effectively engage a key resource provided through expert knowledge and in depth understanding of their subject species. A streamlined process will allow experts to engage with the process without too greater demands on their time that would otherwise make such an assessment and request unfeasible at this scale. If assessments are envisaged to cover all species within CMS appendices and beyond to further to incorporate other migratory species into such a review, with the objective of identifying species requiring inclusion into CMS appendices, then this study has made it clear that a fast track approach using a wide network of species specialists would be very beneficial, and in fact necessary if the objective to also identify gradings of vulnerability for each species.

A streamlined approach can also be taken without the use of species specialists, taking this more in house rather then outsourcing assessments to individual species experts. This would require a similar assessment process to be taken, as outlined in Phase 2 methodology, whereby assessors identify the scenarios most applicable to each species. However the time required for each assessor, who is not a species expert, to review the species fully to make such a selection would be a limiting factor and be a considerable constraint to the speed at which assessments can be done. Each assessor would have to familiarise themselves with all the factors associated with the species and their traits and characteristic that could make them vulnerable to climate change. Although this would provide a more standardised approach in terms of a few assessors inputting into the process it would negate the large benefits that would be presented by engaging experts with this process. Further discussion of how this process would be applied is provided within the Phase 3 methodological discussion section within this report.

Clarity of Requirements

The current study presents the more resource intensive in depth assessment reviews and species individual reports (Phase 3 and 4 of the proposed phased assessment methodology). Case study assessments carried out on a selection of chosen Appendix I migratory species has allowed for development and testing of a methodology to effectively assess species vulnerability to climate change. Piloting of the assessment process has been an essential step in the development of the phased methodological approach outlined, including Phase 2 streamlined expert focussed assessments and Phase 1 reviews of current research.

The next step will be to clarify the requirements of CMS in terms of required outputs and available inputs to inform the most appropriate selection and depth of any further reviews. If the objective is to inform policy of threats, already identified within papers, to species in terms of (1) climate change processes most affecting each species, (2) the biological factors which make a species vulnerable and (3) the climate change interactions with other threat processes affecting species then Phase 1 of the assessment process would be adequate. These would provide valuable policy input that would be achievable with potentially less intensive time and resource requirements. However this assessment phase would not be able to grade and rank species but instead give an overall picture of threats and vulnerabilities. If the objective is to grade species as to their vulnerability (high, medium or low vulnerability) using a wider base of information that would result in novel information being presentable to policy makers then Phase 2 and 3 would be more appropriate. If in depth information is required on species to develop management and action plans then Phase 4 would be more appropriate.

A recommendation for phased assessments has been provided that outlines a number of different approaches, each with beneficial outputs to inform policy and conservation management decisions. These have been detailed in full for CMS consideration. The objective of this is to provide CMS with a strong foundation for discussion as to the best way forward that will tailor the level of resource inputs available and type of assessment outputs possible to the needs of CMS. This is very dependent on the final objectives of CMS which needs clarification. Pertinent questions need to be raised such as; whether CMS requires a warning system that identifies species highlighted in wider research as vulnerable and a mechanism by which attention can be drawn to this quickly and communicated to policy makers? Or whether CMS requires new research to be carried out, even on species which currently have little climate change vulnerability information, so that all species within appendices can be graded with a high, medium or low score of vulnerability through detailed assessments? Whether CMS would find a static system suitable, where once species have been graded in terms of vulnerability, these assessment results are set in place until a date when the next round of assessments can be carried out in the long term future? Or whether CMS requires a dynamic system where species reviews are constantly being updated as new information becomes available?

All of these approaches have their benefits and trader offs. A static system will require species to have a large amount of research carried out for there to be comfortability in the vulnerability grading. It would also not be responsive to new information coming in both biological and climatic. A dynamic system would mean that new information would be more easily incorporated but that species will all have different levels of review and work carried out on them, which would not allow for a grading of species but would simply indicate those that are coming up currently as "concern" or "likely concern" species. This is why a phased approach has been recommended to gain the benefits from all approaches and tailor the detail of assessment work to level that is really required for each species in question.

Taking on board all of these considerations it is clearly essential that CMS clarify exactly the type of outputs required from any follow on work before any further species reviews are carried out. The phased methodological approach outlined provides a baseline for selection of output options available and clarifies the relative trade offs, benefits and limitations of each approach.

5. Preliminary Review of CMS Appendix I Migratory Species

This part of the study aims to identify how climate change is likely to affect a selected number of individual migratory species, and the degree of threat that they face. Results show that climate change will have negative impacts on populations of all these species.

5.1. Scope of Study

The UNEP/CMS Secretariat commissioned a "**preliminary review of CMS listed migratory species within Appendix I, assessing their vulnerability to climate change.**" This study was also given the objective of assigning each species studied a climate change vulnerability grading of high, medium or low. As detailed level of assessments are required to provide gradings for species, and as time and resources were limiting factors, a number of case study species had to be selected from within CMS Appendix I for review. This preliminary review has focused on species that undergo cyclic and predictable long-distance migrations within Appendix I of CMS. Of these species, 18% were freshwater species, 47% marine species, 29% terrestrial species, 2% marine/freshwater species, 4% marine / terrestrial species (using IUCN Systems Type 2010 categorisation, .

Selecting a number of case study species for in depth review has allowed for the development and testing of an assessment process that can provide climate change vulnerability gradings for each species to a degree which gives a high level of scientific confidence, making these more valuable to inform policy. This is in comparison to a much lower level detail of review that would have covered all of Appendix I species but would not have allowed for the final output of gradings of species and would give much less confidence in final results as well as a limited ability to pilot this assessment process. Piloting the assessment process has allowed for a more streamlined assessment process to be developed (outlined in Phase 1 and 2), that will speed up review of species in future. More detail is provided on this issue in other sections of the document.

5.1.1. Definition of Migratory Species

This preliminary review focuses on a selected number of species within CMS Appendix I. However the development of the assessment process is aimed at maximising our ability to review all species listed on CMS appendices as well as being able to incorporate migratory species not currently listed so that policy can be informed of any potential need to include new species in future.

To this end we will give clarification on what defines a species as migratory. The CMS definition of migratory is:

> *"the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries"*
>
> (CMS 1979, Article 1)

The CMS definition of migratory is limited to species which cross national jurisdictional boundaries due to the political application of this convention warranting such a selection process.

However the term migratory species covers a much broader selection of species when political limitations are not included. The Global Registry of Migratory Species (GROMS) identifies that there are potentially over 5000 migratory species worldwide, with 1000 being fish species. GROMS currently lists 2880 migratory species and these are focused on long distance migrants with a minimal migration distance of >100 km. Species with small scale migrations, such as amphibians, would not be included unless such a species were to be listed on CMS appendices.

5.1.2. Selection of Case Study Species

This preliminary review is limited to species within Appendix I of the Convention on Migratory Species with one case study example, on request, within Appendix II.

Species have been selected for case study attention within Appendix I that have (1) the largest migrational and dispersal distance and therefore the highest mobility and where (2) all of the species population undergoes predictable and cyclic migrations. 41 of these 'most biologically migrant species' were case studied including 7 reptile species, 14 mammal species, 4 fish species and 16 bird species.

This selection process has filtered out most species within Appendix I that fall under the category of (1) small scale migrants or (2) those where only part of their population migrates, apart from 2 mammal species and 1 bird species which provide examples of 'least biologically migrant species' studied.

Within this species of reptiles and fish have taken priority for assessment selection as these were identified as most likely to be impacted by climate change due to their vulnerability to temperature dependent factors within their life cycles. Although birds make up the majority of Appendix I species less focus has been given to these species in terms of proportional representation in the final assessment selection as they have received much attention in previous studies of climate change impacts on migratory species.

Species listed under Appendix I of the convention are tabled below with common and scientific names in order of Taxa class. Each species has further details provided including GROMS migration classification information, relevant CMS agreements identified, IUCN RED list 2010 classification and IUCN RED list population trend as of 2010. Species that have been selected as case study candidates for inclusion in this preliminary review with completed climate change vulnerability assessments and gradings have been marked. Remaining species within Appendix I that have not already been fully assessed and graded on their climate change vulnerability have been given a priority rating (high, medium or low), where information was made available, giving an indication of those to consider as priority and focus if further assessments are to be carried out. For information German, French and Spanish names of species have also been included.

No	Class	English	Latin	Migration Classification	Relevant CMS Agreements Identified	Climate Change Vulnerability Assessment pilot case studies	Red List 2010 *Version 2010.1*	Population Trend 2010	Suggested prioritisation for further Climate Change Vulnerability Assessments	CMS Appendix	Family	German	French	Spanish
1	Reptilia	Arrau Turtle, South American River Turtle	*Podocnemis expansa*	Potamodromous	-		LR/cd	Not provided	High	I	Pelomedusidae	Arrauschildkröte	Tortue de l'Amazone	Tortuga Arrau

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2	Reptilia	Gharial, Indian Gavial	*Gavialis gangeticus*	potamodromous	-	X	CR	Decreasing	Case Studied	I	Gavialidae	Ganges-Gavial	Gavial du Gange	Gavial del Ganges
3	Reptilia	Green Turtle	*Chelonia mydas*	interoceanic	IOSEA MoU	X	EN	Decreasing	Case Studied	I	Cheloniidae	Pazifische Suppenschildkröte	Tortue verte	Tortuga verde
4	Reptilia	Hawksbill Turtle	*Eretmochelys imbricata*	intraoceanic	IOSEA MoU	X	CR	Decreasing	Case Studied	I	Cheloniidae	Echte Karettschildkröte	Tortue imbriquée	Tortuga carey
5	Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	*Lepidochelys kempii*	intraoceanic	IOSEA MoU	X	CR	Not provided	Case Studied	I	Cheloniidae	Atlantische Bastardschildkröte	Tortue de Ridley	Tortuga lora
6	Reptilia	Leatherback Turtle,	*Dermochelys coriacea*	interoceanic	IOSEA MoU	X	CR	Decreasing	Case Studied	I	Dermochelyidae	Lederschildkröte	Tortue luth	Tortuga laud
7	Reptilia	Loggerhead Turtle	*Caretta caretta*	interoceanic	IOSEA MoU	X	EN	Not provided	Case Studied	I	Cheloniidae	Unechte Karettschildkröte	Caouanne	Tortuga boba
8	Reptilia	Olive Ridley	*Lepidochelys olivacea*	intraoceanic	IOSEA MoU	X	VU	Decreasing	Case Studied	I	Cheloniidae	Bastardschildkröte	Tortue batarde	Tortuga olivácea
9	Pisces	Basking Shark	*Cetorhinus maximus*	oceanodromous	Sharks MoU	X	VU	Decreasing	Case Studied	I				
10	Pisces	Common Sturgeon	*Acipenser sturio*	anadromous	-	X	CR	Decreasing	Case Studied	I				
11	Pisces	Giant Catfish	*Pangasius gigas*	potamodromous	-	X	CR	Decreasing	Case Studied	I	Pangasiidae	Riesenwels	Silure de verre géant	Siluro gigante
12	Pisces	Great White Shark, White Shark	*Carcharodon carcharias*	oceanodromous	Sharks MoU	X	VU	Unknown	Case Studied	I	Lamnidae	Weißer Hai	Mangeur d'hommes	Tiburón antropófago
13	Mammalia	Addax	*Addax nasomaculatus*	intracontinental	Sahelo-Saharan Antelope Action Plan	X	CR	Decreasing	Case Studied	I	Bovidae	Mendesantilope	Addax à nez tacheté	Adax
14	Mammalia	American Manatee, West Indian Manatee	*Trichechus manatus*	range extension	West African Aquatic Mammal MoU		VU	Decreasing	High	I	Trichechidae	Seekuh	Lamantin des Caraïbes	Manatí norteamericano
15	Mammalia	Atlantic Humpbacked Dolphin	*Sousa teuszii*	possibly migratory	West African Aquatic Mammal MoU		VU	Decreasing	Medium	I				

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16	Mammalia	Barbary Stag, Barbary Deer, Red Deer	*Cervus elaphus*	technical migrant	-		LC	Increasing	No info	I	Cervidae	Berberhirsch	Cerf de Barbarie	Ciervo de Berbería
17	Mammalia	Blue Whale	*Balaenoptera musculus*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	EN	Increasing	Case Studied	I	Balaenopteridae	Blauwal	Baleine bleue	Ballena azul
18	Mammalia	Bowhead Whale	*Balaena mysticetus*	interoceanic	-	X	LC	Increasing	Case Studied	I	Balaenidae	Grönlandwal	Baleine du Groenland	Ballena de Groenlandia
19	Mammalia	Cheetah	*Acinonyx jubatus*	not included	-		VU	Decreasing	No info	I				
20	Mammalia	Common Bottlenose Dolphin	*Tursiops truncatus*	partial	ACCOBAMS, ASCOBANS		LC	Unknown	Medium	I				
21	Mammalia	Cuvier's Gazelle	*Gazella cuvieri*	data deficient	Sahelo-Saharan Antelope Action Plan	X	EN	Unknown	Case Studied	I	Bovidae	Atlasgazelle	Gazelle de Cuvier	Gacela de Cuvier
22	Mammalia	Dama Gazelle	*Gazella dama*	intracontinental	Sahelo-Saharan Antelope Action Plan	X	CR	Decreasing	Case Studied	I	Bovidae	Damagazelle	Gazelle dama	Gacela dama
23	Mammalia	Dorcas Gazelle	*Gazella dorcas*	nomadising	Sahelo-Saharan Antelope Action Plan		VU	Decreasing	Medium	I	Bovidae	Dorkasgazelle	Gazelle Dorcas	Gacela Dorcas
24	Mammalia	Fin Whale	*Balaenoptera physalus*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU		EN	Unknown	Medium	I	Balaenopteridae	Finnwal	Baleine fine	Rorcual común
25	Mammalia	Ganges River Dolphin, Blind River Dolphin, South Asian River Dolphin	*Platanista gangetica*	potamodromous	-		EN	Decreasing	No info	I	Platanistidae	Ganges-Delphin	Platanista du Gange	Delfín del Río Ganges
26	Mammalia	Grevy's Zebra	*Equus grevyi*	technical migrant	-		EN	Stable	No info	I	Equidae	Grevy Zebra	Zèbre de Grevy	Cebra de Grevy
27	Mammalia	Humpback Whale	*Megaptera novaeangliae*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	LC	Increasing	Case Studied	I	Balaenopteridae	Buckelwal	Mégaptère	Yubarta
28	Mammalia	Irrawaddy Dolphin	*Orcaella brevirostris*	potamodromous	-		VU	Decreasing	No info	I				

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29	Mammalia	Kouprey, Grey Ox	*Bos sauveli*	technical migrant	-		CR	Unknown	No info	I	Bovidae	Kuprey	Kouprey	Kouprey
30	Mammalia	La Plata Dolphin, Franciscana	*Pontoporia blainvillei*	technical migrant	-		VU	Decreasing	Low	I	Platanistidae	La-Plata-Delphin	Dauphin de la Plata	Franciscana
31	Mammalia	Lowland Gorilla	*Gorilla gorilla*	nomadising	Gorilla Agreement		CR	Decreasing	High	I	Hominidae	Gorilla	Gorille	Gorila
32	Mammalia	Marine Otter	*Lontra felina*	technical migrant	-	X	EN	Decreasing	Case Studied	I	Mustelidae	Meerotter	Loutre de mer	Chungungo
33	Mammalia	Mediterranean Monk Seal	*Monachus monachus*	range extension	Mediterranean Monk Seal MoU		CR	Decreasing	High	I	Phocidae	Mittelmeer-Mönchsrobbe	Phoque moine de Méditerranée	Foca monje del Mediterráneo
34	Mammalia	Mexican Free-tailed Bat, Brasilian free-tailed bat	*Tadarida brasiliensis*	intercontinental	-	X	LC	Stable	Case Studied	I	Molossidae	Brasilianische Bulldogfledermaus	Chauve-souris à queue-libre du Mexique	Rabudo mejicano
35	Mammalia	Mountain Gorilla, Eastern Gorilla	*Gorilla beringei*	nomadising	Gorilla Agreement		EN	Decreasing	High	I				
36	Mammalia	NARWHAL	*Monodon monoceros*	intraoceanic	-	X	NT	Unknown	Case Studied	II				
37	Mammalia	North Pacific Right Whale	*Eubalaena japonica*	interoceanic	-	X	EN	Unknown	Case Studied	I				
38	Mammalia	Northern Atlantic Right Whale, Biscayan Right Whale	*Eubalaena glacialis*	interoceanic	-	X	EN	Unknown	Case Studied	I	Balaenidae	Nordkaper	Baleine de Biscaye	Ballena franca
39	Mammalia	Scimitar-horned Oryx	*Oryx dammah*	intracontinental	Sahelo-Saharan Antelope Action Plan		EW		No info	I	Bovidae	Säbelantilope	Oryx gazelle	Orix cimitarra
40	Mammalia	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	*Balaenoptera borealis*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	EN	Unknown	Case Studied	I	Balaenopteridae	Seiwal	Baleinoptere de Rudolphi	Rorcual norteño

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41	Mammalia	Short-beaked Common Dolphin	*Delphinus delphis*	intraoceanic	ACCOBAMS, ASCOBANS, Pacific Island Cetaceans MoU, West African Aquatic Mammal MoU	X	LC	Unknown	Case Studied	I				
42	Mammalia	Slender-horned Gazelle, Rhim	*Gazella leptoceros*	nomadising	Sahelo-Saharan Antelope Action Plan		EN	Decreasing	Medium	I	Bovidae	Dünengazelle	Gazelle leptocère	Gacela de astas delgadas
43	Mammalia	Snow Leopard	*Uncia uncia*	nomadising	-	X	EN	Decreasing	Case Studied	I	Felidae	Schneeleopard	Panthère des neiges	Pantera de las nieves
44	Mammalia	South Andean Deer, Patagonian Huemul	*Hippocamelus bisulcus*	technical migrant	-		EN	Decreasing	No info	I	Cervidae	Südandenhirsch	Cerf des Andes méridionales	Huemul
45	Mammalia	Southern Right Whale	*Eubalaena australis*	interoceanic	-	X	LC	Increasing	Case Studied	I	Balaenidae	Südkaper	Baleine australe	Ballena franca austral
46	Mammalia	Southern River Otter	*Lontra provocax*	technical migrant	-		EN	Decreasing	No info	I	Mustelidae	Südlicher Flussotter	Loutre du Chili	Huillín
47	Mammalia	Sperm Whale	*Physeter macrocephalus*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	VU	Unknown	Case Studied	I	Physeteridae	Pottwal	Cachalot	Ballena esperma
48	Mammalia	Vicugna)	*Vicugna vicugna*	nomadising	-		LC	Increasing	Low	I	Camelidae	Vikunja	Vigogne	Vicuña
49	Mammalia	West African Manatee	*Trichechus senegalensis*	intracontinental	West African Aquatic Mammal MoU	X	VU	Unknown	Case Studied	I				
50	Mammalia	Wild or Bactrian camel	*Camelus bactrianus*	NONE PROVIDED	-		CR	Decreasing	High	I	Camelidae			Camello Bactriano
51	Mammalia	Wild Yak, Yak (Domestic species)	*Bos grunniens (Bos mutus)*	technical migrant	-		VU	Decreasing	High	I	Bovidae	Wildyak	Yack sauvage	Yak
52	Aves	Amsterdam Albatross	*Diomedea amsterdamensis*	intraoceanic	ACAP		CR	Decreasing	Medium	I	Diomedeidae	Amsterdamalbatros	Albatros d'Amsterdam	Albatros de la Amsterdam

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53	Aves	Andean Flamingo	*Phoenicopterus andinus*	intracontinental	High Andean Flamingo MoU	X	VU	Decreasing	Case Studied	I	Phoenicopteridae	Andenflamingo	Flamant des Andes	Parina grande
54	Aves	Aquatic Warbler	*Acrocephalus paludicola*	intercontinental	Aquatic warbler MoU	X	VU	Decreasing	Case Studied	I	Muscicapidae	Seggenrohrsänger	Phragmite aquatique	Carricerín
55	Aves	Audouin's Gull	*Larus audouinii*	partial	-		NT	Decreasing	Low	I	Laridae	Korallenmöwe	Goéland d'Audouin	Gaviota de Audouin
56	Aves	Baikal Teal	*Anas formosa*	intracontinental	-		VU	Decreasing	Low	I	Anatidae	Gluckente	Sarcelle élégante	Cerceta del Baikal
57	Aves	Balearic Shearwater	*Puffinus mauretanicus*	interoceanic	-	X	CR	Decreasing	Case Studied	I				
58	Aves	Basra Reed-warbler	*Acrocephalus griseldis*	intercontinental	-	X	EN	Decreasing	Case Studied	I				
59	Aves	Bermuda Petrel	*Pterodroma cahow*	intraoceanic	ACAP	X	EN	Increasing	Case Studied	I	Procellariidae	Bermudasturmvogel	Pétrel des Bermudes	Petrel cahow
60	Aves	Black-faced Spoonbill	*Platalea minor*	intracontinental	-		EN	Decreasing	High	I	Threskiornithidae	Schwarzgesichtlöffler	Petite Spatule	Espátula menor
61	Aves	Black-necked Crane	*Grus nigricollis*	intracontinental	-		VU	Decreasing	No info	I	Gruidae	Schwarzhalskranich	Grue à cou noir	Grulla cuellinegra
62	Aves	Blue Swallow	*Hirundo atrocaerulea*	intracontinental			VU	Decreasing	No info	I	Hirundinidae	Stahlschwalbe	Hirondelle bleue	
63	Aves	Broad-billed Sandpiper	*Limicola falcinellus*	intercontinental	-		LC	Not provided	Low	I				
64	Aves	Buff-breasted Sandpiper	*Tryngites subruficollis*	intercontinental	-		NT	Decreasing	Low	I	Scolopacidae	Grasläufer	Bécasseau roussâtre	Correlimos canelo
65	Aves	Chestnut Seedeater	*Sporophila cinnamomea*	intracontinental	-		VU	Decreasing	No info	I	Emberizidae		Sporophile cannelle	Capuchino corona gris
66	Aves	Chinese Crested Tern	*Sterna bernsteini*	intracontinental	-		CR	Decreasing	Low	I	Laridae	Bernsteinseeschwalbe	Sterne d'Orient	Charrán chino
67	Aves	Chinese Egret	*Egretta eulophotes*	intracontinental	-		VU	Decreasing	Low	I	Ardeidae	Schneereiher	Aigrette de Chine	Garceta china
68	Aves	Cock-tailed Tyrant	*Alectrurus tricolor*	migrantory	-		VU	Decreasing	No info	I	Tyrannidae		Moucherolle petit	Yetapá chico

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69	Aves	Dalmatian Pelican	*Pelecanus crispus*	partial	AEWA		VU	Decreasing	Low	I	Pelecanidae	Krauskopfpelikan	Pélican frisé	Pelicano ceñudo
70	Aves	Dark-rumped Petrel, Galapagos Petrel, Galápagos petrel	*Pterodroma phaeopygia*	intraoceanic	-		CR	Decreasing	Medium	I	Procellariidae	Galapagossturmvogel	Pétrel des HawaÔ	Petrel Hawaiano
71	Aves	Dark-rumped Petrel, Hawaiian Petrel, Uau	*Pterodroma sandwichensis*	intraoceanic	-		VU	Decreasing	No info	I	Procellariidae	Hawaiisturmvogel	Pétrel à croupion sombre	Petrel hawaiano
72	Aves	Eastern Imperial Eagle, Asian Imperial Eagle, Imperial Eagle	*Aquila heliaca*	intercontinental	Raptors MoU		VU	Decreasing	High	I	Accipitridae	Kaiseradler	Aigle impérial	Águila imperial oriental
73	Aves	Egyptian Vulture	*Neophron percnopterus*	partial	Raptors MoU		EN	Decreasing	High	I				
74	Aves	Eskimo Curlew	*Numenius borealis*	intercontinental	-	--	CR	Not provided	Case Studied	I	Scolopacidae	Eskimo-Brachvogel	Courlis esquimau	Zarapito boreal
75	Aves	Ferruginous Pochard, Ferruginous Duck	*Aythya nyroca*	intercontinental	AEWA		NT	Decreasing	Low	I	Anatidae	Moorente	Fuligule nyroca	Porrón pardo
76	Aves	Great bustard	*Otis tarda*	partial	Great Bustard MoU		VU	Decreasing	High	I	Otididae	Großtrappe	Grande Outarde	Avutarda euroasiática
77	Aves	Greater Spotted Eagle, Spotted Eagle	*Aquila clanga*	intercontinental	Raptors MoU		VU	Decreasing	Low / Medium	I	Accipitridae	Schelladler	Aigle criard	Águila moteada
78	Aves	Grey-cheeked Parakeet	*Brotogeris pyrrhopterus*	possibly migratory			EN	Decreasing	No info	I	Psittacidae	Feuerflügelsittich	Toui flamboyant	Catita macarena
79	Aves	Henderson Petrel	*Pterodroma atrata*	NON PROVIDED	-		EN	Decreasing	No info	I				

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80	Aves	Hooded Crane	*Grus monacha*	intracontinental	-		VU	Decreasing	No info	I	Gruidae	Mönchskranich	Grue moine	Grulla capachina
81	Aves	Houbara Bustard	*Chlamydotis undulata*	partial	-		VU	Decreasing	Low	I	Otididae	Kragentrappe	Outarde houbara	Avutarda hubara
82	Aves	Humboldt Penguin	*Spheniscus humboldti*	intraoceanic	-	X	VU	Decreasing	No info	I	Spheniscidae	Humboldtpinguin	Manchot de Humboldt	Pingüino de Humboldt
83	Aves	Japanese Murrelet, Crested Murrelet	*Synthliboramphus wumizusume*	intracontinental	-		VU	Decreasing	No info	I	Alcidae	Japanalk	Guillemot du Japon	Mérgulo japonés
84	Aves	Japanese Night Heron	*Gorsachius goisagi*	intracontinental	-		EN	Decreasing	No info	I	Ardeidae	Rotscheitelreiher	Bihoreau goisagi	Martinete japonés
85	Aves	Kirtland's Warbler	*Dendroica kirtlandii*	intercontinental	-		NT	Increasing	No info	I	Parulidae	Kirtlands Waldsänger	Paruline de Kirtland	Silbador de Kirtland
86	Aves	Lesser Kestrel	*Falco naumanni*	intercontinental	Raptors MoU		VU	Decreasing	High	I	Falconidae	Rötelfalke	Faucon crécerellette	Cernícalo primilla
87	Aves	Lesser White-fronted Goose	*Anser erythropus*	intercontinental	AEWA, Action Plan		VU	Decreasing	Low	I	Anatidae	Zwerggans	Oie naine	Ánsar chico
88	Aves	Madagascar Pond-heron	*Ardeola idae*	intracontinental	AEWA		EN	Decreasing	Low	I				
89	Aves	Manchurian Crane, Japanese Crane, Red-crowned crane	*Grus japonensis*	intracontinental	-		EN	Decreasing	No info	I	Gruidae	Mandschurenkranich	Grue du Japon	Grulla de Manchuria
90	Aves	Marbled Teal	*Marmaronetta angustirostris*	partial	AEWA		VU	Decreasing	Low	I	Anatidae	Marmelente	Marmaronette marbrée	Cerceta pardilla
91	Aves	Marsh Seedeater	*Sporophila palustris*	intracontinental	-		EN	Decreasing	No info	I	Emberizidae		Sporophile des marais	Capuchino pecho blanco
92	Aves	Olrog's Gull	*Larus atlanticus*	range extension	-		VU	Decreasing	No info	I	Laridae	Olrogmöwe	Goéland d'Olrog	Gaviota de Olrog
93	Aves	Oriental White Stork	*Ciconia boyciana*	intracontinental	-		EN	Decreasing	Low	I	Ciconiidae	Schwarzschnabelstorch	Cigogne orientale	Cigüeña oriental

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94	Aves	Pallas Fish Eagle, Pallas's fish-eagle	*Haliaeetus leucoryphus*	partial	Raptorss MoU	X	VU	Decreasing	Case Studied	I	Accipitridae	Bindenseeadler	Pygargue de Pallas	Pigargo de Pallas
95	Aves	Peruvian diving petrel	*Pelecanoides garnotii*	intraoceanic	-		EN	Decreasing	Medium	I	Pelecanoididae	Garnot-Lummensturmvogel	Puffinure de Garnot	Potoyunco peruano
96	Aves	Peruvian Tern	*Sterna lorata*	data deficient	-		EN	Decreasing	No info	I				
97	Aves	Pink-footed Shearwater	*Puffinus creatopus*	interoceanic	-		VU	Unknown	No info	I	Procellariidae	Rosafuß-Sturmtaucher	Puffin à pieds roses	Pardela patirrosa
98	Aves	Puna Flamingo	*Phoenicopterus jamesii*	intracontinental	High Andean Flamingo MoU	X	NT	Decreasing	Case Studied	I	Phoenicopteridae	Jamesflamingo	Flamant de James	Parina chica
99	Aves	Red Knot (Rufa)	*Calidris canutus (rufa)*	intercontinental	AEWA		LC	Not provided	Low	I				
100	Aves	Red-breasted Goose	*Branta ruficollis*	intercontinental	AEWA	X	EN	Decreasing	Case Studied	I	Anatidae	Rothalsgans	Bernache à cou roux	Barnacla cuelliroja
101	Aves	Relict Gull	*Larus relictus*	intracontinental	-	X	VU	Decreasing	Case Studied	I	Laridae	Gobi-Schwarzkopfmöwe	Mouette relique	Gaviota de Mongolia
102	Aves	Ruddy-headed Goose	*Chloephaga rubidiceps*	partial	Ruddy-headed goose MoU		LC	Not provided	High	I	Anatidae	Rotkopfgans	Ouette à tête rousse	Cauquén cabeza colorada
103	Aves	Rufous-rumped Seedeater	*Sporophila hypochroma*	migrantory	-		NT	Decreasing	No info	I	Emberizidae		Sporophile à croupion roux	Capuchino castaño
104	Aves	Saffron-cowled Blackbird	*Agelaius flavus*	migrant	-		VU	Decreasing	No info	I	Icteridae	Gelbhaubenstärling	Carouge safran	Tordo amarillo
105	Aves	Saunder's Gull, Chinese Blackheaded Gull	*Larus saundersi*	local migrant	-		VU	Decreasing	No info	I	Laridae	Kappenmöwe	Mouette de Saunders	Gaviota de Saunders
106	Aves	Short-tailed Albatross, Steller's Albatross	*Diomedea albatrus*	interoceanic	ACAP	X	VU	increasing	Case Studied	I	Diomedeidae	Kurzschwanzalbatros	Albatros à queue courte	Albatros colicorto
107	Aves	Siberian Crane	*Grus leucogeranus*	intracontinental	AEWA, Siberian crane MoU	X	CR	Decreasing	Case Studied	I	Gruidae	Schneekranich	Grue de Sibérie	Grulla siberiana

No	Class	English	Latin	Migration Classification	Relevant CMS Agreements Identified	Climate Change Vulnerability Assessment pilot case studies	Red List 2010 *Version 2010.1*	Population Trend 2010	Suggested prioritisation for further Climate Change Vulnerability Assessments	CMS Appendix	Family	German	French	Spanish
108	Aves	Slender-billed Curlew	*Numenius tenuirostris*	intercontinental	AEWA, Slender-billed curlew MoU		CR	Decreasing	Low	I	Scolopacidae	Dünnschnabel-Brachvogel	Courlis à bec grêle	Zarapito de pico fino
109	Aves	Sociable Plover (Sociable Lapwing)	*Vanellus gregarius*	intercontinental	AEWA	X	CR	Decreasing	Case Studied	I	Charadriidae	Steppenkiebitz	Vanneau sociable	Avefría sociable
110	Aves	Spanish Imperial Eagle, Adalbert's Eagle, Spanish Eagle	*Aquila adalberti*	partial	Raptors MoU		VU	Increasing	Low	I	Accipitridae	Spanischer Kaiseradler	Aigle ibérique	Águila imperial ibérica
111	Aves	Spoon-billed Sandpiper	*Eurynorhynchus pygmeus*	intracontinental	-		CR	Decreasing	Low	I	Scolopacidae	Löffelstrandläufer	Bécasseau spatule	Correlimos cuchareta
112	Aves	Spotted Greenshank, Nordmann's Greenshank	*Tringa guttifer*	intracontinental	-		EN	Decreasing	High	I	Scolopacidae	Tüpfelgrünschenkel	Chevalier tacheté	Archibebe motaedo
113	Aves	Steller's Eider	*Polysticta stelleri*	intercontinental	AEWA	X	VU	Decreasing	Case Studied	I	Anatidae	Scheckente	Eider de Steller	Eider menor
114	Aves	Steller's Sea-eagle	*Haliaeetus pelagicus*	intracontinental	Raptors MoU		VU	Decreasing	Medium	I	Accipitridae	Riesenseeadler	Pygargue empereur	Pigargo gigante
115	Aves	Strange-tailed Tyrant	*Alectrurus risora*	intracontinental	-		VU	Decreasing	No info	I	Tyrannidae		Moucherolle à queue large	Yetapá de collar
116	Aves	Streaked Reed-warbler	*Acrocephalus sorghophilus*	intracontinental	-		VU	Decreasing	No info	I				
117	Aves	Swan Goose	*Anser cygnoides*	intracontinental	-	X	VU	Decreasing	Case Studied	I	Anatidae	Schwanengans	Oie cygnoïde	Ánsar cisnal
118	Aves	Syrian Serin	*Serinus syriacus*	range extension	-		VU	Decreasing	High	I	Fringillidae	Zederngirlitz	Serin syriaque	Serín de Siria
119	Aves	Waldrapp, Hermit Ibis, Northern Bald Ibis	*Geronticus eremita*	partial	AEWA		CR	Decreasing	Low	I	Threskiornithidae	Waldrapp	Ibis chauve	Ibis eremita
120	Aves	White Pelican, Great White Pelican	*Pelecanus onocrotalus*	partial	AEWA		LC	Not provided	Low	I	Pelecanidae	Rosapelikan	Pélican blanc	Pelicano vulgar

No	Class	English	Latin	Migration Classification	Relevant CMS Agreements Identified	Climate Change Vulnerability Assessment pilot case studies	Red List 2010 *Version 2010.1*	Population Trend 2010	Suggested prioritisation for further Climate Change Vulnerability Assessments	CMS Appendix	Family	German	French	Spanish
121	Aves	White-eyed Gull	*Larus leucophthalmus*	range extension	AEWA		NT	Stable	Low	I	Laridae	Weißaugenmöwe	Goéland à iris blanc	Gaviota de Adén piquirroja
122	Aves	White-headed Duck	*Oxyura leucocephala*	partial	AEWA		EN	Decreasing	Low	I	Anatidae	Weißkopfruderente	Érismature à tête blanche	Malvasía
123	Aves	White-naped Crane	*Grus vipio*	intracontinental	-	X	VU	Decreasing	Case Studied	I	Gruidae	Weißnacken-Kranich	Grue à cou blanc	Grulla de cuelle blanco
124	Aves	White-taled eagle; Grey Sea Eagle	*Haliaeetus albicilla*	partial	Raptors MoU	X	LC	Not listed	Case Studied	I	Accipitridae	Seeadler	Pygargue à queue blanche	Pigargo europeo
125	Aves	Whitewinged Flufftail	*Sarothrura ayresi*	intracontinental	AEWA		EN	Decreasing	Low	I	Rallidae	Spiegelralle	Râle à miroir	Polluela especulada
126	Aves	Zelich's Seedeater	*Sporophila zelichi*	possibly migratory	-		CR	Decreasing	No info	I	Emberizidae		Sporophile de Narosky	Capuchino de collar

Table 1: Full list of CMS Appendix I species indicating which ones have been covered by the climate change vulnerability assessments, their threat status, coverage by CMS agreements (both legally binding and non-binding) and migratory behaviour. The one CMS Appendix II species that is being covered by the assessment, the Narwhal, has been included. The categories of the "migration classification" are taken from GROMS (Global Register of Migratory Species, groms.gbif.org). Glossary of table information provided in Appendix I of this report.

Suggested prioritisation for further Climate Change Vulnerability Assessments column displays the results of a consultation with CMS regarding prioritisation of further species assessments taking into account their political context. Further discussion is provided below.

5.1.3. Prioritisation of Further Species for Assessment

Of the species remaining within Appendix I, CMS was consulted and gradings given to species which politically were seen to have low, medium or high requirements for climate change vulnerability assessments to be carried out in future. These are identified in table 1, column titled "**Suggested prioritisation for further Climate Change Vulnerability Assessments." Species currently covered by CMS agreements or MoU's have been given high priorities as the**se will have active mechanisms by which action can be taken politically. Some bird species covered by AEWA have already been assessed and graded on their climate change vulnerability and these species have been given a low priority for this reason. Others given low priority have either low population levels or other threats that were seen to be more significantly critical for the species survival then climate change. It was felt that these species would not be resilient to climate change impacts, with or without effective management plans put in place to combat such changes unless either the problem of low population or other significant threats have been resolved first. Identifying species which (1) would be most responsive to policy and management plans to build resilience to climate change impacts and (2) where this would have the most positive impacts on long term survival of the species should be a key consideration when selecting species for assessment and more in depth reviews. Focusing limited resources on areas that would provide the most benefits is a key consideration for conservation overall and climate change impacts management is no exception. Species which have not been assessed and have not been given a priority rating are awaiting priority rating confirmation from CMS.

6. Assessment Process Methodology and Discussion

	STATUS IN METHODOLOGICAL DEVELOPMENT
PHASE 1: LITERATURE REVIEWS	DEVELOPED, TESTED & PROPOSED
PHASE 2: CLIMATE CHANGE VULNERABILITY ASSESSMENTS - EXPERT SCOPING REVIEWS	DEVELOPED & PROPOSED
PHASE 3: CLIMATE CHANGE VULNERABILITY ASSESSMENTS – IN DEPTH REVIEWS	DEVELOPED, TESTED, APPLIED & PRESENTED
PHASE 4: INDIVIDUAL SPECIES REPORTS	APPLIED & PRESENTED

An assessment methodology to identify gradings of species vulnerability to climate change has been developed and piloted on case study species within Appendix I of CMS. This assessment methodology is outlined in *Phase 3: Climate Change Vulnerability Assessments In-depth Reviews*. Whilst carrying out the species assessments a large amount of information is required to be reviewed. For effective record keeping it is recommended that this information is gathered into background documents. These background documents form the basis of the next stage in the assessment process *Phase 4: Individual Species Reports*. An example set of these are provided later in this report.

Developing and piloting Phase *3: Climate change Vulnerability Assessments In-Depth Reviews* was a key first step in generating the full proposed assessment methodological process. Firstly this allowed full identification and testing of all criteria and factors that would need to be taken into consideration when reviewing a species climate change vulnerability in a standardised methodology. This has had to be developed to be applicable both across taxa and for species with varying and wide range of habitat types, traits and life history characteristics. Secondly this has tested the validity of using scenarios to identify gradings for species vulnerabilities to climate change and whether this provides a true representation of all the information gathered and entered into the in depth assessments.

Developing and testing *Phase 3: Climate Change Vulnerability Assessments In-Depth Reviews* has provided the foundation for the development of a standardised approach to surveying species specialists with a streamlined version of the same assessment. This is presented as *Phase 2: Climate Change Vulnerability Assessments Expert Reviews*. Scenarios for species climate change vulnerability are provided to experts to grade species vulnerability. In depth write-ups are not required for each assessment section in Phase 2 however rational and some indication of factors are requested to back up scenario selection.

Developing and testing Phase *3: Climate Change Vulnerability Assessments In-Depth Reviews* has also provided the foundation for the development of a standardised approach to reviewing current research that will maximise output potential of this less resource intensive analysis of climate change vulnerabilities. It has also allowed for identification of factors required to be incorporated into this further streamlined review process, as presented in *Phase 1: Review of Current Research Findings* within the methodology.

6.1. PHASE 1: REVIEW OF CURRENT RESEARCH FINDINGS

Stage 1: Overview of research directly relating species with climate change impacts and vulnerabilities

This stage represents a first wave review of all literature identifying species directly with observed and / or potential impacts from climate change. Reference lists are collated on each species, taxa and relevant group and presented in a format that allows for easy identification of gaps in literature.

Stage 2: Review of research directly relating species with climate change impacts and vulnerabilities

This stage compares available information against a standardised set of factors for review. This provides a mechanism that allows for easy analysis of factors once this stage of species review has been completed. It also provides complimentary policy information driven assessment process.

Phase 2 and 3 assessments carried out on species focus on providing a climate change vulnerability grading for each species, giving High/Medium/Low vulnerability indicators for flagging up species for further attention by CMS. However it has also become apparent that other information would be of use to CMS for policy analysis. In light of these findings a Phase 1 quick assessment process has been developed for consideration. This assessment process will not give an output of high/medium/low climate change vulnerability gradings for each species. However it will provide information such as; number of migratory species which are threatened by, for example, temperature increases or ocean acidification.

Key factors that have been identified as of value to CMS are outlined in the table below. Further factors of value for review may become apparent after discussion with CMS, for example, such as threat from desertification if CMS wish to highlight species of concern to the UNCCD.

Table 2: Key factors identified for Phase 1 Stage 2 review.

Climate Change Impact / Vulnerability Overall
Climate Change Process - Temperature Impacts / Vulnerability
Climate Change Process - Precipitation Impacts / Vulnerability
Climate Change Process - Sea Level Rise Impacts / Vulnerability
Climate Change Process - Ocean Circulation Impacts / Vulnerability
Climate Change Process - Ocean Acidification Impacts / Vulnerability
Climate Change Process - Extreme Weather Events Impacts / Vulnerability
Climate Change Process - Season Changes Impacts / Vulnerability
Climate Change and Biological Response Process - Phenological Shifts Impacts / Vulnerability
Climate Change and Biological Response Process - Biome Shifts Impacts / Vulnerability
Climate Change and Biological Response Process - Food Availability Impacts / Vulnerability
Climate Change and Biological Response Process - Species Interactions (prey/competitor/symbionts) Impacts / Vulnerability
Climate Change and Biological Response Process - Reproduction (rates and fecundity) Impacts / Vulnerability
Climate Change and Biological Response Process – Range Shifts Impacts / Vulnerability
Climate Change and Biological Response Process - Adaptation Potential
Climate Change Interactions with other Threats - Limits to Dispersal / Migration to Suitable Future Habitats
Climate Change Interactions with other Threats - Disease Impacts / Vulnerability
Climate Change Interactions with other Threats - Invasive Species Threats Impacts / Vulnerability
Climate Change Interactions with other Threats - Habitat Fragmentation / Degradation Impacts / Vulnerability
Climate Change Interactions with other Threats - Other Synergistic Anthropogenic Threats Impacts / Vulnerability

A potential format for gathering this information has been outlined below. The section highlighted would be repeated for each factor under review for each species.

Table 3: Potential format for Phase 1 Stage 2 and Stage 3 reviews.

						Climate Change Process – Temperature Impacts / Vulnerability			
						Temperature	**Temperature**	**Temperature**	**Temperature**
	Taxa	**IUCN RED list Status**	**Population Trend**	**Habitat Type**	**Regional Extent**	**Directly observed climate change impacts**	**Peer reviewed literature directly predicts climate change impacts on species**	**Indirect evidence of species vulnerability from peer reviewed literature**	**This study concludes (using indirect evidence and compares vulnerability indicators identified with climate change predictions)**
Species name - Common, *Latin*	*Taxa*	*IUCN Status*	*Increasing / Decreasing / Stable*	*Habitat Type*	*Regions*	*Yes / No / No evidence available and further research required / NA*	*Yes / No / No evidence available and further research required / NA*	*Yes / No / No evidence available and further research required / NA*	*Yes / No / No evidence available and further research required / NA*
						Identifier details / Impact markers / Direction of change / Importance (with reference marker on each (1) (2) (3) ..)	*Identifier details / Impact markers / Direction of change / Importance (with reference marker on each (1) (2) (3) ..)*	*Identifier details / Impact markers / Direction of change / Importance (with reference marker on each (1) (2) (3) ..)*	*Identifier details / Impact markers / Direction of change / Importance (with reference marker on each (1) (2) (3) ..)*
						References (Hyperlinked to original) (1) (2) (3) (4) (5)	*References (Hyperlinked to original) (1) (2) (3) (4) (5)*	*References (Hyperlinked to original) (1) (2) (3) (4) (5)*	*References (Hyperlinked to original) (1) (2) (3) (4) (5)*

OPTIONAL Stage 3: Review of research indirectly relating species with climate change impacts and vulnerabilities.

This stage uses the same format in Stage 2 of reviews but additional information is added and marked as non-direct species related information. A wider review of current information relating to but not directly linked to species would be required to fulfil this stage. Our study has shown that this is often the most valuable part of the assessments with the most relevant information being found here, especially for species which currently have no direct literature relating them to climate change impacts and / or vulnerabilities. Clear links i.e. reductions in krill which have not yet been linked in the literature directly to individual species responses (such as those with an obligate dependency on krill resources) can be picked up in such a review. This compensates for the time lag that occurs between (1) observations and research findings and (2) the publication or output of these findings through formal avenues. This stage of the assessment process will also highlight areas for further research where none have been found and highlight potential links. Resources permitting, this stage will provide a very valuable part of the assessment process allowing for wider scope of species review.

Potential format for Phase 1 Stage 3 reviews has been incorporated into table 3 above.

6.2. PHASE 2: CLIMATE CHANGE VULNERABILITY ASSESSMENTS – EXPERT SCOPING

The development and application of Phase 3 in depth reviews has allowed this study to test the potential for expert scoping reviews using a more streamlined method.

Piloting the assessment process on case studies has allowed for identification of potential areas where problems may have occurred when experts completed such an assessment and the methodology has been altered accordingly to be most explanatory and self guiding. It was felt that scenario selection was the most appropriate method by which experts could grade species. This method makes it very clear that we are using expert opinion to identify the most likely case for each species. Under time and resource constraints this is the most affective means to review a large number of species and allow for pick up of the key species recognised at most risk. Further information points are requested so that these reviews can be picked up in more detail in Stage 3 if felt necessary. This stage provides a useful means of flagging species up for further research or initiate climate policy focus on species likely to be most at risk.

It also will help develop a network of specialists linked to CMS that are engaged with research into the climate change vulnerability of their focal species. Developing relationships early on will be key if a proactive and responsive approach to climate change is to be taken in future. As climate change increases in intensity it is essential that the foundations are built with specialists to advise policy makers as well as mechanisms for effective action to be taken, so that responses do not have to lag considerably behind events. There is the potential for climate change events to become more extreme and unpredictable and in such a situation a more adaptive approach to conservation management will have to be taken to protect species that allows for rapid and effective responses to changing conditions and situations.

6.2.1. Expert Scoping Review Process

- **Specialist identification and contact**

Identification and engagement of a minimum of one specialist will be required per species under review. Phase 1 review of individual species current research provides a good foundation for identification of key specialists whose species work relates to climate change. Species specialists who are already considering climate change and species vulnerabilities / impacts are preferred subjects to approach for this stage of review. Preliminary work has been carried out on Appendix I species identifying the experts most involved in climate change research for each species. Please see Appendix 3 of this report for an initial proposed list of specialists for contact. These contacts have been identified through this study and have not provided by CMS. Current relationships CMS has with species specialists will also be a beneficial resource for use. It is recommended that CMS use its network of experts currently linked through the Scientific Council to disseminate and facilitate engagement. To this end it is recommended that the Scientific Council leads in terms of (1) identifying, contacting and engaging specialists, (2) facilitating dissemination of expert scoping reviews and (3) collating results and providing feedback. This engagement will form the basis of any systematic ongoing review of species with species specific specialist involvement. It is recommended that long term relationships be formed by CMS with key species specialists to provide a mechanism by which they can input into policy and management decisions and communicate the latest information on climate change impacts and vulnerabilities, both observed and predicted, of their associated migratory species thereby increasing capacity for responsive, proactive and effective decision making.

- **Feedback from experts**

An initial expert scoping review pilot study is recommended. Expert scoping review forms should be sent to selected experts and a further form providing them with the opportunity to give feedback on the process so that any issues or queries can be identified early on. This can then be reviewed alongside expert scoping assessments. The objectives of such an assessment is that results are standardised across the range of specialists contacted so that bias does not enter into the assessment or affect final species vulnerability gradings.

Once such aspects of the expert scoping review have been clarified and the review template modified as required the final template can be sent out to the full range of experts for engagement. This process of communication with experts should be lead by CMS to facilitate long term engagement and this will also have the added benefit of potentially increasing the number of responses and quality of feedback from experts.

- **Collating and analysing results**

Expert scoping reviews will be collated and results analysed. Reviews must be checked for standardisation of results and for any gaps in the assessments made. Any areas that specialists have not been able to complete need to be referred to further experts for review.

- **Potential referral to further experts**

A second set of species specialist contacts should be kept for referrals where primary contacts have been unable complete assessments. These set of experts would benefit from having a range of climate change specialists represented. There is the potential that the first section of the assessment, which reviews habitats vulnerability to climate change, may be deferred by species specialists. Although they will be able to identify the species habitat requirements and usage they may not have full knowledge of climate model predictions for these areas and may not feel confident in their selection of appropriate scenario to assign. Where necessary this section would benefit from applied knowledge being gathered from the selected species specialist and further information overlaid from climate change specialist sources.

- **Final assignment of vulnerability gradings**

Assessments and rational for scenario selection will require review and final confirmation of gradings will need to be assigned by a centralised source to standardise final outputs.

- **Reporting**

Final outputs in terms of climate change vulnerability gradings for species reviewed will be analysed and reported in a defined format to fit the purposes of CMS.

6.2.2. Proposed Expert Scoping Review Assessment Form

Climate Change Vulnerability of Migratory Species

Species Assessment

Specialist name:	
Institutional links:	
Position:	
Email:	
Phone:	
Species scientific name:	
Species common name:	

Guidelines for Grading Severity of Threat from Climate Change

This assessment will provide scenarios of climate change threat that will be used to grade species vulnerability. As species specialists you are being asked to identify scenarios most applicable to the species under review for each assessment criteria outlined. **Further information is also requested to support and provide rational for your selections.** This information will indicate species vulnerability, with grades ranging from; 1 low risk, 2 low/medium risk, 3 – medium risk, 4 – medium/high risk and 5 high risk.

Impacting factor	Severity of impacting factor					Other considerations
	1	2	3	4	5	
Vulnerability of habitat/s:						
Resilience to change >Climatic changes projected for habitat area. >Impact that projected changes will have upon the habitat.	Minimal impact on habitat(s) utilised. Habitat likely endure climatic changes largely unchanged	Some impacts on habitat(s) utilised. Habitat likely to endure climatic changes with few changes	Moderate projected changes within habitat(s) due to climate change. System function and essential niche occupied by species operational to some extent but degraded and fragile.	One or more vital habitat(s) projected to be highly degraded by climatic changes	One or more vital habitat(s) projected to be severely degraded by climatic changes	Ability of the habitat to maintain pace with the projected eco-zone (bioclimatic envelope) shift and any barriers to that shift should be considered. Will habitats shift across large distances? Will changes occur rapidly?
Further Information ▪ State habitat type used and regional range extent ▪ State climate change model projections of concern ▪ Grading must be based on the mid range climate change scenario AB1						
Supporting evidence / references						

Impacting factor	Severity of impacting factor					Other considerations
	1	2	3	4	5	
Ecological flexibility and adaptation potential:						
Degree of specialisation	Dynamic species with a wide diet and a broad niche. Species may utilise many habitats. Equipped to manage a changing environment.	Species has a wide niche and a varied diet. Species may utilise a number of habitats.	Some degree of specialisation, some biological requirements, including dietary and habitat, are limited / rare or found in few areas.	Specialised species with a well defined niche. Specific and limited dietary and habitat requirements.	Highly specialised species. Sensitive species with a narrow niche breadth. May be endemic to one region/area.	Ability to adapt to changing conditions and switch food or other resource requirements. Is the species current habitat and/or resource use facultative or obligate? What factors limit species adaptation potential?
Environmental triggers and phenological cues	No fixed dependency on phenological cues or triggers that will be affected by climate change.	Little dependency on phenological cues or triggers that will be affected by climate change and high ability to adapt.	Potential dependency on phenological cues or triggers that will be affected by climate change but some ability to adapt.	Dependency on phenological cues or triggers that will be affected by climate change but some ability to adapt.	Fixed dependency on phenological cues or triggers that will be affected by climate change. Little ability to adapt.	Will changes in environmental triggers lead to phenological mismatch?
Evidence of adaptation in the past	Evidence of rapid migration and adaptation response to climatic changes in the recent past. Culturally driven migration rather than genetically driven migration.	Migration and adaptation response to climatic changes in the past have been good and is likely to be sufficient to keep pace with projected rates of ecosystem shift.	Some migration and adaptation response to climatic changes in the past.	Migration and adaptation response to climatic changes in the past have been slow and is likely to be slower than projected rates of ecosystem shift.	No evidence of migration or adaptation response to climatic changes. Genetically driven migration rather than culturally driven migration.	Is there any evidence of migration/ecological changes since the end of the last ice age? What does this evidence infer upon the prospects of future adaptation? If no evidence is found at all in regard to this section please identify as NA.

Dispersability	High ability to disperse to new areas and shift migration patterns. No natural barriers to migration to new or more suitable range/ habitats.	Some ability to disperse to new areas and shift migration patterns. Minimal natural barriers to migration to new or more suitable range/ habitats.	Moderate ability to disperse to new areas and shift migration patterns. Some natural barriers to migration to new or more suitable range/ habitats.	Little ability to disperse to new areas and shift migration patterns. Several natural barriers to migration to new or more suitable range/habitats which will make dispersal hard but not impossible.	Migration patterns are fixed to specific areas. No ability to disperse to new or more suitable range/ habitats. Natural barriers prevent dispersal to more suitable range/ habitats.	Are species dependent on a vector such as wind and water currents for migration and dispersal? Are these vulnerable to change and will this limit the species ability to disperse to new suitable habitats? Are critical life stages threatened by these changes? Are there sufficient metapopulation numbers in areas adjacent to new suitable habitats that will facilitate effective dispersal?
Reproduction rate and resilience: Climate related changes to fecundity or reproductive success	Rapid reproduction rate, no known climate related changes to fecundity or reproductive success. Species environmental tolerances will not be exceeded due climate change and reproductive resilience is shown.	Good reproduction and little climate-related reduction of fecundity or reproductive success expected. Displays reproductive resilience to potential climate change impacts.	Average reproduction rate. Some climate-related reduction of fecundity or reproductive success expected. Non optimal environmental tolerances experienced with some impacts on reproductive success.	Below average rate of reproduction. Reproduction likely to be hampered by climate change related decrease in fecundity. Low reproductive resilience to potential climate change impacts.	Slow rate of reproduction. Reproduction likely to be hampered by climate change related decrease in fecundity. Species environmental tolerances will be exceeded resulting in low reproductive resilience to climate change impacts.	The biological aspects of dispersability should be considered. Are specific metapolulations at greater risk?
Further Information ▪ State diet / niche utilised ▪ State key environmental triggers of concern ▪ State evidence of migration in due past climatic changes and rate ▪ State ecosystem shifts of concern (rate of shift where possible)						

▪ State key dependencies that are vulnerable to climate change ▪ State adaptation type ▪ State natural barriers to dispersal ▪ State reproductive rate and limiting factors		
Supporting evidence / references		

Impacting factor	Severity of impacting factor					Other considerations
	1	**2**	**3**	**4**	**5**	
Species interactions:						
Changing dynamics of predator/ prey/ competitor interactions	No known dependency on any interspecific predator / prey / competitor interactions that are likely to be disrupted by climate change.	Major disturbance of the foodweb unlikely due to climate change impacts. Impacts on interspecific predator / prey / competitor interactions and community likely to be small	Moderate disturbance of foodwed possible due to climate change impacts. Moderate reduction of food resources or moderate increase in predation likely. Some impacts on interspecific predator / prey / competitor interactions and community likely.	Moderate to high disturbance of foodwed probable due to climate change impacts. Some major impacts on interspecific predator / prey / competitor interactions and community likely.	Disappearance of prey species or inability to catch dependent prey due to climate change impacts. Increase in threat to species due to burgeoning predator or competitor populations	The degree of reliance on other species that may be affected by climate change. How will climate change affect the foodweb and timing of resource availability? What is the cumulative impact for populations of the species in question? Will predator / prey / competitor species be affected by changes in environmental triggers or phenological cues and how will this impact on subject species?

Impacts upon mutualisms/ symbiosis.	No disorientation of important mutualism. Moderate disorientation of some non-dependent mutualisms due to climate change.	Partial disorientation of some important mutualism. Moderate disorientation of some non-dependent mutualisms due to climate change.	Serious disruption of some non-dependent mutualisms. Moderate disorientation of dependent mutualisms due to climate change.	Serious disruption of dependent mutualism/s due to climate change.	Evidence of breakdown of the necessary dependant mutualisms due to climate change.	Number of mutulisms important, as is the relative reliance upon those mutulisms
Further Information ▪ State linked species and type of interaction affected; predator/ prey/ competitor/ mutualistic/ symbiotic ▪ State climate change impacts on interspecific species ▪ State phenological interactions affected						
Supporting evidence / references						

Impacting factor	Severity of impacting factor					Other considerations
	1	2	3	4	5	
How do other threats act synergistically with climate change?						
Habitat loss/ fragmentation	Intact habitat, little evidence of disturbance affecting habitat and species resilience to climate change impacts	Some habitat disturbance, loss or fragmentation, but habitat largely intact and resilience to climate change impacts not seen to be greatly affected.	Fragmented/depleted habitat but large areas still intact. Habitat and species resilience to climate change impacts has been greatly depleted but still opportunities for bounce back if good management and restoration practices are put in place and adhered to.	A high level of habitat loss/fragmentation. Significant implications for habitat and species resilience to climate change	Habitat loss/fragmentation severe. Greatly impacting habitat and species resilience to climate change	Other threats should also be noted. Will anthropogenic activities act synergistically with climate change to increase habitat loss/ fragmentation? Will anthropogenic transformation of migration route or newly climatically suitable areas create barriers to migration or dispersal? Will this be due to agriculture, deforestation, urbanization or other activities?
Exploitation	No significant exploitation. No affect on species resilience and adaptation potential to climate change.	Low levels of exploitation with minor impact on resilience and adaptation potential of species to climate change.	Moderate levels of exploitation with some impacts on species resilience and adaptation potential to climate change.	High levels of exploitation impacting on species resilience and adaptation potential to climate change.	Unsustainable exploitation posing a serious threat to the viability of the species. Exploitation levels give little chance that species will be able to adapt and have resilience to climate change impacts.	Will exploitation increase with climate change predictions or will species be exposed to new exploitation threats as they migrate to new areas?
Disease	No known disease threat and no predicted disease threat increase due to climate change	Low disease threat and some increase due to climate change	Medium level of disease threat with impacts on population levels increasing as a result of climate change.	Significant level of disease threat with strongly increased impacts on population levels as a result of climate change.	Disease a serious threat to the viability of the species and threat levels will be greatly increased by climate change.	Will disease spread to new areas that will affect species due to climate change?

Invasive species	No known threat from invasive species due to climate change	Some invasive species will compete indirectly for resources due to climate change	Likely that some invasive species will compete directly for resources due to climate change	Available resources substantially diminished by invasive species due to effects of climate change increasing their competitive advantage	Habitat very likely to be invaded by species which will directly outcompete the subject species, or destroy the dependent food-web, due to climate change	Will invasive species range be increased by climate change? How will this impact species both directly and indirectly?
Further Information ▪ State threat and source of threat to habitats ▪ State exploitation type ▪ Name disease of concern ▪ State invasive species of concern						
Supporting evidence / references						

6.3. PHASE 3: CLIMATE CHANGE VULNERABILITY ASSESSMENTS – IN DEPTH REVIEWS

This preliminary review and pilot study has focused on the development of in depth reviews for selected species within Appendix I, fulfilling Phase 3 and 4 of the proposed species assessment process. This was seen to be a key step towards the effective development and testing of this phased approach.

Climate Change Vulnerability Assessment Methodology

Each species have been evaluated against 4 categories of factors:

- Vulnerability of habitat/s
- Ecological flexibility
- Species interactions
- Synergistic threat processes

We performed a review of the peer reviewed literature for information directly relating climate change threat to species. Where direct information was not available peer reviewed literature was used to identify traits, characteristics and trends in species that could make them vulnerable to climate change impacts. A whole range of life history traits, species characteristics and factors that make species vulnerable to climate change were identified in the following studies; Silwood Park Species Vulnerability Workshop 2007 and the CMS Climate Change and Migratory Species paper 9.24. From this basis we compiled all those most relevant to migratory species into the four factor headings defined above during the development of the assessment process. These factors were then compared to the A1B scenario of climate change as outlined by the IPCC as a "mid range scenario" to identify potential relationships between predicted climate change impacts and effects on species and related habitats, interspecific interactions and synergistic threats. Any inferences made by the assessment are made explicit within the assessment process. Areas where information was lacking have also been identified and made explicit.

Information collected on the four categories and factors within them were assessed against Assessment Criteria. These Assessment Criteria provide a choice of 5 scenarios to which the situation of the species being assessed was matched accordingly to the best available information as reviewed during the assessment process. These scenarios provide a guide by which species can be given a threat grade to standardise outputs.

6.3.1. Vulnerability of Habitat/s

In the context of this project, we define species habitat/s as those that provide the species niche requirements and not just the areas in which they currently inhabit. Anthropogenic pressures may be excluding species from certain areas which would otherwise be suitable. Therefore we would consider historic range when identifying key habitat/s. Consideration was also given to the 'climatic envelope' of key habitats identified. Within this section of the assessment, wherever possible and appropriate information was gathered to cover key questions such as:

- Has modelling been carried out to identify the climate change impacts on habitat extent and area coverage?
- How will the climate projections affect the habitat of the species?
- What are the likely affects of climate projections on the species future populations and range?
- Are there any natural barriers to habitat shift or species utilisation of optimum future habitat areas? Will there be mismatch between the climatic envelopes of habitats and the rate at which habitat shifts can occur?

When carrying out this section of the assessment the information on habitat vulnerability within the following reference was used as a key baseline from which to carry out the review:

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007: Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

All impacts were based upon the A1B projections for the end of the 21st Century, unless other data more specific to the area, was available. If an emissions scenario used which was not A1B, this would be made clear in the assessments. This point is very important as it gives a standardised climate change scenario by which species were reviewed. If in reality this scenario is found to be less reflective of the true emission levels and related climatic warming occurring then this section will have to either be reviewed or final scoring of this section upgraded to relate fully to the increased effects of warming and climate change on species studied.

The Habitat Vulnerability sections were scored on a 'weakest-link' basis. If one habitat highly relied upon by the species in question was likely to be 'highly degraded' by climate change whilst the other habitat highly relied upon by the species would see 'minimal impact'; the overall habitat vulnerability score was based on the degree to which the most vulnerable habitat would be impacted by climate and the degree to which the species displayed obligate or facultative dependency on each habitat. It was felt that if a species had an obligate dependency upon a specific habitat at some point in its life cycle and that habitat is likely to be degraded then that makes the species vulnerable, regardless of the stasis in the other habitat/s utilised.

6.3.2. Ecological Flexibility

Ecological flexibility was assessed to identify the capacity of the species to adapt to climate change. A whole range of life history traits and species characteristics were identified as influencing adaptability and these were reviewed in this section. Two main factors were considered and these results of these sections given priority when during the grading species on their overall ecological flexibility: rate of reproduction and degree of specialisation. Further factors were also considered in this part of the assessment that have been shown to influence species responses to climate change and therefore adaptability. These included environmental triggers and phenological cues, evidence of adaptation in the past, evolution and genetic plasticity, life-cycle dynamics, dispersal rate and any climate related changes in fecundity. Information on each factor was gathered for species and graded according to scenarios

The **Degree of Specialisation** assessment factor was used to identify with the apparent ability of the species to adapt to climatic change. If the degree of specialisation is very high (requiring a very specific food source or habitat), there is a greater likelihood that the species would be unable to adapt to climatic changes. If the degree of specialisation is low, then the species is more likely to be able to move to a different niche: for example, they may be able to alter their diet if traditional food items become increasingly scarce, or breed in a different habitat if the traditional habitat no longer holds the correct physio-chemical or biological conditions.

The **Rate of Reproduction** was used as an indicator to infer to what extent a species may adapt to environmental changes. This can inform us of its capability to maintain a viable population during times of increased pressure and it can also help to describe how a population might be expected to recover after a period of low productivity. Here we are looking into more details about the species population dynamics. Rapid reproduction rates suggest a species would be capable of a rapid recovery, whereas a slow reproduction rate suggests that the species is more likely to have poor recovery rates after episodes of population loss. The longer the species population requires to recover from a low level, the less chance it has of surviving increasingly frequent years with harsh conditions.

Evidence of adaptation in the past including changes in migration patterns and changes in diet, especially those which have been directly correlated to climatic changes and pre-anthropogenic influences, were noted within this section. These were used to inform the degree of specialisation of the species only if the information was valid and relevant. Evidence of a recent change in life history was also noted if it suggested that the species may have a better than average chance of adapting to different habitat conditions. However it is also clear that a lack of evidence of past adaptation is not an indication that the species does not possess ecological flexibility. There is also no evidence that past success and adaptability predicts future success and ability to adapt so any information gathered for this section was only used to inform the assessment rather then specifically used to grade the species ecological flexibility. For many species no data was available for this section; however it was felt that it could not be completely overlooked in cases where it may be informative.

Genetic plasticity: It is well documented that climatic influences play a major role in limiting species range (Bale et al. 2005; Parmesan et al., 2005; Hoegh-Guldberg, 2005), however it is the capacity for evolutionary adaptability and phenotypic plasticity within a species which governs the response times between environmental pressures and biological alterations. Whilst it is well documented that some biota show local adaptation to climatic changes at specific sites (Hill et al. 1999; Thomas et al., 2001), Parmesan (2006) reported that during the Pleistocene glacial events, temperature shifts were 5-10 times the magnitude of that observed during the twentieth century, yet no major speciation events were documented. Therefore, if it is assumed that biological responses to climatic change will be similar to those in the Pleistocene, species are more likely to shift their geographical distribution, rather than remaining stationary and evolving adaptations with which they can remain stationary, albeit in a changed habitat.

Species with short generation-times may show more potential for evolutionary adaptation, however the CMS Appendix I covers only large vertebrates, which are much longer-lived than average fauna. It is therefore highly unlikely that most species will have the capacity to evolve to adapt to projected climatic changes under the timescales in consideration. Because of this, capacity for evolutionary adaptation was not identified as a key factor for grading the Ecological Flexibility of species within the assessment, however if references to this for specific species are encountered during the literature search, these were noted.

There are some situations where a long-lived and slow-breeding species may survive periods of low productivity. For example, in a period of drought where short-lived, fast breeding species are unable to reproduce successfully, the population is likely to suffer as reproduction fails and the older individuals perish. Longer lived species may in some situations be capable of coping better with such periods of low productivity as they can "sit-out" such events and await the return of more favourable conditions. This scenario would require the mature individuals having sufficient resources to persist and would also require a low mortality rate. Again, if a situation is encountered where a species is likely to be subject to sporadic severe climatic periods where a long-life cycle may prove to be advantageous for the long-term viability of the population, this will be considered in the assessment, but it would not form a part of the assessment grading.

Climate related changes in fecundity: There is evidence to show that climatic changes can affect the fecundity of biodiversity. For example, the fecundity of the lemur (Propithecus edwardsi) in Madagascar was shown to be over 65% lower during El Nino years. Dunham et al. (2008) predicted that if El Nino events occurred at high frequency, this would have serious implications for the lemur population. The vulnerability which the species in question faces due to a change in fecundity depends upon the reproduction rate of the species in question and will be considered accordingly. Any climate related changes in fecundity either observed or predicted within current research have been identified within this section and incorporated into the assessments. Any climate related limitations to fecundity have also been identified. These were used to inform the rate of reproduction criteria under projected climate regimes.

Sex Ratio: In addition to changes in fecundity, climatic changes have also been observed to affect the sex ratios of offspring. For all species where evidence was available on likely impacts of climate change, most prominently temperatures, on the offspring sex ratio this was recorded and incorporated into the assessments. Results of these were most strongly linked to the rate of reproduction criteria gradings of species.

Dispersal rate refers to the ability of the population to colonise or re-colonise areas beyond their range boundary. The rate of dispersal is a significant factor in the species ability to adapt to climate change. A species which is highly mobile, can tolerate a broad range of environmental conditions, shows good population recovery in areas where they have become locally extinct but re-colonised or has been identified as having colonised new areas should be capable of higher rates of dispersal.

6.3.3. Species Interactions

Species interactions were assessed to evaluate how projected climatic changes might impact the species via the interactions which it shares with other species. This includes predator – prey dynamics, symbiotic relationships, competitor relationships and mutualisms. Note that vegetation interactions were assessed in the Habitat Vulnerability section and not included in this section.

Identification of each species prey, predator, symbiotic, competitor and mutualistic interspecific relationships was required for each species. Reviews were then carried to see if any direct information was available linking the study species to species interactions and the impacts of climate change on these. Where there was a lack of direct information, which was often the case, reviews were carried out on each related species identified to see if there was any evidence of climate change impacts or vulnerabilities presented within previous research.

The key question that was posed to assessors when carrying out this section of the assessment was :

- What species interactions are the most important to the survival of the subject species and how will these be impacted by climate change?

For some species it was difficult to find any relevant data, as the White-Tailed Eagle assessment exemplifies. But at the other end of the spectrum, a substantial body of work on this could be found for other species, for example the Balearic shearwater.

6.3.4. Synergistic Threat Processes

The way that other anthropogenic threats interact with climate change threats is very important. In the absence of other anthropogenic threats, extinction risk from the impacts of climatic change would be substantially reduced. However, many anthropogenic impacts have had a deleterious effect upon ecological resilience and as a result many species are increasingly vulnerable to climate change impacts (CBD, 2010).

Degradation and fragmentation of habitat is regarded as the principal threat to terrestrial biodiversity (MEA, 2005). With decreasing areas of suitable habitat, the population of a species is limited. In conjunction with this, the more fragmented a habitat becomes, the more "edge effect" threats the species is likely to face (Leakey & Lewin, 1995). These edge effects include increased interaction with humans, exposure to predators and competitors and a high chance that further habitat loss or fragmentation will occur in the future. The interaction these impacts would have with climate change was reviewed within the assessments. A major key point which was assessed in this section was the potential for habitat degradation and fragmentation to limit species ability to migrate, shift their ranges and gain access to suitable habitat areas under new climate change regimes.

Human activities such as agricultural expansion, livestock grazing, and exploitation have increased the threats faced by the species. The interaction these impacts would have with climate change was reviewed within the assessments.

If virulent **diseases** which increase mortality or reduce fecundity are known to be prevalent within the population, the vulnerability or the capacity of the species to persist through and adapt to climatic changes are likely to be diminished. In this section, any references found showing increased disease risk due to the projected climate change were noted.

The presence of **invasive species** which may diminish resources or out-compete the species for habitat or resources can have a significant impact upon the resilience of a species. If climate change increased the threat of invasive species spread this would be included in the assessment process.

Any potential for anthropogenic impacts to increase due to climate change or climate change mitigation and adaptation measures that would likely impact on the species was also noted.

6.3.5. Management and Policy Recommendations

Currently, climate change does not constitute a large consideration when management plans are produced to protect endangered species. This section aims to use species assessments to highlight potential effective conservation and policy measures that can be taken to mitigate the worst impacts of climate change identified for each species as well as facilitate species adaptation to climate change.

In this initial scoping phase, these assessments sections do not claim to represent a comprehensive overview of actions that must be taken. However, by noting management options that become apparent during the assessment, this can be used as a starting point from which policies or more comprehensive and conclusive recommendations can grow. Any recommendations made within this review section are initial comments on and identify areas for consideration in further reviews.

The CBD (2010) states…

> "***The resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation, restoration and sustainable management strategies.***"

…and therefore any improvements that were encountered during the review process which deal with these factors were also noted for further investigation.

Some initial questions which were kept in mind when reviewing this section of the assessments and addressed whenever appropriate or where information was found to be available included:

- How can threats affecting species resilience be mitigated by altering conservation efforts?

- Do current conservation practices appear to be affective or are there important threats that are still unaddressed that will limit species resilience or adaptation to climate change?
- Can restoration improve the adaptive potential of the habitat when threats affecting the habitat and its resilience to climate change are considered of vital importance to species survival?
- If habitat loss due to climate change is one of the main threats to the species, can conservationists aid the shifting of the habitat to areas where the climate would be more suited?
- Are the international policies in place to protect the species sufficient? Would new transboundary policies help alleviate threats/assist adaptation?
- Is there a CO_2 threshold past which this species will not survive? If a reference to a specific threshold exists, this is important factor to consider in management plans and was noted whenever information was available.

Within this preliminary review this section is not included within the case study assessments that have been made available. These can be obtained on request.

6.3.6. Rational for a Qualitative Approach to Species Assessments

The assessment process currently developed is a qualitative one rather then a quantitative one. This was felt necessary to use a qualitative assessment process as the boundaries and thresholds that would be required for a quantitative assessment are currently not well understood. Alongside this are issues of information gaps and the wide range of un-standardised information types available for species that would not easily fit within set boundaries defined by a quantitative assessment process.

There is a critical need for assessments that clarify which species are most likely to be vulnerable to climate change before it is too late for action to be taken to mitigate or reduce such risks. This need has prompted the development of a qualitative approach that will be able to take full advantage of all information available to make an assessment based on best current knowledge. This qualitative assessment approach attempts to deal with the lack of information availability and provides a transparent set of rules by which the assessment can attempt to clarify the relative threats posed to each species listed on CMS Appendix I from climate change. A qualitative approach has been currently viewed as best method of dealing with the current uncertainties involved, in climate change and species response, as these can be made explicit within the assessments. It has also provides the foundation for comparison of all the facets of the wide range of taxa within CMS appendices. These assessments can be reviewed and updated as new information becomes available.

A quantitative approach would clearly be better if a standardised set of information for species vulnerability to climate change were available. Without this however a quantitative approach may obscure and omit potentially important information that is valuable when assessing species vulnerability. Although the current qualitative approach makes best use of current available information it has been developed and compiled in a way that was felt would allow for adaptation to a more quantitative system in the future as more information becomes available.

Within this preliminary review specialists were also consulted whenever possible on the completed assessments which were provided to them for review and inclusion of any further information for consideration. It has been noted from the response that these assessments provide a valuable framework for discussion with specialists of the climate change vulnerabilities of individual species. A rigid and quantitative approach would not lend itself to this level of review.

A major limitation of using such a qualitative approach is it does not lend itself to easy analysis of factors that are involved in species vulnerability. Phase 1 reviews do however go some way to reconciling this issue as these do provide another level of review that splits the results into different categories allowing for a more detailed quantitative level of analysis which would easily output figures such as number of species impacted by ocean acidification. Applying this process is beyond the scope of the current study however this assessment methodology is outlined within this report for further consideration.

6.3.7. Guidelines for Grading Species Vulnerability

The data collected on the four categories were assessed against Assessment Criteria (provided below) and given a grade from 1-5 (1 low risk, 2 low/medium risk, 3 – medium risk, 4 – medium/high risk, 5 high risk). The Assessment Criteria provides a choice of 5 scenarios to which the situation of the species being assessed was matched accordingly to available information as reviewed during the assessment process. These scenarios provide a guide by which species can be given a threat grade to standardise outputs.

Scenarios of Climate Change Threat used to Grade Species Vulnerability

Impacting factor	Severity of impacting factor					Other considerations
	LOW (1)	LOW / MEDIUM (2)	MEDIUM (3)	MEDIUM / HIGH (4)	HIGH (5)	
Vulnerability of habitat/s:						
Resilience to change >Climatic changes projected for habitat area. >Impact that projected changes will have upon the habitat.	Minimal impact on habitat(s) utilised. Habitat likely endure climatic changes largely unchanged	Some impacts on habitat(s) utilised. Habitat likely to endure climatic changes with few changes	Moderate projected changes within habitat(s) due to climate change. System function and essential niche occupied by species operational to some extent but degraded and fragile.	One or more vital habitat(s) projected to be highly degraded by climatic changes	One or more vital habitat(s) projected to be severely degraded by climatic changes	Ability of the habitat to maintain pace with the projected eco-zone (bioclimatic envelope) shift and any barriers to that shift should be considered. Will habitats shift across large distances? Will changes occur rapidly?
Ecological flexibility and adaptation potential:						
Degree of specialisation	Dynamic species with a wide diet and a broad niche. Species may utilise many habitats. Equipped to manage a changing environment.	Species has a wide niche and a varied diet. Species may utilise a number of habitats.	Some degree of specialisation, some biological requirements, including dietary and habitat, are limited / rare or found in few areas.	Specialised species with a well defined niche. Specific and limited dietary and habitat requirements.	Highly specialised species. Sensitive species with a narrow niche breadth. May be endemic to one region/area.	Ability to adapt to changing conditions and switch food or other resource requirements. Is the species current habitat and/or resource use facultative or obligate? What factors limit species adaptation potential?
Environmental triggers and phenological cues	No fixed dependency on phenological cues or triggers that will be affected by climate change.	Little dependency on phenological cues or triggers that will be affected by climate change and high ability to adapt.	Potential dependency on phenological cues or triggers that will be affected by climate change but some ability to adapt.	Dependency on phenological cues or triggers that will be affected by climate change but some ability to adapt.	Fixed dependency on phenological cues or triggers that will be affected by climate change. Little ability to adapt.	Will changes in environmental triggers lead to phenological mismatch?

Evidence of adaptation in the past	Evidence of rapid migration and adaptation response to climatic changes in the recent past. Culturally driven migration rather than genetically driven migration.	Migration and adaptation response to climatic changes in the past have been good and is likely to be sufficient to keep pace with projected rates of ecosystem shift.	Some migration and adaptation response to climatic changes in the past.	Migration and adaptation response to climatic changes in the past have been slow and is likely to be slower than projected rates of ecosystem shift.	No evidence of migration or adaptation response to climatic changes. Genetically driven migration rather than culturally driven migration.	Is there any evidence of migration/ecological changes since the end of the last ice age? What does this evidence infer upon the prospects of future adaptation? If no evidence is found at all in regard to this section please identify as NA.
Dispersability	High ability to disperse to new areas and shift migration patterns. No natural barriers to migration to new or more suitable range/ habitats.	Some ability to disperse to new areas and shift migration patterns. Minimal natural barriers to migration to new or more suitable range/ habitats.	Moderate ability to disperse to new areas and shift migration patterns. Some natural barriers to migration to new or more suitable range/ habitats.	Little ability to disperse to new areas and shift migration patterns. Several natural barriers to migration to new or more suitable range/habitats which will make dispersal hard but not impossible.	Migration patterns are fixed to specific areas. No ability to disperse to new or more suitable range/ habitats. Natural barriers prevent dispersal to more suitable range/ habitats.	Are species dependent on a vector such as wind and water currents for migration and dispersal? Are these vulnerable to change and will this limit the species ability to disperse to new suitable habitats? Are critical life stages threatened by these changes? Are there sufficient metapopulation numbers in areas adjacent to new suitable habitats that will facilitate effective dispersal?
Reproduction rate and resilience: Climate related changes to fecundity or reproductive success	Rapid reproduction rate, no known climate related changes to fecundity or reproductive success. Species environmental tolerances will not be exceeded due climate change and reproductive resilience is shown.	Good reproduction and little climate-related reduction of fecundity or reproductive success expected. Displays reproductive resilience to potential climate change impacts.	Average reproduction rate. Some climate-related reduction of fecundity or reproductive success expected. Non optimal environmental tolerances experienced with some impacts on reproductive success.	Below average rate of reproduction. Reproduction likely to be hampered by climate change related decrease in fecundity. Low reproductive resilience to potential climate change impacts.	Slow rate of reproduction. Reproduction likely to be hampered by climate change related decrease in fecundity. Species environmental tolerances will be exceeded resulting in low reproductive resilience to climate change impacts.	The biological aspects of dispersability should be considered. Are specific metapolulations at greater risk?

Species interactions:						
Changing dynamics of predator/ prey/ competitor interactions	No known dependency on any interspecific predator / prey / competitor interactions that are likely to be disrupted by climate change.	Major disturbance of the foodweb unlikely due to climate change impacts. Impacts on interspecific predator / prey / competitor interactions and community likely to be small	Moderate disturbance of foodwed possible due to climate change impacts. Moderate reduction of food resources or moderate increase in predation likely. Some impacts on interspecific predator / prey / competitor interactions and community likely.	Moderate to high disturbance of foodwed probable due to climate change impacts. Some major impacts on interspecific predator / prey / competitor interactions and community likely.	Disappearance of prey species or inability to catch dependent prey due to climate change impacts. Increase in threat to species due to burgeoning predator or competitor populations	The degree of reliance on other species that may be affected by climate change. How will climate change affect the foodweb and timing of resource availability? What is the cumulative impact for populations of the species in question? Will predator / prey / competitor species be affected by changes in environmental triggers or phenological cues and how will this impact on subject species?
Impacts upon mutualisms/ symbiosis.	No disorientation of important mutualism. Moderate disorientation of some non-dependent mutualisms due to climate change.	Partial disorientation of some important mutualism. Moderate disorientation of some non-dependent mutualisms due to climate change.	Serious disruption of some non-dependent mutualisms. Moderate disorientation of dependent mutualisms due to climate change.	Serious disruption of dependent mutualism/s due to climate change.	Evidence of breakdown of the necessary dependant mutualisms due to climate change.	Number of mutulisms important, as is the relative reliance upon those mutulisms
How do other threats act synergistically with climate change?						
Habitat loss/ fragmentation	Intact habitat, little evidence of disturbance affecting habitat and species resilience to climate change impacts	Some habitat disturbance, loss or fragmentation, but habitat largely intact and resilience to climate change impacts not seen to be greatly affected.	Fragmented/depleted habitat but large areas still intact. Habitat and species resilience to climate change impacts has been greatly depleted but still opportunities for bounce back if good management and restoration practices are put in place and adhered to.	A high level of habitat loss/fragmentation. Significant implications for habitat and species resilience to climate change	Habitat loss/fragmentation severe. Greatly impacting habitat and species resilience to climate change	Other threats should also be noted. Will anthropogenic activities act synergistically with climate change to increase habitat loss/ fragmentation? Will anthropogenic transformation of migration route or newly climatically suitable areas create barriers to migration or dispersal? Will this be due to agriculture, deforestation, urbanization or other activities?

Exploitation	No significant exploitation. No affect on species resilience and adaptation potential to climate change.	Low levels of exploitation with minor impact on resilience and adaptation potential of species to climate change.	Moderate levels of exploitation with some impacts on species resilience and adaptation potential to climate change.	High levels of exploitation impacting on species resilience and adaptation potential to climate change.	Unsustainable exploitation posing a serious threat to the viability of the species. Exploitation levels give little chance that species will be able to adapt and have resilience to climate change impacts.	Will exploitation increase with climate change predictions or will species be exposed to new exploitation threats as they migrate to new areas?
Disease	No known disease threat and no predicted disease threat increase due to climate change	Low disease threat and some increase due to climate change	Medium level of disease threat with impacts on population levels increasing as a result of climate change.	Significant level of disease threat with strongly increased impacts on population levels as a result of climate change.	Disease a serious threat to the viability of the species and threat levels will be greatly increased by climate change.	Will disease spread to new areas that will affect species due to climate change?
Invasive species	No known threat from invasive species due to climate change	Some invasive species will compete indirectly for resources due to climate change	Likely that some invasive species will compete directly for resources due to climate change	Available resources substantially diminished by invasive species due to effects of climate change increasing their competitive advantage	Habitat very likely to be invaded by species which will directly outcompete the subject species, or destroy the dependent food-web, due to climate change	Will invasive species range be increased by climate change? How will this impact species both directly and indirectly?

Grading Different Sections of the Assessment

Grading of some sections of the assessment require consideration of several factors and others fewer. The Habitat Vulnerability section for example deals only with the vulnerability of the habitat to climate change. If the impact of climate change on the habitat utilised by the species will be minimal, it scores a 1. If a vital habitat of the species is likely to be severely degraded by the projected climate change, then this category would score a 5.

However, in the Ecological Flexibility section there are a greater number of considerations and there may be a situation where a species appears to be highly vulnerable on one facet of the section whilst resilient on another. When a species has high vulnerability in one part of the assessment e.g. Reproduction Rate and low vulnerability in another part of the assessment e.g. Degree of Specialisation, the scores were balanced. This is not to say that the median or the mean of the assessment was selected. If a species has a very high degree of specialisation, but this is compensated for, or buffered by a high reproductive rate then the species could score a 3. However, if a species has a very high degree of specialisation, and the high reproduction rate will not increase the chances of the species enduring environmental changes, then the outcome of the assessment could still be a 4 or a 5, depending on the evidence.

Like the habitat vulnerability section, the species interactions assessment sections would be more straightforward to score than the ecological flexibility section which requires more consideration. The main problem that would arise when completing this section was the scarcity of data available. Whilst some species have a number of publications on observed or predicted impacts of climate change impacts on prey species, for other species it would sometimes be difficult even to confirm what their main source of prey was from the sparse information available.

In situations where assessors felt that there was insufficient information to make their assessment with confidence these scores were marked with a * for further attention or review if and when the information becomes available.

The scoring for the Interactions with Other Processes section is based upon the threat that non-climatic processes are likely to have on the species resilience and ability to adapt to climate change in the future, and more specifically, how climate change might exacerbate these threats. For example, the threats posed to nesting turtles are likely to be exacerbated by sea level rise. As rising seas reduce beach area, the squeeze of coastal development and tourism is likely to impact more acutely on marine turtle populations.

When scoring against the criteria, the cumulative threat of the different facets of the assessment determined the overall score.

6.3.8. Overall Vulnerability Threshold Levels

For this project to effectively identify those species on the CMS Appendix I which are at highest risk from projected climate changes, three vulnerability threshold levels have been set.

Rules for Grading Vulnerability Threat Levels:

High Vulnerability	**Medium Vulnerability**	**Low Vulnerability**
1 or more x 5 scores in assessment section 2 or more x 4 scores in assessment section Over 12 total assessment score	1 or more x 4 scores in assessment Equal to or under 12 total assessment score Equal to or over 7 total assessment score	Under 7 total assessment score

6.3.9. Rationale

A high score on any one of the four criteria represents a high risk to the survival of the species. A species ability to cope with climate change impacts and show resilience to the changes will only be as effective as their “weakest link”. Displaying higher resilience in other sections of the assessment will improve their overall resilience however this will not increase their chances of survival if a key area is compromised. The vulnerability status assessments and gradings have been developed to flag any species that may require management and a focused effort in future to improve survival rates for species. If a species has scored very well in all other areas of the assessment but has one section which makes them highly vulnerable this will be a limiting factor to their survival. Flagging this species will allow for review of potential actions that can be taken to resolve such issues. Therefore, any species which scores a five on any section will be highlighted as having a ***High Vulnerability*** to climate change. A collection of lower impacts can increase the pressure upon a species and, depending on the number and magnitude of impacts, the cumulative affect can pose a large risk to the survival of the species. Therefore, any species that scores a total of >12 will also be highlighted as a vulnerable species.

Several considerations must be taken whilst scoring. For example the ecological flexibility score indicates how adaptable a species will be to climate change and will affect how species will be able to cope with other threats identified. If a species is shown to be very un-adaptable to changes but then overall has a lower score there could be some validity in this being taken into account when setting the higher score. In the current assessment this has not been necessary however with further assessments this issue may need clarification. A degree of review as to how the sections may interact to give an overall vulnerability grading is advisable and has taken place here to double check that overall threat vulnerability levels are being assigned in the current way. No overall gradings have had to be changed indicating that for this number or level of species review the rules for grading are suitable. Checks have also been done across taxa to show that scoring has been equally assigned even with the wide degree of variability in taxa from i.e. the common sturgeon to the blue whale or Dama gazelle.

Further Potential for Refinement

Species threat status from current and future anthropogenic impacts are being included in the grading of synergistic impacts section of the assessment. The rational for this inclusion is that species currently threatened by anthropogenic impacts will have lower resilience to climate change. However this means that current assessment procedure is not responsive in the long term to changes in the IUCN Red List gradings given to species. It also means that if these climate change vulnerability results are combined with Red Listing information there is the risk of “double counting”.

To increase the potential ability for these climate change vulnerability assessment results to be incorporated into the IUCN Red List and increase their responsiveness to changes in the Red List status of species a potential refinement in the assessment could be made. This would involve removing the current and future anthropogenic threat processes out of the assessments and only identifying threats and changes in threats directly caused by climate change and actions taken by humans to mitigate and adapt to these changes. Once a threat level is identified for species removing all other anthropogenic pressures these gradings can then be combined with current IUCN Red List threat status for each species. This would involve the development of differential gradings according to a species Red List status to develop overall climate change vulnerability gradings.

Currently these climate change vulnerability assessments do not include Red List gradings directly into the methodological protocol. This is due to the fact that climate change is partially included, if in a very preliminary form at present, into the Red List assessments. Excluding the Red List status directly as a factor in these assessments limits any risk of "double counting". Depending on how the Red List plans to incorporate climate change threat into their species gradings in the future will define how beneficial it would be for climate change vulnerability assessment methodologies currently being used to be modified and limited to represent only the added threat due to climate change, with a second step put in place to identify each species overall vulnerability to climate change when current Red list status is taken into account. This could result in a more transparent methodology and allow for tracking of overall climate change vulnerability as the Red List status of species changes. Further investigation of the potential costs and benefits of refining the assessment process should be carried out in discussion with IUCN Red List.

One area where this studies assessment differs from the Red List is that it specifically looks at and identifies anthropogenic threats that interact with climate change. If this section of the review was removed it would remove potentially valuable information for the formulation of conservation management plans that aim to increase species resilience to climate change through reduction in other anthropogenic impacts.

6.3.10. Measures to Improve Confidence in the Results

The procedural approach put in place for species assessments to be carried out allowed for several assessors to be reviewing each species. Each assessor would be tasked with their specialised category (habitat vulnerability, ecological flexibility, species interactions or synergistic threats) and go across species focusing on this section. During this process assessors would cross check other sections of the assessment and provide further information and input if required. This measure has meant that each species has automatically been reviewed several times during the assessment process. A final validation stage would be taken where all finalised assessments would be checked by a lead team member before final sign off.

Background documents were developed for each species which allowed assessors to log all relevant peer reviewed information gathered into a larger draft format allowing for detailed referencing. Assessments would compose of a concise review and analysis of information gathered. Background documents also provide a basis for more detailed reports on specific species vulnerabilities to climate change. Examples of background documents are provided later in this report.

6.3.11. Limitations

A major limitation to this level of detailed review of individual species is time. Due to a lack of specific species information on currently observed and predicted impacts of climate change, this study has required a much more detailed review and analysis of each species traits, characteristics and vulnerabilities to extract necessary information then previously anticipated to complete assessments. This is hugely time consuming especially as assessors are not specialists in each species they assess and need to gather even the basic ecological and biological information to the finest detail to make sure there are no areas that they are missing important information on.

A process whereby species specialists are consulted on each species assessment would prove to be valuable in reducing the time requirements of this type of assessment, and is outlined in Phase 2 of the assessment methodology.

6.3.12. Further Streamlining of the Assessment Process

Developing a database (potentially using Access) for analysis and review of climate change impacts and vulnerabilities of species will increase the value of outputs for CMS. It will increase the ability for information to be analysed and processed to provide valuable policy informing outputs. It will also increase the efficiency and standardisation of data input. It would need investment to set this up but once done it would mean that assessments could be done faster and therefore would reduce cost in the long term.

6.4. PHASE 4: INDIVIDUAL SPECIES REPORTS

Individual species reports provide a method by which information collected on each species can be presented in a manner that is more engaging and allow for more background information discussing the threats, processes and variability in different model or response projections. These can be formatted depending on the primary target audience, whether it be a policy maker or a conservation manager. Examples of individual species reports are provided within this document.

7. APPLYING PHASE 3: CLIMATE CHANGE VULNERABILITY ASSESSMENTS – IN DEPTH REVIEWS

7.1. Case Study Assessment Overview

A total of 45 species case studies are presented here: 44 are within CMS Appendix I and one example species is within CMS Appendix II. Other species within Appendix I have been partially assessed but results of these are not listed within this current report.

List of Species Assessed:

No.	Class	English	Latin	GROMS Migration Classification	Relevant CMS Agreements Identified	Red List 2010 *Version 2010.1*	Population Trend 2010	CMS Appendix	Family	German	French	Spanish
1	Reptilia	Gharial, Indian Gavial	*Gavialis gangeticus*	potamodromous	-	CR	Decreasing	I	Gavialidae	Ganges-Gavial	Gavial du Gange	Gavial del Ganges
2	Reptilia	Green Turtle	*Chelonia mydas*	interoceanic	IOSEA MoU	EN	Decreasing	I	Cheloniidae	Pazifische Suppenschildkröte	Tortue verte	Tortuga verde
3	Reptilia	Hawksbill Turtle	*Eretmochelys imbricata*	intraoceanic	IOSEA MoU	CR	Decreasing	I	Cheloniidae	Echte Karettschildkröte	Tortue imbriquée	Tortuga carey
4	Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	*Lepidochelys kempii*	intraoceanic	IOSEA MoU	CR	Not provided	I	Cheloniidae	Atlantische Bastardschildkröte	Tortue de Ridley	Tortuga lora
5	Reptilia	Leatherback Turtle,	*Dermochelys coriacea*	interoceanic	IOSEA MoU	CR	Decreasing	I	Dermochelyidae	Lederschildkröte	Tortue luth	Tortuga laud
6	Reptilia	Loggerhead Turtle	*Caretta caretta*	interoceanic	IOSEA MoU	EN	Not provided	I	Cheloniidae	Unechte Karettschildkröte	Caouanne	Tortuga boba
7	Reptilia	Olive Ridley	*Lepidochelys olivacea*	intraoceanic	IOSEA MoU	VU	Decreasing	I	Cheloniidae	Bastardschildkröte	Tortue batarde	Tortuga olivácea
8	Pisces	Basking Shark	*Cetorhinus maximus*	oceanodromous	Sharks MoU	VU	Decreasing	I				
9	Pisces	Common Sturgeon	*Acipenser sturio*	anadromous	-	CR	Decreasing	I				
10	Pisces	Giant Catfish	*Pangasius gigas*	potamodromous	-	CR	Decreasing	I	Pangasiidae	Riesenwels	Silure de verre géant	Siluro gigante
11	Pisces	Great White Shark, White Shark	*Carcharodon carcharias*	oceanodromous	Sharks MoU	VU	Unknown	I	Lamnidae	Weißer Hai	Mangeur d'hommes	Tiburón antropófago
12	Mammalia	Addax	*Addax nasomaculatus*	intracontinental	Sahelo-Saharan Antelope Action Plan	CR	Decreasing	I	Bovidae	Mendesantilope	Addax à nez tacheté	Adax
13	Mammalia	Blue Whale	*Balaenoptera musculus*	interoceanic	ACCOBAMS, Pacific Island Cetaceans	EN	Increasing	I	Balaenopteridae	Blauwal	Baleine bleue	Ballena azul

No.	Class	English	Latin	GROMS Migration Classification	Relevant CMS Agreements Identified	Red List 2010 *Version 2010.1*	Population Trend 2010	CMS Appendix	Family	German	French	Spanish
					MoU							
14	Mammalia	Bowhead Whale	*Balaena mysticetus*	interoceanic	-	LC	Increasing	I	Balaenidae	Grönlandwal	Baleine du Groenland	Ballena de Groenlandia
15	Mammalia	Cuvier's Gazelle	*Gazella cuvieri*	data deficient	Sahelo-Saharan Antelope Action Plan	EN	Unknown	I	Bovidae	Atlasgazelle	Gazelle de Cuvier	Gacela de Cuvier
16	Mammalia	Dama Gazelle	*Gazella dama*	intracontinental	Sahelo-Saharan Antelope Action Plan	CR	Decreasing	I	Bovidae	Damagazelle	Gazelle dama	Gacela dama
17	Mammalia	Humpback Whale	*Megaptera novaeangliae*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	LC	Increasing	I	Balaenopteridae	Buckelwal	Mégaptère	Yubarta
18	Mammalia	Marine Otter	*Lontra felina*	technical migrant	-	EN	Decreasing	I	Mustelidae	Meerotter	Loutre de mer	Chungungo
19	Mammalia	Mexican Free-tailed Bat, Brasilian free-tailed bat	*Tadarida brasiliensis*	intercontinental	-	LC	Stable	I	Molossidae	Brasilianische Bulldogfledermaus	Chauve-souris à queue-libre du Mexique	Rabudo mejicano
20	Mammalia	NARWHAL	*Monodon monoceros*	intraoceanic	-	NT	Unknown	II				
21	Mammalia	North Pacific Right Whale	*Eubalaena japonica*	interoceanic	-	EN	Unknown	I				
22	Mammalia	Northern Atlantic Right Whale, Biscayan Right Whale	*Eubalaena glacialis*	interoceanic	-	EN	Unknown	I	Balaenidae	Nordkaper	Baleine de Biscaye	Ballena franca
23	Mammalia	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	*Balaenoptera borealis*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	EN	Unknown	I	Balaenopteridae	Seiwal	Baleinoptere de Rudolphi	Rorcual norteño

No.	Class	English	Latin	GROMS Migration Classification	Relevant CMS Agreements Identified	Red List 2010 *Version 2010.1*	Population Trend 2010	CMS Appendix	Family	German	French	Spanish
24	Mammalia	Short-beaked Common Dolphin	*Delphinus delphis*	intraoceanic	ACCOBAMS, ASCOBANS, Pacific Island Cetaceans MoU, West African Aquatic Mammal MoU	LC	Unknown	I				
25	Mammalia	Snow Leopard	*Uncia uncia*	nomadising	-	EN	Decreasing	I	Felidae	Schneeleopard	Panthère des neiges	Pantera de las nieves
26	Mammalia	Southern Right Whale	*Eubalaena australis*	interoceanic	-	LC	Increasing	I	Balaenidae	Südkaper	Baleine australe	Ballena franca austral
27	Mammalia	Sperm Whale	*Physeter macrocephalus*	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	VU	Unknown	I	Physeteridae	Pottwal	Cachalot	Ballena esperma
28	Mammalia	West African Manatee	*Trichechus senegalensis*	intracontinental	West African Aquatic Mammal MoU	VU	Unknown	I				
29	Aves	Andean Flamingo	*Phoenicopterus andinus*	intracontinental	High Andean Flamingo MoU	VU	Decreasing	I	Phoenicopteridae	Andenflamingo	Flamant des Andes	Parina grande
30	Aves	Aquatic Warbler	*Acrocephalus paludicola*	intercontinental	Aquatic warbler MoU	VU	Decreasing	I	Muscicapidae	Seggenrohrsänger	Phragmite aquatique	Carricerín
31	Aves	Balearic Shearwater	*Puffinus mauretanicus*	interoceanic	-	CR	Decreasing	I				
32	Aves	Basra Reed-warbler	*Acrocephalus griseldis*	intercontinental	-	EN	Decreasing	I				
33	Aves	Bermuda Petrel	*Pterodroma cahow*	intraoceanic	ACAP	EN	Increasing	I	Procellariidae	Bermudasturmvogel	Pétrel des Bermudes	Petrel cahow

No.	Class	English	Latin	GROMS Migration Classification	Relevant CMS Agreements Identified	Red List 2010 *Version 2010.1*	Population Trend 2010	CMS Appendix	Family	German	French	Spanish
34	Aves	Black-faced Spoonbill	*Platalea minor*	intracontinental	-	EN	Decreasing	I	Threskiornithidae	Schwarzgesichtlöffler	Petite Spatule	Espátula menor
35	Aves	Humboldt Penguin	*Spheniscus humboldti*	intraoceanic	-	VU	Decreasing	I	Spheniscidae	Humboldtpinguin	Manchot de Humboldt	Pingüino de Humboldt
36	Aves	Pallas Fish Eagle, Pallas's fish-eagle	*Haliaeetus leucoryphus*	partial	Raptorss MoU	VU	Decreasing	I	Accipitridae	Bindenseeadler	Pygargue de Pallas	Pigargo de Pallas
37	Aves	Puna Flamingo	*Phoenicopterus jamesii*	intracontinental	High Andean Flamingo MoU	NT	Decreasing	I	Phoenicopteridae	Jamesflamingo	Flamant de James	Parina chica
38	Aves	Red-breasted Goose	*Branta ruficollis*	intercontinental	AEWA	EN	Decreasing	I	Anatidae	Rothalsgans	Bernache à cou roux	Barnacla cuelliroja
39	Aves	Relict Gull	*Larus relictus*	intracontinental	-	VU	Decreasing	I	Laridae	Gobi-Schwarzkopfmöwe	Mouette relique	Gaviota de Mongolia
40	Aves	Short-tailed Albatross, Steller's Albatross	*Diomedea albatrus*	interoceanic	ACAP	VU	increasing	I	Diomedeidae	Kurzschwanzalbatros	Albatros à queue courte	Albatros colicorto
41	Aves	Siberian Crane	*Grus leucogeranus*	intracontinental	AEWA, Siberian crane MoU	CR	Decreasing	I	Gruidae	Schneekranich	Grue de Sibérie	Grulla siberiana
42	Aves	Sociable Plover, Sociable Lapwing	*Vanellus gregarius*	intercontinental	AEWA	CR	Decreasing	I	Charadriidae	Steppenkiebitz	Vanneau sociable	Avefría sociable
43	Aves	Steller's Eider	*Polysticta stelleri*	intercontinental	AEWA	VU	Decreasing	I	Anatidae	Scheckente	Eider de Steller	Eider menor
44	Aves	Swan Goose	*Anser cygnoides*	intracontinental	-	VU	Decreasing	I	Anatidae	Schwanengans	Oie cygnoïde	Ánsar cisnal
45	Aves	White-naped Crane	*Grus vipio*	intracontinental	-	VU	Decreasing	I	Gruidae	Weißnacken-Kranich	Grue à cou blanc	Grulla de cuelle blanco

7.2. Case Study Vulnerability Gradings

Details of the case study climate change gradings identified for each species are provided below:

Most Biologically Migrant Species

	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other Processes	Total
Reptiles					
Gharial, Indian Gavial	Medium	Medium / High	Medium	High	High (15)
Green Turtle	High	High	Medium	High	High (18)
Hawksbill Turtle	High	Medium / High	Medium / High	High	High (18)
Kemp's Ridley Turtle, Atlantic Ridley Turtle	Medium / High	Medium / High	Medium	High	High (16)
Leatherback Turtle	Medium / High	Medium	Low / Medium	High	High (14)
Loggerhead Turtle	Medium / High	Medium	Medium	High	High (15)
Olive Ridley	Medium / High	Medium / High	Low / Medium	Medium / High	High (14)

Mammals					
Addax	Medium / High	Low / Medium	Medium	Medium / High	High (13)
Blue Whale	Medium / High	Medium / High	Medium / High	Low	High (13)
Bowhead Whale	High	Medium	Medium / High	Medium	High (15)
Cuvier's Gazelle	Medium	Low / Medium	Low / Medium	Medium / High	Medium (11)
Dama Gazelle	Medium / High	Low / Medium	Medium	High	High (14)
Humpback Whale	Medium	Low / Medium	Medium	Low / Medium	Medium (10)
Mexican Free-tailed Bat	Low / Medium	Medium	Low / Medium	Medium	Medium (10)
North Pacific Right Whale	Medium / High	Medium / High	Medium / High	Medium / High	High (16)

	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other Processes	Total
Northern Atlantic Right Whale, Biscayan Right Whale	Medium / High	Medium / High	Medium / High	Medium / High	High (16)
Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	Low / Medium	Medium	Medium	Medium	Medium (11)
Short-beaked Common Dolphin	Low / Medium	Low / Medium	Medium	Medium / High	Medium (11)
Southern Right Whale	Medium	Medium	Medium / High	Medium / High	High (14)
Sperm Whale	Low / Medium	Medium	Low / Medium	Medium	Medium (10)
West African Manatee	Medium / High	Medium / High	Medium	Medium / High	High (15)

Fish					
Basking Shark	Medium	Medium	Medium	Medium	Medium (12)
Common Sturgeon	Low / Medium	Medium	Low	High	High (11)
Giant Catfish	Low / Medium	Medium	Low / Medium	High	High (12)
Great White Shark, White Shark	Low	Low / Medium	Low / Medium	Medium	Medium (8)

Birds					
Andean Flamingo	Low / Medium	Medium / High	Low / Medium	Low / Medium	Medium (10)
Aquatic Warbler	Medium	Medium	Low / Medium	Medium / High	Medium (12)
Balearic Shearwater	Medium / High	Medium / High	Medium / High	High	High (17)
Basra Reed-warbler	Medium / High	Low / Medium	Low / Medium	Medium / High	High (12)
Bermuda Petrel	Medium	Medium / High	Low / Medium	Low / Medium	High (11)
Humboldt Penguin	Low / Medium	Medium	Low / Medium	Medium	Medium (10)
Pallas Fish Eagle	Medium	Low / Medium	Low / Medium	Medium	Medium (10)
Puna Flamingo	Low / Medium	Medium	Low / Medium	Low / Medium	Medium (9)
Red-breasted Goose	Medium / High	Medium	Low / Medium	Medium / High	High (13)

	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other Processes	Total
Relict Gull	High	Medium / High	Medium	Medium / High	High (16)
Short-tailed Albatross, Steller's Albatross	Medium	Medium / High	Medium / High	Medium / High	High (15)
Siberian Crane	High	Medium	Low / Medium	Medium	High (13)
Sociable Plover	Medium	Medium	Medium / High	Medium / High	High (14)
Steller's Eider	Medium / High	Medium	Medium	Medium	High (13)
Swan Goose	Medium	Medium	Low / Medium	Medium	Medium (11)
White-naped Crane	Medium	Medium / High	Low / Medium	Medium / High	High (13)

Least Biologically Migrant Species

	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Mammals					
Marine Otter	Low	Low	Low	Medium / High	Medium (7)
Snow leopard	Low	Medium	Low / Medium	Medium / High	High (10)
Birds					
White-tailed Eagle	Low / Medium	Low / Medium	Low	Low / Medium	Medium (7)

Example Appendix II Species

	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Mammals					
Narwhal	High	Medium / High	Medium / High	Medium / High	High (16)

8. APPLYING PHASE 4: INDIVIDUAL SPECIES REPORTS

Background documents were produced for each species assessed. These provided a format in which assessors could provide all background evidence for their assessment conclusions. These were produced in draft format for most species yet could provide a strong foundation for more detailed species level reports if required.

Several examples of the background documents that have been produced to final standards are provided.

8.1. Case Study Example Reports

Climate Change Impacts on Migratory Species

Species Review: Background Document

Addax, *Addax nasomaculatus*

ZSL LIVING CONSERVATION

Distribution: Sahelo-Saharan Africa

Native: Chad, Mauritania, Niger
Regionally Extinct: Algeria, Egypt, Libyan Arab Jamahiriya, Sudan, Sahara
Reintroduced: Morocco, Tunisia
Presence uncertain: Mali

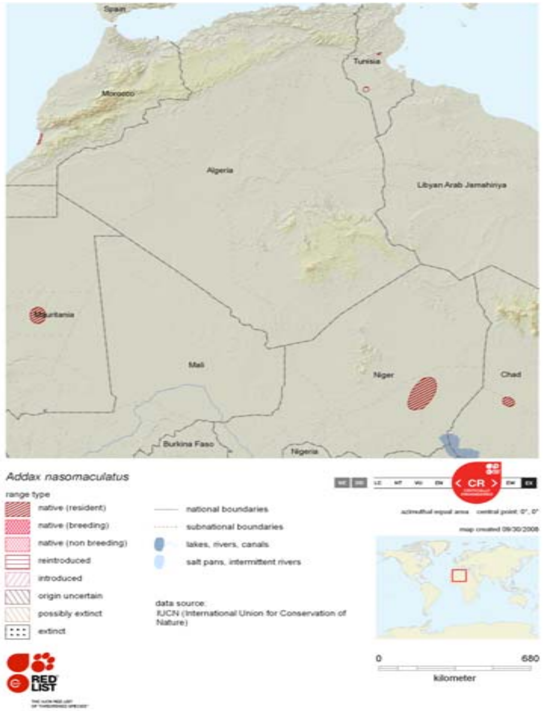
IUCN Classification: Critically Endangered A2cd; C1+2a (ii)

Population Estimate: <300

CMS Appendix: I

1. Background Information

Addax (*Addax nasomaculatus*) is found only in small numbers in the wild, with the only native populations situated in Chad, Mauritania and Niger. The Addax species has undergone over an 80% population decline over the past 3 generations or 21 years. The majority of the remaining population is reported to be distributed unevenly along a narrow, 600-km-long band lying between Termit/Tin Toumma in Niger and the Bodélé Depression in Chad (Newby, 2008).



At Addax is well adapted to desert environments, but at the end of the dry season it heads to lower latitudes to the sub-desert Sahelian savannahs (Beudels-Jamar *et al.* 1999). The Addax is known as the mist desert-loving large ungulate which can occur in areas of extreme temperature and aridity (less than 100 mm annually). Addax are nomadic and wander over large areas in search of grazing. In central Niger, migration routes move occur from north to south or from more arid desert to less arid sub-desert and Sahel. In Central Niger they may also move from east to west from open desert to more varied and wooded habitats of the Air and Termit Mountains.

Figure 1: Species Range Map (left)

2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability

Under the most conservative emissions scenarios reviewed by the IPCC FAR (2007), the mean temperatures in the Sahel region by 2080 and 2099 in comparison to the 1980-1999 mean temperatures are projected to increase is by least 2°C with top end of the range of the projections hitting 4°C. In the A1B scenario, the projected temperature rise lies between 2.6°C to 5.4°C, with the median model predicting 3.6°C. The median A1B model predicts a modest reduction in annual precipitation over the same period, although the amount of uncertainty that the climate models' predication is large (Christensen, 2007). Moderate precipitation decline could prove to substantially increase the vulnerability of the habitat, as perennial grazing come under increased pressure from pastoral agriculture (see Interactions with Other Processes). In the drought that the region experienced in the second-half of the 20th Century, perennial vegetation habitats were particularly hard-hit, with numerous anthropogenic pressures on top of natural impacts (Held *et al*., 2005). A more variable climate with increased extreme weather events would seriously risk the viability of the present ecosystem in the Sahelo-Saharan regions.

2.2. Ecological Flexibility

The Addax have been recorded in all major habitat types in the Sahara and Sahel regions, from sand and gravel plains, to pans and wadi systems and sandy basins and depressions (Newby and Wacher, 2008). Although this range of habitat types is broad within the Sahelo-Saharan region, the viability of all of these systems to provide a suitable habitat for the Addax is intrinsically linked to the level of rainfall that the region receives. The Addax can live most of their lives without drinking water (Altan, 2000), but if the perennial vegetation on which this species relies fails due to drought, its niche will be severely diminished. In previous drought periods, the Addax is most likely to have occupied the steppes of the northern-Sahelian zone (White, 1983). However there is growing pressure on these regions, especially in periods of drought when migratory pastoralists also rely on these areas where vegetation cover is more likely (UNEP, 1998).

Female Addax are capable of giving birth to one calf as often as one every year. Female sexual maturity is usually reached at 2-3 years of age, whilst male Addax tend to reach sexual maturity at 2 years of age. Young can be weaned between 23-39 weeks (Altan, 2000).

As a largely nomadic species, the Addax would be capable of shifting its range should the drought make its current location untenable. However, pressures from a growing human population for viable pastoral land for their livestock may prevent this. Reintroduction programmes are underway in fenced sectors of protected areas in Tunisia (Bou Hedma NP) and Morocco (Souss-Massa: 70 animals released 1994-97, increased to c. 550 by 2007 (Newby and Wacher 2008).

2.3. Species Interactions

The Addax is a herbivore which was at one time predated upon by lions, hyenas and leopards (IUCN, 2009). These species however have generally been exterminated from the habitat of the Addax. The vegetation which this species relies upon is diverse, but is heavily linked to rainfall.

2.4. Interactions with other Processes

White (1983) asserts that in past periods of drought it is likely that Addax shifted to the steppes in the northern Sahel zone to find suitable vegetation. However, during the last drought these more humid regions were also subjected to growing pressures from migratory pastoralists and other nomad populations were fleeing the drought (Newby, 1988). The IPCC (Christensen *et al.,* 2007) suggest that areas of the Sahelo-Saharan region are likely to be the most vulnerable to climate change by 2100 with predicted agricultural losses of between 2 and 7% of GDP, with a growing population to feed.

Reduced agricultural outputs, a growing population and decreased access to suitable grazing and browsing areas is likely to bring the Addax into much closer proximity to humans. This increased proximity to humans is likely expose the Addax to more direct exploitation (Newby, 1988)

2.5. Management and Policy Recommendations

Some models show large-scale drying of the Sahel, whilst others predict an increase in rainfall. Reduction of this uncertainty would aid planning for adaptation to future climates.

The major anthropogenic threats which have lead to the extreme decline of the Addax include uncontrolled hunting, habitat encroachment and harassment, livestock farming, agriculture and irrigation. This combined with the effects of climate change induced changes to the habitat such as severe weather and drought are as well as the very small size of sub-populations and extreme fragmentation are having detrimental effects on the Addax survival (Newby 2008).

Under the CMS Sahelo-Saharan Antelopes Action Plan 2005 Addax are now protected under national legislation in Morocco, Tunisia and Algeria and hunting is banned in Libya and Egypt. It is vital to protect not just the Addax but also the areas where the Addax remain with viable populations. These protected areas need to be established especially in Mali, Niger and Chad however this management strategy will only work with the co-operation of local people with sustainable strategies for survival. Addax have already been reintroduced into fenced sectors of protected areas in Tunisia and Morocco.

List of Conservation Actions:

- Land/water protection & management
- Site/area protection & management
- Species management and reintroductions
- Law and policy to protect species and habitats
- Compliance and enforcement at local, regional, national and international levels.

(Newby 2008)

There is no doubt that as the Addax has had no previous acknowledgement as a species vulnerable to climate change impacts, that it should be included in the CMS Index of Recommendations for the Conference for COP15.
The Addax was included in the Resolution 3.2 in 1991 .

The future of the Addax lies within transboundary parks, applying science ands research to management, adopting community based action and understanding and possible ex-situ conservation in zoos, partnership with range states, IGO's and other stakeholders, and regular review of action plans to respond to the emerging threat of climate change.

To save the Addax we need to save the Sahelo-Saharan ecosystem which is under serious threat from drought. The present vulnerability of the Addax and its ecosystem with the prospect of climate change calls for immediate proactive action to minimize these local, regional and national scale impacts (Downing *et al,* 1997).

Complete agreement in predictions made by climate models can not be solely relied on as a prerequisite for action. Some climate models predict that due to an enhanced CO2 fertilisation effect there will be an increase in rainfall and vegetation in the Sahara with increased carbon emissions. A precautionary approach must be taken as if these are inaccurate and no safeguards are put in place the consequences could be disastrous for species such as the Addax. Models that predict an enhanced CO2 fertilisation effect are also limited to a threshold level of 550 by 2050. If carbon levels exceed this amount these climate model predictions will have little relevance to the final outcomes. Without drastic action to cut emissions, GHG levels are likely to rise to levels between 550 and 750 ppm. Within these parameters there is overall agreement within climate models that this will result in an intense warming of the southern hemisphere and the northern Indian ocean compared to northern hemisphere which will be associated with drought in Africa.

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Bowhead Whale, *Balaena Mysticetus*

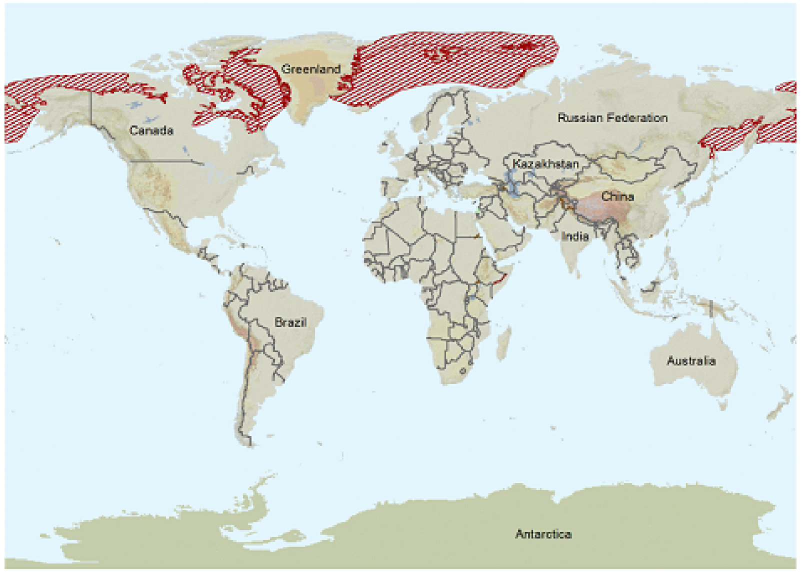
Distribution: Circum-polar

IUCN Classification: Least Concern

Population Estimate:

- 10,500 in the Bering and Chukchi-Beaufort Seas
- 10,933 in the Hudson Bay and Foxe Basin and Baffin Bay-Davis Strait
- No Data in the Okhotsk Sea and Svalbard-Barents Sea

CMS Appendix: 1



1. Background Information

The Bowhead whale is a baleen whale and a taxonomic relative of the right whale family. It can grow up to 20m in length, and females are generally larger than males. Overall their bodies are far less stream-lined than other baleen whales and therefore they are slower (Bisby *et al.*, 2007). They have the longest baleen plates of any whale, measuring up to 4.3 m in length and 30 cm in width (Marine Bio, 2009). Their longevity is unknown but some evidence suggests they can live up to 200 years. In fact, some individuals have been found with ancient ivory and stone harpoon heads embedded in their skins, making them the longest lived mammalian species. However their average age is estimated at 60 – 70 years (Justice, 2002).

Figure 1 : Range Map (Reilly et al, 2009)

Bowheads are found primarily in the Arctic and sub-Arctic realms (NOAA, 2009). They spend the majority of their lives around pack ice. They migrate to the high Arctic in summer and retreat southward in winter with the advancing ice edge (Reilly *et al.*, 2008). They often travel in groups of 3 or less in the spring, but larger groups of around 50 are common during migration in the autumn. The whales are well known for their ability to break air holes through ice of less than 0.3 m thick. However, Inuit's have reported seeing whales break through 23 inches of ice (WWF, 2009). The International Whaling Commission recognises five population stocks of Bowhead whales; the Bering-Chukchi-Beaufort Seas population (US, Alaska, Canada, Russian), the Hudson Bay-Foxe Basin population (Canada), the Davis Strait-Baffin Bay population (Denmark, Greenland & Canada), the Svalbard-Barents Sea population (Spitsbergen, Denmark, Greenland, Norway, and Russian Federation), and the Okhotsk Sea population (Russian Federation and Japan).

By the early 20th Century, high hunting pressure from the commercial whaling fleet had reduced the population to extremely low numbers (Bockstoce & Burns, 1993). However in the period 1978-2001, the population grew at 3.4% per annum (George et al. 2004). Bowhead numbers in eastern Canada and West Greenland are thought to remain below their historical levels, however the population on the whole is thought to be close to that of the pre-whaling period (Reilly et al 2009).

This population recovery is reported to be due to reduced anthropogenic mortality, well managed subsistence hunt and a near-pristine habitat (George et al., 2004). However, disturbance to marine food webs through changes to the climate system and increased anthropogenic disturbance due to a retreating ice-cap now threatens the species.

2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability

Bowhead whales are circumpolar, living in high latitude oceans at the Arctic sea-ice margin. They migrate with the seasonal expansion and contraction of Arctic sea-ice cover feeding predominantly on krill (Reilly *et al.*, 2009). This means that the impacts of climate change on high latitude Arctic waters will affect the habitats of Bowhead Whales. The main impacts on these habitats are likely to be; changes to sea ice, warming of the oceans, alterations to the currents as well as variations in salinity and pH.

Arctic temperatures are predicted to rise by between 5°C and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average (See Figure 1) (Christensen et al, 2007). This will have large effects on Arctic waters and sea-ice. In fact this magnitude of warming is likely to greatly reduce the thickness and extent of sea ice. Moreover, by 2100 some models predict that Arctic sea ice will be seasonal (See Figure 2) (Meehl et al, 2007). With reduced sea ice, Bowheads will have a smaller habitat, with less space to feed and shelter from predators. Meanwhile the extent of their

Figure 1:

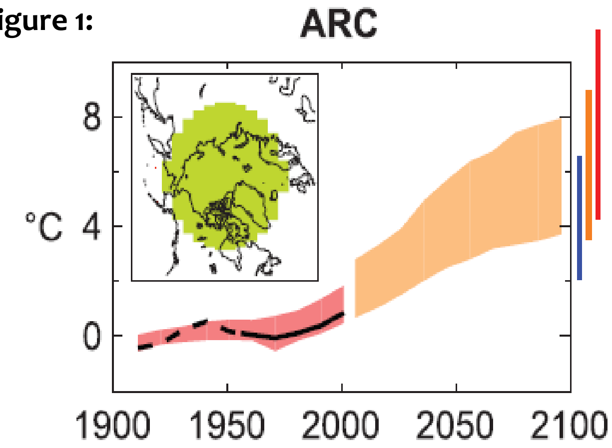


Figure 1: *Shows temperature anomalies with respect to 1901 – 1950 for the whole of the Arctic for 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the timeline present the range of projected temperature changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). Source –extracted from IPCC AR4 Chapter 11 (Christensen, 2007).*

Figure 2:

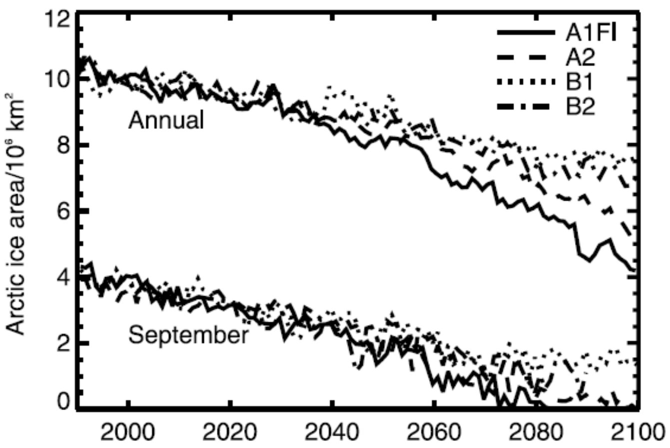


Figure 2: *Shows 4 model predictions for the extent of Arctic sea ice. It is possible to see that by September 2100, the models show no sea ice or a very limited extent (Gregory et al, 2002).*

migration will also be affected. Furthermore with less sea ice, many mechanisms in the Arctic and the circumpolar oceans will be affected, from the ranges of species present, to rates of chemical reactions. These processes will affect the habitat of Bowhead Whales (Tynan and DeMaster, 1997; Robinson et al, 2005).

From 1961 to 2003, ocean temperature has risen by 0.1 degrees centigrade, from 0 to 700m in depth, absorbing 2/3 of the insolation received by the oceans (Bindoff et al, 2007). Therefore ocean temperatures are likely to rise in the future in line with air temperature. In the Arctic, climate models predict higher magnitudes of warming than the global average. Therefore, it is likely that ocean temperatures will increase in the Arctic more than average. This will have ramifications on a wide variety of ocean processes, from the ranges of species present, to rates of chemical reactions, which will affect the habitat of Bowhead Whales.

Temperature and salinity drive ocean circulation, increasing temperatures and reduced salinity are therefore likely to alter ocean circulation and thus the oceans. This will affect numerous ocean processes particularly nutrient cycles, thus species distributions (Bindoff et al, 2007). Changes in salinity will be caused by melting ice caps, causing extra freshwater influx. This will affect more than just the circulation of the oceans. It will also affect processes such as species abundance and chemical processes, which will change the Bowhead Whales' habitat.

Ocean acidification is a partner to climate change. Since 1800, oceans have absorbed around a third of the total anthropogenic CO2 emissions (Sabine, 2004), and CO_2 is the primary actor maintaining the pH of oceans (Caldeira & Wickett, 2003). Whilst Wootton *et al.,* (2008) observed that pH levels can vary both seasonally and diurnally due to a number of different factors, since pre-industrial times the global average pH of the oceans has dropped by 0.10 units, or around 30% (Caldeira & Wickett, 2003). Caldeira & Wickett (2003) also predict that if unmitigated, the pH of the oceans is likely to decrease by 0.40 units by the end of the century and 0.77 units by 2300. Siegenthaler *et al*. (2005) estimate that atmospheric CO2 concentrations are increasing more rapidly than at any point in the past 650,000 years.

A change in pH from CO2 dissolved in the oceans is likely to have a large effect on the entire ocean system. High latitude oceans are particularly sensitive to this process (Orr *et al*., 2005). In Polar Regions, the affects of ocean acidification are clearly detectable, for example since the end of the 18^{th} Century there has been a 30-35% decline in the shell weight of Antarctic foraminfera (Moy *et al.,* 2009). Globally, pH is expected to decrease by 0.3 to 0.4 units by 2100.

In the Arctic Ocean aragonite undersaturation is projected to occur earlier very soon, Steinacher *et al*., (2009) shows that this may happen as soon as 2016. They report that once pCO2 values reaches 409µatm, for at least one month per annum, the entire water column will become undersaturated with respect to aragonite in as much as 10% of the Arctic Ocean. These low saturation areas will be associated with freshwater inputs, not least due to increased ice-melt (Steinacher *et al*., 2009)

Calcification of planktonic organisms is also thought to suffer in high CO2 environments (Riebesell *et al.* 2000; Feng *et al.* 2008). Whilst Orr et al., (2005) reported corrosion to pteropods in low pH environments, copepods appear to be relatively resistant to the near-future CO2 levels (Kurihara,& Ishimatsu., 2008), the life cycles of other organisms in the zooplankton appear to be very sensitive (Fabry et al., 2008). The overall affects on the vast majority of species is uncertain at presence, but it appears that the zooplankton species composition and therefore Krill abundance is almost certain to change (Meehl et al, 2007).

The future of aragonite based organisms such as Pteropods are therefore cause for serious concern in the near future. Turley C. *et al., (*2009) predict that under current emissions projections, 80% of Arctic waters are likely to be undersaturated in both aragonite and calcite by 2060. The overall impact of these changes is so far uncertain, however it has the potential to have severe implications for the Bowhead whale.

Figure 3 shows that of the most important and dramatic vital signs of climate change is the reduction in Arctic Minimum Summer Sea Ice. The amount of sea ice has reduced by **34%** during the period 1979 to 2007, with most of the reduction occurring between 2003 and 2007. This can be explained by figures 4 which show that warming of surface temperatures is concentrated around the Northern Realms.

This has serious implications on the survival species such as the Bowhead Whale species, which rely on the extent of sea ice cover for feeding, protection, migrating and reproduction.

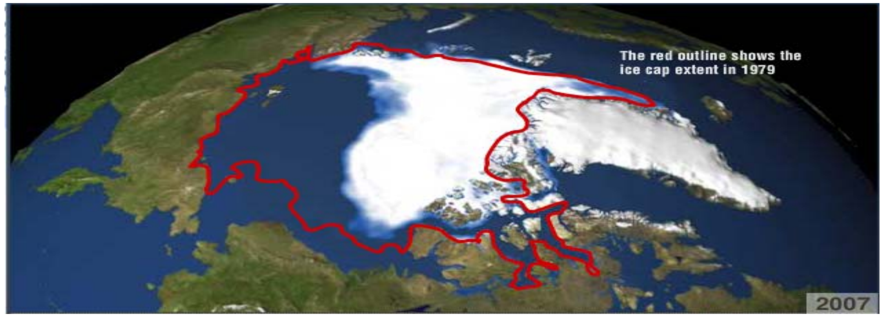


Figure 3: Image of change in extent of the arctic minimum summer sea ice cover 1979-2007

The implications in the major loss of sea ice will have enormous implications regionally and globally. This will reduce the albedo of the ice, reflecting less solar radiation and reducing the cooling effect thus enhancing global warming. Ice that forms on the ocean reduces the movement of moisture and energy into the air, thereby affecting climate patterns and atmospheric circulation. When openings, called leads, appear in melting sea ice, more water can evaporate to form more clouds and precipitation. The freezing over of sea ice and the melting of ice sheets and glaciers also influence the global circulation of oceans by affecting the ratio of fresh water to salt (NCAR, 2009). The increased melting of the summer Arctic sea ice is accumulating heat in the ocean, raising the air temperatures in the region, what is known as Arctic amplification. As this was detected 10 or 15 years before what it was expected, is thought that the Arctic has already passed the climatic tipping-point towards ice-free summers (Connor S. 2008) & (Serreze M. & Stroeve J. 2008).

2.2. Ecological Flexibility

The Bowhead whale is restricted to high latitudes in the northern hemisphere, ranging between 55°N in winter and 80°N in the summer (UNEP-WCMC). Its morphology is well adapted for these arctic conditions (Harrington 2008), and it is the only baleen whale to remain in these cold waters throughout its lifecycle (Carroll, G). This makes the Whale relatively specialised in its choice of habitat, which climate change is likely to influence, mainly because they remain close to the southern boundary of the winter ice, and move northward as the ice recedes during spring (Kovacs & Lydersen, 2009).

The bowhead has huge baleen feeding plates that, like other baleen whales, are adapted to filter small prey out of large volumes of water (Kovacs & Lydersen, 2009). They feed on a variety of zooplankton (over 60 species have been recorded) taking primarily crustaceans (Reilly 2008). Their major prey items are krill and copepods, typically 3-30mm (Carroll, 2009). Bowheads feed at all depths throughout the water column, and are known to use a variety of strategies to increase their feeding efficiency, such as swimming in formation within groups, and feeding under ice (Carroll, 2009). They are assumed to take most of their necessary food during the summer months, though it is likely that additional feeding takes place at other times of year (Kovacs & Lydersen). Diets differ across regions and over time, suggesting it relates to seasonal availability of prey and that they locate prey concentrations arsing from oceanographic features such as upwelling and fronts (Laidre 2008).

Female Bowheads reach sexual maturity when they reach lengths of about 13.5 m and males at 12-13 m (or about 20 years of age) and individuals are thought to live on average for 60-70 years. They mate during the late winter with a gestation period of approx 13 months with one calf born every 3 – 4 years so they have a relatively low reproductive rate. Calves are weaned when they reach 9-15 months of age (Justice, 2002).

Radiocarbon-dating of Bowhead remains indicates this species has experienced extensive expansions and contractions in its range in the last 10,000 years. These changes in distribution mirrored the changing extent of the sea ice with varying temperatures (Harrington 2008). This suggests the bowhead whale has the capacity to adjust its range to some extent to cope with a changing habitat and climate.

This large species is capable of travelling 1000s of kilometres (Heide-Jørgensen 2006), following the seasonal melting of the pack ice at high latitudes. They swim fairly slowly and make long dives during their migratory journeys (Carroll, N.D.). Bowhead migrations are not fully understood, but studies indicate they take similar routes every year. It is possible that these routes are fixed through matrilineal learning behaviour, which may 'lock' populations into traditional habitat use and limit their ability to adapt to changing conditions (Laidre 2008). This is also combined with low reproductive rate signifies that this species has relatively low adaptability (Justice, 2002).

Bowhead whales are regarded as an ice adapted species but are not always associated with ice. They typically select habitats with moderate to light ice cover. Reduced ice cover could therefore expand foraging opportunities however it is uncertain whether Bowhead whales would be able to adjust to ice free waters and this species may be heat intolerant (Elliott & Simmonds, 2007). Unfortunately we cannot know the full impact on the species until it happens and by then it may be too late.

The Bowhead whale is the only mysticete endemic to the Arctic and therefore has minimal overlap of ecological niche, prey choice and focal area use with the other cetaceans present such as Narwhals and belugas (Laidre *et al* 2008).

2.3. Species Interactions

Small to medium-sized crustaceans, such as krill and copepods, form the bulk of the bowhead's diet (Reilly et al., 2009). In the high Arctic, the base of the food chain consists of ice algae which are formed on the underside of the ice at the ice-seawater interface (COSEWIC, 2005). Algal cells are then sloughed off into the surrounding water column, during spring warming and ice melt, where a seasonal bloom of phytoplankton is initiated (COSEWIC, 2005). Many species of copepods, the primary prey of bowheads, reproduce under the ice before the phytoplankton bloom and feed on sedimenting ice algae (COSEWIC, 2005).

With a continuing loss in ice habitat, there would be less ice algae produced, resulting in less food for copepods, and in turn, for bowhead whales (COSEWIC, 2005, Reilly et al., 2009).

In a recent study the complex relationship between krill and salpa (a pelagic tunicate) have been documented (UNEP-GRID, accessed 2009). Extensive seasonal ice cover promotes early krill spawning, inhibits population blooms of pelagic salpas and favours the survival of krill larvae through their first winter (UNEP-GRID, accessed 2009). In essence, salpa bloom affects adult krill reproduction and the survival of krill larvae. If sea temperatures were to continue to increase and there was a subsequent decrease in the frequency of winters with extensive sea-ice development, the frequency of failed krill recruitment would increase, and the krill population would decline (UNEP-GRID, accessed 2009). This would have a significant impact on the bowhead whale population, which depends on krill for their main source of food (UNEP-GRID, accessed 2009). However, the degree to which climate change will affect bowhead populations, by altering the food web, is still uncertain, and may bring about a net positive or a negative effect (COSEWIC, 2005).

In the Bering-Chukchi-Beaufort population, bowhead whales stay with the ice edge as it advances and retreats each year, and a reduction in the southern extent of seasonal sea ice could displace southern ranges of bowheads northward (COSEWIC, 2005). The inter-annual changes in the onset and severity of seasonal sea ice may also affect the length of feeding seasons, timing of migration, fecundity, and survivorship of not only bowhead whales but other marine mammal species as well (COSEWIC, 2005).

2.4. Interactions with other Processes

The main threat to bowhead whales is overhunting. Commercial hunting and whaling for food and fuel by indigenous people have led to the depletion of the species. Other threats to bowhead whales include ship strikes, accidental catch in fishing gears, oil spills and the bioaccumulation of toxins. Environmental noise and pollution from tourist activities, disposal of industrial effluents and plastics in the sea has also caused a significant decline in the population of bowhead whales (Laidre et al, 2008). Disturbance from oil and gas exploration is also considerable. With the melting of sea ice in the Arctic it is expected that oil and gas exploration would increase (NOAA Fisheries Fact, 2006). However, it is unknown as to how this would affect the status of the bowhead whale.

The reduction in summer ice cover has a high certainty of making commercial shipping feasible in the Northern Sea Route by 2020. The reduction in sea ice over the past 40 years has reduced available habitat and hunter access to many marine mammals, which are an important subsistence and cultural resource for many coastal indigenous peoples of the Arctic. Northern oil and gas development may also influence marine mammals. Noise from offshore oil exploration in the Beaufort Sea disturbs bowhead whales and could deflect them from migration routes, making them less accessible to hunters. Autumn-migrating bowheads, for example, stay 20 km from seismic vessels (Chapin F.S. *et al* 2005). If commercial shipping increases due to sea ice loss this will further endanger the Bowhead whales if they come into contact with ships or they can be scared away by them. Increased shipping will also result in greater risk of oil and chemical spills as well as acoustic disturbance and collisions between ships and whales.

Bowhead whales are perhaps the most sensitive of all large whales with reaction distances of over 30 km to seismic and shipping noise and this could lead them to abandon feeding areas if they become polluted by industrial noise, it is reasonable to assume that Bowheads will fare badly in the face of increased fishing activities. The opening of the Northwest passage is highly likely to have a negative impact on whales and most cetaceans in the area, especially when the synergistic effects of these human activities and climate change induced shifts in ecosystems are combined (Elliott & Simmonds 2007).

3. Species Management

By saving the habitat and saving the Bowhead we also be saving hundreds of other species in the arctic which also depend on sea ice. At present the IUCN classifies the Bowhead whale as least concerned. Taking all the above climate change impacts into consideration this current status could dramatically change over a matter of years or decades to a more threatened status, perhaps on the verge of extinction, along with many other marine and polar species, unless appropriate action is taken. The main objective of this action is to reduce carbon dioxide emissions, which drives both ocean acidification and climate change.

There are however additional methods which can be used for mitigating these such as:

- The addition of limestone (calcium carbonate) powder to surface layers in regions where the depth of the boundary between supersaturated and unsaturated water is relatively shallow (250-500 m) (Harvey L.D.D. 2008). This is possible in the Arctic Ocean as the ocean depth is relatively shallow south west of the Lomonosov Ridge (200 m compared to the north east side which has an unprecedented depth, over 4,000 m – this deep ocean minimises tidal and lunar effects on the ice) (Robinson B. 1999). Limestone powder can also be added to regions where upwelling velocity is large (30-300 ma^{-1}) to partially reverse or hinder the acidification process. This absorption of CO_2 would have the potential to largely offset the increase in mixed layer pH and carbonate supersaturation from the added limestone (Harvey L.D.D. 2008).
- The addition of Iron to the ocean known as Iron Fertilisation or 'seeding' parts of the ocean with Iron, a micronutrient which stimulates the growth of plankton which would thus remove excess CO_2 from the atmosphere, however it would be stored in the oceans instead. This process raises a number of questions including its effectiveness as a market based sequestration system, possible negative effects on the ocean and other environmental systems (Sagarin R. *et al* 2007).

International agreements have saved whales from extinction in the past. The International Whaling Convention has effectively halted the hunting of Bowheads, thus eradicating the main threat to the species. This has been aided by work done by CMS and other organizations, which has further helped safeguarded the future of the species from hunting and development (Reilly et al, 2008). However, Climate change has the potential to push Bowheads back to the edge of extinction, particularly considering the populations are still vulnerable from historic whaling, due to low reproduction rates.

Climate change is most likely to impact upon Bowheads through reduced sea ice, ocean acidification and changes to ocean circulation, with these processes changing habitats and prey abundances. This means that research and monitoring will be needed to assess the impacts of climate change on Bowhead Whales. Firstly, monitoring of the extent of sea ice needs to be maintained, and this should mostly be undertaken using a combination of remote sensing and GIS. Secondly, the pH of Arctic waters needs to be monitored. Finally, it would be desirable to monitor changes to ocean currents and therefore prey species distribution, however this would be technically challenging and expensive. Reduced sea ice cover has direct impacts on the whales so the monitoring can understand these processes. However, many of the processes that affect the whales do so indirectly, by changing prey abundances. Therefore more research needs to be undertaken to improve understandings of the effects of reduced sea ice and increased ocean acidification on prey species and specifically krill.

Protecting Bowhead Whales from climate change through traditional conservation methods is unlikely to be possible, as the processes which affect the polar oceans and the whales occur over such large scales. This means that even with conservation, Bowhead Whales are unlikely to be able to adapt to climate change. Therefore mitigating climate change impacts is the only way to reduce the effects of climate change on Bowhead whales, and through this, it is potentially possible to stop the complete collapse of oceanic and arctic ecosystems.

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West African Manatee, *Trichechus senegalensis*

Distribution: West African Coast

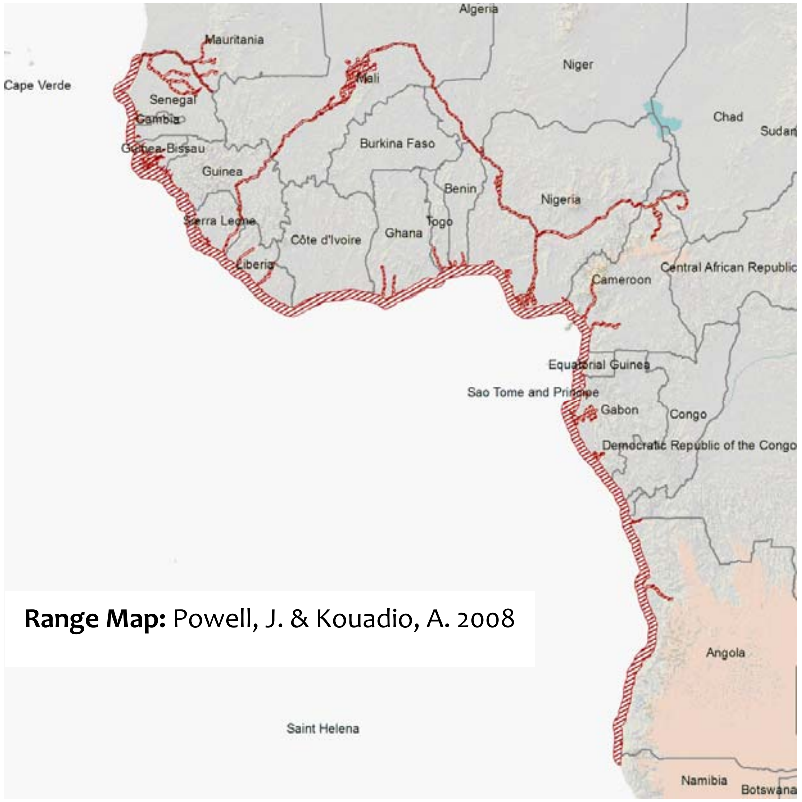
IUCN Classification: Vulnerable A3cd C1

Population Estimate: No estimates available <10,000

CMS Appendix: 1

1. Background Information

The West African Manatee (*Trichechus senegalensis*) is a large aquatic mammal found in coastal and inland wetlands of Western Africa between Mauritania and Angola, and as far as 2000 km from the ocean in the upper reaches of the Niger delta in Mali (Powell and Kouadio, 2008). In general it occurs in coastal and estuarine habitats, coastal lagoons and the lower reaches of most river systems from the Senegal River of Mauritania/Senegal to the Longa River in Angola. Manatees have been observed found up to 75 km offshore among shallow coastal flats and mangrove creeks. A few populations are now effectively "land-locked," and are unable to reach the sea, the Lake Volta population is separated from the sea by the Volta Hydroelectric Dam, whilst the population farthest from the ocean on the Niger River inland delta Mali, is cut off from the sea by natural rapids in the river (Powell and Kouadio, 2008). The range of this species appears to be close to its historic levels, whereas the population of this species is was substantially diminished during the 20th Century (Powell and Kouadio, 2008).



Range Map: Powell, J. & Kouadio, A. 2008

2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability

The West African Manatee inhabits coastal and fresh waters, migrating up and down rivers seasonally, due to changes in water level. It prefers calm, shallow, estuarine waters, although it can be found in all types of inland and coastal wetlands. Its range extends throughout West Africa (Powell and Kouadio, 2008), this means that climate change in West Africa will affect the habitats of the West African manatee. The most important alterations to these habitats are likely to be related to changes to temperature, precipitation, severe weather, Sedimentation rates, sea level as well as ocean circulation, salinity and pH.

West Africa is predicted to warm by 3.3°c by 2100 (See Figure 1) (Christensen *et al*., 2007). This will increase the water temperature of inland wetlands, particularly during low water periods. This warming is also expected to warm coastal areas but to a lesser extent. This increase in temperature has the potential to impact upon the manatees in many ways from individuals overheating, particularly when they are confined in channels, to changing chemical processes (Learmonth *et al*., 2006). The higher temperatures are also likely to lead to higher rates of evaporation. This could reduce water availability in the Manatee's habitats.

Changes to precipitation regimes also have to the ability to reduce water availability. Across East Africa, precipitation is predicted to either decrease or increase, somewhere in the range of between -9% and +13% by 2100, with the predicted response around +2% by 2100 (See Figure 2). This is highly uncertain and local differences are expected to be much more pronounced. This is due to uncertainty surrounding the position of the inter-tropical convergence zone and the associated West African monsoon, the intensity of which could change by 30% by 2100 (Christensen *et al*., 2007).

Figure 1

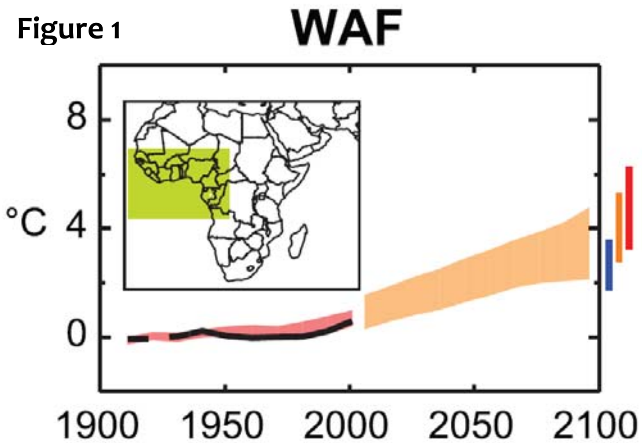


Figure 1: *Shows temperature anomalies with respect to 1901 – 1950 for West Africa from1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the timeline present the range of projected temperature changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).*

This means that the manatee's habitat is likely to receive more and less rainfall, varying temporally and spatially. Thus rainfall, and therefore river levels, will become increasingly variable. This is likely to be particularly damaging to manatees. They suffer from the fast flowing waters characteristic of high rainfall as it impedes their ability to move freely, whilst they also suffer from low river levels that are induced by low rainfall, as under these conditions the manatees can become stranded. This can directly induce mortality, and it makes them more vulnerable to other processes. Both high water and low water levels are likely to become more common in the future, almost certainly causing problems for the manatees (Powell and Kouadio, 2008).

Figure 2

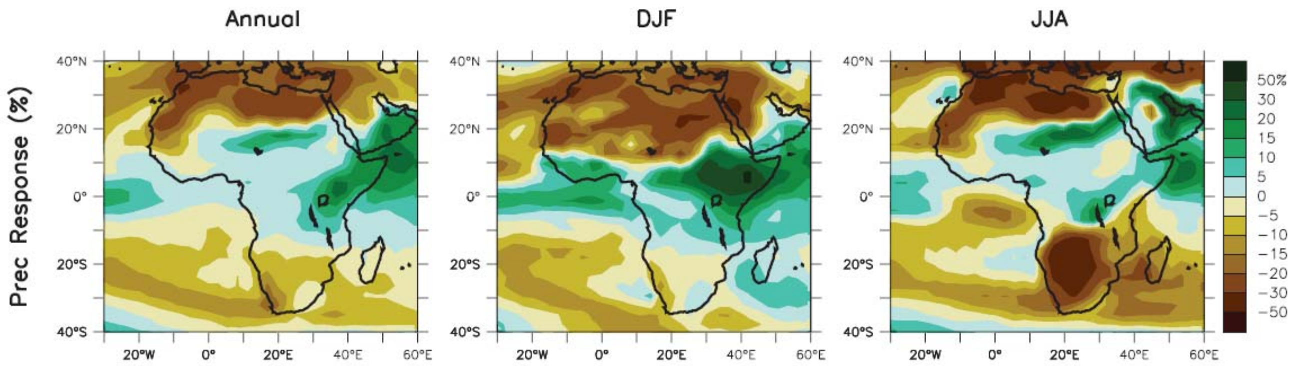


Figure 2: *Projected precipitation variations for the 2080 – 2099 period compared with 1980 – 1999 conditions. Projections are averaged over the 21 models utilised in the IPCC AR4. Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).*

These changes to precipitation regimes are related to the increased chance of extreme weather events in West Africa (Niasee et al, 2004). These events are predicted to have impacts other than just changing water levels, thus the extent of the manatee's habitats. For example, increased rainfall has the potential to create algal blooms through increased nutrient flux. These blooms can be poisonous and have caused manatee mortality in the past (Evans *et al*., 2007). Whilst low water levels can concentrate pollutants already present in the water (Smith and Braulik, 2008).

Changes in precipitation regimes are also likely to change sedimentation rates. This is likely to affect the Manatees freshwater and estuarine habitats. Increased rainfall means increased sediment flux, whereas decreased rainfall means decreased sediment flux. Increases in rainfall could potentially lead to freshwater habits becoming unsuitable due to excess deposition of silt, whilst estuarine habits would benefit from the extra sediment increasing their size. With less rainfall, rivers will contain less sediment, therefore remaining navigable, whilst estuaries will shrink. Either way, it appears to be very likely that the habitat of the manatee will be affected (Walling and Fang, 2003).

The changes to estuaries from sedimentation are likely to be limited compared to the effects of sea level change. The IPCC Fourth Assessment Report predicts by 2100, sea levels will have risen by 0.18m- 0.59m compared to the 1980-1999 mean (Bindoff et al, 2007). Models of how basal sliding could affect rates of sea level rise were not incorporated into the IPCC projections (Kerr, R.A. 2007). Incorporating these important uncertainties into the sea level rise projection models, Rahmstorf (2007) predicted that the level of sea level rise by 2100 is more likely to be in the range of 0.5m - 1.4m (See Figure 3).This has the potential to inundate large areas of the coast, particularly the shallow areas the manatees frequent, significantly degrading the manatee's coastal habitats.

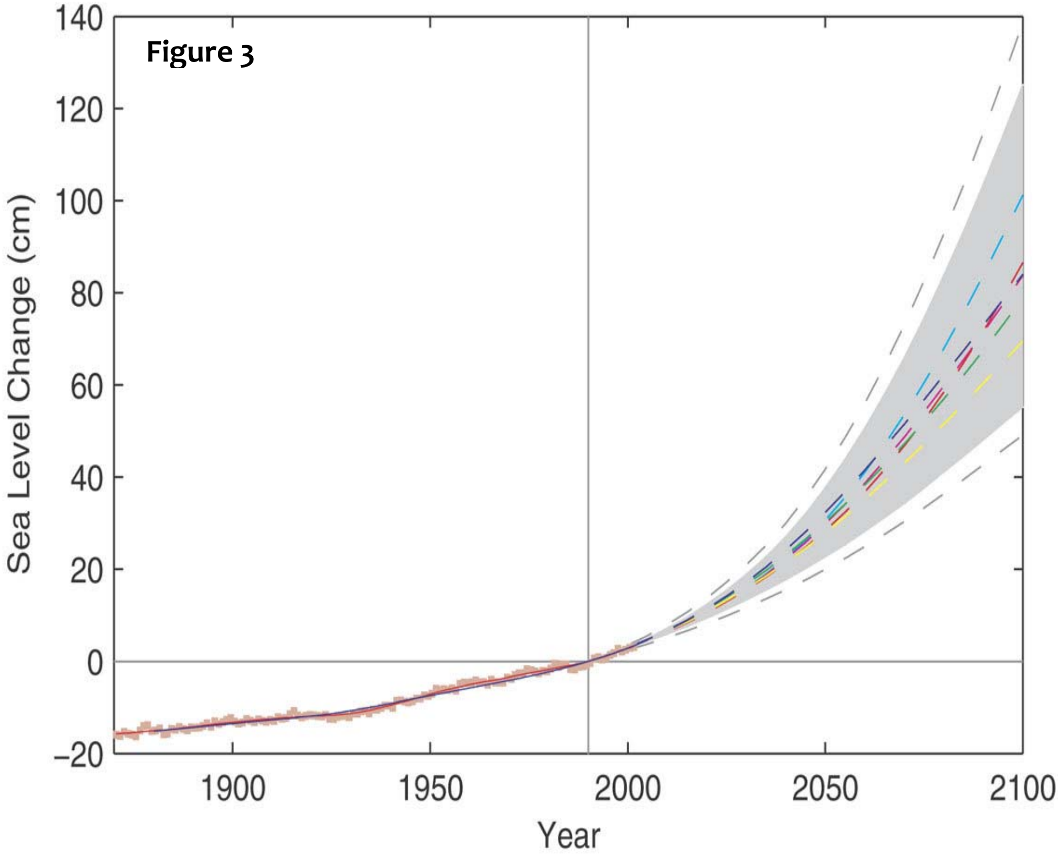


Figure 3: *Past sea level and sea level predictions. The grey area represents uncertainty, whilst the coloured lines represent different emissions scenarios from light blue, the A1FI scenario, to yellow the B1 scenario (Rahmstorf, 2007).*

Changes in the wider ocean are also likely to affect the coastal habitats of the manatee. Temperature and salinity drive ocean circulation, increasing temperatures and reduced salinity are therefore likely to alter ocean circulation and therefore the oceans. This will affect numerous coastal processes and their spatial distributions (Bindoff *et al*., 2007). Changes in salinity will be caused by melting ice causing extra freshwater influx. This will affect more than just the circulation of the oceans. It will also affect habitat parameters such as species abundance and chemical processes, impact upon the manatee. Changes in pH from CO2 dissolved in the oceans are likely to have a large effect on the entire ocean system, and particularly costal habitats. PH is expected to decrease by 0.3 to 0.4 units by 2100. This will also affect the Manatee's coastal habitats. These changes to the oceans are likely to be significant, and may well alter the coastal food-webs upon which the manatee relies (Meehl *et al*., 2007).

4.1. Ecological Flexibility

The West African manatee's main habitat requirements include sheltered water, with access to food and freshwater (Marshall et al., 2003; Powell & Kouadio, 2008). Optimal coastal habitats include coastal lagoons with an abundant growth of mangrove or emergent herbaceous growth; estuarine areas of larger rivers with abundant mangrove in the lower reaches and lined with grasses; and shallow (<3 m depth), protected coastal areas with fringing mangroves or marine macrophytes (Powell & Kouadio, 2008). In riverine habitats they prefer areas with access to deep pools or connecting lakes for refuge during the dry season (Powell & Kouadio, 2008). Although the manatees can travel freely from salt to freshwater, they appear to prefer estuarine areas where there is little disturbance and waters are shallow and calm (Powell & Kouadio, 2008).

They feed primarily on vegetation including hippo grasses (Vossia sp.), water hyacinth (Eichornia crassipes), rigid hornwort (Ceratophyllum demersum), red mangrove (Rhizophora racemsoa), water cabbage (Pistia stratioties), several species of sea grass (Cymodocea nodosa, Halodule sp.) and many more (Powell & Kouadio, 2008). They have also been documented feeding on small fish and shell remains of mollusks have been found in their stomachs (Powell & Kouadio, 2008). It is thought that sea grasses are not an important part of the West African manatee's diet, as the murky water within their main habitat range does not support extensive submerged aquatic vegetation and it is more likely that they rely upon emergent aquatic and semi-aquatic vegetation (Marshall et. al, 2003). They feed mainly at night and travel in the late afternoon and at night, resting during the day in water that is 1-2m deep or hidden in mangrove roots or under natant vegetation (Powell & Kouadio, 2008).

Manatees have low reproductive rates and on average give birth to 1 calf, after a 9 month gestation period and have a calving interval of 2-5 years (savethemanatee, accessed 2009). Females become sexually mature at around 5 years and males 9 years (savethemanatee, accessed 2009).

West African Manatees are mostly solitary, with mothers and calves the principal social unit (Powell & Kouadio, 2008). However, they will sometimes rest together in small groups of 2 – 6 individuals (Powell & Kouadio, 2008). Seasonal migrations have been documented in response to changes in water level, which affects food availability and/or water salinity (CMS, -). Some populations however are isolated (Powell & Kouadio, 2008).

4.2. Species Interactions

Manatees need an abundance of plant life to survive. Raised temperatures may effect vegetation growth, preventing many of the plant species from growing as they normally would (Manatee-world).

The effect of temperature on the physiology of aquatic plants may ultimately influence community composition and species distribution. Increases in the concentration of dissolved inorganic carbon (e.g. carbon dioxide and bicarbonate) may directly affect aquatic plants and also have indirect effects by increasing the growth of algae. Changes to photosynthesis can lead to altered plant growth, which may greatly disrupt foodwebs by altering seasonal timing of availability and plant biomass. Coastal waters will increase in depth as sea levels rise, causing inland and upstream salinity intrusion which will affect aquatic vegetation here (U.S. Geological Survey, 1997).

Sandy sediments are often deposited in sea grass beds growing leeward's or behind protective barrier islands, as a result of overwashes caused by storms. Increased storm disturbance and overwash alters the community composition of sea grass beds. Different sea grass species support different food webs, therefore changes in sea grass community composition will have result in changes at higher levels in the food chain. Frequent severe overwash and barrier island erosion may even cause total loss of all sea grasses from an area. Climate change is likely to affect the frequency and severity of these storms (U.S. Geological Survey, 1997).

West African Manatees are fairly defenceless, and may occasionally be attacked by crocodiles and even sharks (Mbina, in prep), with young manatees being particularly vulnerable to these predators (Manatee-world). Climate change may take its toll on these predator species. Their main food sources may become more scarce which potentially could lead to increased predation on Manatees (Manatee-world). It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution (Hearn et al., 2009). However, it is likely that climate change will have negative effects on Crocodilians, for example changing temperatures are predicted to affect crocodile fecundity due to temperature dependent sex determination, and climate change is expected to lead to a decrease in suitable nesting habitat etc.

4.3. Interactions with other Processes

The population decline of manatees has been attributed mostly to hunting and incidental capture in fishing nets. Despite legal protection, the manatee is still hunted throughout its range. As well as incidental capture, fishing practices are also in conflict with the manatees feeding and migratory behaviour. Fishermen remove floating vegetation altering the aquatic habitats to the detriment of the manatees. Fish harvesting methods also cause problems because fishermen use live vegetation thus restrict access to feeding resources (Sirenian.Org April 2007).

Changes to the manatee's habitat, including mangrove destruction (for rice farming, wood, fish smoking, salt extraction and other needs), and development projects such as dams also negatively effect manatees (Sirenian.Org April 2009). Manatees are sometimes killed in turbines or control gates of dams. They can also become trapped behind dams, whilst increased dam construction for irrigation and other purposes has led to low water levels, which can leave manatees stranded or without food (Sirenian.Org April 2009).

The decline of the manatee is also partly due to their coastal wetland habitat being heavily degraded. Woodcutting is resulting in the clearance of mangrove swamps as well as erosion due to forest clearance upstream. This increases sedimentation that silts up lagoons and estuaries degrading the habitat (Animalinfo.Org 2009). Mangroves have thick copses and interconnected roots that are essential for purifying sea water, regulating the tides, balancing underwater ecosystems, and mitigating the effects of floodwater damage, thus their loss can a number of problems in the manatees' coastal habitats (African Conservation.Org 2007).

The construction of sea wall defences along coastal habitats against sea level rise could also degrade mangroves, interfere with migration routes and restrict the manatee movements along the coast (Gibson 2006). The IUCN Red list estimates that a further 30% population reduction is expected in the next 90 year, during a 3 generation period due to habitat loss by mangrove harvesting, siltation, dams. This percentage could increase when combined with the effects of climate change as discussed above.

3. Species Management

Currently Manatees are protected throughout their range by national laws. However, this is relatively ineffective due to difficulties with enforcement. This means that opportunistic poaching is a problem. Developments and deforestation are also a problem for manatees and there is limited action against this. However there are a number of national parks throughout their range (Powell and Kouadio, 2008).

To help protect manatees from climate change monitoring will need to be undertaken to track changes to processes that affect manatee populations. These changes are manifold and therefore a large amount of monitoring is required to accurately track the effects of climate change on manatees. Ecological monitoring needs to be undertaken on dynamics which will affect possible predators, and therefore their interactions with manatees. Furthermore, the affects of climate change on vegetation which the manatees eat, also needs to be monitored. The largest amount of change and therefore monitoring efforts will need to be spent on assessing climate induced changes to habitat. Temperature, rainfall, river levels, river state and sediment load all need to be monitored to understand changes to riparian habitats, and particularly processes such as floods and droughts, which are likely to be most detrimental to Manatee. Sea level and ocean ph needs to be monitored to asses the implications for manatee's coastal habitats, whilst more research is necessary to full understand the implications of these processes on the manatees.

Policies designed to help Manatees adapt to climate change may be very difficult to implement. Changes to ecosystems and coastal habitats will be particularly hard to mitigate, and traditional forms of conservation are unlikely to be able cope. Dams could be used to regulate water levels in rivers, thus keeping water levels at a safe level for manatees. However, local governance of this sort of strategic policy is likely to be difficult. Furthermore, the uses of dams and river systems in this way may not be beneficial to local people or the local environment. This means that the best policy to protect manatees from the large number of climate change threats they face is climate change mitigation. Reducing emissions is likely to be the most effective and efficient way to protect manatees' ecosystems and habitats, as well as other climate change threatened species.

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Aquatic Warbler, *Acrocephalus paludicola*

Distribution:

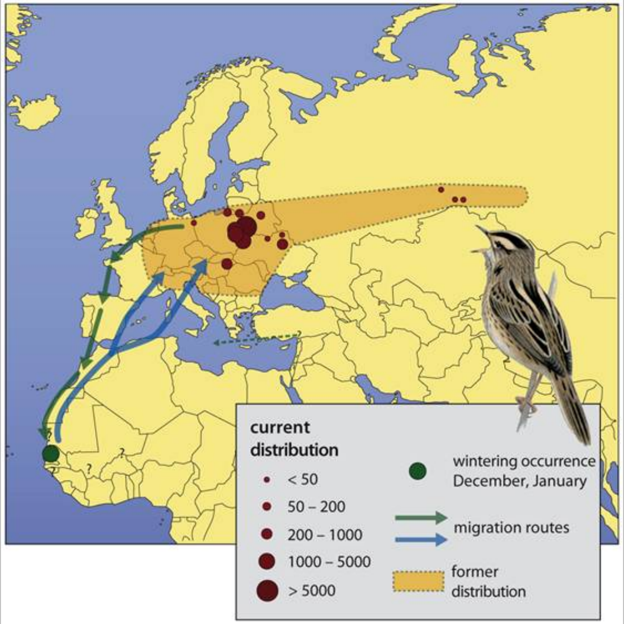
- **Eastern-Europe (summer)**
- **Sahelian Belt of sub-Saharan Africa (winter)**

IUCN Classification: Vulnerable

Population Estimate: 22,000 – 30,000

CMS Appendix: 1&2

Image Source: *AWCT (2009)*



1. Background Information

Once widespread and abundant on fen mires and wet meadows throughout Europe, the Aquatic Warbler is now absent from most of its former range and today breeds across fragmented breeding sites in central-eastern Europe. As Figure 1 shows, a large proportion of the population breeds in just three countries: Belarus, Poland and the Ukraine (AWCT, 2009). Its breeding area is generally situated in large open lowland marsh habitats with low grassy vegetation, where water-cover is generally less than 0.1m in depth (BirdLife International, 2008). During migration, they favour reeds and sedges near open water, in their wintering habitat they utilise large open grass marshes on the Senegal Delta (AWCT, 2009).

A number of new populations were discovered between 1995 and 2005 which considerably increased the population estimate of this species, however it had suffered a rapid decline until the late 1990s due to habitat destruction; the population decreased at a rate equivalent to 40% in ten years (BirdLife International, 2009). Its once widespread distribution has now decreased to the extent that there are less than 40 regular breeding sites remaining across just six countries, with 80% of the population supported by just 4 sites (AWCT, 2009).

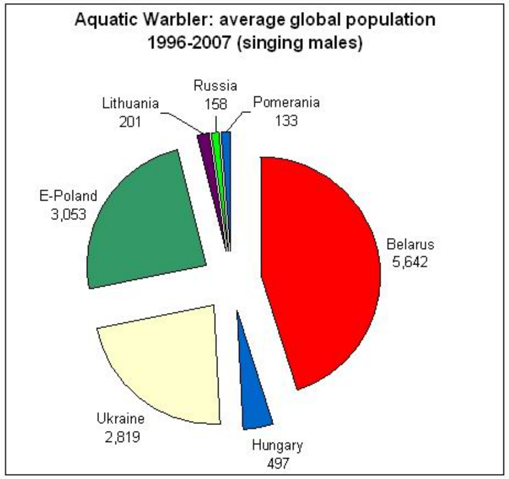


***Figure 1.** Average global population 1996-2005. (Singing males). Source: AWCT, 2009*

A. paludicola arrives in the central-European breeding grounds from early May onwards, probably not arriving into western Siberia before mid-May. They leave the breeding grounds between July and September, arriving in western Africa in late October-November, where they remain until March (AWCT, 2009).

2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability

The aquatic warbler breeds across fragmented breeding sites in central-eastern Europe, and a large proportion of the remnant population breed in just three countries: Belarus, Poland and the Ukraine. Its breeding area is generally situated in large open lowland marsh habitats with low grassy vegetation, where water-cover is generally less than 0.1m in depth (BirdLife International, 2008). Figure 2, taken from the IPCC Fourth Assessment Report (2007) shows that the temperature for the breeding areas of this bird is going to rise by around 2.5°C in the summer months, when the bird will be nesting and the total summer precipitation is expected to remain close to the 1981-1999 average. Although the increased summer temperatures are likely to increase evaporation rates thereby decreasing the amount of water in the wetlands, the overall annual precipitation rate is expected to increase by 5-15% which should be sufficient to offset any increased evapo-transpiration rates.

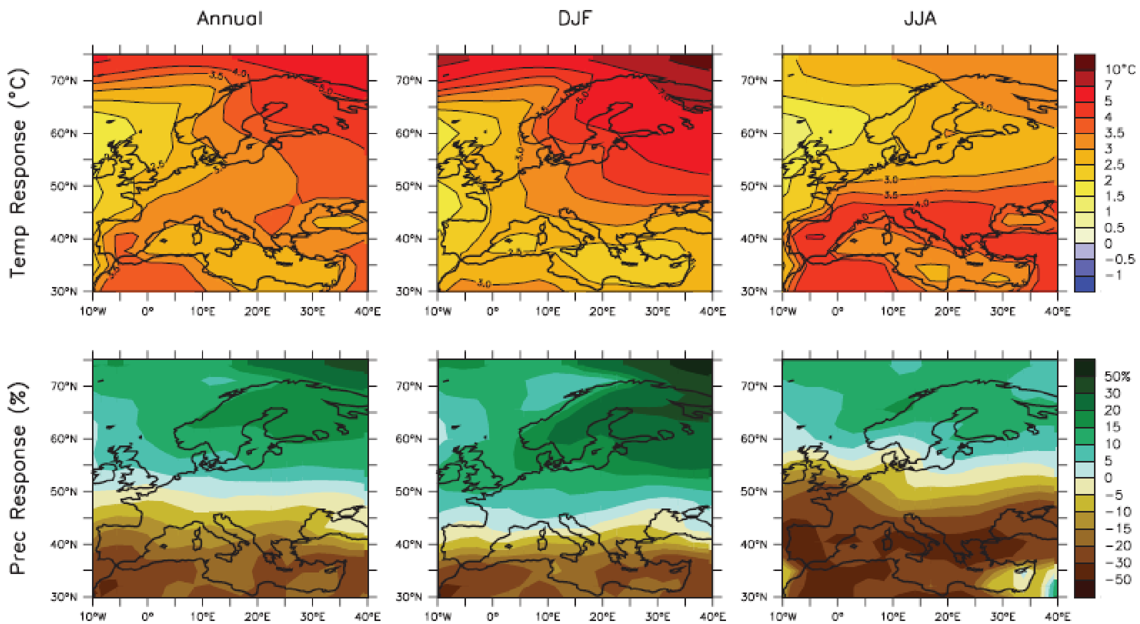


***Figure 2.** Temperature changes (top) and precipitation changes over Northern Europe under A1B scenarios for 1980-1999 and 2080-2099 time period. DJF indicates winter variations, and JJA indicates summer variations whilst Annual indicates the annual mean. Source: Christensen et al., 2007*

Figure 3 (right) shows the changes in conditions that the aquatic warbler can expect to encounter when it arrives in west Africa for the winter months. By 2100 under an A1B emissions scenario, the minimum temperature response in the winter months (December, January and February) due to anthropogenic radiative forcing expected is 2.3°C, and the maximum response modelled is 4.6°C. Under the same scenarios and interrogating the same time-frame, the projected precipitation response to climate change for the winter months is between a 16% drop in precipitation and a 23% increase. Again, with increased temperatures we can expect a higher evapo-transpiration rate, but it is difficult to infer what will happen to the wetland habitat as the uncertainty in future precipitation is so high. Research by Kamga and , Buscarlet (2006), showed that six GCMs projecting rainfall in the west African Sahelian belt all predicted the start of the rainy season between 1-2 months before the actual observed date.

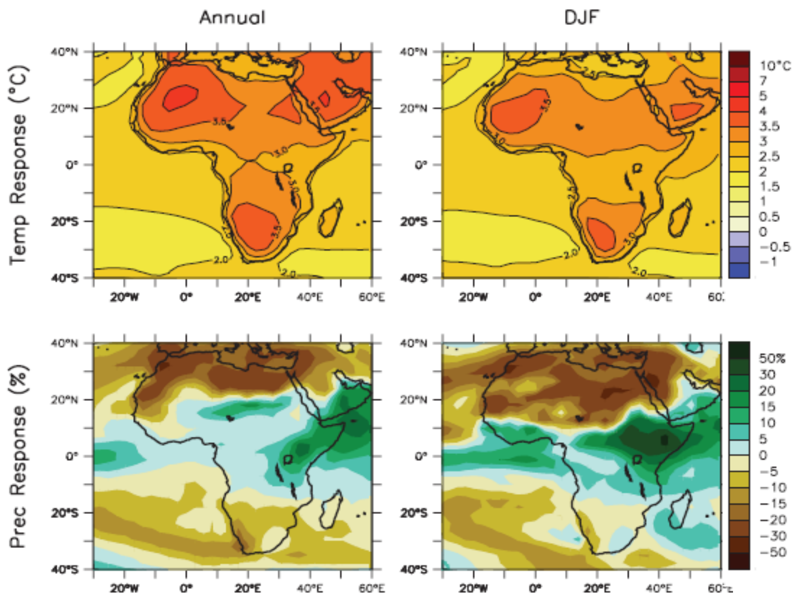


Figure 3. *Temperature changes (top) and precipitation changes over Africa under A1B scenarios for 1980-1999 and 2080-2099 time period. DJF indicates winter variations whilst Annual indicates the annual mean. Source: Christensen et al., 2007*

Such uncertainty makes it almost impossible to produce a useful assessment on the habitats on which the aquatic warbler relies in west Africa. From the IPCC models it appears that it is marginally more likely that the rainfall will increase during the winter months, and it is also marginally more likely that the annual precipitation rate will increase (Christensen et al., 2007). However, as the wetland habitat in this area is reliant upon artificial flooding, even if the amount of annual precipitation increases the amount of warbler habitat is unlikely to extend, rather the extent of the rice-fields and agriculture in the area (Tegetmeyer, C. *personal communication, 2009*).

Whilst precipitation response is so uncertain, Walther et al., (2007) concluded from a study of aquatic warbler sites that few trends were apparent between site location and climate.

2.2. Ecological Flexibility

Specialisation: The diet of the aquatic warbler consists mainly of large arthropods, particularly spiders, caterpillars, beetles and flies. The prey intake may vary considerably through the seasons, and annually due to fluctuations in the arthropod fauna. When breeding, this bird tends to forage in close proximity to the nest (10-50m). Feeding frequency is also high, as the habitat is very rich in food (Schulze-Hagen et al., 2004).

Whilst the range of food items taken by this species is fairly broad, its habitat requirements are quite specific. Its breeding area is generally situated in large open lowland marsh habitats with low grassy vegetation, where water-cover is generally less than 0.1m in depth (BirdLife International, 2008). During migration, they favour reeds and sedges near open water, in their wintering habitat they utilise large open grass marshes on the Senegal Delta (AWCT, 2009). However, Walther *et al.* (2007), concluded from a study of roosting sites in west Africa that there was a pronounced annual variation in the temperature and precipitation levels at the nesting sites chosen by individuals. Although there appeared to be a lack of relationship between climate and the nest-location chosen, this bird does appear to be tied to habitats with shallow water-cover, which indicates that it is a specialised species.

Walther et al. 2004 conducted a study to identify the potential range of the Aquatic Warbler. Although there appears to be suitable habitat along the eastern Sahalian belt, this species seems fixed to wintering in a relatively small area within West Africa.

Reproductive rate: Nesting success in aquatic warblers is very good, with 83% of the young surviving until they fledge the nest (AWCT, 2009). This coupled with a low nest predation-rate, and a 50% rate of second broods some years ensures a high reproductive output (Schulze-Hagen et al., 2004).

Climate related changes in fecundity: There have been suggestions that warmer temperatures can alter the sex-ratio of aquatic warbler broods. In 2004, Dyrcz et al. undertook a study to determine which factors were playing a role in the sex-determination of chicks, which did show some correlation between lower temperatures and the proportion of females hatching. However the outcome of the research was not conclusive as lower temperatures could also affect the availability of food as cool weather can often reduce the number of insects available (Dyrcz et al., 2004).

2.3. Species Interactions

Species from the Arachnida, Diptera, Lepidoptera and Trichoptera families form about 70 % of the prey of the aquatic warbler. Although the composition of the arthropod fauna may alter due to changing climatic conditions, the prey intake of this species already varies considerably through the seasons, and annually due to fluctuations in the arthropod fauna (Schulze-Hagen et al., 2004). Therefore, assuming no overall decline in arthropod density, it is reasonable to infer that the aquatic warbler could adapt to changes in the arthropod community.

The Aquatic Warbler Conservation Team (2009) report that predation upon nests lead to 11% mortality of young. Predators are thought to be primarily and shrews (*Sorex* sp) (Vergeichik and Kozulin, 2006). Other predators are a factor, Marsh Harrier (*Circus aeruginosus*), White Stork (*Ciconia ciconia*), Water Vole (*Arvicola terrestris*), Ermine (*Mustela vision*), Raccoon Dog (*Nyctereutes procyonoides*) have all been known to devastate aquatic warbler nests, however according to Vergeichik and Kozulin (2006) predation by these species is thought to be casual and to usually occur only when the nests are built in unusual areas.

As there is more than one shrew species involved in this predation yet no indication as to the relative importance of each on the warbler population, it is difficult to project how climatic changes will impact upon the warbler's breeding.

2.4. Interactions with other Processes

The breeding habitat of the aquatic warbler has suffered a severe decline in western and central Europe. (BirdLife International, 2008). The main drivers behind this habitat loss were drainage to intensify agricultural use and to aid peat extraction. Alterations to the hydrological regime of the habitat has also had a large impact – increasing the rate of stream flow through digging channels and deepening riverbeds has been deleterious to the wetlands. (BirdLife International, 2008). These processes can lead to a lack of water which leads to reduced breeding success and subsequently population decline, summer flooding which can destroy nests and vegetation loss.

Land-use change in the breeding habitats is also cited as a severe threat (AWCT, 2009). Whilst in many parts of Europe harvesting of wetlands was commonplace, increasingly such practices are being abandoned, which leads to overgrowth by reeds, grasses and bushes or trees. These decrease the quality of the aquatic warbler's habitat.

In the wintering habitats, the main habitat losses are observed due to the creation of reservoirs or the cultivation of water intensive crops such as rice and sugar cane. The major wintering site for the global population of this species is now dependent on the artificial flooding (AWCT, 2009). Drought, overgrazing and salinisation are also cited as important threats in the wintering sites (AWCT, 2009).

Another less severe threat stems from the eutrophication of the wetlands in both the wintering and breeding habitats (BirdLife International, 2008).

BirdLife International (2009) regards the three major threat facing *Acrocephalus paludicola* as threats which have rapid severity, but medium impacts in scope. These threats are:

- Agriculture: the intensification and expansion of agricultural land
- Biological resource use – gathering terrestrial plants and the unintentional side effects/direct effects of hunting
- Natural system modification: water management, use and the creation of large dams.

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Balearic Shearwater, *Puffinus mauretanicus*

Distribution: Mediterranean and North-west Europe

IUCN Classification: Critically Endangered

Population Estimate: 6,000 – 10,000 individuals

CMS Appendix: 1

1. Background Information

The Balearic Shearwater breeds in the Spanish Balearic Islands. The most recent reliable estimate of the breeding population is showed 2,000-2,400 breeding pairs across 24 different sites, with the islands of Mallorca having 350-550 pairs; Cabrera 50-100 pairs; Ibiza 200-300 pairs and Formentera up to 1,000 pairs (BirdLife international, 2008). In Menorca there are 100-175 pairs but genetic evidence suggests that there is a high degree of hybridisation within this population (Genovart et al., 2007). During the breeding period, this species primarily forages for small pelagic fish over the eastern Iberian continental shelf (Arcos et al. 2000, Louzao *et al.* 2006). Its preference for species popular for human consumption such as pilchard (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) means that it is in conflict for resources with commercial fishing fleets, however evidence suggests that its breeding success may improve with discards from fishing trawlers (Arcos & Oro 2002, Navarro *et al.* 2009). In summertime, after breeding, many of the birds migrate north to the coastal waters off France and the South-west British Isles; some reach the southern Scandinavian Peninsula (Aguilar, 1999).

Like other Procellariiformes (family including albatrosses, petrels, shearwaters and fulmars), Balearic Shearwaters are long-lived long-distance foragers (Louzao *et al.* 2006a). They have just a single offspring per brood, and the adult success of this bird is much lower than expected for one of the Procellariiformes family, which is a major concern for such a long-lived species with a low reproductive rate (Oro *et al.* 2004).

The mean growth rate of this species showed a 7.4% annual decrease which guided the models towards the estimate species extinction in 40.4 years time (Oro *et al*. 2004).

2. Species Vulnerability to Climate Change

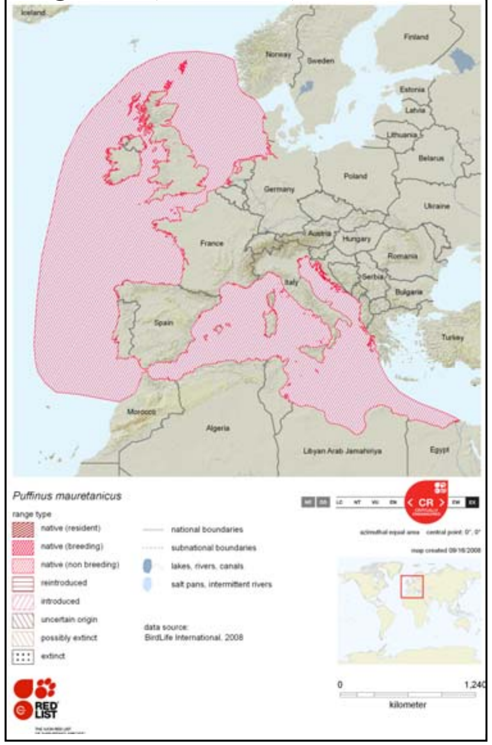
2.1. Habitat Vulnerability

The Balearic Shearwater habitat includes marine coastal, marine neritic and marine oceanic environments. Whilst breeding, it relies on sea-cliffs and rocky islands, with its food foraged from coastal inshore waters and the continental shelf to the east of the Iberian Peninsular. The non-breeding population also utilises pelagic deep waters when fishing conditions permit (BirdLife International, 2009).

There is evidence to suggest that the distance between the breeding colonies of this bird and its summer feeding areas is increasing (Ye´sou, P. 2003; Wynn *et al.* 2007). Observations of the Balearic shearwater around the British Isles and Ireland have increased since the mid 1990s (see figure 1). This is a trend that has also been witnessed across other northwest European waters (Wynn *et al.*, 2007).

This apparent increase in the number of Balearic shearwaters is however disputed by Votier *et al.* (2008). They argue that the number of Balearic shearwater observations have increased, whereas the actual number of shearwaters has not necessarily altered. This increase in observations they argue is due to a change that occurred in the taxonomic status of the species which elevated its profile, rather than due to an actual increase.

Range Map (IUCN, 2009)



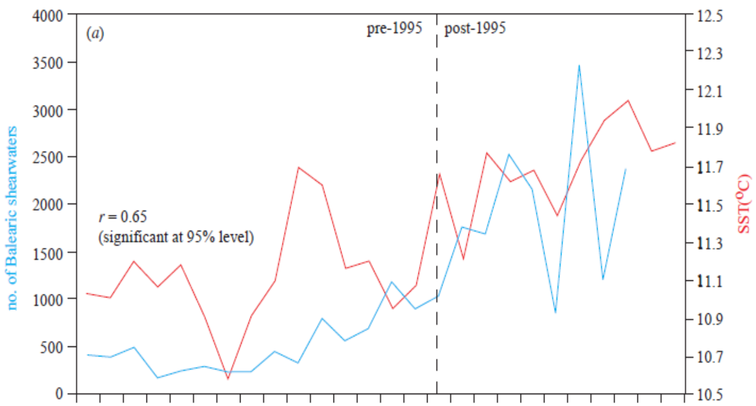


Figure 1. *Red line - The average total of shearwaters in UK and Irish waters in the time period 1980-2003. Blue line - The average annual SST in the UK and Ireland region during the time period 1980-2003. (Source: Wynn et al. 2007)*

Figure 2 shows the change in the sea surface temperatures (SST) from the 1980-1994 period and the 1995-2005 period. Wynne *et al.* (2007) suggest that the temperature increases shown in the marked area around the UK correlated with the rise in Balearic shearwater numbers, however the study could not establish direct causal connection. The decrease of Balearic shearwaters along the French Biscay coast in the mid-late 1990s (ICES, 2006) coincided with a crash in the anchovy and pilchard populations in the area (Yesou, 2003). Wynne *et al.,* (2007) report that this also coincided with a rapid increase in anchovy and pilchards in the UK waters, with many studies showing this has a strong correlation with SST (Perry *et al.*, 2005; Poulard and Blanchard, 2005).

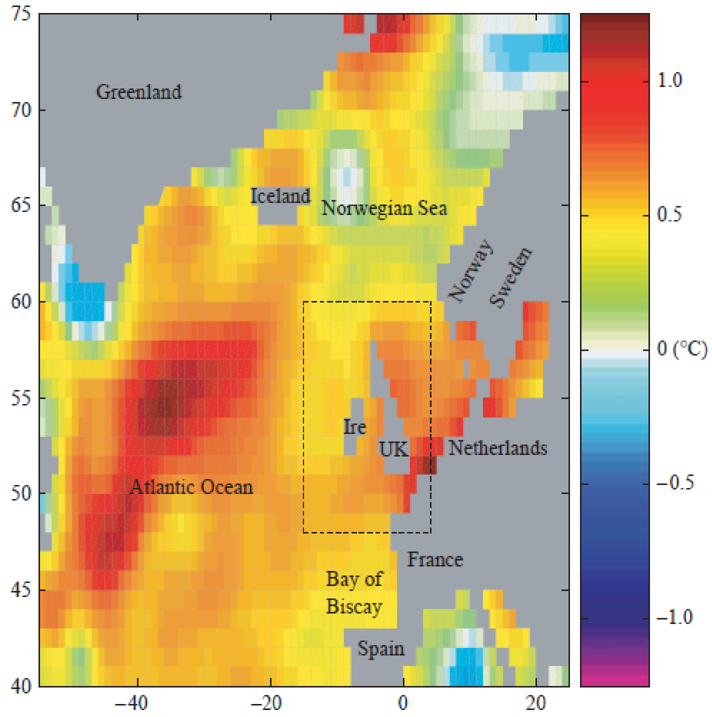


Figure 2*. Change in annual mean sea surface temperatures between the two periods 1995–2005 and 1980–1994. Source: Wynn et al. (2007).*

This northward shift is strongly linked to the copepod populations which provide food for the fish species. According to Beaugrand & Reid (2003), the species of copepod which are associated with warm temperate waters have moved north by 10° latitude in north-eastern Atlantic waters since the mid 1980s, along with a corresponding retreat of arctic and sub-arctic species. A rise in average SST therefore appears to have far reaching effects, stemming from plankton species, through herbivorous fish, up to the predators at the top of the food-web.

Further warming of SST is likely to push cool water-associated copepod species further north, an impact which, due to tight trophic coupling would rapidly propagate up from herbivorous copepods through to zooplankton carnivores right to the top of the food-web (Richardson & Schoeman, 2004).

In the northern Europe region, terrestrial temperatures in the 2080-2099 period are projected to warm by between 2.3°C and 5.3°C higher than during the 1980-1999 period. Unfortunately accurate projections for SST in the North Atlantic area are not available, but one can predict that as the ocean absorbs a large proportion of the thermal energy entering the biosphere, and as there is a considerable time-lag between surface temperatures and ocean temperatures, the ocean is likely to increase in temperature at an increasingly rapid rate.

Although the majority of GCMs project an increase in greenhouse gas concentrations will lead to a weakening of the Atlantic Meridional Overturning Circulations which would reduce the warming in north-western Europe, it is very unlikely to reverse the warming of temperatures (Christensen *et al.*, 2007).

This oceanic warming is likely to increase the pressure on this species which already shows very high adult mortality rates when compared to other Procellariiformes. Increased SST could also impact the locations of the anchovy and pilchard stocks which provide prey species off the Iberian Peninsula during their breeding period; an effect that could have severe impacts.

This species nests on rocky cliffs which are unlikely to be detrimentally affected by climate change. There is research showing that windiness may increase significantly in Europe by the end of the century (Pryor et al., 2005; van den Hurk et al., 2006), however at present the confidence in these models is very low (Christensen *et al*., 2007).

2.2. Ecological Flexibility

The Balearic Shearwater breeds in the Balearic Islands on cliffs and in small islets. The diet of this species consists of small pelagic fish, especially pilchard (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*). This bird has the ability to travel widely to forage for food sources, however during the breeding season it is limited to the western Mediterranean by the need to feed young. In this area, they take advantage of the high productivity around the Ebro Delta (Oro et al., 2004; Louzao et al. 2006a).

This species appears to have the ability to alter its migratory feeding patterns to match that of its prey as Wynne *et al* (2007) report that the Balearic Shearwaters feeding areas have shifted 10° north following changing distributions of its prey. However, its breeding area is limited to the Balearic Islands of the western Mediterranean (BirdLife International, 2008) and therefore a greater northward-shift in prey species is likely to be detrimental to the population waters (Wynn *et al.* 2007).

Reproductive rate: This species does not reach sexual maturity until the individuals third year and the breeding pair expend their energy raising just one chick (BirdLife International, 2008). It is a very long-lived species and therefore, adult mortality is an important factor in its population decline. Indeed, the adult success-rate of this species is much lower than those expected of other species of the Procellariiformes family (Oro et al., 2004).

There are no reported direct climate-related changes in the fecundity

2.3. Species Interactions

Balearic Shearwaters rely on small pelagic fish, especially pilchard (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*). Whilst the nesting habitat of this bird has remained static in the western Mediterranean, the distance that they must travel to catch their preferred prey outside of the breeding season has increased considerably since the 1980s (Wynn *et al.* 2007). This northwards shift has been linked to a myriad of ecosystem changes which have altered the northeast-Atlantic food-web. Rising sea surface temperatures are the major forces behind the northwards shift of phytoplankton (Richardson & Schoeman, 2004). Subsequently, this has impacted upon the distributions and composition of zooplankton communities (Beaugrand and Reid, 2003) and numerous numbers of fish species have either increased their latitude or increased their depth (Perry et al., 2005). The changing feeding distribution of the Balearic Shearwater shows that the change is sea surface temperatures have affected species from the base of the food-chain, right through to the apex.

There is a good probability that these distribution shifts will be spatially and temporally differentiated across species; threatening decoupling of phenological relationships and disruption cross-species interactions (Edwards & Richardson, 2004).

2.4. Interactions with other Processes

As the Balearic Shearwater is a long-lived, slow-breeding species with a low population, any impact that threatens adult survival can have a serious effect on the integrity of the population (Oro et al. 2004; Louzao *et al.* 2006). According to BirdLife International (2009) the threats that this species faces come from three main sources; the fishing industry, invasive species and marine pollution. These threats are all assessed to pose a "moderate" risk to the remaining Balearic Shearwater. However studies have shown that rats have coexisted with shearwaters on Mediterranean islands for thousands of years, seemingly without substantial negative effects (Ruffino *et al*,. 2009). Also, D. Oro (*personal communication,* 2009) states that there is no evidence of Balearic Shearwater mortality events due to marine pollution.

Domestic cats (*Felis catus*), the common genet (*Genetta genetta*) and the black and brown rats (*Rattus rattus* and *Rattus norvegicus*) all pose a threat to nesting populations by consumption of eggs and chicks and disturbance to the roosting adults (BirdLife International, 2009). The Balearic Shearwater nests upon the ground and possesses virtually no adaptations against terrestrial predators, though the populations show buffering capacities against rats (Igual *et al*., 2007 and 2009).

Puffinus mauretanicus has a complicated relationship with the fishing industry. The fishing industry is detrimental to the species primarily due to by-catch whilst longlining fishing methods are employed (Cooper *et al.*, 2003). Conversely, during the breeding period, the mating pairs have become reliant upon the discards from fishing trawlers as their prey species are much less readily available (Arcos & Oro 2002, BirdLife International, 2008). Whilst stopping the discarding of unwanted by-catch from fishing vessels would generally help increase the size of the available food source in the oceans (Hall, S.J, 1999), reducing the amount of unwanted fish taken from the sea would directly impact upon the breeding success of the Balearic Shearwater (Navarro *et al.* 2009).

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Climate Change Impacts on Migratory Species

Species Review: Background Document

Basra reed warbler, *Acrocephalus griseldis*

IUCN Classification: Endangered

Population Estimate: 2,500 – 9,999

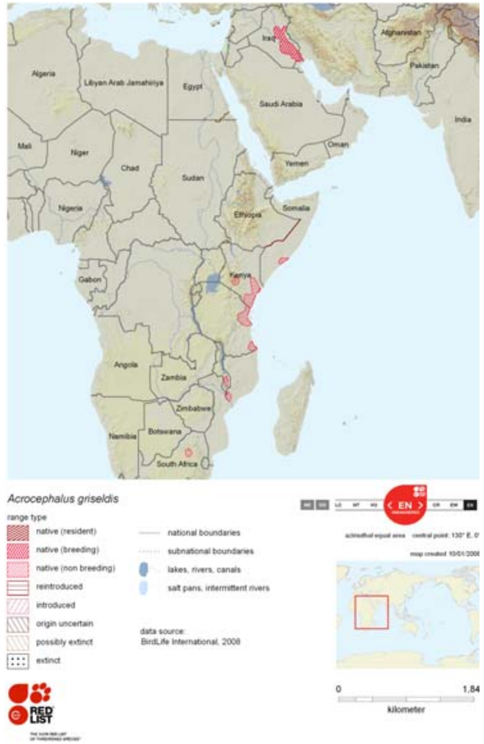
CMS Appendix: 1

1. Background Information

The Basra Reed Warbler breeds in the brackish or freshwater reedbeds of Mesopotamia, predominantly south-east Iraq, and probably also south-west Iran (Fadhel 2007; BirdLife International, 2008). It can be seen in Saudi Arabia and Kuwait on-passage to eastern Africa where it winters. Wintering populations can be observed in Sudan, Ethiopia, south Somalia, south-eastern Kenya, Ethiopia and eastern Tanzania (BirdLife International, 2008). This species can be seen in low reeds above water, in mangroves and also in gardens when on migration, and a variety of densely vegetated wetlands during the winter.

2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability



Following the diversion of large quantities of water from the Mesopotamian wetlands during the regime of Saddam Hussein, during the early 1990s the remaining area of the marshlands compared to 1970s levels was just 7% (BirdLife International, 2008). However, by the 2005, 58% of the 1970s extent of marshlands had been re-flooded (UNEP, 2006). So, rather than this habitat being one in decline, the breeding areas for the Basra Reed Warbler should be expanding. However, figure 1 shows that precipitation to the south-west of Asia is expected to drop substantially over course of this century, however the resolution of the GCMs utilised for the IPCC Fourth Assessment Report is poor.

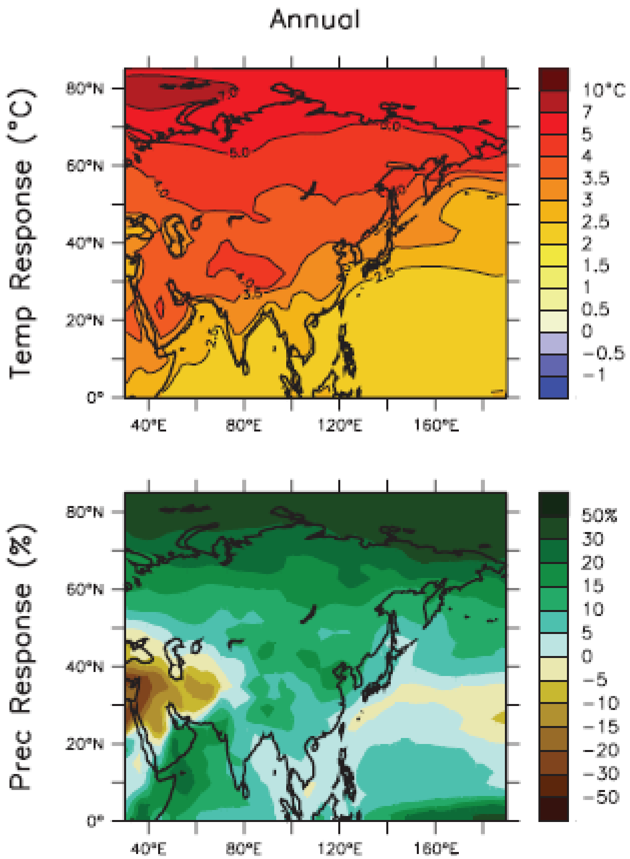
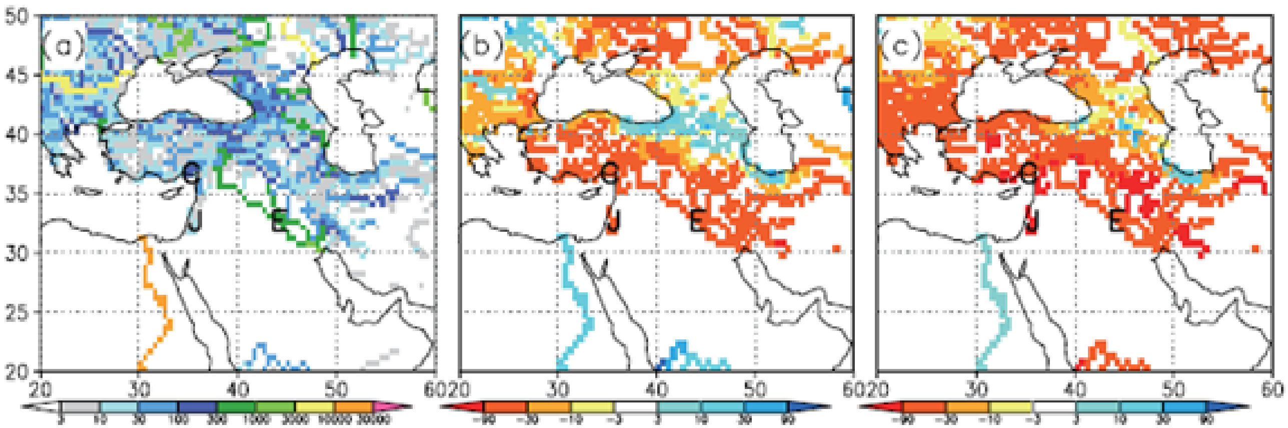


Figure 1. *Temperature changes (top) and precipitation changes over Asia under A1B scenarios for 1980-1999 and 2080-2099 time period. Source: Christensen et al, 2007*

Kitoh *et al* (2008) have produced the first "super-high resolution" GCM to predict the stream flow for the Fertile Crescent, a model which boasts a fine resolution of 20km. This GCM was proven capable of accurately reproducing the precipitation and the stream flow of the present-day Fertile Crescent. Using two different temperature scenarios – a moderate warming scenario (2.6˚C rise in average annual temperatures by the period 2081-2100) and a high warming scenario (4.8° C rise in average annual temperatures by temperatures by the period 2081-2100). Figure 2 shows the results of the projections from this GCM. The amount of water that would filter onto the marshlands varies greatly depending on whether moderate warming or high warming are factored into the model. The model predicts that the annual discharge of the Euphrates, one of the main sources for the Mesopotamian wetlands, will decrease by 29-73% by 2081-2100.

The New Scientist (2009) report that the 'Fertile Crescent' is already experiencing serious drought and that the re-flooding of the wetlands is being abandoned. A breeding pair was discovered in Israel in 2007 (BirdLife International, 2008), however it remains to be seen if the birds can be successful in this new area.



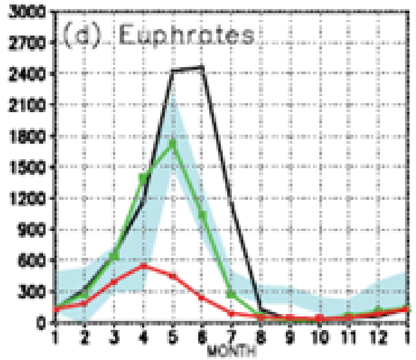


Figure 2. *Boxes a-c show the annual streamflow on the 'Fertile Crescent'. (a) shows the present day average streamflow ($m^3 s^{-1}$); (b) shows the % change in annual streamflow projected with the moderate warming scenario, and (c) shows the % change in annual streamflow projected with the high warming scenario. Box (d) shows the hydrograph for the Euphrates River. The black line represents streamflow under present day climatology (m^3 s-1), the green line represents the projected streamflow under a moderate warming scenario, and the red line denotes the projected streamflow under a high warming scenario. The shading denotes observed climatological mean plus/minus one standard deviation. Source: Kitoh et al 2008*

During the winter this bird nests in Sudan, Ethiopia, south Somalia, south-eastern Kenya, Ethiopia and eastern Tanzania. They seek flooded grasslands, pools, lakes, marshes, swamps and ditches overgrown with reeds, mangroves, coastal and riverine scrub. There is a lack of data on the exact whereabouts of this species in the winter months (Walther et al, 2004), however from this information it seems reasonable to assume that precipitation and water resources in eastern Africa are important factors in determining the integrity and quantity of available habitat. Figure 3, below, shows the IPCC's projection for average precipitation change in the period 2081-2100 compared to 1981-1999.

The regions which appear to be frequented by the Basra Reed Warbler during the winter months are projected to increase in their total precipitation, especially during the winter months when the bird will be present.

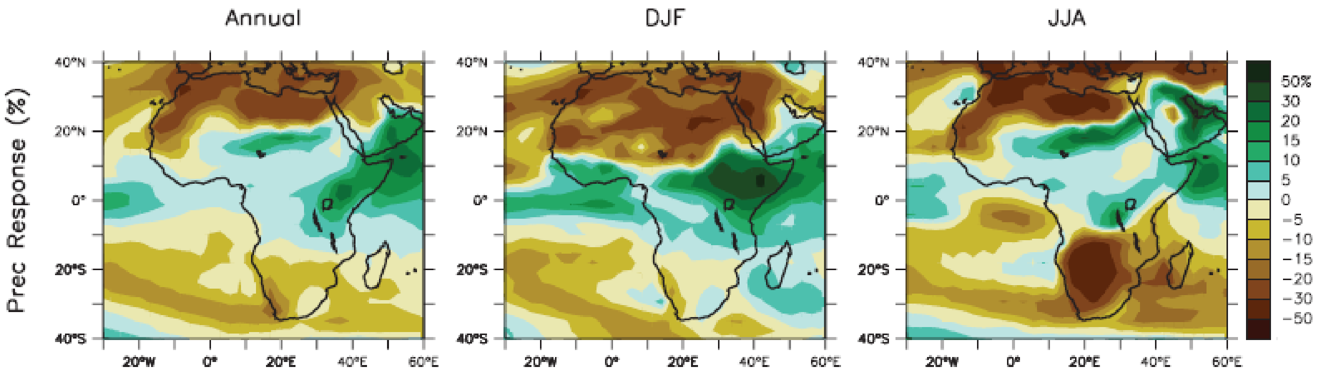


Figure 3. *Projected average precipitation change in the period 2081-2100 compared to 1981-1999.*
Source: Christensen et al. 2007

2.2. Ecological Flexibility

The Basra Reed Warbler is capable of nesting in a variety of wet environments, however there have been some reports of individuals nesting in dry thickets away from water (Newson et al. 1992). The diet of this species appears to be very broad, consisting of insects, small vertebrates, snails and spiders, along with fruits and berries (Stamps of Israeli Birds, 2002). There is little data available for this species - no evidence of reproductive rate, fecundity, dispersal. However, there is evidence to suggest some individuals have recently been discovered breeding in Israel (Birdlife International, 2008) which could indicate a reasonable level of ecological flexibility

2.3. Species Interactions

No predator threats to this species are mentioned in the available literature, so it is difficult to infer how predation upon this species will alter with the projected climatic changes. There is no evidence of a large preference for any one food-source. The Stamps of Israeli Birds group (2002) state that this species has a diet consisting of insects, small vertebrates, snails and spiders, along with fruits and berries. Walther *et al.* (2004) report that with increasing rainfall, more plant growth and higher insect densities can be observed. Taking the climate projections for the habitat of this species, this would mean more food opportunities in the wintering habitat but reduced food opportunities in the breeding habitat. However, the diet of this species is broad, so there is a good chance that if some insect species populations decreased, there would still be sufficient alternatives.

2.4. Interactions with other Processes

This species utilises wetland habitats throughout its range, and destruction of these fragile habitats is the biggest threat to survival that it faces (CMS, 2005). Since the 1950s, the wetlands that the Basra Reed Warbler utilises to breed have been under pressure from hydrological projects. Following the diversion of large quantities of water from the Mesopotamian wetlands during the regime of Saddam Hussein, during the early 1990s the remaining area of the marshlands compared to 1970s levels was just 7% (BirdLife International, 2008). However, by the 2005, 58% of the 1970s extent of marshlands had been re-flooded (UNEP, 2006). This led to the population of this bird increasing in Iraq between 2006 and 2007 (BirdLife International, 2009). However, water extraction for Turkish hydrological programmes and irrigation in Iraq, combined with drought in the Mesopotamian area have culminated in further reduction of the marshlands recently (New Scientist, 2009). In recent decades, wars and political instability have also degraded the breeding habitat of this species (BirdLife International, 2009). There is also the concern that as the exact breeding grounds of this species are unknown, as are many of the stopover and wintering sites, crucial habitats are difficult to locate and protect (CMS, 2005).

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Bermuda Petrel, *Pterodroma cahow*

Distribution: Atlantic Ocean, Bermuda, USA

IUCN Classification: Endangered

Population Estimate: 250 (increasing)

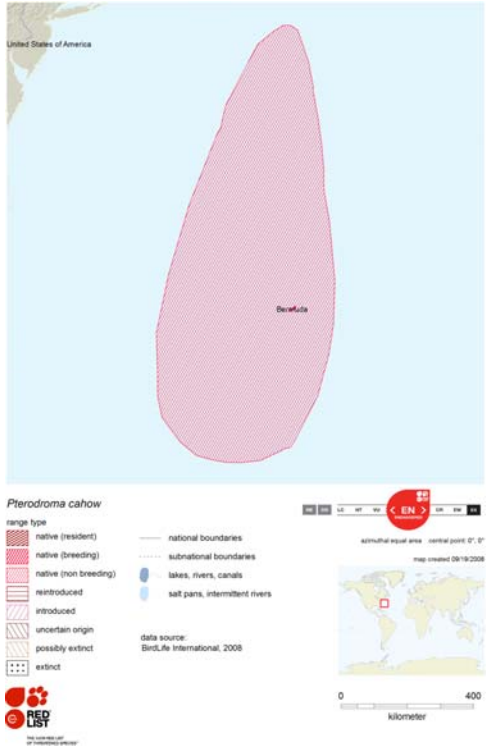
CMS Appendix: 1

Picture: BirdLife International (2008)

1. Background Information

The Bermuda Petrel was thought to be extinct for almost 300 years until specimens were discovered at the beginning of the 20th Century. The species breeds around Bermuda, and then they travel north along the western fringes of the Gulf Stream to forage for food (BirdLife International, 2008). Bermuda Petrels breed exclusively on suboptimal rocky islets in Castle Harbor, within the Bermuda island group. During the non-breeding season, the birds range widely in the North Atlantic, to the western edge of the Gulf Stream, where they feed on squid and fish (Sibley, 2000). When Bermuda was colonised by the British in the 1600s, the bird was exploited for food, their breeding habitat was degraded and an influx of invasive species predated upon the species, all resulting in the belief that the bird had been pushed into extinction (Audubon, 2005). Following its rediscovery in 1951, conservation measures were introduced in an effort to preserve the species and the population has been slowly recovering ever since.

Figure 1: Range Map (IUCN, 2009)



2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability

The projected climate change impacts upon small island states are difficult to identify and quantify with any real detail. This is because Atmospheric/Oceanic Global Climate Models AOGCMs currently do not give enough resolution to identify specific islands, many of the processes relating to the oceans which have such a big influence on the islands climate are not fully understood and future SSTs are currently very difficult to predict (Christensen, 2007).

The breeding habitat of this species appears to be at risk from climate change through rising sea levels and increasing storminess. Sea level rise already appears to be having a negative affect on this species – in the 25 years prior to the 1990s there were no significant problems arising from flooding, however during the 1990s there were 5 separate events were flooding caused inundation of the nest of the Bermuda Petrel. The IPCC Fourth Assessment Report predicts by 2100, sea levels will have risen by 0.18m- 0.59m compared to the 1980-1999 mean (Bindoff et al, 2007). As models of how basal sliding could affect rate of sea level rise, this was not incorporated into the projections (Kerr, 2007). Incorporating these important uncertainties into the seal level rise projection models, Rahmstorf (2007) predicted that the level of sea level rise by 2100 is more likely to be in the range of 0.5m - 1.4m. This has the potential to greatly reduce the nesting success of this species and the number of coastal habitats available to it for breeding.

An increase in the frequency and intensity of storms and cyclones is also likely to be detrimental to the breeding success of this petrel (BirdLife International, 2008). However, due to the difficulties simulating ocean temperature changes and a lack of resolution over many ocean areas, the future intensity and frequency of cyclones is very difficult to predict. Walsh (2004) conducted a study on the data relating to future cyclone characteristics which concluded that there were no clear trends showing the future frequency and movement of cyclones but the data indicated that there would be an increase in storm intensity.

From 1961 to 2003, global ocean temperature has risen by 0.1°C, from 0 to 700m in depth, absorbing 2/3 of the insolation received by the oceans (Bindoff et al, 2007). Therefore ocean temperatures are likely to rise in the future in line with air temperature. This will have ramifications on a wide variety of ocean processes, from the ranges of species present, to rates of chemical reactions, which will affect the habitat of the Bermuda Petrel.

Temperature and salinity drive ocean circulation, increasing temperatures and reduced salinity are therefore likely to alter ocean circulation and thus the oceans. This will affect numerous ocean processes particularly nutrient cycles and their spatial distributions (Bindoff et al, 2007). Changes in salinity will be caused by melting ice caps, causing extra freshwater influx. This will affect more than just the circulation of the oceans. It will also affect processes such as species abundance and chemical processes, which will change the Short-tailed Albatross' habitat.

Changes in pH from CO2 dissolved in the oceans are likely to have a large effect on the entire ocean system. pH is expected to decrease by 0.3 to 0.4 units by 2100. This will affect the habitat of Short-tailed Albatrosses, for example by altering fish abundances of oceanic environments, because of changes in plankton abundance (Meehl et al, 2007).

2.2. Ecological Flexibility

This species formerly nested in burrows which are excavated in and or soft soils, but such habitat is not available on current breeding islands and it now nests in suboptimal, natural erosion limestone crevices and artificial burrows (Audubon, 2005). This shows some degree of ecological flexibility, however without the artificial breeding sites, this species have been unable to cope with increasing environmental pressures over the last half-century. Their nesting appears to be confined to a few of the Bermudan Islands, however in 2003 there was an individual found nesting in the Azores (Bried, & Magalhães, 2004). However, so far there is no indication that this is the start of a new Cahow population.

During the non-breeding season, the birds range widely in the North Atlantic, to the western edge of the Gulf Stream, where they feed on squid, fish (Sibley, 2000) and shrimp (Audubon, 2005). Due to the lack of specific information about exactly what species this bird feeds upon, it is difficult to assess the specialisation in this species. However, its ability to feed upon fish and squid, two distinct types of prey, suggests that they are not highly specialised or overly limited as to what prey items they can take.

Dispersal: The potential dispersal range for this species is very large, as the individual discovered in the Azores demonstrates. However their realised dispersal is generally much more limited, their nesting appears to be confined to a few of the Bermudan Islands (BirdLife International, 2009).

Reproductive rate: Bermuda petrels breed at four years of age. They show fidelity to their breeding sites, nesting close to where they hatched (BirdLife International, 2009). They are slow breeders, laying only one egg per year. This egg is incubated for 51-54 days. Once hatched, the chick is fed for over three months before it fledges the nests (Audubon, 2005). Although breeding success increased from >5% in the 1950s to <25% in the 1990s, this is still a very low success rate considering the low recruitment level.

There is no evidence of climate change-related changes in fecundity in this species, nor is there evidence of adaptation in the past.

2.3. Species Interactions

Cahows, predominately predate upon squid, but also take small fish and shrimps (Audubon, 2005). Due to the lack of specific information about exactly what species this bird feeds upon, it is difficult to assess the specilisation in this species. However, all cephalopod species are vulnerable to climate change as their embryonic development and hatching, growth, migration patterns and range are all influenced by temperature (Robinson et al., 2005). Temperature can also directly affect the age of sexual maturity, timing of spawning, incubation time, growth, and survival of certain fish species (Robinson et al., 2005). It can also have an effect on the distribution, abundance and migration of several fish species (Robinson et al., 2005).

Cahows do not face any predatory threats, however they do face competition for the available nesting habitats from the White-Tailed Tropicbird, *Phaethon lepturus.* This species also lays one egg per year and feeds upon fish and squid. This niches of this species therefore appear to be reasonably close and as such, they are not likely to be impacted any differently from the cahow.

2.4. Interactions with other Processes

Due to an extensive conservation programme and managed protection, the threats upon this species have been reduced, however, The birds' nocturnal aerial courtship is now disrupted by lights from human facilities (BirdLife International, 2009). The main threat that they face is through the degradation of suitable habitats or the competition for suitable habitats, however this is mitigated by the conservation efforts which provide artificial nesting areas for this species and also engage in relocation effort to recolonise islands where it was once prevalent.

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Humboldt Penguin, *Speniscus humboldti*

Distribution: Coastal Peru and Chile

IUCN Classification: Vulnerable

Population estimate: 3,300-12,000

CMS Appendix: 1

Range map (IUCN, 2009)

1. Background information

The Humboldt Penguin (Speniscus humboldti) is a medium-sized, black and white penguin. It is found in coastal Peru and Chile with vagrants recorded in Colombia (Morales Sanchez, 1988) and Ecuador (Ridgely and Greenfield, 2001). The Humboldt Penguin has a very broad latitudinal breeding area, ranging from 5°S – 42°S (Willaims, 1995). It tends to burrow in guano, and it is generally found in small colonies (Martinez 1992).

Speniscus humboldti dives in pursuit of its prey, usually foraging close to the coast although they will travel considerably further to find prey during ENSO years (BirdLife International 2009). A study by Culik and Luna-Jorquera (1997a) showed that during the breeding season 90% of Humboldt penguins from Pan de Azúcar Island tended to stay within a 35 km radius of their nests in order to feed their chicks, however some individuals have been known to travel over 600km from their nesting area (Birdlife International, 2009), although there is no confirmation that these individuals were feeding young.

Ellis et al., (1998) estimate that prior to the mid 19th Century the population of this bird stood at around 1 million individuals. However, BirdLife International (2009) report that the population of this species has been declining since the mid-19th Century, but two recent El Nino Southern Oscillation (ENSO) events; 1982-3 and 1997-8 severely depleted the remaining numbers. The population is now estimated at between 3,300 and 12,000 (BirdLife International, 2009).

2. Species vulnerability to climate change

2.1. Habitat vulnerability

The Humboldt Penguin can be found across a vast latitudinal range, from 5°S – 42°S (Williams, 1995). This species nests in guano on islands or rocky stretches of mainland coast. There is no evidence to suggest that climatic changes to the physical environment will have a continuous detrimental effect upon this species. However, El Niño-Southern Oscillation (ENSO) events are expected to occur more regularly due to global warming (Stenseth et al., 2002; van der Werf et al., 2004), but there is large uncertainty in the predictions of how much more regularly El Nino events will happen (Christensen, 2007).

The International Penguin Working Group report that during the ENSO of 1997/8 severe rain and flooding washed out the breeding sites of many Humboldt Penguin populations. If ENSO events do increase in frequency, they will impact upon nesting sites.

2.2. Ecological flexibility

This species mainly feeds in near-shore waters, predating on pelagic school fish and squid (Martinez, 1992), especially anchovy (Engraulis ringens) (Culik and Luna-Jorquera, 1997b). Although this penguin can feed on a number of different species of marine organisms, they are all strongly linked to the ENSO cycles. If the ENSO cycles are to increase in frequency and severity as some suggest, this species is likely to have very poor breeding success more frequently. Adult penguins are capable of travelling very long distances, (Birdlife International, 2009), however increases in the necessary foraging distances required to feed young will have a deleterious effect on chick survival rates.

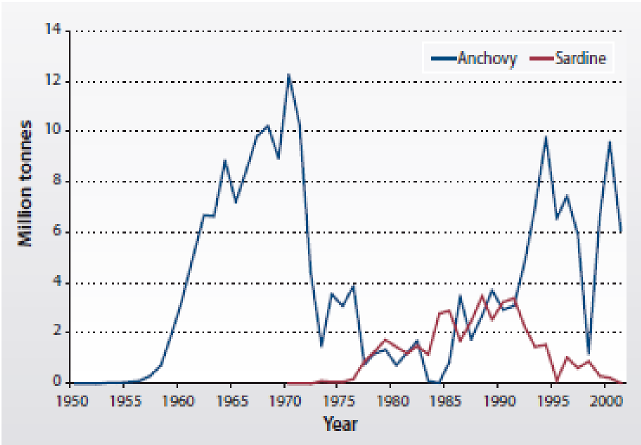
The Humboldt Penguin is capable of breeding year-round, and they are able to take advantage of favourable years by producing two successive broods in a single season (BirdLife International, 2009). According to the International Penguin Working Group, two eggs are laid in each clutch and the incubation period is around 40-42 days. The potential to take advantage of favourable conditions provides some resilience against ENSO years when breeding success is likely to drop. Recovery from the two most recent ENSO events suggests that recovery from years of low breeding success is good (Paredes et al., 2003).

Although the penguins tend to stay within a 35 km radius of their nests in order to feed their chicks (Birdlife International, 2009), research by Simeone and Hucke-Gaete, (1997) suggests that they may have a greater capacity for displacement than originally thought. Some individuals have been known to travel over 600km from their nesting area (Birdlife International, 2009). This suggests that the Humboldt Penguins may be able to migrate south to avoid the worst effects that ENSO has upon their food supply.

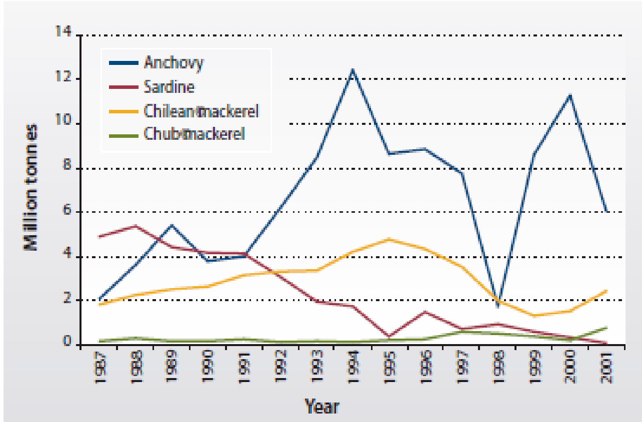
2.3. Species interactions

The Humboldt Current region's marine component has a massive productive capacity. It is the world's largest upwelling area with a productivity of >300 gC/m2/year (UNEP, 2006). The Humboldt Penguin has a reasonably large breadth of diet, however all of its prey species are effected by ENSO. In general, productivity drops during El Nino events and prey populations are decreased. This concentrates large fishing activity on the remaining fish species, leaving little food remaining in the near shore areas for the penguin. Figure 1 shows the variations in commercial seafood catch in the area.

Figure 1



Peruvian catches of sardine and anchovy 1950 – 2001. Source: UNEP 2006



Catches of small pelagic fish in the Southeast Pacific 1987 – 2001. Source: UNEP 2006

As demonstrated these fish species have the potential recover well after a poor year. After an ENSO event, the main prey of the Humboldt Penguin; anchovy, can recover in 1-2 years (UNEP, 2006).

2.4. Interactions with other processes

Historically, population declines have been due to habitat loss and degradation caused by the harvesting of guano for fertiliser (BirdLife International, 2009). This harvesting is known to cause damage to breeding sites and is likely lead to pairs locating their nests in below optimum areas where they are more vulnerable to predation and environmental conditions (Paredes et al., 2003). It is no thought that utilised habitat is being lost today across much of the penguins' range, however it is likely to prevent them from re-colonising areas.

The increased human interaction with the species through this harvesting of guano also led to hunting for their meat, oil and skins, whilst collection eggs was also common (CMS, 2003). Consumption of penguin meat today is limited (Cheney, 1998).

Mortality due to entanglement in fishing gear is a problem which has recently come to light (Simone et al. 1999). Gillnets have traditionally been linked to the bycatch of Humboldt Penguins, however this problem now appears to be confined to the waters of northern Peru (BirdLife International, 2008). Simone et al. (1999) reported that along a 14km stretch of coast in central Chile between 1991 and 1996, an annual average of 120 adult penguins were reported to have become entangled in fishing gear.

Overfishing is a major issue. The two main prey of this species, the Anchovy, Engraulis ringens and the Sardine, Sardinops sagax were both assessed by the FAO (1997) as fully-exploited in its whole distribution range and highly-exploited in its whole distribution range. The fishing industry in the area is at high capacity depletion of the anchovy in ENSO years has led to overexploitation of the sardine population in the past (UNEP, 2006). Although fishing quotas have now been implemented in Peru, overfishing is likely to slow any penguin population recovery.

Invasive species are also a threat to adult penguin, young and eggs. Rats, foxes, cats and dogs all have a detrimental impact upon the Humboldt Penguin population (CMS, 2003).

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Narwhal, *Monodon Monoceros*

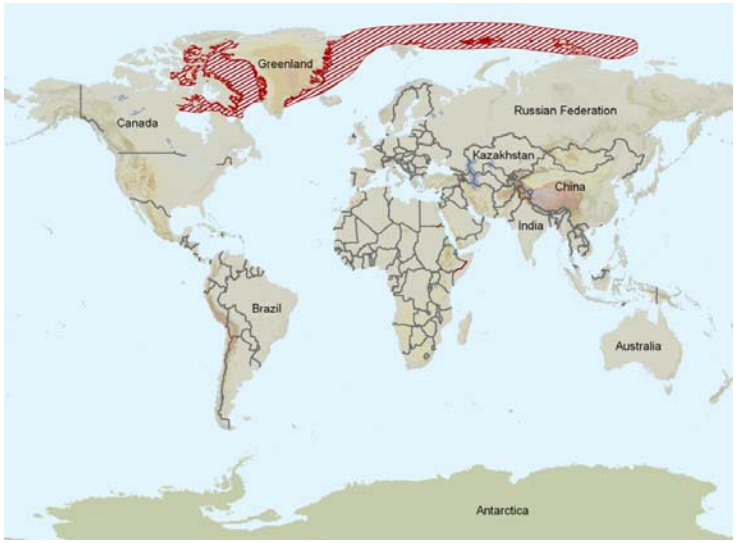
Distribution: Arctic

IUCN Classification: Near Threatened

Population Estimate: 80,000

CMS Appendix: 2

Picture: Helmore (2008), Jefferson et al. (2008)



Range Map (IUCN, 2009)

1. Background Information

Narwhals live in the North Atlantic and Arctic oceans, and can sometimes be seen as far east as the Bearing Sea. The most important area for the species is the Canadian High Arctic, where 70,000 individuals reside, making up the majority of the population. Narwhals migrate seasonally following the sea ice northwards and southwards. They spend the summer months in ice free bays and fjords in the High Arctic, calving and socialising whilst rarely feeding. They winter in deep waters on the continental slope, with relatively dense sea ice cover. During the winter, the majority of feeding takes place, mainly on Greenland halibut, Arctic cod, and polar cod. As these species are often found under sea ice the majority of hunting takes place within the pack ice. Breeding also takes place here in April before the northward migration (Jefferson et al, 2008).

The Narwhal is classified as near threatened by the IUCN. This is due to the small population size and limited range. Historically, the main threats to Narwhals have come from hunting by

Inuit communities for meat and ivory. However industrial actives in the Arctic are becoming an increased problem, particularly as there is legislation in place protecting Narwhals from unsustainable hunting throughout their range, whilst resource prospecting and shipping are becoming more common (Jefferson *et al.*, 2008). However, the evidence presented in this document suggests that climate change is the single biggest threat to the species.

2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability

Narwhals live in the marine Arctic environments, an area very susceptible to climate change. The effects of climate change are amplified in high latitude areas, whilst the ocean systems will also be significantly affected. The main processes that are likely to affect the Narwhal's habitat are likely to be changes to temperature, sea ice cover, ocean circulation as well as ocean salinity and pH.

Arctic temperatures are predicted to rise by between 5°C and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average (See Figure 1) (Christensen *et al.*, 2007). This will have large effects on Arctic waters and sea-ice. In fact this magnitude of warming is likely to greatly reduce the thickness and extent of sea ice. Moreover, by 2100 some models predict that Arctic sea ice will be seasonal (See Figure 2) (Meehl et al, 2007).

Furthermore global sea surface temperature has risen by 0.1 degrees centigrade, from 0 to 700m in depth, absorbing 2/3 of the insolation received by the oceans (Bindoff *et al.*, 2007). Therefore ocean temperatures are likely to rise in the future in line with air temperature In the Arctic. As climate models predict higher magnitudes of warming than the global average in the Arctic, it is likely that ocean temperatures will increase in the Arctic more than average.

Increases in Arctic Ocean temperature represent a large threat to Narwhals. Warmer waters will lead to changes in prey abundances and other ocean processes which will have important ramifications for the species. However it is the reduction to sea ice cover which will have the greatest impact, because Narwhals' range includes areas of pack ice precisely because they are a habitat which contains large amounts of Halibut, the Narwhals favoured prey species.

Figure 1

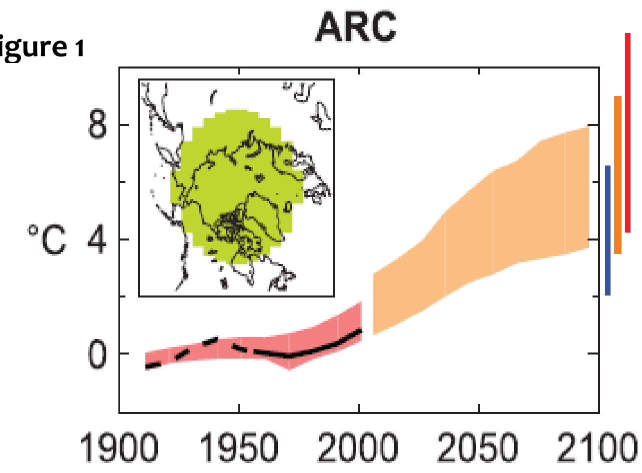


Figure 1: *Shows temperature anomalies with respect to 1901 – 1950 for the whole of the Arctic for 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the timeline present the range of projected temperature changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).*

It is also possible that Arctic weather could become more variable (Christensen *et al.*, 2007). This could have negative effects on the Narwhals. This increase in variability could cause an increase in entrapments which the Narwhals already suffer from. Sudden cold spells can cause areas of water the Narwhals use to become iced over, leaving only limited access to the air (Jefferson et al, 2008). With increased variability and changes to the species' range, this process may become more common if there are more sudden cold snaps, particularly if Narwhals start to use higher latitude areas. Also as Narwhals start to use new areas of habit, judgments about what constitute safe areas within the sea ice may become impaired. However these processes are likely to have only a limited effect in the short term, before sea ice becomes too rare.

Figure 2

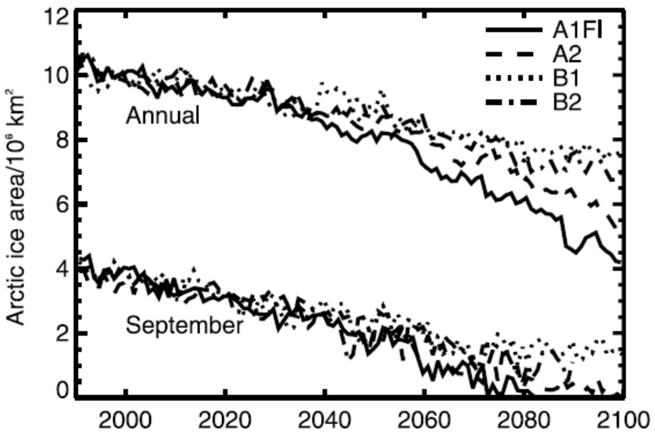


***Figure 2:** Shows 4 model predictions for the extent of Arctic sea ice. It is possible to see that by September 2100, the models show no sea ice or a very limited extent (Gregory et al, 2002).*

Temperature and salinity drive ocean circulation. Increasing temperatures and reduced salinity, from melting ice caps and increased precipitation, are therefore likely to alter ocean circulation and thus the oceans. This will affect numerous ocean processes particularly nutrient cycles. This will affect abundances of planktons, as they are the basis of the food web, they will in turn affect the abundances of Narwhal prey species (Bindoff et al, 2007). Changes to salinity itself will have some effects on the Narwhals habitats particularly as reduced ocean salinity will be most prevalent in Arctic regions, particularly near the melting Greenland ice cap.

A change in pH from CO2 dissolved in the oceans is likely to have a large effect on the entire ocean system. pH is expected to decrease by 0.3 to 0.4 units by 2100 across the whole ocean (Meehl et al, 2007). However, the problem of acidification is likely to be much worse at higher latitudes, because more carbon dioxide can dissolve in colder waters. This will affect the habitat of the Narwhal, by altering the species composition of oceanic Arctic environments (Meehl et al, 2007).

2.2. Ecological Flexibility

Narwhals are relatively specialist. They feed only on specific fish species, squid and shrimp, however they endeavour to feed predominantly on one species, the Greenland halibut. Thus, in relation to prey they are adaptable yet self-limiting (Laidre & Heide-jorgensen, 2005). Their range is also specialist. This is partly because of the abundance of Greenland habitat under pack ice but also as pack ice provides the Narwhal with refuge. This means that their range is limited to certain Arctic areas (Laidre *et al*.,2008). During the Little Ice Age Narwhals where found as far south as the UK. However with warmer temperatures their range has contracted northwards. This shows that Narwhals can change their distribution in relation to changes in climate. However, if climate significantly reduces the extent of sea ice, which seems likely, then Narwhals will suffer as they cannot change habitat type (Laidre *et al*.,2008). Narwhals reproduction rates are also relatively low being calculated at about 0.07. This is due to a long gestation period, leading to a period of about 3 years between births (Culik, 2003). This means that Narwhals are unlikely to be able to quickly adapt to and recover from large changes to their habitats.

2.3. Species Interactions

It is likely that prey species of the Narwhal will suffer significantly from climate change. Reduced sea ice is likely to reduce numbers of Greenland habitat as their preferred habitat is bellow sea ice (Jefferson et al, 2008) . Furthermore, ocean acidification is likely to severely damage the food web on which the Narwhals prey species rely through reducing the abundances of planktons. In addition to this, copepods are particularly vulnerable to acidification thus removing a prey species from their habitat, whilst others decline (Learmouth et al, 2006).

The Narwhal's two main predators are Polar Bears and Killer Whales. Polar Bears hunt Narwhals from the sea ice particularly when they are trapped. In the interim this process could become more common. However, in the long term as sea ice becomes less common, and so do the Polar Bears, there will be less predation on Narwhals in this way. Killer whales on the other hand, hunt Narwhals away from the sea ice as Killer Whales do not often inhabit areas with sea ice. This means that as the extent of sea ice becomes reduces, Narwhals will have less refuge, and therefore higher levels of predation from Killer Whales (Jefferson et al, 2008; Laidre et al 2008).

2.4. Interactions with other Processes

Hunting and interference from industrial acuities represent the greatest non-climate change threats to Narwhals. Hunting is managed yet there is some concern that some of the hunting is unsustainable. Climate change could make hunting more common through changes to Inuit livelihoods. However, legislation in place should provide some protection as quotas are generally enforced. Industrial activity is lightly to increase in the Arctic as climate change makes the environment less harsh and more accessible. This means that there is greater potential for negative anthropogenic interactions (Jefferson *et al*., 2008). This situation underlines by the use of the North East Passage for commercial shipping for the first time (Halpin, 2009).

3. Species Management

Currently Narwhals receive limited protection however, they are still hunted and their ivory is still traded. However, national legislation and CITIES convention is limiting these effects (Jefferson *et al*., 2008). Conversely, more needs to be done if the species is to survive the serious threat that climate change posses. Climate change is likely to impact upon Narwhals through reduced sea ice cover and ocean acidification. This means that these processes need to be monitored to determine their affects on Narwhals. This should be done using remote sensing and GIS of the Arctic sea ice, whilst the pH of the Arctic Ocean should also be measured. Further research also needs to be undertaken on the effect of acidification on the Narwhals food-web.

Policies to limit the affects of climate change on Narwhals are likely to be difficult to implement. However it would be possible to limit the expansion of developments and the use of industry in the Arctic. Nevertheless, protecting Narwhals from ocean acidification and the loss of sea ice using traditional conservation methods would be ineffective. Therefore the only way to protect Narwhals from the affects of climate change is to reduce global carbon emissions.

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Siberian Crane, *Grus leucogeranus*

Distribution: Arctic Russia and Siberia to East and Western Asia

IUCN Classification: Critically endangered

Population estimate: 3,200

CMS Appendix: 1

Picure: Birdlife International (2009)

1. Background information

The Siberian Crane (*Grus leucogeranus)* breeds in Arctic Russia and Western Siberia (Birdlife International, 2009). There are two populations of Cranes, one which follows the East Asia Flyway, whilst the other follows the West/Central Flyway. The Eastern population of Cranes contains approximately 3,500 birds, more than 99% of the world's population (SCFC,2004).

The main wintering sites are situated on the lower reaches of the Yangtze river, particularly in the vicinity of the Poyang Hu Lake. 95% of the global population of the Siberian Crane reside in this region during the winter (BirdLife International, 2000). The western population is extremely vulnerable, with between 9-11 individuals remaining. This population breeds in the Tyumen District of Russia, and winters in Fereydoon Kenar and Esbaran in Iran (NPWRC, 2006).

There was a third population of this species which bred in the lower valley of the Kunovat River and wintered in Indian state of Rajasthan, most regularly at Keoladeo National Park. However, there have been only unconfirmed sightings in the wintering habitat since 2002. Non-breeding birds summer in Dauria, on the border between Russia, Mongolia and China. This means the cranes occupy habitats which are important for many threatened wetland species (BirdLife International 2009).

Range Map: *by the International Crane Foundation 2005. Cartographer: Zoe Rickenback, Taken from: CMS (2008).*

The main breeding habitat for the cranes is the lowland tundra as well as taiga/tundra transition environments. It prefers large expanses of shallow freshwater with good visibility, with only shallow wetlands being used for roosting and feeding. Whilst over-wintering, the Cranes can use a wider range of wetland habitats, including wetlands in arid areas.

2. Species Vulnerability to Climate Change

2.1. Habitat vulnerability

The Siberian Crane breeds in open tundra/taiga wetland areas. Good visibility due to the lack of trees is an important factor in the cranes breeding success (Archibald & Meine 1996). However, tundra/taiga habitats are likely to be seriously affected by the impacts of climate change (Piersma & Lindström 2004). This is due to the fact that very sparse tree cover in tundra and taiga habitats is largely due to the presence of permafrost, which will recede due to climate change (Harding et al. 2002).

Global warming is projected to be amplified in Polar Regions (see figure 1, below). This includes Northern wetlands (areas with a latitude >60°N). This means that high altitude areas are vulnerable when a comparison is made to the rest of the planet (Christensen *et al.*, 2007). Indeed, temperature amplification has already been observed in these regions (Chapin et al., 2005). In addition to the direct effect of reduced permafrost, intensified fire regimes are likely to impact boreal forests (Flannigan *et al.*, 2000). This is likely to accelerate the transitions from tundra to forest by allowing pioneer shrubs and trees into the tundra (Johnstone and Chapin, 2006).

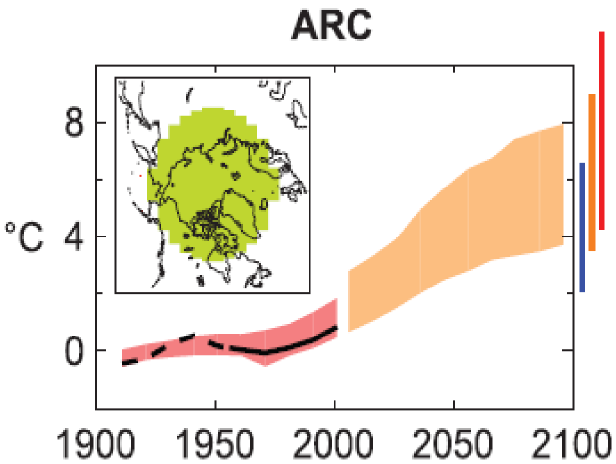

Figure 1: *Shows temperature anomalies with respect to 1901 – 1950 for the whole of the Arctic for 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the timeline present the range of projected temperature changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). Source –extracted from IPCC AR4 Chapter 11 (Christensen, 2007).*

Figure 2:

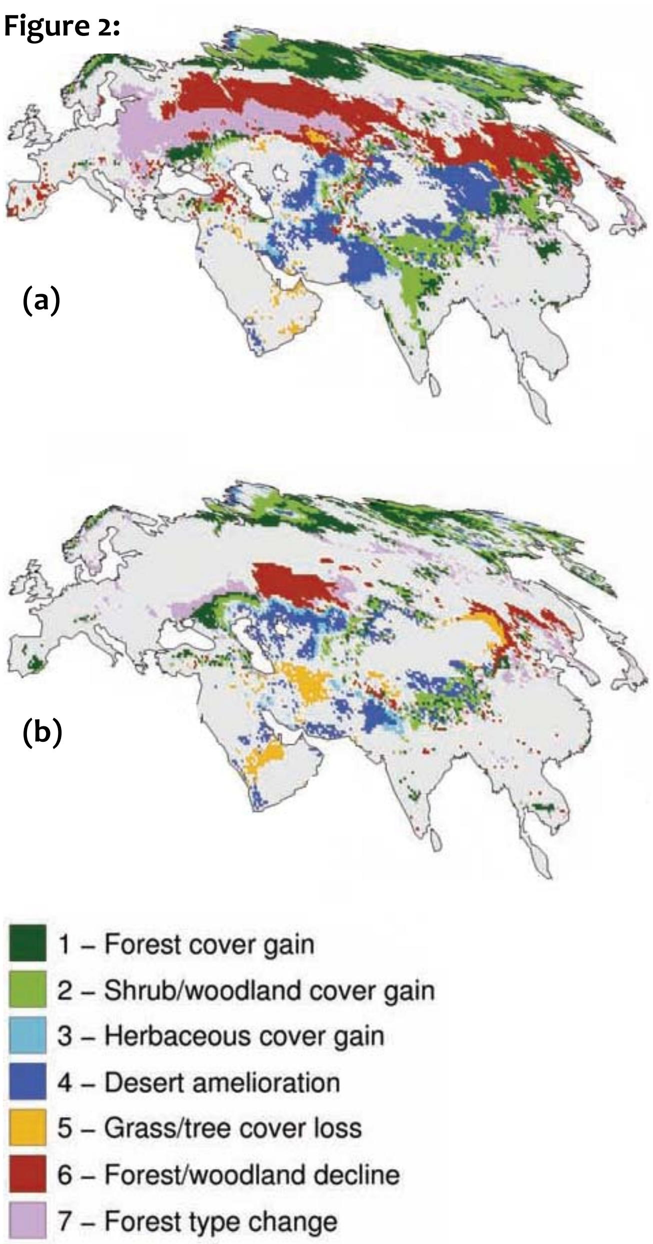

Figure 2 shows the projected appreciable changes in boreal ecosystems relative to 2000 under a) A2 and b) B1 scenarios. Both models show a significant encroachment of forest cover and woodland towards tundra and taiga habitats. However the A2 model shows the encroachment to be much more extensive, almost ubiquitous across the breeding areas.

Although Piersma & Lindström (2004) predict 70% of the northern tundra and southern taiga will be lost between 100 and 200 years time, in the shorter-term it is also very likely that Siberian Cranes will be adversely affected by climate-related breeding habitat loss.

Climatic change is already impacting upon habitats utilized by the cranes in the Arctic. Analysis by the Institute of Biological Problems of the Cryolithozone has shown that there has been a significant increase in area covered by lakes in the Siberian Crane nesting grounds (ICF, 2008).

Figure 2: *Projected appreciable changes in boreal ecosystems by 2100 relative to 2000 as simulated by DGVM LPJ (Sitch et al., 2003; Gerten et al., 2004) for two SRES emissions scenarios (Nakicenovic et al., 2000) forcing two climate models: (a) HadCM3 A2, (b) ECHAM5 B1 (Lucht et al.,2006; Schaphoff et al., 2006). (Changes are considered appreciable and are only shown if they exceed 20% of the area of a simulated grid cell) Adapted from Ecosystems, their properties, goods and services, IPPC AR4, Chapter 4*

The population breeds around lakes across an extensive area, some 26,000 sq. km. Research analyzing aerial surveys and satellite images from 1954 to 2004, covering 47 lakes, shows only three of these lakes had increased in size, whilst 42 reduced their area, and two disappeared completely. Of those that reduced in area, 17 lakes (1.7 – 35 sq. km) lost 15.9 – 31.5% of their size (SCWP, 2009b).

Siberian Cranes require very low-lying wetland to nest. Given the projected warming for this area over the coming century, suitable habitat for this bird may become very scarce. This species is highly territorial and pairs defend large areas against the presence of other cranes (SCFC, 2004). This makes the bird highly vulnerable to a loss of breeding areas around tundra lakes.

In addition to the threats that climatic changes pose to the breeding areas of this species, drought and reductions in precipitation are also affecting the wintering and staging areas utilised by this species. Poyang Lake reduced considerably in size in the winter of 2003-2004. The increased occurrence of such drought conditions will pose a considerable threat to the population in the future (BirdLife International, 2008).

Figure 3

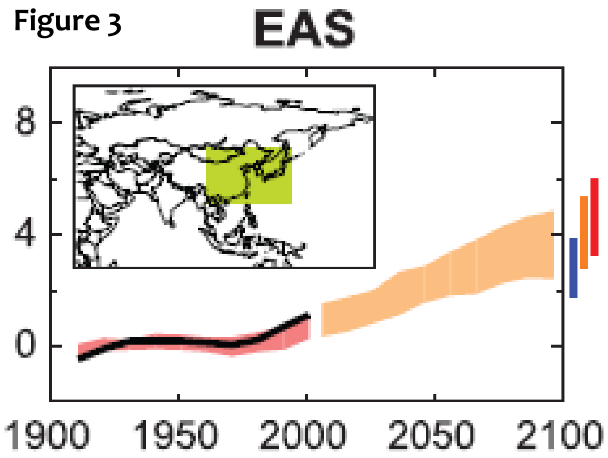

Figure 3 shows the future temperature predictions for the Eastern Asia region up to 2100. The multi-model data set for the A1B emissions scenario, shows a median warming of 3.3°C by the end of this century, with the majority of this warming occurring in the winter. Figure 4 shows the projected annual variation in temperatures. The East Asia region is expected to see a 3.0°C rise in the summer and 3.6°C rise in the winter. Along with the projected increase in temperature, evapo-transpiration rates will rise. Meanwhile precipitation rates will changes across the East Asia region with increased variability (see Figure 5). Overall, the areas utilised by the Siberian Crane are projected to see increased annual precipitation rates, especially during the winter months during which the cranes are present.

Research conducted by Zhai *et al.* (2005) showed that the intensity of rainfall events in these regions is likely to increase substantially. Thus the precipitation for this region is likely to become more variable with increased droughts and floods. These processes are likely to have negative effects, directly on the cranes, and on the aquatic plants which they feed on (DEFRA, 2005).

Figure 3*: Shows temperature anomalies with respect to 1901 – 1950 for the East Asian Region 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The bars at the end of the timeline present the range of projected temperature changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). Source –extracted from IPCC AR4 Chapter 11 (Christensen, 2007).*

Figure 4

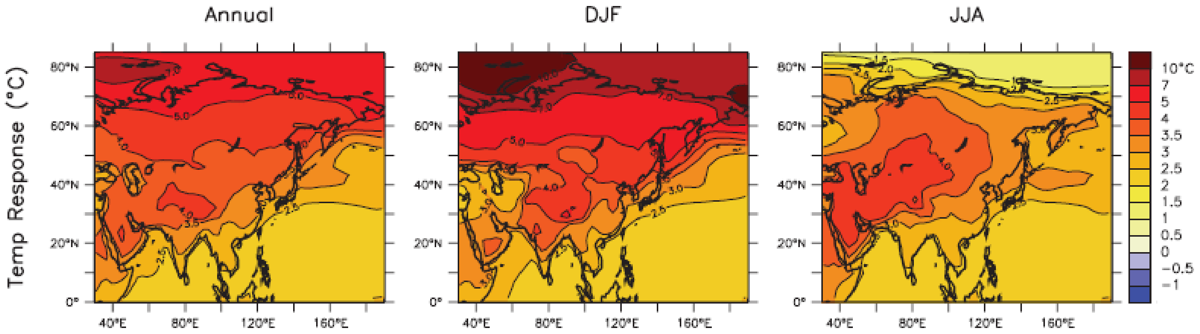

Figure 4: Projected temperature variations for the 2080 – 2099 period compared with 1980 – 1999 conditions. Projections are averaged over the 21 models utilised in the IPCC AR4. Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).

Figure 5

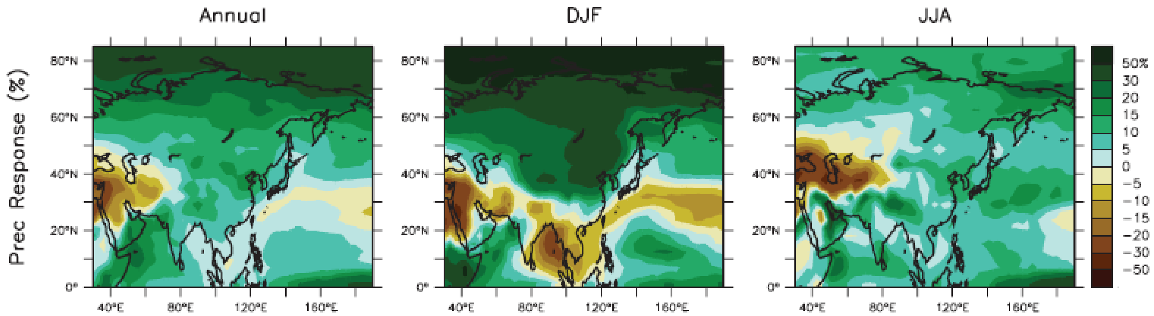

Figure 5: Projected precipiation variations for the 2080 – 2099 period compared with 1980 – 1999 conditions. Projections are averaged over the 21 models utilised in the IPCC AR4. Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).

2.2. Ecological flexibility

The diet of the Siberian Crane on their breeding grounds is broad. This spring diet consists of fish, insects, cranberries and rodents (Meine *et al.,* 1996). For the rest of the year they are predominately vegetarian. This species has the propensity to excavate wet soils for food. The wintering population in the Poyang Lake basin use this ability to feed upon the tubers of the submerged aquatic macrophyte *Vallisneria spiralis* (Li *et al*., 2005).

Whilst the diet of this species is relatively broad, they are tied to what they can find in the narrow specification for their breeding habitat. Although this species has the ability to change its migration habitats and where it breeds across an extensive area, it requires a breeding habitat which is in significant decline, leading to fewer available resources.

There are records of the Siberian Crane breeding from Scandinavia to Northern Kazakhstan, Northern Mongolia, and Eastern Siberia. There is also evidence to suggest that this species wintered more widely along the Southern Caspian Sea region in Iran, in the Gangetic Basin in India, on the Balkan Peninsula, in Turkey and other areas of the Black Sea region (NPWRC, 2006). This information, coupled with reports of evidence of mixing between the Central and Western Siberian Crane populations (SCFC, 2004) suggests that some degree of ecological flexibility is present.

2.3. Species interactions

In the breeding season this species is omnivorous; taking in a wide range of food items (Meine *et al.,* 1996) of which none were reported as vulnerable to climatic changes in the literature. However, in their wintering habitat, this species relies much more heavily on one food source – the aquatic macrophyte *Vallisneria spiralis.* A report from DEFRA (2005) suggests that the abundance of this plant may drop significantly due to increased intensity of flooding and drought events, which are likely in the region.

In the extensive and remote wetlands where this species lives, pressure from terrestrial predators is very low (NPWRC, 2006) and there are no reports of the threat of predation increasing due to climate change.

2.4. Interactions with other processes

The population decline of the Siberian crane's western population is attributed to widespread hunting and trapping of the bird along its flyway. Traditional hunting of this species in Afghanistan and Pakistan, along with subsistence hunting in Central Asia is cited as the primary factor leading to the population's decline (SCWP, 2009a). The western population of cranes is subject to varying levels of anthropogenic threat along their migration flyway. Their breeding area is remote and expansive, and therefore the pressures that this specie faces are generally low, consisting of hunting, fishing and forestry operations. However, oil and gas exploration is a growing threat in the Uvat area, and oil pollution in the River Ob is a significant problem (CMS, 2001).

The key threat for this species is wetland loss and degradation, most affected are the wintering habitats, critical staging areas and migration stopover grounds. The main driver of this habitat loss is agricultural development and fossil-fuel extraction (BirdLife International, 2008). In addition to these factors, water diversion for human use from rivers which supply key wetlands is a concern. Protected wetlands in the semi-arid areas of north-eastern China are particularly affected, as traditional water sources become increasingly scarce (SCFC, 2004).

Development of hydro-electric schemes is also a major threat. The staging areas in the Kyupsky Resource Reserve could be affected by a hydro-electric scheme close to the source of the Aldan River. This could alter the hydrological regime in a number of ways which could be detrimental to the Cranes (SCFC, 2004).

The development of the Three Gorges Dam is also expected to have deleterious effects upon the Poyang Lake habitat where 95% of the global Siberian Crane population spend their winter. According to Li *et al.* (2005) the hydro-electric scheme is likely to affect the hydrology of the lake. This is likely to lead to lower water visibility which could decrease the production of the aquatic macrophyte *Vallisneria spiralis*, the Siberian Crane's main food source in this area.

3 Species Management

Currently, most management practices focus on protecting the Cranes from the two main threats they face currently, namely, poaching and habitat loss from developments. International agreements and national legislation protect the Cranes in all the countries within which the Cranes migrate, whilst in some countries the Cranes are culturally exonerated. This means that in the majority of nations hunting pressures are greatly reduced. However, due to poor environmental governance in some countries illegal hunting is still a large concern. In fact poaching is thought to be the main cause for the decline in numbers, given the resources that have been expended on education in these countries (NPWRC 2006).

Many of the areas which the Cranes rely on are either very remote, or are protected as National Parks and under the RAMSAR convention. However, there are development pressures on their Northern breeding grounds, due to exploitation of natural resources, and their wintering grounds, due to dams and other developments. This means that the habitats of the Siberian Cranes are generally protected. However, pressures for development compete with this leading to limited degradation of some of the crane's habitats (NPWRC 2006).

These measures reduce the vulnerability of the Cranes to climate change by making the population more resilient. However, they could be more effective and in the face of serious habitat degradation due to climate change, their benefits are limited. As the main climate change threat to the cranes comes from the tundra becoming afforested, monitoring of this process needs to be undertaken. As the areas are remote and expansive, measuring land cover change using remote sensing and GIS seems to be the best method to asses this. Water level change from changes in climate in the wintering sites also needs to be monitored as this could cause other pressures.

Policies directly reducing the impacts of climate change on the habitats of the Crane may be difficult to implement. If water levels were a problem it might be possible to offset some of the change using dams and by altering drainage basin dynamics. However, this would be very difficult. Slowing the advance of the Boreal forest into the tundra is likely to be even harder due to nature of the process, and the extent of the areas. Using grazing animals to maintain an open habitat is possible; however, it is likely that this change could alter other important processes. The Cranes also will not be able to adapt to the changes by altering their range. The wintering areas are already under pressure from development, whilst the breeding areas are already on the northern fringe of Siberia, therefore not allowing for any further northward range shift.

The most efficient and in the long term, effective method to protect the Siberian Crane from climate change is through abating greenhouse gas emissions. As climate change is likely to degrade the habitat of this species to such a great extent, conventional conservation methods are likely to be largely impotent. Figure 2 outlined showed the difference between emissions following an A2 or a B1 scenario. Under a B1 scenario, forest gain is much less rapid, perhaps slow enough for conservationists to find a new area where this magnificent species can nest. This demonstrates the value of greenhouse gas abatement. Conservation policies have shown that threats to species can be overcome by the actions of policy makers, and in the case of climate change and the Siberian Crane, this is also true.

** further information needed to exhibit the difference between the vegetation cover under A2 and B1 scenarios* - case for mitigation*

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9. Case Study Assessment Analysis

9.1. Ranking and Gradings of Species Overall Vulnerability to Climate Change

- Most vulnerable species are listed first. Out of the 44 Appendix I species assessed:
    - 28 species (64%) have been identified as having a **high vulnerability** to climate change
    - 16 species (36%) have been identified as having **medium vulnerability** to climate change.
    - Rankings provide a guide but not an absolute rational for prioritisation as relative rankings will change as new information becomes available and more species are assessed
    - Gradings of high / medium / low provide a more accurate picture of species vulnerability to climate change.
- The example species assessed CMS Appendix II, the Narwhal, has been identified as having a **high vulnerability** to climate change.

Rank	Species	Total Vulnerability Grade
1	Green Turtle	High (18)
1	Hawksbill Turtle	High (18)
2	Balearic Shearwater	High (17)
3	Kemp's Ridley Turtle, Atlantic Ridley Turtle	High (16)
3	North Pacific Right Whale	High (16)
3	Northern Atlantic Right Whale, Biscayan Right Whale	High (16)
3	Relict Gull	High (16)
4	Loggerhead Turtle	High (15)
4	Gharial, Indian Gavial	High (15)
4	Bowhead Whale	High (15)
4	West African Manatee	High (15)
4	Short-tailed Albatross, Steller's Albatross	High (15)
5	Olive Ridley	High (14)
5	Leatherback Turtle	High (14)
5	Dama Gazelle	High (14)
5	Southern Right Whale	High (14)
5	Sociable Plover	High (14)
6	Addax	High (13)
6	Blue Whale	High (13)
6	Siberian Crane	High (13)
6	Steller's Eider	High (13)
6	Red-breasted Goose	High (13)
6	White-naped Crane	High (13)
7	Giant Catfish	High (12)
7	Basra Reed-warbler	High (12)
8	Common Sturgeon	High (11)
8	Bermuda Petrel	High (11)
9	Snow leopard	High (10)
10	Basking Shark	Medium (12)
10	Aquatic Warbler	Medium (12)
11	Cuvier's Gazelle	Medium (11)
11	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	Medium (11)
11	Short-beaked Common Dolphin	Medium (11)
11	Swan Goose	Medium (11)
12	Andean Flamingo	Medium (10)
12	Humboldt Penguin	Medium (10)

12	Humpback Whale	Medium (10)
12	Mexican Free-tailed Bat	Medium (10)
12	Pallas Fish Eagle	Medium (10)
12	Sperm Whale	Medium (10)
13	Puna Flamingo	Medium (9)
14	Great White Shark, White Shark	Medium (8)
15	Marine Otter	Medium (7)
15	White-tailed Eagle	Medium (7)

Appendix II:

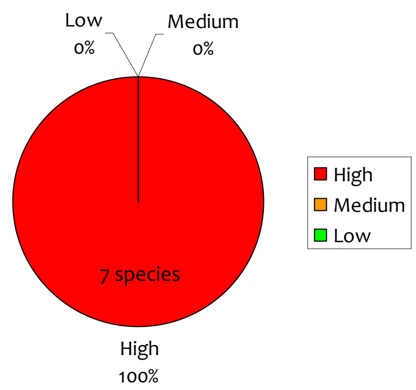
2	Narwhal	High (17)

9.2. CMS Appendix I Case Study Species Vulnerabilities to Climate Change reviewed by Taxonomic Group

Overview of Reptiles

- 7 species (88%) out of the total of 8 species of reptiles listed on CMS Appendix I have been included in case study assessments
- All (100%) species of reptiles included in this study have been identified as having a HIGH VULNERABILITY to climate change.
- Apart from the Gharial (a freshwater crocodile) all species of reptiles on CMS Appendix I are turtles. All turtles included in case studies are marine turtles.
- The Green Turtle and the Hawksbill Turtle rank as the most vulnerable migratory reptile species to climate change out of those studied within CMS Appendix I

Reptiles (Reptilia) Climate Change Vulnerability Gradings



RANK	Reptiles	Climate Change Vulnerability Gradings Identified for Species
1	Green Turtle	High (18)
1	Hawksbill Turtle	High (18)
2	Kemp's Ridley Turtle, Atlantic Ridley Turtle	High (16)
3	Gharial, Indian Gavial	High (15)
3	Loggerhead Turtle	High (15)
4	Olive Ridley	High (14)
4	Leatherback Turtle	High (14)

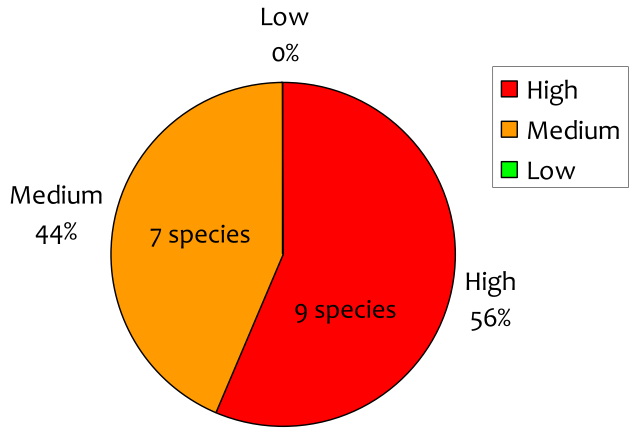
- The Olive Ridley and the Leatherback Turtle rank as the least vulnerable migratory reptile species to climate change out of those studied within CMS Appendix I. However these still have very high vulnerability compared to other species studied ranking 5th place in overall species vulnerability.

Overview of Mammals

- 16 species (42%) out of the total 38 species of mammals on CMS Appendix I have been included in case study assessments
- 9 species (56%) of mammals studied have been identified as having a HIGH VULNERABILITY to climate change
- 7 species (44%) of mammals studied have been identified as having a MEDIUM VULNERABILITY to climate change
- The North Pacific Right Whale and the Northern Atlantic Right Whale rank as the most highly vulnerable migratory mammal species within CMS Appendix I to climate change impacts, of those included in this study.

RANK	Mammals	Climate Change Vulnerability Gradings Identified for Species
1	North Pacific Right Whale	High (16)
1	Northern Atlantic Right Whale, Biscayan Right Whale	High (16)
2	West African Manatee	High (15)
2	Bowhead Whale	High (15)
3	Dama Gazelle	High (14)
3	Southern Right Whale	High (14)
4	Addax	High (13)
4	Blue Whale	High (13)
5	Snow leopard	High (10)
6	Cuvier's Gazelle	Medium (11)
6	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	Medium (11)
6	Short-beaked Common Dolphin	Medium (11)
7	Humpback Whale	Medium (10)
7	Mexican Free-tailed Bat	Medium (10)
7	Sperm Whale	Medium (10)
8	Marine Otter	Medium (7)

- The Marine Otter ranks as the least vulnerable migratory mammal species to climate change impacts, of those included in this study. It is also one of the least migratory from the list.
- If the Narwhal, which is listed on CMS Appendix II, was included in the ranking opposite it would rank first as the most highly vulnerable mammal species studied to climate change above the Northern Pacific Whale and the Northern Atlantic Whale.

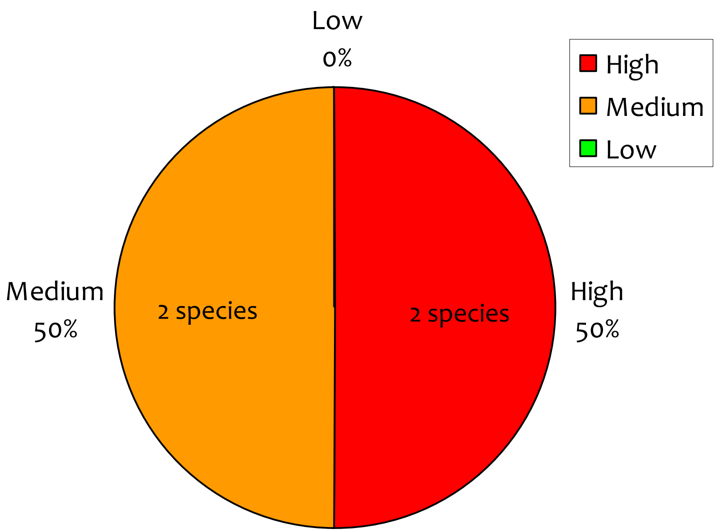


Mammals (Mammalia) Climate Change Vulnerability Gradings

Overview of Fish

- All 4 species (100%) of fish in CMS Appendix I have been included in this study and fully assessed.
- 2 species (50%) of fish assessed have been identified as having a HIGH VULNERABILITY to climate change
- 2 species (50%) of fish assessed have been identified as having a MEDIUM VULNERABILITY to climate change
- The Giant Catfish ranks as the most vulnerable migratory fish species to climate change in CMS Appendix I.
- The Great White Shark ranks as the least vulnerable migratory fish species to climate change within CMS Appendix I

RANK	Mammals	Climate Change Vulnerability Gradings Identified for Species
1	Giant Catfish	High (12)
2	Common Sturgeon	High (11)
3	Basking Shark	Medium (12)
4	Great White Shark, White Shark	Medium (8)

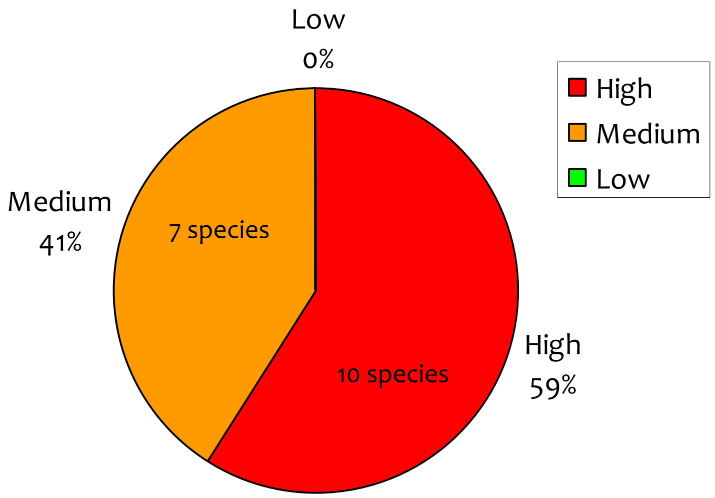


Fish (Pisces) Climate Change Vulnerability Gradings

Overview of Birds

- 17 species (23%) out of the total 75 species of birds on CMS Appendix I have been included in case study assessments
- 10 species (59%) of birds assessed have been identified as having a HIGH VULNERABILITY to climate change
- 7 species (41%) of birds assessed have been identified as having a MEDIUM VULNERABILITY to climate change
- The Balearic Shearwater ranks as the most vulnerable migratory bird species to climate change of those included in this study.
- The White-Tailed Eagle ranks as the least vulnerable migratory bird species to climate change of those included in this study. It is also one of the least biologically migratory bird species within CMS Appendix I.

RANK	Birds	Climate Change Vulnerability Gradings Identified for Species
1	Balearic Shearwater	High (17)
2	Relict Gull	High (16)
3	Short-tailed Albatross, Steller's Albatross	High (15)
4	Sociable Plover	High (14)
5	Steller's Eider	High (13)
5	White-naped Crane	High (13)
5	Red-breasted Goose	High (13)
5	Siberian Crane	High (13)
6	Basra Reed-warbler	High (12)
7	Bermuda Petrel	High (11)
8	Aquatic Warbler	Medium (12)
9	Swan Goose	Medium (11)
10	Andean Flamingo	Medium (10)
10	Humboldt Penguin	Medium (10)
10	Pallas Fish Eagle	Medium (10)
11	Puna Flamingo	Medium (9)
12	White-tailed Eagle	Medium (7)



Birds (Aves) Climate Change Vulnerability Gradings

Details of Reptile Species Vulnerability

All reptiles studied have been identified as having a high vulnerability to climate change. The Green Turtle and the Hawksbill Turtle have both been identified as having highest vulnerability. The Leatherback turtle and the Olive Ridley turtle show the lowest overall climate change vulnerability out of all the reptiles studied.

A life history characteristic shared by all reptile species studied is temperature dependent sex determination, which will increases their vulnerability to climate change. As temperatures rise, this is likely to cause feminisation of these species populations. Alongside this is the vulnerability of breeding sites to climate change impacts, which will further reduce reproductive success. Current anthropogenic threats are also high for the majority of reptile species studied and have been identified as a major factor limiting these species resilience to climate change impacts.

Gradings for Individual Criteria within Reptile Species Assessments:

	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other Processes	Total
Reptiles					
Gharial, Indian Gavial	Medium	Medium / High	Medium	High	High (15)
Green Turtle	High	High	Medium	High	High (18)
Hawksbill Turtle	High	Medium / High	Medium / High	High	High (18)
Kemp's Ridley Turtle, Atlantic Ridley Turtle	Medium / High	Medium / High	Medium	High	High (16)
Leatherback Turtle	Medium / High	Medium	Low / Medium	High	High (14)
Loggerhead Turtle	Medium / High	Medium	Medium	High	High (15)
Olive Ridley	Medium / High	Medium / High	Low / Medium	Medium / High	High (14)

Habitat Vulnerability:

- Both the Green Turtle and the Hawksbill Turtle show the highest vulnerability due to Habitat Vulnerability of all the reptiles studied.
  - *Most important were the number of beaches that would be impacted by sea level rise for both of these species. Ocean acidification will also affect both species, the Hawksbill Turtle most prominently due to its impacts on coral habitat. Sea grass habitats vital for the Green Turtle will be severely affected by temperature stress, sea level rise, changing tidal circulation that will prompt sea grass range shift and degradation of habitats. Alongside this increased cyclone rates, altered ocean currents and changes in ocean upwelling's will also have major affects on the Green Turtle.*
- The Gharial was identified as having the lowest Habitat Vulnerability of all reptile species.

- *However this is mainly due to low confidence levels in global climate model predictions for river flow and precipitation within their habitat area. Impacts on sandbanks were identified as the main vulnerability for the Gharial with increased flooding events or water level rises likely to inundate these vital nesting and basking areas.*

Ecological Flexibility:

- The Green turtle has been identified as having the least Ecological Flexibility of all the reptile species studied, which indicates they are the least likely to be able to adapt to climatic changes.
  - *Although the Green Turtle shares the same characteristics that will limit the ecological flexibility of all reptiles studied, temperature dependent sex determination being the most important to note. This species is also very specialised; having specific habitat requirements, being the slowest development to sexual maturity of all reptile species studied (of up to 50 years in some populations) and having females which exhibit strong natal homing, indicating limited flexibility in migratory patterns.*
- The Leatherback Turtle has been identified as having the most Ecological Flexibility, alongside the Loggerhead Turtle, indicating these species are the most likely to be able to adapt to climate change out of all the reptiles assessed.
  - *Key factors influencing these species adaptability is their wide distribution, tolerance of varying temperatures and good dispersability. Loggerhead Turtles are also generalist opportunistic feeders.*

Species Interactions:

- The Hawksbill Turtle has been identified as having the highest vulnerability of all species of reptiles studied from climate change impacts on Species Interactions, in this case the climate change vulnerability of species used as a primary food resource.
  - *Adult Hawksbill Turtles are primarily specialist spongivores and the availability of this food source will be negatively affected by rising sea surface temperatures.*
- Both the Leatherback Turtle and the Olive Ridley Turtle have the lowest vulnerability due to Species Interactions out of all the reptiles studied.
  - *Whilst Leatherback Turtles are more specialised then some other turtle species, feeding mainly on gelatinous planktons such as jellyfish, these key prey species are widely distributed are likely not be so directly affected by impacts such as ocean acidification as species, for example, limited to coral reefs.*
  - *Compared to other turtle species studied the Olive Ridley turtle will be the least likely to suffer prey shortages as it is an opportunistic omnivores feeding on variety of organisms, and therefore has a greater ability to adapt its feeding habits compared to other sea turtle species.*

Interactions with other Processes:

- All species have been identified as having a high vulnerability due to Interactions with other Threat Processes, apart from the Olive Ridley which scored a medium/high.
- A common factor identified for all reptiles assessed is the value of reducing anthropogenic pressures to build their resilience and to climate change impacts. The Leatherback Turtle would likely benefit the most from this focus as it is the species that scores relatively low in other vulnerabilities to climate change, indicating that it has the best chances of adapting and coping with climate change impacts if other threat

processes and potential for interactions with these were reduced. Most importantly the Leatherback Turtle has been identified as having a high Ecological Flexibility showing that it is likely to be one of the most adaptable reptile species studied to climate change impacts and therefore potentially one of the most likely to respond to effective conservation measures that aid adaptation to climate change and mitigate impacts.

Details of Mammal Species Vulnerability

All mammals within this study have been identified as having a high or medium vulnerability to climate change.

- Mammal species identified as having the highest climate change vulnerability within this study are the North Pacific Right Whale, the Northern Atlantic Right Whale and the Narwhal. The Narwhal has the highest vulnerability ranking of all mammal species studied.

Gradings for Individual Criteria within Mammal Species Assessments:

Mammals Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Blue Whale	Medium / High	Medium / High	Medium / High	Low	High (13)
Bowhead Whale	High	Medium	Medium / High	Medium	High (15)
Humpback Whale	Medium	Low / Medium	Medium	Low / Medium	Medium (10)
North Pacific Right Whale	Medium / High	Medium / High	Medium / High	Medium / High	High (16)
Northern Atlantic Right Whale	Medium / High	Medium / High	Medium / High	Medium / High	High (16)
Sei Whale	Low / Medium	Medium	Medium	Medium	Medium (11)
Short-beaked Common Dolphin	Low / Medium	Low / Medium	Medium	Medium / High	Medium (11)
Southern Right Whale	Medium	Medium	Medium / High	Medium / High	High (14)
Sperm Whale	Low / Medium	Medium	Low / Medium	Medium	Medium (10)
Addax	Medium / High	Low / Medium	Medium	Medium / High	High (13)
Cuvier's Gazelle	Medium	Low / Medium	Low / Medium	Medium / High	Medium (11)
Dama Gazelle	Medium / High	Low / Medium	Medium	High	High (14)
Marine Otter	Low	Low	Low	Medium / High	Medium (7)
Mexican Free-tailed Bat	Low / Medium	Medium	Low / Medium	Medium	Medium (10)
Snow leopard	Low	Medium	Low / Medium	Medium / High	High (10)
West African Manatee	Medium / High	Medium / High	Medium	Medium / High	High (15)

Appendix II Mammal Species:

Narwhal	High	Medium/High	Medium/High	Medium/High	High (17)

Habitat Vulnerability:

- Of all the mammal species studied on CMS Appendix I the Bowhead Whale has been identified as having the highest vulnerability due to Habitat Vulnerability. The Narwhal which is currently listed on CMS Appendix II has also been identified as having the highest vulnerability due to Habitat Vulnerability.
    - *This vulnerability is due to the likely reduction in the extent of Arctic sea ice, a habitat of critical importance to the survival of both the Bowhead Whale and the Narwhal. Predictions of Arctic temperatures have indicated a potential rise of between 5°C and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average (Christensen et al, 2007). This magnitude of warming is likely to greatly reduce the thickness and extent of sea ice with some models predicting that by 2100 Arctic sea ice will be seasonal (Meehl et al, 2007).*
- The Mexican free-tailed Bat and the Snow Leopard have been identified as having the lowest Habitat Vulnerability of all mammal species studied. Both these species fall within the category of least biologically migratory species within CMS Appendix I, as defined by this study.
    - *The current range of the Mexican Free-tailed Bat is likely to become more arid overall, however due to this species wide use of habitats and wide altitudinal range (up to 3000m) it is likely to be buffered from the most negative affects of climate change as it is more likely to be able to track habitat shifts within its range and withstand arid environments.*
    - *The Snow Leopard inhabits the high alpine tundra and subalpine ecological zones. Although some warmer temperatures could be experienced which will shift tree lines to higher elevations and cause some snow melt at lower elevations the overall habitat is not threatened greatly by these changes and the Snow Leopards range could track these changes, shifting to higher elevations and latitudes. However if climate change rises higher then predicted within the A1B scenario, which has been used as a baseline for these assessments, the impacts on its habitat will be substantially greater.*

Ecological Flexibility:

- All of the mammals showed some level of Ecological Flexibility with none of them scoring the lowest Ecological Flexibility grade.
- Mammal species identified as having the highest vulnerability from a lack of Ecological Flexibility include the Blue Whale, North Pacific Right Whale, the Northern Atlantic Right Whale and the West African Manatee.
    - *The Blue Whale, North Pacific Right Whale, the Northern Atlantic Right Whale are all limited in Ecological Flexibility due to their slow reproductive rate and high age to sexual maturity. All are very specialised feeders with physiological limitations to adaptation of their food sources. Blue Whales are specialised in feeding on Krill leaving them vulnerable to predicted climate impacts on Krill stocks from to oceanic warming and ocean acidification. Both the North Pacific Right Whale and the Northern Atlantic Right Whales are also inflexible in their diet and rely on oceanographic processes to concentrate high enough densities of zooplankton for feeding. These will be disrupted by climate*

change impacting on ocean currents. There are some indications that these impacts could be buffered to some degree by these species ability to adapt their feeding migratory patterns to areas where their food source are most abundant.

- The species that has been identified as having the lowest vulnerability from having a high degree of Ecological Flexibility is the Marine Otter.
    - *The Marine Otter inhabits areas with strong winds, heavy seas, and does not display specialised behaviour as it can thrive at a range of different latitudes and has an omnivorous diet. These characteristics indicate that it is unlikely that the fecundity of Marine Otter populations will be affected by rising temperatures or other climatic changes.*

Species Interactions

- None of the mammal species studied have been identified as having the most severe levels of vulnerability due to Species Interactions, with none scoring a high grade for this section of their assessments.
- Mammal species that have been identified as having the highest vulnerability due to Species Interactions include the Blue whale, Bowhead Whale, North Pacific Right Whale, the Northern Atlantic Right Whale and the Southern Right Whale, all scoring medium/high.
    - *Continuing loss of sea ice habitat will reduce the abundance of ice algae, which forms the base of the food chain within Arctic regions, in turn reducing abundance of copepods and krill on which all of these whales feed. This will also affect the length of feeding season for such species. Bowhead Whales are most likely to display the first direct impacts of this system collapse on their survival rates as their range is limited to the Arctic sea ice margins. However other species which rely on krill and copepod abundance including Blue Whale, North Pacific Right Whale, the Northern Atlantic Right Whale and the Southern Right Whale are also greatly threatened.*
- The species identified as having the lowest vulnerability from species interactions is the Marine Otter due to its diverse prey base and few natural predators.

Interactions with other Processes:

- The Dama Gazelle has been identified as having the highest level of vulnerability due to Interactions with other Threat Processes of all mammal species studied.
    - *Under the most conservative emissions scenario the mean temperatures in the Sahel region by 2080 and 2099, in comparison to the 1980-1999 mean temperatures, are projected to increase is by at least 2°C with top end of the range of the projections reaching 4°C. In the A1B scenario, the projected temperature rise lies between 2.6°C to 5.4°C, with the median model predicting 3.6°C. Drought and desertification will be a major risk to the Dama Gazelle which lives in the Sahelian zone. The impacts of climate change will be greatly increased by current anthropogenic threats. As suitable grazing land reduces due to climate change, human use and livestock will compete directly with the Dama Gazelle for this increasingly limited resource. Anthropogenic activities also have the potential to interact with climate change impacts and increase desertification rates further. Without limiting current anthropogenic impacts and protecting areas vital for the Dama Gazelle under future climate change scenarios it is unlikely that this species will be able to cope with the changes predicted.*
- The Blue Whale has been identified as having the lowest level of vulnerability from Interactions with other Threat Processes.
    - *Protection of Blue Whales is currently highly effective with all global populations increasing, with accidental deaths from anthropogenic causes being rare. The possibilities for anthropogenic threats to limit the Blue Whales ability to adapt to climate change are low.*

Climate Change Vulnerabilities of Cetaceans Highlighted

Cetacean Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Blue Whale	Medium / High	Medium / High	Medium / High	Low	High (13)
Bowhead Whale	High	Medium	Medium / High	Medium	High (15)
Humpback Whale	Medium	Low / Medium	Medium	Low / Medium	Medium (10)
North Pacific Right Whale	Medium / High	Medium / High	Medium / High	Medium / High	High (16)
Northern Atlantic Right Whale	Medium / High	Medium / High	Medium / High	Medium / High	High (16)
Sei Whale	Low / Medium	Medium	Medium	Medium	Medium (11)
Short-beaked Common Dolphin	Low / Medium	Low / Medium	Medium	Medium / High	Medium (11)
Southern Right Whale	Medium	Medium	Medium / High	Medium / High	High (14)
Sperm Whale	Low / Medium	Medium	Low / Medium	Medium	Medium (10)

Appendix II Cetacean Species:

Narwhal	High	Medium/High	Medium/High	Medium/High	High (17)

Nine marine cetaceans from CMS Appendix I have been included in case study assessments and have been identified as having a range of climate change vulnerabilities with the majority having a high vulnerability. Five out of nine species have been graded as having a high vulnerability and the remainder being very close to the border between medium and high vulnerability. One marine cetacean species from CMS Appendix II has been included in case studies, the Narwhale, and has been identified as having the highest vulnerability of all mammal species studied. A major concern for many of the whale species studied is the impacts of oceanic temperature increases, polar sea ice melt and ocean acidification on phytoplankton and zooplankton. Species which have a wide food base that includes fish show the lowest vulnerability scores within this subset of species (including Humpback Whale, Sei Whale, Short Beaked Common Dolphin and the Sperm Whale), apart from the Narwhal which is highly dependent on vulnerable sea ice habitat.

The North Pacific and North Atlantic Right Whales have been identified as having the highest vulnerability to climate change within CMS Appendix I. Both show a high degree of threat from Interactions with other Processes, suggesting that this is one area that conservation could aim to reduce to improve their overall resilience to climate change. For species such as the Blue Whale, which show a low degree of threat from Interaction with other Processes, enhancing current protection legislation will do little to improve their resilience to climate change impacts. Instead conservation efforts must focus much wider to have an impact on this species long term survival and this will have to include involvement in efforts to reduce global emissions levels and mitigation of climate change.

Other species identified as having a high vulnerability include the Bowhead Whale and Narwhale, the migratory patterns are most closely related to seasonal expansion and contraction of Arctic sea-ice cover making them most directly vulnerable to the impacts of predicted and currently observed reductions in sea ice thickness and expanse. For the Bowhead Whale this will also impact on krill and copepods abundance which is their primary food source. By 2100 some models predict that Arctic sea ice will be seasonal (Meehl et al, 2007) greatly reducing these species habitat, and limiting the areas in which they can feed and shelter from predators. Meanwhile the extent of their migration will also be affected. As Arctic climate models predict higher magnitudes of warming at an earlier time period than the global average it is likely that the Bowhead Whale will be one of the first species within Appendix I to show direct and observable impacts from climate change. It is also likely that the Narwhal will show direct and observable impacts from climate change earlier then many other migratory species. Alongside these impacts from warming, ocean acidification will have major affects on the food chain of the Arctic and this will be seen much earlier within polar cold waters then in the warmer waters of the lower latitudes. This will have further impacts on the food source of the Bowhead Whale and potentially, but less directly, on the Narwhal. Due to these concerns it is recommended that further research and policy attention be prioritised for the Bowhead Whale and the Narwhal.

Climate Change Vulnerability Scores of Antelopes Highlighted

Antelope Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Addax	Medium / High	Low / Medium	Medium	Medium / High	High (13)
Cuvier's Gazelle	Medium	Low / Medium	Low / Medium	Medium / High	Medium (11)
Dama Gazelle	Medium / High	Low / Medium	Medium	High	High (14)

Two species of antelopes specific to dryland regions of the Sahel and Sahara region have been identified as having a high vulnerability to climate change (the Addax and Dama Gazelle). Another species of antelope, the Curvier's Gazelle, has been studied which inhabits semi-arid forest and mountain steppe areas and this has been shown to have a medium vulnerability to climate change. Due to their herbivorous nature these species are highly dependent on the vulnerability of their habitats to climate change. All exhibited a basic high level of adaptability to climate change impacts, shown in their low gradings of vulnerability due to Ecological Flexibility, however their long term survival is dependent on either the resilience of vital habitat within their current range or their ability to locate new suitable areas once climate change shifts occur. All species of antelopes studied have high levels of anthropogenic threats which will reduce their resilience to climate change if action is not taken to alleviate these. Anthropogenic habitat degradation and actions leading to increased desertification rates will act synergistically with climate change to further exacerbate the problems faced by these species. Hunting will also lower species resilience and ability to adapt. A key concern for consideration is whether new areas that could suitably support species under climate change projections are protected from degradation from anthropogenic activities and whether species migration to these potentially new areas will firstly be supported by suitable habitat corridors and secondly species will be pushed towards interactions with humans that will incur an increase in hunting pressure. Identification of "climate safe" areas for these species as well as the development of legislation to prevent land degradation and hunting in preparation for species range shifts could provide potentially very rewarding outcomes due to these species high degree of adaptability.

Details of Fish Species Vulnerabilities

Two species of fish, Common Sturgeon and Giant Catfish, have been identified as having a high vulnerability to climate change impacts. The Common Sturgeon also shows a low vulnerability from Species Interactions, the lowest of all fish species. Both species show high vulnerability due to Interactions with other Processes, the highest of all fish species studied.

Gradings for Individual Criteria within Fish Species Assessments:

Fish Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Basking Shark	Medium	Medium	Medium	Medium	Medium (12)
Common Sturgeon	Low / Medium	Medium	Low	High	High (11)
Giant Catfish	Low / Medium	Medium	Low / Medium	High	High (12)
Great White Shark	Low	Low / Medium	Low / Medium	Medium	Medium (8)

Habitat Vulnerability:

- Habitat vulnerability does not rank very highly as a threat to fish species with all grades ranging from medium to low.
- The Basking Shark shows the highest vulnerability due to habitat vulnerability of all the fish species studied.
  - *Changes in sea temperatures, ocean acidification and weakening of the Thermohaline circulation are predicted impacts of climate change that are likely to alter the physio-chemical factors in the North Atlantic and have a negative impact on the biology of Basking Sharks. A recent study of long-term sightings data collected off southwest Britain between 1988 and 2001 indicates that the number of basking sharks recorded was highly correlated with abiotic factors, principally sea surface temperature (SST) and the lagged effect of SST in the previous month.*
- The Great White Shark shows a low vulnerability due to habitat vulnerability, the lowest of all fish species.
  - *As the Great White Shark occupies a large range of habitats, habitat changes brought about by climate change are unlikely to have a large impact on this species, although their range may shift by the end of the century to track favourable conditions.*

Ecological Flexibility:

- The majority of fish, including the Basking Shark, Common Sturgeon and Giant Catfish have been identified as having medium levels of Ecological Flexibility. This indicates that overall fish species have a degree of intrinsic adaptability to climate change impacts which could be promoted effectively through conservation actions.

- *The Basking Shark undertakes extensive migration and displays an ability to forage for zooplankton prey along shifting thermal fronts which indicates an ability to adapt to a changing environment. However its very low reproductive rate would limit this species overall populations resilience to climate change impacts.*
  - *The Common Sturgeon has a large historical range, a widely distributed marine phase distribution and a broad diet of benthic invertebrates which indicates a fairly generalist species. However, the Common Sturgeon also requires a variety of specialised habitats throughout its lifecycle. In addition, its specialised breeding biology, relatively high age at sexual maturity and low survival rate would reduce this species ability to adapt and will likely reduce its resilience to climate change impacts.*
- The Great White Shark shows the highest levels of Ecological Flexibility (low/medium vulnerability) of all fish species studied.
  - *Great White Sharks have one of the widest habitat and geographic ranges of any fish-like vertebrate, and are adaptable to a broad range of temperatures giving them a broad niche tolerance of temperatures ranging from 4 - 26 degrees. They also have a very broad diet indicating a low degree of specialisation. This species spends most of their lives in deep waters and are able to migrate where conditions are favourable. There are no known barriers preventing them from migrating and therefore their adaptation potential to climate change impacts is high.*

Species Interactions:

- The Basking Shark has been identified as having the highest level of vulnerability from Species Interactions of all fish species studied.
  - *Rising sea temperatures and increases in extreme weather events around coastlines are predicted that will likely disrupt the timing and distribution of plankton blooms upon which the basking shark relies, impacting feeding behaviour and migratory patterns of these sharks. Calm coastal sea conditions are correlated with copepod blooms which are their primary food source.*
- The Common Sturgeon has been identified as having a low level of vulnerability from Species Interactions, the lowest of all fish species studied.
  - *The Common Sturgeon does not appear to be dependent on any one prey species as they feed opportunistically on bottom dwelling creatures and there do not appear to be any significant competitors, predators or important symbiotic relationships that would be impacted by climate change.*

Interactions with other Processes:

- The Common Sturgeon and the Giant Catfish both have high vulnerabilities due to climate change Interactions with Other Processes. This means that other threat processes, most significantly anthropogenic impacts, will limit these species ability to be resilient and adapt to climate change.
  - *Both the Common Sturgeon and the Giant Catfish are vulnerable to climate change mitigation measures that affect watercourses upon which they depend. Dams have already been identified as limiting their ability to migrate upstream to spawn. Modification of estuaries for hydropower will also impact on the Common Sturgeon.*
  - *The Common Sturgeon is reported to be a "living fossil" and has a large historical range (Gardiner, 1984) with early remains of this species being found dating back to 26 million years (Kirchhofer & Hefti, 1996). This potentially suggests that the main limiting factor for this species are anthropogenic impacts rather then a lack of ability to adapt to changing environmental conditions. The Common Sturgeon is known to spawn in very limited locations, and yet their distribution while at sea is quite wide. This indicates the potential for Common Sturgeons to*

colonise new rivers in the region if suitable habitat is available under new climate change conditions and effective conservation action is taken to reduce anthropogenic impacts that limit their breeding potential.

- The Basking Shark and the Great White Shark both have medium vulnerabilities due to climate change Interactions with Other Processes.
    - *There is the potential that fish stocks will be reduced due to impacts from climate change that may cause increasing competition from anthropogenic fishing on the Great White Shark's prey.*
    - *A major concern for the Basking Shark is overfishing. Exploitation of this long-lived species which is slow to reach maturity puts the population under pressure. If fishing pressures cannot be kept to a minimum the population will be ill-equipped to cope with the challenges posed by climate change*

This study has indicated that the high degree of vulnerability from interactions with other anthropogenic threats will cause both the Common Sturgeon and the Giant Catfish to have a high level of overall climate change vulnerability. This suggests that if these threats were reduced for both species this would be a key action to take to reduce their vulnerability to climate change impacts. Both show a degree of Ecological Flexibility, indicating that they intrinsically have a level of ability to adapt to climate change and cope with these impacts. The Common Sturgeon also has a low vulnerability from Species Interactions which means that this species will not be indirectly impeded from adapting to climate change through climate change impacts on species upon which its survival dependents.

Details of Bird Species Vulnerability

The Relict Gull and the Short-Tailed Albatross have been identified as having the highest overall vulnerability to climate change of all bird species studied. The White Tailed Eagle and the Puna Flamingo have been identified as having the lowest vulnerability to climate change.

Gradings for Individual Criteria within Bird Species Assessments:

Bird Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Andean Flamingo	Low / Medium	Medium / High	Low / Medium	Low / Medium	Medium (10)
Aquatic Warbler	Medium	Medium	Low / Medium	Medium / High	Medium 12)
Balearic Shearwater	Medium / High	Medium / High	Medium / High	High	High (17)
Basra Reed-warbler	Medium / High	Low / Medium	Low / Medium	Medium / High	High (12)
Bermuda Petrel	Medium	Medium / High	Low / Medium	Low / Medium	High (11)
Humboldt Penguin	Low / Medium	Medium	Low / Medium	Medium	Medium (10)
Pallas Fish Eagle	Medium	Low / Medium	Low / Medium	Medium	Medium (10)
Puna Flamingo	Low / Medium	Medium	Low / Medium	Low / Medium	Medium (9)

Bird Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Red-breasted Goose	Medium / High	Medium	Low / Medium	Medium / High	High (13)
Relict Gull	High	Medium / High	Medium	Medium / High	High (16)
Short-tailed Albatross	Medium	Medium / High	Medium / High	Medium / High	High (15)
Siberian Crane	High	Medium	Low / Medium	Medium	High (13)
Sociable Plover	Medium	Medium	Medium / High	Medium / High	High (14)
Steller's Eider	Medium / High	Medium	Medium	Medium	High (13)
Swan Goose	Medium	Medium	Low / Medium	Medium	Medium (11)
White-naped Crane	Medium	Medium / High	Low / Medium	Medium / High	High (13)
White-tailed Eagle	Low / Medium	Low / Medium	Low	Low / Medium	Medium (7)

Habitat Vulnerability:

- The Relict Gull and the Siberian Crane show the highest vulnerability due to Habitat Vulnerability of all bird species studied.
  - *Both species are highly vulnerable as both breeding and feeding areas of these species are vulnerable to negative climate change impacts.*
  - *Relict Gulls only breed on islands in saline and slightly saline lakes in arid and semi-arid areas. The breeding areas of the Relict Gull are very sensitive to climate change and likely to become severely degraded by climate change impacts mainly as a result of changes in precipitation. Relict Gulls will not breed if the islands become connected to the shore due to low water levels or if the islands are flooded. Furthermore, other areas including the estuarine environments in which they feed are likely to be moderately degraded by climate change.*
  - *The Siberian Crane breeds in open tundra/taiga wetlands which are highly vulnerable to climate change as increased temperatures will deplete permafrost upon which these habitats are based. Climatic changes are already impacting upon Siberian Arctic habitats with a significant increase in area covered by lakes in the Siberian Crane nesting grounds (ICF, 2008). Drought and reductions in precipitation are also effecting the wintering and staging areas utilised by this species.*
- The lowest gradings for Habitat Vulnerability identified for bird species studied is a low/medium. The Andean Flamingo, Humboldt Penguin, Puna Flamingo and White-tailed Eagle all show the lowest scores of Habitat Vulnerability of bird species studied.
  - *Although wetlands in the Altiplano used by the Andean Flamingo and Puna Flamingo could be affected by climate change, due to temperature increase, seasonal changes and a potential reduction in rainfall, it is though that this habitat will endure these changes.*
  - *The habitat of the Humboldt Penguin is likely to be resilient to climate change over the next century, however periodic or more frequent ENSO events will have deleterious effects on the breeding habitat.*
  - *Individual habitat sites and concurrent populations of White -tailed Eagle may be under a higher risk of negative effects from climatic changes. For example, in Greenland a change in climate of higher precipitation since the 1970s has been linked to the reduction in productivity of the White-tailed Eagle. However, in general the habitat requirements for this species are broad and there are no threats which are consistent across the whole of the species' range*

Ecological Flexibility:

- The Basra Reed Warbler, Palas Fish Eagle and White-tailed Eagle have all been identified as having the highest Ecological Flexibility (lowest vulnerability) of all bird species studied. This indicates they are the most adaptable and potentially resilient bird species studied to climate change.
  - *The Basra Reed Warbler has a broad diet and is capable of nesting in a variety of wet environments. There have also been reports of it utilising both different locations to breed, and breeding away from water signalling an adaptive potential.*
  - *The Palas Fish Eagle lives at a diverse range of altitudes and across a large range. The only requirement necessary for this species appears to be access to freshwater wetlands, lakes or rivers. It also has a broad carnivorous diet, consuming a wide variety of live or dead prey.*
  - *The White Tailed Eagle is less specialised then many raptors in feeding habits and has a wide differentiation of breeding periods depending on the location and the climate of the population, and therefore, physiologically it should be able to adapt to modest climatic variations. It also has a preference for breeding in natal home ranges or areas which have already had breeding pairs previously. This indicates that areas of habitat which are relatively resilient to negative climate impacts for this species should be prioritised for conservation protection.*
- Species identified as having the lowest Ecological Flexibility (highest vulnerability grade) include the Andean Flamingo, Balearic Shearwater, Bermuda Petrel, Relict Gull, Short-tailed Albatross and White-naped Crane. All fall under the category of medium/high vulnerability.
  - *Low reproductive rate or low success of breeding is a limiting factor in adaptability for all bird species identified within this category. For example the Bermuda petrel only rears one chick per year and rearing success is just 25%.*
  - *Several birds within this category exhibit highly specialised requirements for breeding, for example the Balearic Shearwater. Although there is some evidence that this species is capable of altering its migration, it appears anchored to its breeding habitat on Balearic Island. Nesting of the Bermudan Petrel also appears to be confined to a few of the Bermudan Islands. The Relict Gull is also a highly specialised species requiring strict ecological requirements both in and outside of their breeding season. These gulls will not breed successfully if these requirements are not met and with a relatively high death rate in young birds, they are particularly vulnerable to even the slightest changes in habitat as a result of climate change.*
  - *Several birds have highly specialised dietary requirements requiring specific habitats. For example the Andean Flamingos are a specialised species which require a certain type of wetland to fulfil their dietary requirements (Hurlber and Chang, 1983).*
  - *Some birds do show some ability to adapt their migration patterns to climate change including the Andean Flamingo whose seasonal migration is driven by climate. Others such as the Short-Tailed Albatross show a potential adaptability due to former range extent.*
- No bird species studied show a high level of vulnerability due to lack of Ecological Flexibility, suggesting that all bird species studied have a degree of adaptability to climate change impacts. A general theme that all migratory bird species have in common is their ability to disperse as they have fewer geographical boundaries limiting their dispersal then many other species studied due to their mode of travel. This makes bird species who are not highly specialised in their breeding, feeding or migrational patters and those that do not have low reproductive rate potentially very good candidates for conservation priority in terms of specific measures to facilitate their intrinsic adaptability to climate change.

Species Interactions:

- The Balearic Shearwater, Short tailed Albatross and the Sociable Plover have been identified as having the highest vulnerability due to Species Interactions of all bird species studied.

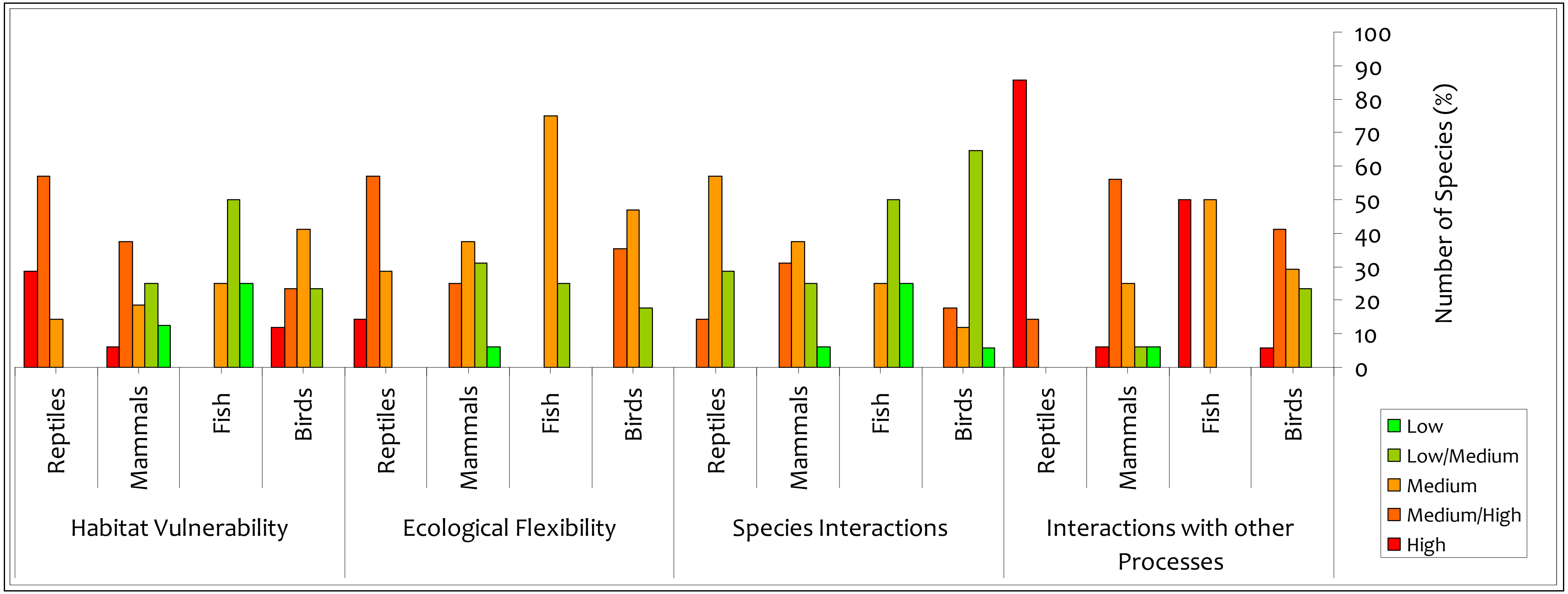
- *Observed rising sea surface temperatures have been identified within studies as a major force behind the northwards shift of the Balearic Shearwaters preferred prey, pelagic fish species which are following whole food web shifts. This has lead to an increase in distance they must migrate between breeding and feeding grounds.*
- *Short-tailed Albatross feed on the ocean surface, preying mainly on squid, fish and shrimp, all of these species are likely to be directly affected by climate change due to changes in ocean upwelling's and surface temperature and indirectly due to changes in salinity and pH. This may increase competition for resources from other species such as the Black-footed Albatross if these become limited.*
- *The Sociable Plover is a generalist feeder however it shows greater potential for impacts from changes in predator dynamics. There are also some indications that it is reliant on the Saiga Antelope to create suitable breeding habitat. There is some evidence to suggest that Saiga Antelope may be threatened by climate change although a thorough review of vulnerability is recommended.*

- The White tailed Eagle has been identified as having the lowest vulnerability due to Species Interactions of all bird species studied.
  - *Research has not found any known links between climatic changes and major variations in species interactions relating to the White-tailed Eagle due to its opportunistic feeding habits.*
- Most bird species studied have been identified as having a relatively low overall vulnerability due to Species Interactions compared to species studied in other taxa, with the majority of bird species having a low/medium vulnerability grading for this criteria.

Interactions with Other Processes:

- The Balearic Shearwater has been identified as having the highest vulnerability due to Interactions with Other Processes of all the bird species studied.
  - *The Balearic Shearwater populations are categorised as critically endangered by the IUC Red List and they are currently exhibiting a dependency on fishing by catch due to a lack of available food source. Feeding on by catch may be encouraging a decoupling of the Balearic Shearwaters range to the range of their prey species as this has been identified as shifting further north with observed rises in sea surface temperatures. If completely decoupled this would leave the Balearic Shearwater dependent on by catch, limiting their natural adaptation to climate change which would leave them highly vulnerable if fishing stopped.*
- The Andean Flamingo, Bermuda Petrel, Puna Flamingo and White-tailed Eagle have been identified as having the lowest vulnerability due to Interactions with Other Processes of all the bird species studied.
  - *The Andean and Puna Flamingos current range is within protected areas limiting the impacts of anthropogenic affects on species. However there may be impacts if climate change forces them to shift their range outside of these parks. The degree to which this will impact the species is unknown and a potential consideration for further research.*
  - *An extensive conservation programme has limited the current anthropogenic impacts on the Bermuda Petrel. However if efforts to provide suitable breeding habitat ceases this will reduce this species resilience to climate change impacts.*

Comparative Overview of Climate Change Vulnerabilities Affecting Different Taxonomic Groups



Graph showing percentages of species within different taxonomic groups and their vulnerability to different criteria assessed within this study.

Habitat Vulnerability:

- Reptiles have the highest percentage of species with a high and medium/high vulnerability due to Habitat Vulnerability.
- Fish have the highest percentage of species with a low and low/medium vulnerability due to Habitat Vulnerability.

Ecological Flexibility:

- Reptiles have the highest percentage of species with a high/ medium to high vulnerability due to their lack of Ecological Flexibility. No reptiles show a low or low medium vulnerability due to intrinsic Ecological Flexibility. This suggests that reptile species are the species least likely to be able to adapt to climate change impacts of all the taxonomic groups studied.
- Mammals have the highest percentage of species with a low to low / medium vulnerability due to their intrinsic Ecological Flexibility. However more species fall under the category of medium to medium / high vulnerability due to lack of Ecological Flexibility. This suggests that there will

be a mixed response from mammal species studied in their adaptability to climate change which is species specific in nature rather then as a trend that runs across the taxonomic group.

- All fish species have a low / medium to medium vulnerability due to their intrinsic Ecological Flexibility. This suggests that all fish species within CMS Appendix I will be relatively adaptable to climate change if given the opportunity.
- All birds have a low/medium to medium/high vulnerability due to their intrinsic Ecological Flexibility. The majority of bird species fall under the medium range of Ecological Flexibility indicating some ability to adapt to climate change. No birds have a low or high grading of Ecological Flexibility suggesting none will have either strong ability or very little to no ability to adapt to climate change impacts.

Species Interactions:

- Fish show the highest percentage of species with low to low /medium scores for their vulnerability due to Species Interactions. This shows that fish species studied generally either have a wide base of prey species upon which they depend or their prey species is not vulnerable to climate change impacts. No effects of climate change impacts on competitor, predator species and symbiotic species could be found however this was thought to be due to a lack of detailed information for most fish species.
- Mammals showed the highest percentage of species with a medium to medium/ high score for their vulnerability due to Species Interactions. This suggests that it is more important for conservation measures of mammals to include a higher degree of measures to preserve species interactions of importance compared to other taxa if they are to effectively mitigate climate change impacts.
- No species from any taxa presented with high vulnerability due to Species Interactions. This is not to say that species interactions are not important for the long term survival of species but that species studied all have a degree of ability to cope with changes in populations, distributions and compositions of species upon which they depend. In general a lack of information was available on the impacts of climate change on competitor, predator and symbiotic/mutualistic species and how this would affect interactions with subject species.

Interactions with other Processes

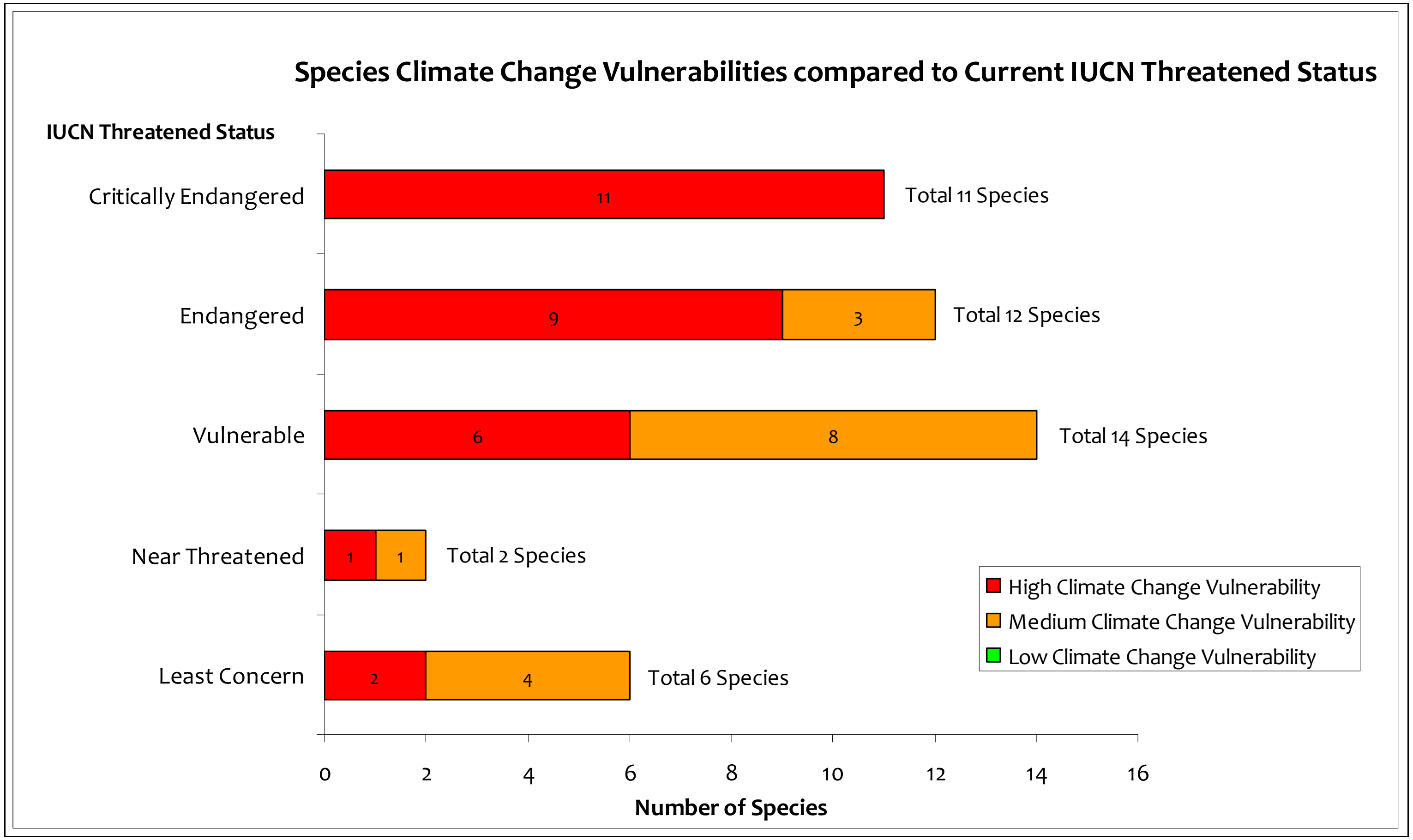
- A higher percentage of high vulnerabilities were recorded across all taxa for these species vulnerabilities to climate change Interactions with other Threat Processes.
- This indicates that a key measure for conservation will be to limit and reduce other threats, primarily anthropogenic driven, to species to build their resilience to cope with climate change impacts. For certain species highlighted, if these issues are not dealt with effectively, these species will have little chance to adapt to climate change. In some cases where other vulnerability scores are low the species has a high chance of being able to adapt to climate change impacts if anthropogenic pressures are removed or relaxed. This heightens the importance of further investment and effort being channelled into conventional conservation efforts alongside climate change focused conservation efforts if species are to survive climate change impacts.
- Reptiles have the highest percentage of species with a high to high/medium score for increased climate change vulnerability due to Interactions with other Threat Processes. This indicates that reptiles require the most effort to reduce added pressures, especially anthropogenic driven, on populations. A key issue here is climate change shifting vital nesting habitats, including beaches and sandbanks, into areas with heightened anthropogenic disturbance. A key response to this problem would be to identify areas for nesting that would be vital for species under climate change scenarios and outline suitable protection for these areas to limit anthropogenic encroachment and future impacts. Current

anthropogenic disturbance is also highly damaging to turtles resilience to climate change. If these can be limited their ability to achieve their adaptation potential will be increased.

- Birds have the lowest percentage of species with lower end ranges of vulnerability due to this factor. In these cases current intensive conservation efforts have been seen to be successfully limiting the impacts on species resilience to climate change.

9.3. Species Climate Change Vulnerabilities compared to Current IUCN Threatened Status

The climate change vulnerabilities of all migratory species studied have been reviewed against their current IUCN threat status (as provided by the RED List 2010.1 assessments). A graph showing the distribution of species assessed within each IUCN threat status category is provided below.



- A general trend can be seen whereby critically endangered species area also highly vulnerable to climate change and the overall comparative percentage of highly vulnerable species decreases as you go down the scale of IUCN threat gradings. A larger sample size would be required to clarify this trend.

There could be a number of reasons for this general trend to occur. Firstly many of the species traits and characteristics which make them currently threatened and vulnerable to anthropogenic impacts also are likely to make them vulnerable to climate change impacts, this includes adaptability and vulnerability of species interactions. Secondly current vulnerability of species and degree to which they are endangered will have large implications on whether species populations will be able to survive and cope with climate change. Populations which are already depleted and under pressure will have less ability to deal with climate change impacts. Concurrently habitats upon which species depend will have less ability to remain intact and viable under climate change pressures if currently threatened and/or degraded. Focus must be given to species which are outliers to this general trend. Species which are currently identified by IUCN as of least concern and near threatened but have been given a high vulnerability to climate change need to be given greater conservation focus then their threatened status indicates t they may be receiving currently. Identification of these outlier species climate change vulnerabilities gives an early warning signal for species which will likely increase in threatened status in the future as climate change impacts become more prevalent. Conservation focus to reduce and mitigate climate change impacts as well as promote adaptation should be given to species which are currently of least concern and near threatened status. As these species populations remain more intact and viable then those currently given more sever gradings within the IUCN Red List, their response to conservation measures to reduce the impacts of climate change on these species are more likely to provide beneficial outcomes then if these measures were focused on species which are already endangered. Such a review of species comparing their climate change vulnerability to their current IUCN Red List threatened status will provide further clarification of species to prioritise for future conservation action and species which currently may not be being given the conservation focus which they require for long term survival under climate change.

IUCN RED List CRITICALLY ENDANGERED Species Vulnerability to Climate Change

- All critically endangered species studied have been identified as having a high vulnerability to climate change. This includes the Hawksbill Turtle which is one of the species identified as most vulnerable to climate change within this study. The Balearic Shearwater which ranks second place in terms of vulnerability to climate change for all species studied, as well as most vulnerable to climate change of all bird species studied, is also critically endangered.

Taxa	English	Latin	Climate Change Vulnerability	Vulnerability Rank in Species Studied	Vulnerability Rank in Taxa Group	Red List 2010	Population Trend (2010)
Reptilia	Hawksbill Turtle	Eretmochelys imbricata	High (18)	1	1	CR	Decreasing
Aves	Balearic Shearwater	Puffinus mauretanicus	High (17)	2	1	CR	Decreasing
Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	Lepidochelys kempii	High (16)	3	2	CR	Not provided
Reptilia	Gharial, Indian Gavial	Gavialis gangeticus	High (15)	4	3	CR	Decreasing
Aves	Sociable Plover , Sociable Lapwing	Vanellus gregarius	High (14)	5	4	CR	Decreasing
Mammalia	Dama Gazelle	Gazella dama	High (14)	5	3	CR	Decreasing
Reptilia	Leatherback Turtle,	Dermochelys coriacea	High (14)	5	4	CR	Decreasing

Aves	Siberian Crane	Grus leucogeranus	High (13)	6	5	CR	Decreasing
Mammalia	Addax	Addax nasomaculatus	High (13)	6	4	CR	Decreasing
Pisces	Giant Catfish	Pangasius gigas	High (12)	7	1	CR	Decreasing
Pisces	Common Sturgeon	Acipenser sturio	High (11)	8	2	CR	Decreasing

IUCN RED List ENDANGERED Species Vulnerability to Climate Change

- The Green turtle which has been identified as one of the most vulnerable species to climate change in this study is listed as Endangered by IUCN.
- The North Pacific and North Atlantic Right Whales are the most vulnerable species to climate change out of all mammal species studied within Appendix I and are also currently listed as Endangered by IUCN.

Taxa	English	Latin	Climate Change Vulnerability	Vulnerability Rank in Species Studied	Vulnerability Rank in Taxa Group	Red List 2010	Population Trend (2010)
Reptilia	Green Turtle	Chelonia mydas	High (18)	1	1	EN	Decreasing
Mammalia	North Pacific Right Whale	Eubalaena japonica	High (16)	3	1	EN	Unknown
Mammalia	Northern Atlantic Right Whale	Eubalaena glacialis	High (16)	3	1	EN	Unknown
Reptilia	Loggerhead Turtle	Caretta caretta	High (15)	4	3	EN	Not provided
Aves	Red-breasted Goose	Branta ruficollis	High (13)	6	5	EN	Decreasing
Mammalia	Blue Whale	Balaenoptera musculus	High (13)	6	4	EN	Increasing
Aves	Basra Reed-warbler	Acrocephalus griseldis	High (12)	7	6	EN	Decreasing
Aves	Bermuda Petrel	Pterodroma cahow	High (11)	8	7	EN	Increasing
Mammalia	Snow Leopard	Uncia uncia	High (10)	9	5	EN	Decreasing
Mammalia	Cuvier's Gazelle	Gazella cuvieri	Medium (11)	11	6	EN	Unknown
Mammalia	Sei Whale Coalfish Whale	Balaenoptera borealis	Medium (11)	11	6	EN	Unknown
Mammalia	Marine Otter	Lontra felina	Medium (7)	16	8	EN	Decreasing

IUCN RED List VULNERABLE Species Vulnerability to Climate Change

- The Relict Gull is currently listed as Vulnerable by IUCN Red List however it has been identified as having a high vulnerability to climate change, ranking third place out of all species studied within Appendix I.

Taxa	English	Latin	Climate Change Vulnerability	Vulnerability Rank in Species Studied	Vulnerability Rank in Taxa Group	Red List 2010	Population Trend (2010)
Aves	Relict Gull	Larus relictus	High (16)	3	2	VU	Decreasing
Aves	Short-tailed Albatross	Diomedea albatrus	High (15)	4	3	VU	increasing
Mammalia	West African Manatee	Trichechus senegalensis	High (15)	4	2	VU	Unknown
Reptilia	Olive Ridley	Lepidochelys olivacea	High (14)	5	4	VU	Decreasing
Aves	White-naped Crane	Grus vipio	High (13)	6	5	VU	Decreasing
Aves	Steller's Eider	Polysticta stelleri	High (13)	6	5	VU	Decreasing
Aves	Aquatic Warbler	Acrocephalus paludicola	Medium (12)	10	8	VU	Decreasing
Pisces	Basking Shark	Cetorhinus maximus	Medium (12)	10	3	VU	Decreasing
Aves	Swan Goose	Anser cygnoides	Medium (11)	11	9	VU	Decreasing
Aves	Andean Flamingo	Phoenicopterus andinus	Medium (10)	12	10	VU	Decreasing
Aves	Humboldt Penguin	Spheniscus humboldti	Medium (10)	12	10	VU	Decreasing
Aves	Pallas Fish Eagle	Haliaeetus leucoryphus	Medium (10)	12	10	VU	Decreasing
Mammalia	Sperm Whale	Physeter macrocephalus	Medium (10)	12	7	VU	Unknown
Pisces	Great White Shark	Carcharodon carcharias	Medium (8)	14	4	VU	Unknown

IUCN RED List NEAR THREATENED Species Vulnerability to Climate Change

- The Narwhal which is currently listed within CMS Appendix II and is also only categorised as Near Threatened by IUCN Red List. However this species has been identified as highly vulnerability to climate change, ranking second most vulnerable of all case study species, as well as ranking as the most vulnerable mammal species of those studied.

Taxa	English	Latin	Climate Change Vulnerability	Vulnerability Rank in Species Studied	Vulnerability Rank in Taxa Group	Red List 2010	Population Trend (2010)
Mammalia	Narwhal	Monodon monoceros	High (16)	2	1	NT	Unknown
Aves	Puna Flamingo	Phoenicopterus jamesi	Medium (9)	13	11	NT	Decreasing

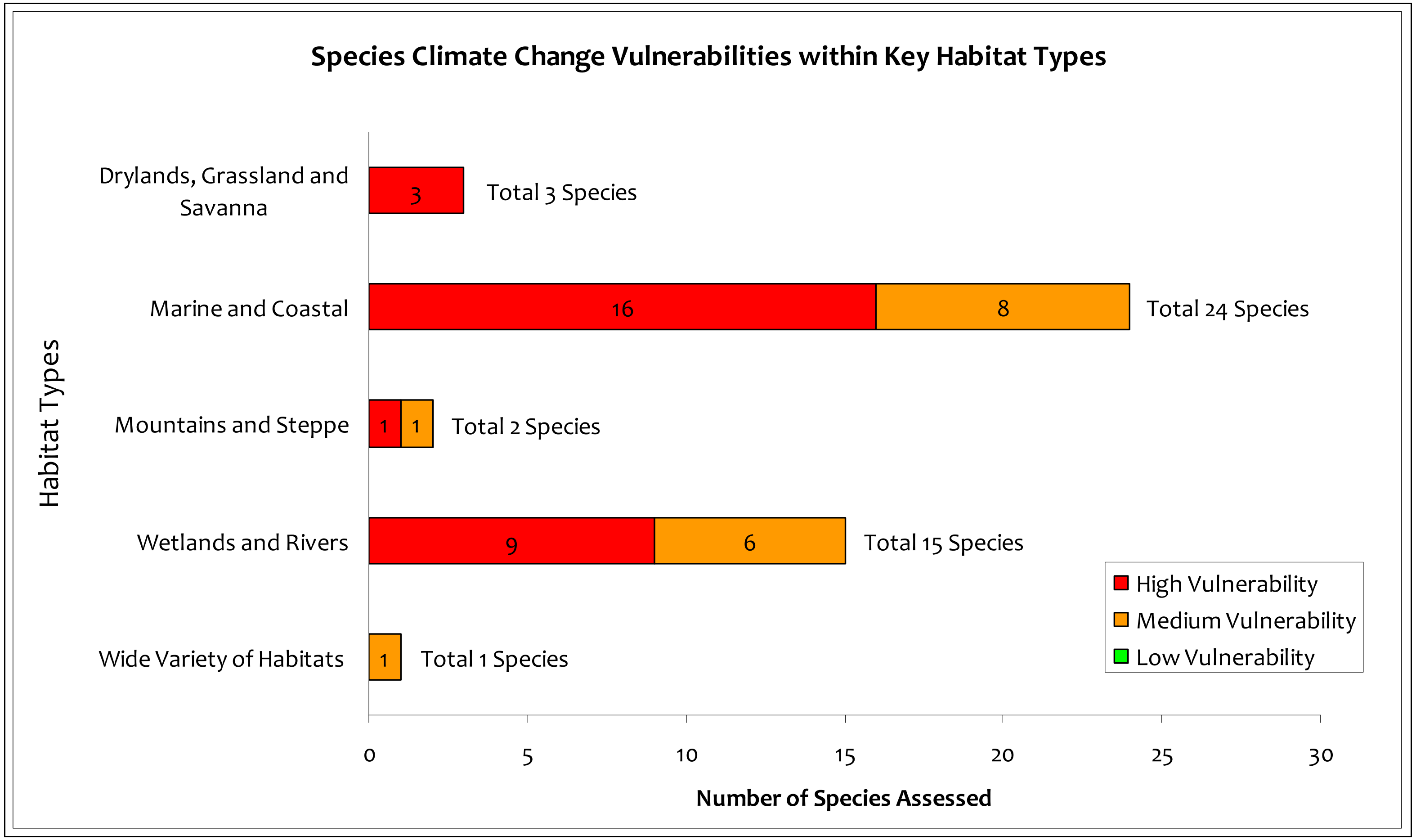
IUCN RED List LEAST CONCERN Species Vulnerability to Climate Change

- The Bowhead Whale and the Southern Right Whale both are currently listed as Least Threatened by the IUCN Red List. However both these species have been identified as having a high vulnerability to climate change. This indicates that both these species are likely to increase in threatened status as climate change impacts occur.

Taxa	English	Latin	Climate Change Vulnerability	Vulnerability Rank in Species Studied	Vulnerability Rank in Taxa Group	Red List 2010	Population Trend (2010)
Mammalia	Bowhead Whale	Balaena mysticetus	High (15)	4	2	LC	Increasing
Mammalia	Southern Right Whale	Eubalaena australis	High (14)	5	3	LC	Increasing
Mammalia	Short-beaked Common Dolphin	Delphinus delphis	Medium (11)	11	6	LC	Unknown
Mammalia	Mexican Free-tailed Bat	Tadarida brasiliensis	Medium (10)	12	7	LC	Stable
Mammalia	Humpback Whale	Megaptera novaeangliae	Medium (10)	12	7	LC	Increasing
Aves	White-tailed eagle	Haliaeetus albicilla	Medium (7)	15	12	LC	Not listed

9.4. Species Climate Change Vulnerabilities Within Key Habitat Types

The climate change vulnerabilities of all migratory species studied have been reviewed against their key habitats types. These have been categorised under (1) Drylands, Grasslands and Savanna, (2) Marine and Coastal (3) Mountains and Steppe, (4) Wetlands and Rivers and (5) Wide Variety of Habitats. A graph showing the distribution of species within these habitats types is provided below.



Graph showing species climate change vulnerabilities within key habitat types.

Drylands, Grasslands and Savanna Habitats

- All species requiring drylands, grasslands and savanna habitats have been identified as having a high vulnerability to climate change.

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Mammalia	Dama Gazelle	Gazella dama	High (14)	5	3	Medium / High	Terrestrial	Arid areas with sparse vegetation including Sahel. Including Algeria, Niger, Chad & Mali.
Aves	Sociable Plover, Sociable Lapwing	Vanellus gregarius	High (14)	5	4	Medium	Terrestrial	Temperate Grasslands and Deserts, Subtropical / Tropical Grasslands, Arable Land. Migrates through North East Africa to North East India. Stopover sites in Middle East in semi arid grass plains near water. Breeds on saline steppes
Mammalia	Addax	Addax nasomaculatus	High (13)	6	4	Medium / High	Terrestrial	Dry Savanna and Grasslands, Desert in North & Sub-Saharan Africa

Marine and Coastal Habitats

- Of the species studied that use coastal and marine habitats two thirds are highly vulnerable to climate change with the remaining species having medium vulnerability. The majority of those with medium vulnerability are not closely linked with coastal regions and spend most of their time in the open ocean, which may provide a degree of buffering from climate change impacts.

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Reptilia	Green Turtle	Chelonia mydas	High (18)	1	1	High	Marine	Marine, Sandy Beaches, Sea Grass
Reptilia	Hawksbill Turtle	Eretmochelys imbricata	High (18)	1	1	High	Marine	Marine, Sandy Beaches, Coral Reefs

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Aves	Balearic Shearwater	Puffinus mauretanicus	High (17)	2	1	Medium / High	Marine	Sea Cliffs and Rocky Offshore Islands, Coastal Freshwater Lakes
Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	Lepidochelys kempii	High (16)	3	2	Medium / High	Marine	Marine, Sandy Beaches, Sea Grasses, Coastal Marshes including East & West Atlantic
Mammalia	Narwhal	Monodon monoceros	High (16)	3	1	High	Marine	Marine Arctic and areas including sea ice
Mammalia	North Pacific Right Whale	Eubalaena japonica	High (16)	3	1	Medium / High	Marine	Marine - Bering Sea to North Pacific
Mammalia	Northern Atlantic Right Whale, Biscayan Right Whale	Eubalaena glacialis	High (16)	3	1	Medium / High	Marine	Marine Coastal - North Atlantic feeding to subtropical shallow coastal waters for breeding
Mammalia	Bowhead Whale	Balaena mysticetus	High (15)	4	2	High	Marine	Marine migrating circumpolar from High Northern latitudes to Arctic
Reptilia	Loggerhead Turtle	Caretta caretta	High (15)	4	3	Medium / High	Marine	Marine, Sandy Beaches, Coral Reefs, Sea Grass, Mudflats
Aves	Short-tailed Albatross, Steller's Albatross	Diomedea albatrus	High (15)	4	3	Medium	Marine	Oceanic, Coastal and Sea Cliffs. Breeds on two small islands South Japan. Found in North Pacific
Reptilia	Leatherback Turtle,	Dermochelys coriacea	High (14)	5	4	Medium / High	Marine	Marine, Tropical Sandy Beaches
Reptilia	Olive Ridley	Lepidochelys olivacea	High (14)	5	4	Medium / High	Marine	Marine Semipelagic Coastal
Mammalia	Southern Right Whale	Eubalaena australis	High (14)	5	3	Medium	Marine	Circumpolar distance 20-60°. Marine Pelagic and Bays. Calfs in Subtropical waters and travels to Polar Southern Ocean to feed.
Mammalia	Blue Whale	Balaenoptera musculus	High (13)	6	4	Medium / High	Marine	Marine Pelagic with global migration from cold to tropical waters
Aves	Bermuda Petrel	Pterodroma cahow	High (11)	8	7	Medium	Terrestrial	Breeds in Bermuda Islands and migrates along Atlantic Gulf Stream

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Pisces	Common Sturgeon	Acipenser sturio	High (11)	8	2	Low / Medium	None Provided (Marine / Freshwater)	Migration through Marine Coastal, Brackish Estuaries to Freshwater Rivers covering North East Atlantic, Mediterranean, UK and French Coast
Pisces	Basking Shark	Cetorhinus maximus	Medium (12)	10	3	Medium	Marine	Marine Pelagic and Coastal
Mammalia	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	Balaenoptera borealis	Medium (11)	11	6	Low / Medium	Marine	Marine Offshore; Global range excluding Polar and North Indian Ocean. Migrating through Tropic, Sub-tropical, Temperate to Sub-polar. Prefers deep continental temperate oceans. In autumn moves towards equator.
Mammalia	Short-beaked Common Dolphin	Delphinus delphis	Medium (11)	11	6	Low / Medium	Marine	Marine Oceanic and Coastal. Global range but mainly found in Atlantic and Pacific Ocean. Prefers upwelling's and ocean shelves
Aves	Humboldt Penguin	Spheniscus humboldti	Medium (10)	12	10	Low / Medium	Marine / Terrestrial	Coastal and Rocky Islands range including Peru and Chile
Mammalia	Humpback Whale	Megaptera novaeangliae	Medium (10)	12	7	Medium	Marine	Marine Pelagic. Global range excluding Polar Regions
Mammalia	Sperm Whale	Physeter macrocephalus	Medium (10)	12	7	Low / Medium	Marine	Marine Meso / Bathypelagic & Continental Shelves. Global migration from tropical to polar up to 50°N/S
Pisces	Great White Shark, White Shark	Carcharodon carcharias	Medium (8)	14	4	Low	Marine	Marine coastal / neritic and epi-pelagic. Global range excluding Polar Regions
Mammalia	Marine Otter	Lontra felina	Medium (7)	16	8	Low	Marine / Terrestrial / Freshwater	Along Pacific coast of South America. Inter-subtidal zones, Coastal Habitats, Estuaries and Rivers.

Mountains and Steppe Habitats

- Only two species of those studied require mountain and steppe habitats. The Snow Leopard has been identified as having a high vulnerability to climate change however this is not due to the vulnerability of the habitat used as this species moves to higher and lower elevations during the seasons and therefore could potentially track changes induced by climate change within its habitat range.

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Mammalia	Snow Leopard	Uncia uncia	High (10)	9	5	Low	Terrestrial	Alpine-Subalpine Tundra remote Mountain Ranges and Rocky Outcrops at elevations above tree line up to 5500m. Occurs in Nepal, China, Mongolia & Russia. Moves to higher or lower elevations during seasons.
Mammalia	Cuvier's Gazelle	Gazella cuvieri	Medium (11)	11	6	Medium	Terrestrial	Semi-arid Mediterranean Forests and Steppes in mountain regions including Atlas mountains North & West Africa

Wetlands and River Habitats

- Of the 15 species studied that require wetland and river habitats, nearly two thirds have been identified as highly vulnerable to climate change.

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Aves	Relict Gull	Larus relictus	High (16)	3	2	High	Terrestrial	Semi Arid Wetlands, Estuaries in Central & Eastern Asia, Sand Flats and Saline Lakes
Reptilia	Gharial, Indian Gavial	Gavialis gangeticus	High (15)	4	3	Medium	Terrestrial / Freshwater	Rivers (slow moving and deep) & Sandbanks in India and Nepal
Mammalia	West African Manatee	Trichechus senegalensis	High (15)	4	2	Medium / High	Marine / Freshwater	West African Coastal & Inland Wetlands, Estuaries, Rivers, Lagoons, Coastal Flats & Mangrove Creeks

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Aves	Red-breasted Goose	Branta ruficollis	High (13)	6	5	Medium / High	Terrestrial	Tundra Wetlands within Central & Western Europe, Siberia. Breeding sites in Caspian and Black sea
Aves	Siberian Crane	Grus leucogeranus	High (13)	6	5	High	Terrestrial	Shallow Wetlands in Taiga/Tundra. Migrates through Arctic Russia, Siberia to East & West Asia (Yangtze River, Poyang Hu Lake)
Aves	Steller's Eider	Polysticta stelleri	High (13)	6	5	Medium / High	Marine	Northern Latitude Wetlands / Coastal. Overwinter in Alaska, Japan and Baltic Coastal Habitats including Low-lying Rocky Coasts, Bays and River Mouths. Summer breeding in Alaskan Planes & North Russia in Arctic Pools, Lakes, Rivers, Tundra Bogs. Habitat includes Fresh, Saline or Brackish waters.
Aves	White-naped Crane	Grus vipio	High (13)	6	5	Medium	Freshwater	In summer breeds in Wetlands, Wet Meadows in Broad River Valleys, Lake Edges, Lowland Steppes, Mixed Forest-Steppe, Grassy Marshes, Wet Sedge-Meadows, Reed Beds in Broad River Valleys, Lake depressions and boggy uplands in North East Asia & Mongolia. Winters in Freshwater Lakes, Farmland and sometimes Coastal Flats in South East Asia Korea, Japan & China.
Aves	Basra Reed-warbler	Acrocephalus griseldis	High (12)	7	6	Medium / High	Freshwater	Brackish, Freshwater Reed Beds, Mangroves, Dense Vegetation Wetlands, Lakes, Marshes, Swamps
Pisces	Giant Catfish	Pangasius gigas	High (12)	7	1	Low / Medium	Freshwater	Freshwater Rivers in Mekong Basin (South East Asia)
Aves	Aquatic Warbler	Acrocephalus paludicola	Medium (12)	10	8	Medium	Terrestrial	Inland Wetlands including Bogs, Marshes, Swamps, Fens, Peat lands from Eastern Europe to Sub-Saharan Africa

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Aves	Swan Goose	Anser cygnoides	Medium (11)	11	9	Medium	Freshwater	Mostly inhabits Wetlands. Summer breeding zones includes Steppes, Forest Steppes, along River Valleys, Deltas, Lakes, Marsh Plains & Grassland in North East Asia, Russia, Mongolia, China & Japan. Wintering zones including Lowland Lake Marshes, Rice Fields, Estuaries, Tidal Flats, Farmland & Coastal in South East Asia, Yangtze basin& Korea.
Aves	Andean Flamingo	Phoenicopterus andinus	Medium (10)	12	10	Low / Medium	Freshwater	Montane Salt Lakes, Salt Flats in the Andes
Aves	Pallas Fish Eagle, Pallas's fish-eagle	Haliaeetus leucoryphus	Medium (10)	12	10	Medium	Freshwater	Wetland habitats including Large Lakes and Rivers at a range of altitudes from Lowlands up to 5000m in Central Asia. It nests close to water either in Trees or on Cliffs
Aves	Puna Flamingo	Phoenicopterus jamesi	Medium (9)	13	11	Low / Medium	Freshwater	Highly specialised inhabiting Soft Substrate Salt Lakes of the high Andean planes. Breeds on islands or islets of Soft Clay or Sand and Shorelines of Salt Lakes
Aves	White-tailed eagle; Grey Sea Eagle	Haliaeetus albicilla	Medium (7)	15	12	Low / Medium	Terrestrial	Extensive range requiring Lakes with productive, shallow waters found in Coast or River Valley, within the Boreal, Temperate and Tundra Zones, nearby to undisturbed Cliffs or Open Stands of Large Old-Growth Trees required for nesting.

Wide Variety of Habitats

- The Mexican Free-tailed Bat uses a wide variety of habitats. Its main vulnerability stems from its dependence on a limited number of caves for breeding, the suitability of which could be impacted by climate change if temperature rise is considerably high.

Taxa Group	English Name	Latin Name	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species	Vulnerability Rank within Taxa Group	Habitat Vulnerability Grade	System Type (IUCN, 2010)	Description of Key Habitats Used
Mammalia	Mexican Free-tailed Bat, Brasilian free-tailed bat	Tadarida brasiliensis	Medium (10)	12	7	Low / Medium	Terrestrial	Wide range of Arid and Semi Arid Habitats from Desert to various types of Woodland within Mexico and the southern United States. Found at altitudes of up to 3000m. Less then 12 Caves used for breeding.

9.5. Ranking and Gradings of Factors Defining Species Vulnerability to Climate Change

Results are provided below for each assessment criteria grading. Species have been ranked in order of level of grading for criteria under review compared to overall species vulnerability gradings. For each grade given within an assessment, for example for habitat vulnerability, each species is listed in order of their overall climate change vulnerability and then ranked accordingly. For example those identified with the highest level of vulnerability from Habitat Vulnerability and highest level of overall climate change vulnerability are ranked first. Further analysis could be carried out that identifies the relationship between the criteria grading and the overall climate change vulnerability of each species that ranks the importance of one factor to the other for each species. However this level of analysis was not thought necessary at this stage of review and with this number of case study species. These rankings provide a potential guide to decision makers as to how to best to focus species actions to reduce climate change vulnerabilities.

Vulnerability due to Habitat

- Species with a high ranking in terms of vulnerability due to Habitat Impacts and with a high overall vulnerability should be prioritised for further action to maintain viability of suitable habitat under climate change scenarios where possible.

Taxa Group	English Name	Latin Name	Habitat Vulnerability Impacts Rank	Habitat Vulnerability Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Reptilia	Green Turtle	Chelonia mydas	1	High	High (18)	1
Reptilia	Hawksbill Turtle	Eretmochelys imbricata	1	High	High (18)	1
Mammalia	Narwhal	Monodon monoceros	2	High	High (16)	3
Aves	Relict Gull	Larus relictus	2	High	High (16)	3
Mammalia	Bowhead Whale	Balaena mysticetus	3	High	High (15)	4
Aves	Siberian Crane	Grus leucogeranus	4	High	High (13)	6
Aves	Balearic Shearwater	Puffinus mauretanicus	5	Medium / High	High (17)	2
Reptilia	Kemp's Ridley Turtle	Lepidochelys kempii	6	Medium / High	High (16)	3
Mammalia	North Pacific Right Whale	Eubalaena japonica	6	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	Eubalaena glacialis	6	Medium / High	High (16)	3
Reptilia	Loggerhead Turtle	Caretta caretta	7	Medium / High	High (15)	4
Mammalia	West African Manatee	Trichechus senegalensis	7	Medium / High	High (15)	4
Reptilia	Leatherback Turtle	Dermochelys coriacea	8	Medium / High	High (14)	5
Reptilia	Olive Ridley	Lepidochelys olivacea	8	Medium / High	High (14)	5
Mammalia	Dama Gazelle	Gazella dama	8	Medium / High	High (14)	5
Mammalia	Addax	Addax nasomaculatus	9	Medium / High	High (13)	6

Taxa Group	English Name	Latin Name	Habitat Vulnerability Impacts Rank	Habitat Vulnerability Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Mammalia	Blue Whale	Balaenoptera musculus	9	Medium / High	High (13)	6
Aves	Red-breasted Goose	Branta ruficollis	9	Medium / High	High (13)	6
Aves	Steller's Eider	Polysticta stelleri	9	Medium / High	High (13)	6
Aves	Basra Reed-warbler	Acrocephalus griseldis	10	Medium / High	High (12)	7
Reptilia	Gharial, Indian Gavial	Gavialis gangeticus	11	Medium	High (15)	4
Aves	Short-tailed Albatross,	Diomedea albatrus	11	Medium	High (15)	4
Mammalia	Southern Right Whale	Eubalaena australis	12	Medium	High (14)	5
Aves	Sociable Plover	Vanellus gregarius	12	Medium	High (14)	5
Aves	White-naped Crane	Grus vipio	13	Medium	High (13)	6
Aves	Bermuda Petrel	Pterodroma cahow	14	Medium	High (11)	8
Pisces	Basking Shark	Cetorhinus maximus	15	Medium	Medium (12)	10
Aves	Aquatic Warbler	Acrocephalus paludicola	15	Medium	Medium (12)	10
Mammalia	Cuvier's Gazelle	Gazella cuvieri	15	Medium	Medium (11)	11
Aves	Swan Goose	Anser cygnoides	16	Medium	Medium (11)	11
Mammalia	Humpback Whale	Megaptera novaeangliae	17	Medium	Medium (10)	12
Aves	Pallas Fish Eagle	Haliaeetus leucoryphus	17	Medium	Medium (10)	12
Pisces	Giant Catfish	Pangasius gigas	18	Low / Medium	High (12)	7
Pisces	Common Sturgeon	Acipenser sturio	19	Low / Medium	High (11)	8
Mammalia	Sei Whale	Balaenoptera borealis	20	Low / Medium	Medium (11)	11

Taxa Group	English Name	Latin Name	Habitat Vulnerability Impacts Rank	Habitat Vulnerability Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Mammalia	Short-beaked Common Dolphin	Delphinus delphis	20	Low / Medium	Medium (11)	11
Mammalia	Mexican Free-tailed Bat	Tadarida brasiliensis	21	Low / Medium	Medium (10)	12
Mammalia	Sperm Whale	Physeter macrocephalus	21	Low / Medium	Medium (10)	12
Aves	Andean Flamingo	Phoenicopterus andinus	21	Low / Medium	Medium (10)	12
Aves	Humboldt Penguin	Spheniscus humboldti	21	Low / Medium	Medium (10)	12
Aves	Puna Flamingo	Phoenicopterus jamesi	22	Low / Medium	Medium (9)	13
Aves	White-tailed eagle	Haliaeetus albicilla	23	Low / Medium	Medium (7)	15
Mammalia	Snow Leopard	Uncia uncia	24	Low	High (10)	9
Pisces	Great White Shark	Carcharodon carcharias	25	Low	Medium (8)	14
Mammalia	Marine Otter	Lontra felina	26	Low	Medium (7)	16

Vulnerability due to Ecological Flexibility

- Species with a low ranking in terms of vulnerability due to Ecological Flexibility and high overall vulnerability should be prioritised for further conservation action as these species exhibit an intrinsic ability to adapt to climate change impacts and are likely to respond well to efforts to facilitate adaptation to climate change.
- Species with a high ranking in terms of vulnerability due to Ecological Flexibility and with a high overall vulnerability present as species of concern which show characteristics that will limit their adaptation to climate change.

Taxa Group	English Name	Latin Name	Ecological Flexibility Impacts Rank	Ecological Flexibility Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Reptilia	Green Turtle	Chelonia mydas	1	High	High (18)	1

Taxa Group	English Name	Latin Name	Ecological Flexibility Impacts Rank	Ecological Flexibility Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Reptilia	Hawksbill Turtle	Eretmochelys imbricata	2	Medium / High	High (18)	1
Aves	Balearic Shearwater	Puffinus mauretanicus	3	Medium / High	High (17)	2
Mammalia	Narwhal	Monodon monoceros	4	Medium / High	High (16)	3
Aves	Relict Gull	Larus relictus	4	Medium / High	High (16)	3
Reptilia	Kemp's Ridley Turtle	Lepidochelys kempii	4	Medium / High	High (16)	3
Mammalia	North Pacific Right Whale	Eubalaena japonica	4	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	Eubalaena glacialis	4	Medium / High	High (16)	3
Mammalia	West African Manatee	Trichechus senegalensis	5	Medium / High	High (15)	4
Reptilia	Gharial, Indian Gavial	Gavialis gangeticus	5	Medium / High	High (15)	4
Aves	Short-tailed Albatross	Diomedea albatrus	5	Medium / High	High (15)	4
Reptilia	Olive Ridley	Lepidochelys olivacea	6	Medium / High	High (14)	5
Mammalia	Blue Whale	Balaenoptera musculus	7	Medium/High	High (13)	6
Aves	White-naped Crane	Grus vipio	7	Medium / High	High (13)	6
Aves	Bermuda Petrel	Pterodroma cahow	8	Medium / High	High (11)	8
Pisces	Common Sturgeon	Acipenser sturio	8	Medium / High	High (11)	8
Aves	Andean Flamingo	Phoenicopterus andinus	9	Medium / High	Medium (10)	12
Mammalia	Bowhead Whale	Balaena mysticetus	10	Medium	High (15)	4
Reptilia	Loggerhead Turtle	Caretta caretta	10	Medium	High (15)	4

Taxa Group	English Name	Latin Name	Ecological Flexibility Impacts Rank	Ecological Flexibility Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Reptilia	Leatherback Turtle	Dermochelys coriacea	11	Medium	High (14)	5
Mammalia	Southern Right Whale	Eubalaena australis	11	Medium	High (14)	5
Aves	Sociable Plover	Vanellus gregarius	11	Medium	High (14)	5
Aves	Siberian Crane	Grus leucogeranus	12	Medium	High (13)	6
Aves	Red-breasted Goose	Branta ruficollis	12	Medium	High (13)	6
Aves	Steller's Eider	Polysticta stelleri	12	Medium	High (13)	6
Pisces	Giant Catfish	Pangasius gigas	13	Medium	High (12)	7
Mammalia	Snow Leopard	Uncia uncia	14	Medium	High (10)	9
Pisces	Basking Shark	Cetorhinus maximus	15	Medium	Medium (12)	10
Aves	Aquatic Warbler	Acrocephalus paludicola	15	Medium	Medium (12)	10
Aves	Swan Goose	Anser cygnoides	16	Medium	Medium (11)	11
Mammalia	Sei Whale,	Balaenoptera borealis	16	Medium	Medium (11)	11
Mammalia	Mexican Free-tailed Bat	Tadarida brasiliensis	17	Medium	Medium (10)	12
Mammalia	Sperm Whale	Physeter macrocephalus	17	Medium	Medium (10)	12
Aves	Humboldt Penguin	Spheniscus humboldti	17	Medium	Medium (10)	12
Aves	Puna Flamingo	Phoenicopterus jamesi	18	Medium	Medium (9)	13
Mammalia	Dama Gazelle	Gazella dama	19	Low / Medium	High (14)	5
Mammalia	Addax	Addax nasomaculatus	20	Low / Medium	High (13)	6
Aves	Basra Reed-warbler	Acrocephalus griseldis	21	Low / Medium	High (12)	7

Taxa Group	English Name	Latin Name	Ecological Flexibility Impacts Rank	Ecological Flexibility Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Mammalia	Cuvier's Gazelle	Gazella cuvieri	22	Low / Medium	Medium (11)	11
Mammalia	Short-beaked Common Dolphin	Delphinus delphis	22	Low / Medium	Medium (11)	11
Mammalia	Humpback Whale	Megaptera novaeangliae	23	Low / Medium	Medium (10)	12
Aves	Pallas Fish Eagle	Haliaeetus leucoryphus	23	Low / Medium	Medium (10)	12
Pisces	Great White Shark,	Carcharodon carcharias	24	Low / Medium	Medium (8)	14
Aves	White-tailed Eagle	Haliaeetus albicilla	25	Low / Medium	Medium (7)	15
Mammalia	Marine Otter	Lontra felina	25	Low	Medium (7)	16

Vulnerability due to Species Interactions

- Species with a high ranking in terms of vulnerability due to Species Interactions and high overall vulnerability should be prioritised for further conservation action that focuses on the species identified as key for these species survival and threatened by climate change. It may also be the mechanism of interaction that will be affected and presenting itself as the main limiting factor. For example, if the range shifts of prey species are moving away from the feeding grounds of the migratory species then there may be de-coupling of this relationship if the migratory species can not adapt. In which case conservation action should look at how best to reduce phenological or range mis-match of this predator / prey relationship and facilitate adaptation of the migratory species to these new circumstances.

Taxa Group	English Name	Latin Name	Species Interaction Impacts Rank	Species Interactions Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Reptilia	Hawksbill Turtle	Eretmochelys imbricata	1	Medium / High	High (18)	1
Aves	Balearic Shearwater	Puffinus mauretanicus	2	Medium / High	High (17)	2
Mammalia	Narwhal	Monodon monoceros	3	Medium / High	High (16)	3

Taxa Group	English Name	Latin Name	Species Interaction Impacts Rank	Species Interactions Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Mammalia	North Pacific Right Whale	Eubalaena japonica	3	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	Eubalaena glacialis	3	Medium / High	High (16)	3
Mammalia	Bowhead Whale	Balaena mysticetus	4	Medium / High	High (15)	4
Aves	Short-tailed Albatross	Diomedea albatrus	4	Medium / High	High (15)	4
Aves	Sociable Plover	Vanellus gregarius	5	Medium / High	High (14)	5
Mammalia	Southern Right Whale	Eubalaena australis	5	Medium / High	High (14)	5
Mammalia	Blue Whale	Balaenoptera musculus	6	Medium / High	High (13)	6
Reptilia	Green Turtle	Chelonia mydas	7	Medium	High (18)	1
Reptilia	Kemp's Ridley Turtle	Lepidochelys kempii	8	Medium	High (16)	3
Aves	Relict Gull	Larus relictus	8	Medium	High (16)	3
Reptilia	Gharial	Gavialis gangeticus	9	Medium	High (15)	4
Reptilia	Loggerhead Turtle	Caretta caretta	9	Medium	High (15)	4
Mammalia	West African Manatee	Trichechus senegalensis	9	Medium	High (15)	4
Mammalia	Dama Gazelle	Gazella dama	10	Medium	High (14)	5
Mammalia	Addax	Addax nasomaculatus	11	Medium	High (13)	6
Aves	Steller's Eider	Polysticta stelleri	11	Medium	High (13)	6
Pisces	Basking Shark	Cetorhinus maximus	12	Medium	Medium (12)	10
Mammalia	Sei Whale	Balaenoptera borealis	13	Medium	Medium (11)	11
Mammalia	Short-beaked Common Dolphin	Delphinus delphis	13	Medium	Medium (11)	11

Taxa Group	English Name	Latin Name	Species Interaction Impacts Rank	Species Interactions Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Mammalia	Humpback Whale	Megaptera novaeangliae	14	Medium	Medium (10)	12
Reptilia	Leatherback Turtle	Dermochelys coriacea	15	Low / Medium	High (14)	5
Reptilia	Olive Ridley	Lepidochelys olivacea	15	Low / Medium	High (14)	5
Aves	Red-breasted Goose	Branta ruficollis	16	Low / Medium	High (13)	6
Aves	Siberian Crane	Grus leucogeranus	16	Low / Medium	High (13)	6
Aves	White-naped Crane	Grus vipio	16	Low / Medium	High (13)	6
Aves	Basra Reed-warbler	Acrocephalus griseldis	17	Low / Medium	High (12)	7
Pisces	Giant Catfish	Pangasius gigas	17	Low / Medium	High (12)	7
Aves	Bermuda Petrel	Pterodroma cahow	18	Low / Medium	High (11)	8
Mammalia	Snow Leopard	Uncia uncia	19	Low / Medium	High (10)	9
Aves	Aquatic Warbler	Acrocephalus paludicola	20	Low / Medium	Medium (12)	10
Mammalia	Cuvier's Gazelle	Gazella cuvieri	21	Low / Medium	Medium (11)	11
Aves	Swan Goose	Anser cygnoides	21	Low / Medium	Medium (11)	11
Aves	Andean Flamingo	Phoenicopterus andinus	22	Low / Medium	Medium (10)	12
Aves	Humboldt Penguin	Spheniscus humboldti	22	Low / Medium	Medium (10)	12
Mammalia	Mexican Free-tailed Bat	Tadarida brasiliensis	22	Low / Medium	Medium (10)	12
Aves	Pallas Fish Eagle	Haliaeetus leucoryphus	22	Low / Medium	Medium (10)	12
Mammalia	Sperm Whale	Physeter macrocephalus	22	Low / Medium	Medium (10)	12

Taxa Group	English Name	Latin Name	Species Interaction Impacts Rank	Species Interactions Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Aves	Puna Flamingo	Phoenicopterus jamesi	23	Low / Medium	Medium (9)	13
Pisces	Great White Shark	Carcharodon carcharias	24	Low / Medium	Medium (8)	14
Pisces	Common Sturgeon	Acipenser sturio	25	Low	High (11)	8
Mammalia	Marine Otter	Lontra felina	26	Low	Medium (7)	16
Aves	White-tailed Eagle	Haliaeetus albicilla	27	Low	Medium (7)	15

Vulnerability due to Interactions with other Threat Processes

- Species with a high ranking in terms of vulnerability due to climate change impacts Interactions with other Threat Processes and high overall climate change vulnerability can be identified in the table below. These species should be prioritised for further conservation action which focuses on reducing anthropogenic and other threats. If action is taken to help mitigate climate change impacts and aid adaptation of species to climate change without these anthropogenic and other threat processes being reduced it is likely that conservation action will not be successful in increasing this species resilience to climate change.
- Current conservation practices should be maintained for species identified as having a low ranking within this section, as these have been highlighted as successful as limiting the impacts of other conventional threats on the climate change resilience of these species. Those which still have a high vulnerability to climate change should have additional conservation action prioritised that deals with other factors such as Habitat Vulnerability, Ecological Flexibility and Species Interaction issues that will cause the species to be vulnerable to climate change impacts. Extra conservation measures should focus on those which promote adaptation and mitigation of climate change impacts on these species rather then on further limiting other threats, if the aim is to build species resilience to climate change.

Taxa Group	English Name	Latin Name	Interactions with Other Processes Impacts Rank	Interactions with Other Processes Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Reptilia	Hawksbill Turtle	Eretmochelys imbricata	1	High	High (18)	1
Reptilia	Green Turtle	Chelonia mydas	1	High	High (18)	1

Taxa Group	English Name	Latin Name	Interactions with Other Processes Impacts Rank	Interactions with Other Processes Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Aves	Balearic Shearwater	Puffinus mauretanicus	2	High	High (17)	2
Reptilia	Kemp's Ridley Turtle,	Lepidochelys kempii	3	High	High (16)	3
Reptilia	Gharial, Indian Gavial	Gavialis gangeticus	4	High	High (15)	4
Reptilia	Loggerhead Turtle	Caretta caretta	4	High	High (15)	4
Mammalia	Dama Gazelle	Gazella dama	5	High	High (14)	5
Reptilia	Leatherback Turtle	Dermochelys coriacea	5	High	High (14)	5
Pisces	Giant Catfish	Pangasius gigas	6	High	High (12)	7
Mammalia	Narwhal	Monodon monoceros	7	Medium / High	High (16)	3
Mammalia	North Pacific Right Whale	Eubalaena japonica	7	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	Eubalaena glacialis	7	Medium / High	High (16)	3
Aves	Relict Gull	Larus relictus	7	Medium / High	High (16)	3
Aves	Short-tailed Albatross, Steller's Albatross	Diomedea albatrus	8	Medium / High	High (15)	4
Mammalia	West African Manatee	Trichechus senegalensis	8	Medium / High	High (15)	4
Aves	Sociable Plover	Vanellus gregarius	9	Medium / High	High (14)	5
Mammalia	Southern Right Whale	Eubalaena australis	9	Medium / High	High (14)	5
Reptilia	Olive Ridley	Lepidochelys olivacea	9	Medium / High	High (14)	5
Mammalia	Addax	Addax nasomaculatus	10	Medium / High	High (13)	6
Aves	Red-breasted Goose	Branta ruficollis	10	Medium / High	High (13)	6

Taxa Group	English Name	Latin Name	Interactions with Other Processes Impacts Rank	Interactions with Other Processes Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Aves	White-naped Crane	Grus vipio	10	Medium / High	High (13)	6
Aves	Basra Reed-warbler	Acrocephalus griseldis	11	Medium / High	High (12)	7
Pisces	Common Sturgeon	Acipenser sturio	12	Medium / High	High (11)	8
Mammalia	Snow Leopard	Uncia uncia	13	Medium / High	High (10)	9
Aves	Aquatic Warbler	Acrocephalus paludicola	14	Medium / High	Medium (12)	10
Mammalia	Short-beaked Common Dolphin	Delphinus delphis	15	Medium / High	Medium (11)	11
Mammalia	Cuvier's Gazelle	Gazella cuvieri	15	Medium / High	Medium (11)	11
Mammalia	Marine Otter	Lontra felina	16	Medium / High	Medium (7)	16
Mammalia	Bowhead Whale	Balaena mysticetus	17	Medium	High (15)	4
Aves	Steller's Eider	Polysticta stelleri	18	Medium	High (13)	6
Aves	Siberian Crane	Grus leucogeranus	18	Medium	High (13)	6
Pisces	Basking Shark	Cetorhinus maximus	19	Medium	Medium (12)	10
Mammalia	Sei Whale	Balaenoptera borealis	20	Medium	Medium (11)	11
Aves	Swan Goose	Anser cygnoides	20	Medium	Medium (11)	11
Aves	Humboldt Penguin	Spheniscus humboldti	21	Medium	Medium (10)	12
Mammalia	Mexican Free-tailed Bat	Tadarida brasiliensis	21	Medium	Medium (10)	12
Aves	Pallas Fish Eagle	Haliaeetus leucoryphus	21	Medium	Medium (10)	12
Mammalia	Sperm Whale	Physeter macrocephalus	21	Medium	Medium (10)	12

Taxa Group	English Name	Latin Name	Interactions with Other Processes Impacts Rank	Interactions with Other Processes Grade	Climate Change Vulnerability Gradings	Vulnerability Rank within Studied Species
Pisces	Great White Shark	Carcharodon carcharias	22	Medium	Medium (8)	14
Aves	Bermuda Petrel	Pterodroma cahow	23	Low / Medium	High (11)	8
Mammalia	Humpback Whale	Megaptera novaeangliae	24	Low / Medium	Medium (10)	12
Aves	Andean Flamingo	Phoenicopterus andinus	24	Low / Medium	Medium (10)	12
Aves	Puna Flamingo	Phoenicopterus jamesi	25	Low / Medium	Medium (9)	13
Aves	White-tailed Eagle	Haliaeetus albicilla	26	Low / Medium	Medium (7)	15
Mammalia	Blue Whale	Balaenoptera musculus	27	Low	High (13)	6

10. Production of Engagement Materials

Climate change is a new threat to species which will rapidly grow to be one of the most important factors upon which long term survival of many species depends. Due to the increasing intensities to which climatic changes may occur, it is essential that capacity is increased both politically and at the ground level to cope with such changes, and develop effective responses. As climate change is not a conventional threat normally considered by those conserving species, building understanding of the implications of this threat is essential part of building capacity to deal with such threats. It is therefore an important process that wide engagement be carried out at all levels of policy and conservation management to communicate the findings of studies, such as these, which demonstrate the vulnerability and potential impacts of climate change on key species.

In line with this requirement, a four page policy brochure was produced for UNFCCC COP15 and distributed at the conference that outlines the findings of this study. This gave an overview of the results to date highlighting climate change processes that will affect species listed under CMS appendices.

Two banner style posters have also been produced for CMS which have been displayed at UNFCCC COP15 and are available for display at further conferences. Posters cover the following topics:

1. Policy Poster / Banner: **"Climate Change Impacts on Migratory Species: Uncertain Destinations"** provides an overview.
2. Case Study Poster / Banner: **"Migrating Towards an Uncertain Future: The Hawksbill turtle (*Eretmochelys imbricata*)"** provides a case study example.

Please see Appendix 4 and 5 of this report to view engagement materials

11. Concluding Comments on the Species Assessment Process

- Identification of species that are highly vulnerable to climate change impacts is a key requirement if early and effective action is to be taken to both mitigate these impacts on species and aid adaptation of species to new climate regimes. Actions that enhance the resilience of species to cope with climate change will become increasingly necessary if species populations are to be conserved in the long term.

- The Convention on Migratory Species provides an unparalleled policy mechanism by which climate change considerations can be incorporated into the policy and conservation management of migratory species globally.

- To facilitate such an outcome it has been observed that the Convention on Migratory Species requires a standardised mechanism by which species can be easily identified for consideration in decision making processes and actions prioritised according to the degree and nature of species climate change vulnerability and threat. However for such a mechanism to be most effective and non-biased towards certain groups of species a standardised process and methodology is necessary by which information can be made available to CMS, on observed and predicted climate change impacts and vulnerabilities of migratory species. It is also important that this mechanism can be applied to the large number of migratory species listed and currently not listed within CMS appendices.

- The need to review all migratory species within the CMS appendices, so that results can be incorporated into policy at the earliest stage, is now critically urgent. Climate change impacts are already being felt by migratory species listed within CMS appendices and action is required now to acknowledge and incorporate these into policy decisions.

- Certain species within CMS Appendix II may require consideration for increased levels of policy protection and inclusion into Appendix I due to the severity of threats faced, as our case study example of the Narwhal shows, and these need to be identified at an earliest stage as possible.

- A wider review of all migratory species will also be necessary to identify species that may not currently be seen as high priority for inclusion into CMS appendices but for which there is a growing concern due to climate change threats that needs to be communicated to decision makers.

- In response to these needs this preliminary review has piloted, developed, tested and proposed a number of methodologies which would deal with the level of information and outputs required by CMS. A phased approach has been recommended by which both a broad scale overview can be achieved of a large number of species, identifying species of *concern* and *likely concern*, that also allows filtering down into more detailed reviews which output gradings of species vulnerabilities.

- This phased approach tackles major limiting factors to the completion of a fully standardised yet effective review of all migratory species. It provides a means by which main policy messages can be outputted at each stage whilst providing clarity of confidence levels and identifying areas where further research is required early on.

- Through this preliminary review a number of major limiting factors to the assessment of species vulnerability to climate change have become apparent. These include (1) time availability, (2) resource availability, primarily in terms of funding and (3) information availability, most importantly at the species level as well as key aspects of ecosystem response and regional climate projections.

- Further issues for consideration have also been highlighted by this preliminary review. This includes the differing trade-offs, benefits and limitations apparent in different assessment approaches as well as more general observations on a rapidly growing yet relatively new climate change and biodiversity linked discipline.

  The current scarcity of information for many species in terms of their climate change threats and vulnerabilities is limiting the rate at which quick reviews and assessments can be made. Instead assessments of species which aim to give a grading of vulnerability and threat often have to gather a vast amount of indirect information upon which to make their assessment and this process will by necessity be slow if high confidence levels are sought. One method to bypass this lengthy review process and fill in information gaps is to seek species specialists for their opinions on the most likely scenarios of vulnerabilities that apply to each species, however this may reduce confidence levels to a degree as information will be based on expert opinion rather then primary evidence or peer reviewed research findings. However if this is made explicit in the communication of these findings then the benefits in terms of achieving gradings for vulnerabilities of species, before time runs out to effectively take action, could outweigh the limitations of such an approach.

  Another important point to note is that information is rapidly expanding within this field of research. Therefore it would be wise to develop an assessment methodology that can incorporate new information as it becomes available. Results of assessments will be influenced by the information that is available at the time of assessment related to climate change influences on species, linked species, habitat and most importantly climate projections. For example if global temperatures were to increase by 4 degrees over the next 100 years then it is likely that the majority of migratory species would be highly threatened by climate change. However some would have the potential to adapt more then others and these details need to be drawn out in reviews to allow prioritisation not only of species most threatened by climate change but also species that would be most responsive to conservation action. If temperatures were to rise far higher then previously anticipated then it may be that the order of vulnerability indexing for species could stay the same but more species would be pushed on this sliding scale towards being more highly threatened as temperatures increase. However certain factors may push specific species higher then others along this gradient.

These could be linked to threshold levels within biological systems as well as Earth's systems which would have a large impact on specific species if certain temperature were breached, for example threshold changes in ocean currents.

Overall species assessments need to have a degree of flexibility built into them to cope with these uncertainties. This is why broad gradings of high, medium and low vulnerabilities have been chosen to be assigned within this study. Gradings should be presented as guidance to decision makers and the assessment processes made transparent and information upon which they are based made available wherever possible so that any uncertainties and omissions are clear. As more information becomes available this will bring more clarity to species level assessments however this does not remove the issue that species assessments are required urgently to provide guidance especially as climate change impacts will likely increase rapidly in pace.

- The assessment process outlined within this study attempts to deal with these issues by applying different phases of assessments that will at each step have useful outputs for decision makers. Thereby outputting valuable information at the earlier possible opportunities at each stage to allow for immediate attention by CMS rather then waiting until the end of an extensive review to provide information useful to decision makers. By acknowledging the differing benefits, limitations and trade-offs of different methodologies, a phased approach allows benefits to be accessed at each stage, reducing limitations and balancing trade-offs between each phase whist also producing information tailored to the level required for each species by CMS.

- The lower phases of study provide a quicker format in which to assess species but also provide less definition in terms of vulnerability ratings. However these have a greater ability to be iterative and responsive to new information.

- The higher phases are more resource and time intensive, making them more accurate but less able to be reviewed in an iterative manner. However as time defined studies they encapsulate the best in current knowledge on this subject for species studied and as such may be more accurate and relevant for the effective development of specific species level policies and management plans.

- The phased assessment process outlined provides the opportunity for a large number of species to be covered with Phase 1 studies and information gained from this can then be fed into a selection process that narrows down the number of species studied in each concurrent phase. With the final end point where only key species recommended for priority and urgent policy and management action be taken to the (Phase 4) individual species review level.

- Now that higher levels of review have been carried out for a case study number of Appendix I species the parameters for assessment of migratory species have been effectively assigned. As the methodology is a bottom up approach, being very broad brush at the bottom across a large number of species and increasing in focus and confidence as each stage is achieved it is important to clarify in detail the end point that you are moving towards in your final assessments to assign a strategic and standardised approach that will be effective throughout. This is especially important as information is to be fed up through each stage of the process to the next stage.

- There is the urgent need to fulfil a much lower level review for remaining Appendix I species. Whether this is at a Phase 1 level that could cover all of Appendix I and potentially some of Appendix II species or a Phase 2 level of review limited to Appendix I is for CMS to consider. There may be other assessment options that arise beyond the scope of this study which should also come under consideration.

- As a long term objective for CMS should be to cover all migratory species both listed within its appendices and those currently not listed, it must be considered that an approach which identifies a high, medium or low vulnerability of species to climate change may be too detailed for the type of extensive and rapid review CMS requires. It may be that initially a Phase 1 level of review, as recommended within this study, is required at an early stage to provide an overview of all migratory species using a process that is not extensively time or resource demanding and is also responsive to new information as it becomes available from the latest research findings. This will allow rapid identification of species that are immediately of apparent "concern" due to direct information being available on vulnerabilities or observed impacts, or "likely concern" due to indirect information being available inferring vulnerability. Such a review needs to be set up using a standardised methodology that allows new information to be entered into the system as it becomes available that would increase relevant species to "concern" or "likely concern" status as well as ensuring results are useful in the long term. Certain species have a large amount of climate change vulnerability information already published and others have none. However this does not mean that species which have no literature published are not vulnerable to climate change. A full assessment of the species at higher phases of review would identify them as such but the key problem is a lack of time and resources available to cover all species to the degree of detail required to give clarification on such issues where no previous research has been carried out. This is where an expert scoping review would be very valuable as it would give an opportunity to provide an overview of all species to the same degree that allows for a preliminary identification of vulnerability threat gradings. This would remove the problem of research bias that is currently apparent however could only be applied to a limited set of migratory species at any one time, for example the full set of Appendix I species.

- It is also vital that all relevant information on species level vulnerabilities to climate change be available to CMS parties and bodies for their consideration and presented in a format this is easily accessible and able to be constantly updated with the latest research findings. A potential mechanism is provided for further CMS consideration through which information, in the form of journal papers and reports, can be collated for CMS species and made readily available online at the following site www.bioclimate.org .

12. Concluding Comments on the Species Case Study Findings

Key Trends and Findings

1. ALL Marine Turtle species within CMS Appendix I are highly vulnerable to climate change

Marine turtles have been identified as a group that represents the most highly threatened species studied. Any marine turtles currently not listed within CMS Appendix I should be considered for inclusion. There are seven species of marine turtle globally, six of which are included on CMS Appendix I. The Flatback Turtle (*Natator depressus*) is listed on CMS Appendix II and is currently listed as data deficient on the IUCN Red List and identified as requiring updating. In light of this studies findings it would be advisable that the Flatback Turtle be prioritised for immediate review in terms of climate change vulnerability and action be taken at the policy level to prepare for its inclusion into Appendix I if seen appropriate. It is likely this species will have a high vulnerability to climate change. All remaining migratory reptiles are also likely to highly vulnerable to climate change, indicated by specific characteristics which will be shared between reptile species. Consideration for further climate change studies on such species and their inclusion or prioritisation within CMS appendices is recommended.

- **All marine turtles will be threatened by sea level rise that will negatively impact beaches and limit availability of suitable breeding habitats**
  - Certain species have characteristics that increase this threat:
    - Natal homing to specific nesting sites limiting adaptation potential (Hawksbill Turtle, Green Turtle)
    - limited nesting range increasing risk that whole populations will be affected
    - specialised breeding behaviour: Arribada nesting strategy increasing risk that whole populations will be affected (Kemp's Ridley Turtle, Olive Ridley)

The IPCC Fourth Assessment Report predicts by 2100, sea levels will have risen by 0.18m- 0.59m compared to the 1980-1999 mean (Bindoff et al, 2007). As models of how basal sliding could affect rate of sea level rise, this was not incorporated into the projections (Kerr, R.A. 2007). Incorporating these important uncertainties into the sea level rise projection models, Rahmstorf (2007) predicted that the level of sea level rise by 2100 is more likely to be in the range of 0.5m - 1.4m. This would have serious implications for the nesting areas of Marine Turtles.

- **All marine turtles will be threatened by increased temperatures that are likely to cause feminisation of populations**
  - All reptiles studied exhibit temperature dependent sex determination. Temperatures of 29.2°C produce a 50:50 sex ratio. If higher temperatures are experienced during egg incubation then species will be skewed toward being female.
  - Increased temperatures predicted will threaten all reptile species that display temperature dependent sex determination.

Reptiles have coped with major climatic shifts in the past (Rage 1998), but the current rate of climate change is unprecedented in the last 50 million years (IPCC, 2007). Between 1990 – 2005 there has already been an observed rise in global average temperature of 0.2° C per decade (IPCC, 2007). The mid range A1B scenario predicts that global temperatures will rise by between 1.7 – 4.4 ℃, with a best likely estimate of 2.8 ℃. However the MET Office Hadley Centre has indicated that temperature are likely to increase by more then 5.5 ℃ within the same time period.

- **Many marine turtles breeding success will be threatened by predicted increases in storm events; including hurricanes and cyclones.**
    - Certain species nest in areas that are more likely to have increased levels of storms (i.e. Olive Ridley)
        - These will inundate and damage nests.
        - Arribada nesting strategy increases risk that whole populations breeding success will be impacted.

- **Marine turtles will be impacted by changes in ocean currents and upwelling**
    - Juvenile stages will be mainly affected (Hawksbill Turtle, Green Turtle, Olive Ridley).

- **Marine turtle species dependent on Coral Reef habitats will be highly threatened by climate change**
    - These ecosystems are at severe risk from ocean acidification and temperature stress (Hawksbill Turtle, Green Turtle, Loggerhead Turtle).
    - All species on CMS appendices that are dependent on coral reef habitats will likely be identified as highly vulnerable to climate change in any further review.

- **Marine turtle species dependent on Sea Grass habitats will be affected by climate change**
    - Growth rates of sea grass will be severely affected by temperature stress, sea level rise and changing tidal circulation affecting their abundance and distribution (Green Turtle, Loggerhead Turtle).
    - All species on CMS appendices that are dependent on sea grass habitats should be prioritised for review as these will likely be highly vulnerable to climate change.

- **Many turtle species displaying specialised feeding have a higher risk of climate change vulnerability**
    - For example, the Hawksbill Turtle primarily feeds on sponges which are threatened by increased temperatures as their symbiotic microbial relationship breaks down at 33°C.

- **All marine turtles resilience to climate change impacts is limited by other anthropogenic driven threats**
    - Beach habitat disturbance limits breeding habitats and will reduce turtle's adaptation potential to other suitable breading habitats as temperatures and sea levels rise.

- As sea levels rise beaches may encroach further towards anthropogenic activities increasing these impacts on species.
- Death due to anthropogenic activities will limit species resilience to climate change by adding further pressures on population numbers.

- **Many reptile species are likely to be highly vulnerable to climate change due to characteristics shared across taxa**
  - The Gharial, a freshwater fish eating crocodile, is also highly vulnerable to climate change due to similar innate characteristics as marine turtles. Highlighting the relevance of prioritising all migratory reptile species for climate change review.
    - Sandbanks which they use for nesting and basking will be threatened by sea level rise as well as increased river flow from extreme precipitation events and in the short term from increased glacial run off.
    - These species also display temperature dependent sex determination.

2. ALL Whale species specialising solely on plankton and krill within CMS Appendix I are highly vulnerable to climate change

- **All whales specialising solely on plankton and krill will be highly vulnerable due to impacts of climate change on food availability. This will emerge as one of the main limiting factors influencing future survival of these species.**
  - Climate change is likely to change **the spatial distributions and abundances of plankton species due to increases in sea surface temperature, reduction in extent of sea ice, ocean acidification, reduction in salinity and changes in ocean currents.**
  - The distribution, abundance and migration patterns of plankton and krill feeding whales are often closely tied with the distribution and abundance of their prey. This is due to the high numbers and densities of krill and plankton required to sustain each individual.
  - Species such as the Sei whale, which feeds on zooplankton, has been identified as having a medium level of vulnerability (on the boundary between medium and high) however this species feeds also on larger prey species including small fish and Japanese flying squid which will buffer the immediate impacts of reduced plankton abundance and distribution on this species.
  - Other species of whale studied that feed higher up the trophic levels, including Humpback whale and Sperm whale, have been identified as medium vulnerability and have a much lower ranking of vulnerability then the Sei whale.

- **All species of whale specialising solely on plankton and krill will be highly threatened by changes in ocean currents and upwellings**
  - Plankton and krill feeding whales are dependent on ocean processes to concentrate high enough densities of prey for feeding

    - Ability for plankton and krill feeding whales to track high concentrations of prey species will be reduced as ocean currents and upwellings become less predictable.

- **All plankton and krill feeding whales will be threatened by the affects of ocean acidification on food availability**

- **Earliest impacts on plankton and krill feeding whales populations will be exhibited by species dependent on Polar Regions**
    - Polar regions are predicted to increase in temperatures much more rapidly then global average temperature rises
    - Ocean acidification will also affect colder waters in polar waters much earlier then other areas, which will have far reaching impacts on marine polar ecosystems, altering species composition.
    - Many baleen whale species migrate to Polar Regions to feed on the currently dense availability of krill and copepods.
    - Loss and reduction of sea ice in Polar Regions will impact krill and plankton abundances, impacting on whale species dependent on this food source (most directly on the Southern Right whales and Bowhead whale).
        - *Krill and plankton feed on microalgae that proliferate on the bottom of sea ice during winter. Sustained warming is causing a reduction in the extent of sea ice in Polar Regions that is already resulting in a significant decrease in krill and plankton numbers.*
    - All species dependent on polar habitats should be prioritised for review as these will likely be highly impacted by climate change.
- **All krill and plankton feeding whales are limited in their ability to adapt to climate change by their specialised diet**
    - Physiological features may limit their ability to switch prey as food availability decreases

3. Initial indication of potential trends which may allow for identification of further migratory species most likely to be highly vulnerable to climate change:

- Antelope species studied inhabiting deserts, grasslands and savannah regions are highly vulnerable to climate change

- **Antelope species inhabiting desert, grassland and savannah regions are likely to experience high temperature increases due to climate change that will affect vital habitats.**
    - Antelope ranges and migrational patterns will shift to match habitat changes and thermal tolerances.

Under the most conservative emissions scenarios reviewed by the IPCC FAR (2007), the mean temperatures in the Sahel region by 2080 and 2099 in comparison to the 1980-1999 mean temperatures are projected to increase is by least 2°C with top end of the range of the projections reaching 4°C. In the A1B scenario, the projected temperature rise lies between 2.6°C to 5.4°C, with the median model predicting 3.6°C.

- **Antelope species studied will be threatened if climate change results in prolonged periods of drought and increasing desertification.**
    - However due to the innate adaptive resilience antelope species display to such threats these only become of major importance to their overall climate change vulnerability when considered alongside interactions with other anthropogenic pressures.

The Sahelian region has experienced a dramatic reduction in mean annual rainfall within the 20th century (Hulme, 2001; Giannini et al., 2003). Between 1950 and 1980 the Sahel region experienced a reduction in rainfall of 40%. This level of change currently has few, if any parallels globally within the 20th Century. This has currently not been attributed to climate change and future projections of precipitation for this region remain uncertain but highlight the variability in predicted rainfall patterns.

- **Antelope species are at risk from anthropogenic pressures on habitats acting synergistically with climate change escalating the risk of desertification and impacts of drought.**
    - Overgrazing is a major threat to antelope species which will be increased by climate change as resources become limited.

- **Antelope species are at risk of increased rates of contact with anthropogenic threats as their migration shifts to track habitat changes.**
    - Anthropogenic activities may inhibit antelope species adaptive response to climate change by limiting their dispersability to new suitable areas.
    - Dispersal of antelope species to new suitable areas will require conservation facilitation and protection as species enter new areas. Predicting such shifts will be beneficial in planning effective long term conservation mechanisms.

- **Antelope species within desert, grassland and savannah regions show a high level of adaptability to climate change however this will be limited if anthropogenic threats can not be reduced.**

- **It is likely that other species of migratory antelopes inhabiting desert, grassland and savannah regions will be subjected to the same pressures and be highly vulnerable to climate change.**
    - A review of all other related species is recommended. Within CMS Appendix I these include the Dorcas Gazelle, Scinmitar Horned Gazelle and the Slender Horned Gazelle.

- All species studied which exhibit a strong dependency on Arctic sea-ice are highly vulnerable to climate change

- **All species studied depended on Arctic sea ice will be threatened by a drastic reduction and loss of suitable habitat**
    - Species range shifts will occur to track sea ice melt and overall reduction in range will be observed.
    - Migration patterns will shift.

Observed warming in the Arctic has been much higher than the global average. Regional climate models predict that air temperatures in the Arctic will rise by between 5°C and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average (Christensen et al, 2007). The most sophisticated models project sea ice extent will experience a linear decline until 2025 - 2040 when summer sea ice will be lost (Wand & Overland, 2009; Kerr, 2009).

- **All species studied dependent on sea-ice for food availability will be highly vulnerable to climate change.**
    - Food resources will become limited in abundance with both phenological and distribution changes occurring due to a reduction in the main source of primary productivity within the Arctic oceans (Bowhead Whale, Narwhal).

A wide range of migratory species depend on the Arctic and Polar oceans for resources. High productivity levels of marine polar ecosystems are closely related to sea-ice. Reduction in sea ice extent will limit the range of algae that grow beneath the sea ice. The summer cycle of sea ice melt releases algae into the oceans which is the basis for the high abundance in food source over the summer months, which many species migrate to take advantage of. Lower trophic levels dependent on algae growth include species of plankton and copepods which in turn are the main food source of species such as the Bowhead Whale and the basis of the whole food web within the Arctic. With reduced sea ice extent there will be significantly less available food for species such as the Bowhead, as this major food-web in the Arctic Ocean is likely to severely depleted.

    - Of the species that are solely depending on sea ice for food availability, species feeding on lower trophic levels are likely to be impacted earlier then species feeding on higher trophic levels.

- **Species that require sea ice for protection will become increasingly vulnerable to predation.**

Narwhals live within the ice pack, also migrating with the seasonal movement of the ice front. Within the pack ice the Narwhals are safe from their main predator, the Killer Whale. However, in open water they are very vulnerable (Jefferson et al., 2008). Without summer sea ice, Narwhal mortality due to killer whale predation is therefore likely to rise, increasing pressure on the population. Prey population for the Narwhal, primarily including halibut, will also be severely impacted by the loss of sea ice combined with other climate change impacts and ocean acidification causing cascading affects throughout the trophic system of the Arctic.

- **It is highly likely that other migratory species dependent on Arctic sea-ice, and potentially all polar ice, will be highly vulnerable to climate change.**
    - A number of other migratory species rely on sea ice for further services, including breeding.
    - A review of all other related species is recommended and prioritisation of species such as the Ringed Seal currently not listed in CMS appendices or those listed in CMS Appendix II, such as the Narwhal, for further consideration.

- All species studied which exhibit a strong dependency on coral reefs are highly vulnerable to climate change impacts

Coral reefs have been identified as one of the first major ecosystems that will collapse globally due to climate change impacts. Increased temperatures, sea level rise, ocean acidification and increased frequency of extreme events will all have major impacts on coral reef ecosystems which already have a lowered resilience to these climate change impacts due to the synergistic pressures of further anthropogenic impacts. Impacts are already being felt with severe degradation of coral habitats occurring at an unprecedented rate. Species dependent on coral reef habitats are likely to be severely threatened by extinction.

- **Species that have an obligate dependency on coral reefs habitats for specific services will be highly vulnerable to climate change impacts**
    - Identification of all migratory species which are linked to coral reef ecosystems is recommended.

- Bird species studied with fixed breeding sites are highly vulnerable to climate change

- **Bird species with fixed breeding sites are more vulnerable to climate change impacts affecting a key reproductive stage**
    - For example, Relict Gulls will not breed if saline lake islands are either inundated or water levels are too low. As climate change is predicted to increase temperatures, increasing evaporation, and precipitation is predicted to become more variable and change, these will likely impact reproduction.

- **Bird species with fixed breeding sites often group their populations into colonies which makes whole populations more vulnerable to climate change impacts**
    - For example, Bermuda Petrel’s entire population breeds on Bermuda Island. This will be impacted by sea level rise and potentially by increased frequency of storm that could inundate breeding areas.

- **Bird species with fixed breeding sites may have to travel further to reach optimal feeding grounds as prey species shift.**
    - Observed impacts linked to climate change are already being reported for the Balearic Shearwater. Distance between the breeding colonies of this bird and its winter feeding areas are increasing. There has been a northward shift of prey species, 10° since mid 1980, which has been linked to increased sea surface temperatures. Comparable northward shifts in latitude on prey species over the next 25 years are very likely to put them out of range of the wintering Balearic.

- **Bird species with fixed breeding sites show lack of ecological flexibility and therefore a lack of ability to adapt to climate change**
    - Conservation measures to increase resilience of species to climate change will need to overcome this key limitation in their adaptation potential to be effective.

- Species studied migrating up estuaries and rivers are highly vulnerable to climate change

- **Species that migrate up estuaries and rivers are more likely to be exposed to anthropogenic threats alongside climate change impacts that increase their overall vulnerability.**
    - All species studied that migrate up estuaries were found to have a high vulnerability from climate change Interactions with other Processes

- **Species that migrate up estuaries and rivers will also be further threatened by increased climate change mitigation activities including hydro-electric constructions.**
    - The Giant Catfish, Gharial, West African Manatee and Common Sturgeon are already being impacted by the development of dams which is altering their habitat and limiting migrations.

- All species studied that are critically endangered are vulnerable to climate change

- **Species that are critically endangered are likely to be highly vulnerable to climate change.**

- **Species that are endangered are more likely to be highly vulnerable to climate change then those with a lower IUCN threatened status.**
    - Species characteristic which make them threatened by anthropogenic impacts may predispose many species to being more vulnerable to climate change impacts.

- Species whose populations are already degraded are more likely to be vulnerable to climate change impacts.

- **Anthropogenic threats act synergistically with climate change impacts, reducing species resilience and ability to adapt to climate change.**

Key Actions

- Prioritise species currently identified as vulnerable to climate change for immediate attention

- **Species identified as a high vulnerability to climate change should have highest priority:**

Hawksbill Turtle, Green Turtle, Balearic Shearwater, Kemp's Ridley Turtle, Narwhal, North Pacific Right Whale, Northern Atlantic Right Whale, Relict Gull, Gharial, Loggerhead Turtle. Short-tailed Albatross, West African Manatee, Bowhead Whale, Dama Gazelle, Leatherback Turtle, Sociable Plover, Southern Right Whale, Olive Ridley, Addax, Red-breasted Goose, White-naped Crane, Steller's Eider, Siberian Crane, Blue Whale, Giant Catfish, Basra Reed-warbler, Common Sturgeon, Bermuda Petrel and Snow Leopard.

- **Species identified as having a medium vulnerability to climate change have less of an urgency for action to be taken however plans should be made early for these to be most effective:**

Aquatic Warbler, Basking Shark, Short-beaked Common Dolphin, Cuvier's Gazelle, Sei Whale, Swan Goose, Humboldt Penguin, Mexican Free-tailed Bat, Pallas Fish Eagle, Sperm Whale, Humpback Whale, Andean Flamingo, Puna Flamingo, Great White Shark, Marine Otter and White-tailed Eagle.

- Identify effective conservation measures that will increase species resilience and adaptation to climate change

- This study has identified species vulnerabilities to climate change and graded species for policy consideration. It also presents in depth reviews to provide a basis upon which conservation measures can considered further, developed and implemented.

- To ensure that conservation measures are effective it is recommended that a vital first step is to identify the key limiting factors to species ability to adapt and cope with climate change. These may often be specific to each species. From this basis reviews can be made to identify conservation and policy mechanisms by which these limiting factors can be reduced. With the consideration of the limited resources available to channel into conservation it may be necessary to identify species, of those identified as vulnerable to climate change, which would also respond well to conservation actions to increase species resilience and adaptation to climate change and prioritise these.

- Within each species assessment, this study has highlighted key factors that will limit species ability to adapt to climate change and reduce their resilience to cope. These are outlined in each section of the assessments for each species and include; Habitat Vulnerability, Ecological Flexibility, Species Interactions and Interactions with other Threat Processes. Each is graded and this provides a clear basis on which to identify areas that are most limiting to species long term survival under changing climatic conditions. Thereby providing an indication of where conservation efforts would be most effective.

- A preliminary overview of potential conservation measures that can be applied to species identified within this study as highly vulnerable to climate change are outlined below. These bring together some initial observations for conservation consideration, drawing upon the main limiting factors identified to each species resilience and ability to adapt to climate change and their potential to respond to conservation measures to reduce these vulnerabilities. Limitations to the effectiveness of conservation measures to improve species ability to survive under changing climate conditions have also been highlighted. It may be that the only effective measure that can be taken to increase a species ability to survive is climate change mitigation itself and this is an important consideration to take into account.

Hawksbill Turtle Eretmochelys imbricata	**- Reduce anthropogenic threats. - Identify alternative 'climate safe' nesting sites. - Ex situ and in situ measures to alleviate feminisation of population - Unless suitable alternative beach nest sites are available and utilised by species in the future, that can withstand sea level rises and are in the range of temperature that will not cause feminisation of populations then the positive impact of alternative conservation measures will be limited. - Conservation measures to protect coral reefs and sponges will be limited if climate change is not mitigated. Coral reefs are already increasingly impacted by bleaching events. Due to the Hawksbills dependence on this habitat this threat will limit the effectiveness of any other measures.**
Green Turtle Chelonia mydas	**- Reduce anthropogenic threats. - Identify alternative 'climate safe' nesting sites. - Ex situ and in situ measures to alleviate feminisation of population. - Unless suitable alternative beach nest sites are available and utilised by species in the future, that can withstand sea level rises and are in the range of temperature that will not cause feminisation of populations then the positive impact of alternative conservation measures will be limited. - Protection of sea grasses current and future range. - Conservation measures to reduce negative impacts on sea grasses will be less effective if climate change is not mitigated.**
Balearic Shearwater Puffinus mauretanicus	**- Reduction of anthropogenic impacts would help increase the resilience of this species to climate change impacts. - However unless conservation measures can effectively facilitate adaptation to changes, most importantly by promoting the shifting of breeding area in line with the shifting of feeding area, no other action will be affective in the long term. - Limiting climate change is essential to prevent sea surface temperatures shifting prey populations out of migrational range. As observed impacts are currently being seen it may already be too late.**

Kemp's Ridley Turtle, Lepidochelys kempii	- Reduction of current anthropogenic impacts. - Identification of alternative 'climate safe' nesting sites. - Ex situ and in situ measures to alleviate feminisation of population. - Conservation measures will not be affective if breeding can not be sustained and adaptation facilitated by some mechanism. - Requires climate change mitigation otherwise species likely to go extinct.
Narwhal Monodon monoceros	- Some potential to increase resilience by limiting hunting, industrial and development disturbance. - Protection of halibut stocks which form main food source. - Conservation measures will be limited if sea ice on which Narwhals depend is substantially depleted by climate change. - Climate change mitigation is required for species long term survival.
North Pacific Right Whale Eubalaena japonica	- Efforts to limit anthropogenic deaths should be maintained (reducing risk of shipping collision and fishing gear entanglement) however as ranges and migrations are likely to shift such efforts may be harder to enforce. - Few conservation measures are available then to limit and mitigate climate change.
Northern Atlantic Right Whale, Eubalaena glacialis	- Efforts to limit anthropogenic deaths should be maintained (reducing risk of shipping collision and fishing gear entanglement) however as ranges and migrations are likely to shift such efforts may be harder to enforce. - Few conservation measures are available then to limit and mitigate climate change.
Relict Gull Larus relictus	- Disturbance of breeding sites and development on important coastal habitats must be limited to improve resilience of this species to climate change impacts. - Modification of breeding habitats to limit climate change impacts. - Mitigation of climate change essential otherwise conservation measures will have limited effects.
Gharial, Indian Gavial Gavialis gangeticus	- Minimise current anthropogenic threats and plan for the increased likelihood of dam construction that will impact habitat. - Protect sandbanks from flooding and erosion. - Unless suitable sandbank habitats can be found that are climate resilient there is little conservation action that will be effective in limiting climate change impacts. - Mitigation of climate change is required for species survival.
Loggerhead Turtle Caretta caretta	- Reduction of current anthropogenic impacts. - Identify alternative 'climate safe' nesting sites. - Ex situ and in situ measures to alleviate feminisation of population. - Conservation measures will not be affective if breeding can not be sustained and adaptation facilitated by some mechanism under new climate regimes. - Requires climate change mitigation otherwise species likely to go extinct.
Short-tailed Albatross, Diomedea albatrus	- Previous large range indicates potential for current range to be extended to areas that are 'climate safe'. - Reduction of a number of anthropogenic threats would greatly improve species resilience to climate change including deaths from fishing nets, predation from invasive rats and cats on islands. - Wider marine impacts of climate change can not be reduced by conservation efforts, therefore mitigation is required.

West African Manatee Trichechus senegalensis	**- Efforts to reduce current anthropogenic impacts most importantly including reduction of pollutants, nutrient run off, protection of mangroves especially in coastal lagoons (which would link in with general efforts for ecosystem based adaptation). - Plan for potential increased impacts from dams, hydroelectric coastal developments and sea wall defences. - Positive benefits would be felt by species from reduced land degradation that would reduce sediment run off and flooding.**
Bowhead Whale Balaena mysticetus	**- Limiting industrial development to minimise boat strikes and disturbance. Plan for potential increase in these threats as oil and gas exploration increases as sea ice loss exposes areas for exploitation. - Climate change mitigation is an essential conservation strategy for the Bowhead Whale to limit main climate change impacts on food abundance.**
Dama Gazelle Gazella dama	**- High potential for adaptation if habitat is available and anthropogenic barriers are limited. - Reduction of anthropogenic pressures will be a vital mechanism to facilitate adaptation.**
Leatherback Turtle, Dermochelys coriacea	**- Reduce anthropogenic threats. - Identify alternative 'climate safe' nesting sites. - Ex situ and in situ measures to alleviate feminisation of population - Conservation measures will not be affective if breeding can not be sustained and adaptation facilitated by some mechanism under new climate regimes. - Requires climate change mitigation otherwise species likely to go extinct.**
Sociable Plover Vanellus gregarius	**- Reduction of anthropogenic threats would significantly increase resilience to climate change impacts.**
Southern Right Whale Eubalaena australis	**- Reducing current anthropogenic impacts.. - Without climate change mitigation this species will be vulnerable and there is limited potential for other conservation mechanisms to be effective.**
Olive Ridley Lepidochelys olivacea	**- Reduce anthropogenic threats. - Identify alternative 'climate safe' nesting sites. - Ex situ and In situ measures to alleviate feminisation of population. - Conservation measures will not be affective if breeding can not be sustained and adaptation facilitated by some mechanism under new climate change regimes. - Requires climate change mitigation otherwise species likely to go extinct.**
Addax Addax nasomaculatus	**- Shows high degree of adaptation potential and ability to withstand harsh environments. This suggests that conservation action to reduce anthropogenic impacts and barriers to adaptation would be very beneficial.**
Red-breasted Goose Branta ruficollis	**- Shows some degree of adaptability. Migration cultural rather then genetically driven so conservation mechanisms that promote migration to 'climate safe' areas could be highly effective. - Species likely to respond well to protection of tundra habitat for breeding in 'climate safe' areas especially carried out alongside facilitation of migrational shift. - Potential for modifications to be made to limit impacts of increased extreme weather events in overwintering sites. - Reduce other anthropogenic pressures, such as hunting, to build resilience to climate change impacts.**
White-naped Crane Grus vipio	**- Protection of wetland areas that are 'climate safe' or areas that will become prime breeding grounds under future climate change scenarios is essential. - Plan and limit increased impacts from dam construction.**

Steller's Eider **Polysticta stelleri**	**- Reduction other anthropogenic threats necessary to increase resilience.**
Siberian Crane **Grus leucogeranus**	**- Efforts should be made to protect habitat and reduce other anthropogenic pressures on the habitat.** **- Mitigation of climate change essential as habitat is threatened with loss.**
Blue Whale **Balaenoptera musculus**	**- Current conservation measures effective at limiting impacts on populations. These should be continued.** **- Few other conservations options are available to increase species ability to adapt to climate change. This species requires climate change mitigation for long term survival.**
Giant Catfish **Pangasius gigas**	**- Limit anthropogenic impacts, including dams.**
Basra Reed-warbler **Acrocephalus griseldis**	**- Species identified as having a high level of adaptability. Indicates this species will respond well if suitable 'climate safe' breeding areas can be found and maintained and other anthropogenic impacts are reduced.**
Common Sturgeon **Acipenser sturio**	**- Limit anthropogenic impacts, including dams.**
Bermuda Petrel **Pterodroma cahow**	**- New suitable 'climate safe' breeding areas need to be identified and efforts made to encourage use of these areas by the Bermuda Petrel.**
Snow Leopard **Uncia uncia**	**- Measures to protect prey species of the Snow Leopard from climate change impacts and anthropogenic impacts.** **- Reduce encroachment by anthropogenic activities as tree line increases in elevation.** **- Reduce other anthropogenic impacts to improve resilience of species.**

- **Acknowledge that climate change mitigation will be a key action if certain species are to survive.**

  - **The most effective action for all species vulnerable to climate change to reduce this threat is to mitigate climate change and reduce the rate at which climatic changes will occur.**

  - **For some species mitigation this is the only effective course of action that can be taken if they are to survive.**

  - **A number of species within CMS Appendix I have been identified for which climate change mitigation is critical due to the highly limited ability for conservation mechanisms to effectively increase species resilience and adaptation potential to climate change impacts without climate change mitigation occurring. These are listed below:**

Hawksbill Turtle, Green Turtle, Balearic Shearwater, Kemp's Ridley Turtle, Narwhal, North Pacific Right Whale, Northern Atlantic Right Whale, Relict Gull, Gharial, Loggerhead Turtle, Short-tailed Albatross, Bowhead Whale, Leatherback Turtle, Southern Right Whale, Siberian Crane, Blue Whale

    - This is not to say that conservation measures should be stopped for these species, but that it should be acknowledged that climate change mitigation is an essential part of the conservation strategy for these species. Other conservation measure will only be effective if mitigation is also achieved.

    - Other species not listed here would also benefit from climate change mitigation as it would reduce the pressures on these species. Species have not been included that have potentially viable conservation options available to them. However it is likely that climate change will further stretch limited conservation resources and capacities and species will not be able to have all available conservation options applied to them effectively to ensure there survival. Therefore for these species it is also vital to take a dual approach to the threat of climate change; whereby proactive adaptation measures are applied to species alongside considerable and rapid emissions abatement to limit further impacts.

Key Recommendations

- **Identify migratory species that are vulnerable to climate change impacts. Identify these species key vulnerabilities and main factors limiting adaptation.**

- **Review CMS appendices and incorporate species not currently listed. Upgrade species which are currently listed but need further protection.**
    - **Due to the high climate change vulnerability of the Narwhal it is recommended that this species be incorporated into Appendix I before major impacts are felt.**

- **Identify conservation measures that would be most effective at increasing species resilience and adaption potential to climate change impacts. Prioritise conservation measures by the degree of positive outcome such measures would have on species survival.**

- **Incorporate effective conservation actions into policy and management plans**

- **Identify species which will be unable to adapt to projected rates of climate change**

- **Engage with policy makers and wider audience to communicate these threats**

- **Identify areas where conservation measures cross over with climate change mitigation measures and prioritise these**

- **Identify actions that can be taken to increase uptake of climate change mitigation at all levels including public, industry and policy**

A dual approach to species conservation will be required in the future; proactive measures must be taken to increase the resilience and ability for species to adapt alongside considerable and rapid emissions abatement to limit impacts.

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13. Appendix

13.1. Appendix 1: Glossary of Table 1 Information

Classification of migratory behaviour as used in GROMS. **Einteilung des Wanderverhaltens im Weltregister wandernder Tierarten.**

Category	Explanation
Major category	
Non-migratory	Non-migratory
GROMS migrant	Migratory according to GROMS definition (movement > 100 km)
Technical migrant	Movements across borders by members of populations living in contiguous areas on either side of one or more national boundaries (border taxa)
Partial	Minor part of population migratory
Possibly migratory	Some references indicate possible migration
Data deficient	Possible migrant for theoretical reasons, but no data available
Subdivisions of GROMS migrants	
Intracontinental	Within continents
Intercontinental	Between continents
Nomadising	Following resources, often without predictable temporal patterns.
Emigration	Mass migrations after population explosions
Range extension	E.g. post-breeding dispersal of birds or bats
Marine organisms (except fish)	
Interoceanic	Movement between different oceans or transoceanic
Intraoceanic	Within oceans or continental shelves
Fish migrations	
Anadromous	Return from ocean to fresh water for reproduction, subdivision of diadromous

Catadromous	Migration into the sea for reproduction, subdivision of diadromous
Amphidromous	Migration between sea and fresh water for feeding, subdivision of diadromous
Potamodromous	Well-defined migration within streams and rivers
Limnodromous	Within lakes
Oceanodromous	Within sea water

Table take from: "Riede, K. (2001): The Global Register of Migratory Species Database, GIS Maps and Threat Analysis. Münster (Landwirtschaftsverlag), 400 pp." + CD

Action Plan Lesser White-fronted Goose (http://www.unep-aewa.org/activities/working_groups/lwfg.htm)
- MEMORANDUM OF UNDERSTANDING ON THE CONSERVATION OF HIGH ANDEAN FLAMINGOS AND THEIR HABITATS (http://www.cms.int/species/monk_seal/monk_seal_bkrd.htm)

Relevant CMS Agreements Identified:

CMS Agreements

- ACAP - Agreement on the Conservation of Albatrosses and Petrels (http://www.acap.aq/)
- AEWA – African-Eurasian Waterbird Agreement (www.unep-aewa.org)
- ACCOBAMS – Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (http://www.accobams.org/)
- ASCOBANS – Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (http://www.ascobans.org/)
- EUROBATSH - European Bat Agreement (http://www.eurobats.org/)
- GORILLAS agreement- CMS Agreement on the Conservation of Gorillas and Their Habitats (http://www.cms.int/species/gorillas/index.htm)
- WADDEN SEA SEALS

Memoranda of Understanding

- Aquatic Warbler MoU - Memorandum of Understanding Concerning Conservation Measures for the Aquatic Warbler (http://www.cms.int/species/aquatic_warbler/aquatic_warbler_bkrd.htm)
- Bukhara Deer MoU – (http://www.cms.int/species/bukhara_deer/bukhara_deer_intro.htm)
- Dugong MoU – (http://www.cms.int/species/dugong/pdf/Annex_08_Dugong_MoU.pdf)
- Grassland Birds of South America
- Great Bustard MoU – Memorandum of Understanding on the Conservation and Management of the Middle-European Population of the Great Bustard (http://www.cms.int/species/otis_tarda/otis_tarda_bkrd.htm)
- High Andean Flamingo MoU - Memorandum of Understanding on the Conservation of High Andean Flamingos and Their Habitats (http://www.cms.int/species/flamingos/flamingos_bkrd.htm)
- Marine Turtles Africa MoU – (http://www.cms.int/species/africa_turtle/AFRICAturtle_bkgd.htm)
- Marine Turtles IOSEA – Indian Ocean South-East Asian Marine Turtle Memorandum of Understanding (www.ioseaturtles.org)
- Mediterranean Monk Seal l MoU - Memorandum of Understanding (MoU) concerning Conservation Measures for the Eastern Atlantic Populations of the Mediterranean Monk Seal (Monachus monachus) (http://www.cms.int/species/monk_seal/monk_seal_bkrd.htm)
- Pacific Islands Cetaceans MoU – Memorandum of Understanding for the Conservation of Cetaceans and Their Habitats in the Pacific Islands Region (http://www.cms.int/species/pacific_cet/pacific_cet_bkrd.htm)

- **Raptors (Birds of Prey)MoU - Memorandum Of Understanding On The Conservation Of Migratory Birds Of Prey In Africa And Eurasia (http://www.cms.int/species/raptors/index.htm)**
- **Ruddy-headed Goose MoU - Memorandum Of Understanding Between The Argentine Republic And The Republic Of Chile On The Conservation Of The Ruddy-Headed Goose (http://www.cms.int/species/ruddy_goose/ruddy_goose_bkrd.htm)**
- **Saiga Antelope MoU (http://www.cms.int/species/saiga/saiga_text.htm)**
- **Sharks MoU - Memorandum Of Understanding On The Conservation Of Migratory Sharks (www.cms.int/species/sharks/sharks_bkrd.htm)**
- **Siberian Crane MoU (http://www.cms.int/species/siberian_crane/sib_bkrd.htm)**
- **Slender-billed Curlew MoU – Memorandum of Understanding concerning Conservation Measures for the Slender-billed Curlew (http://www.cms.int/species/sb_curlew/sbc_bkrd.htm)**
- **West African Aquatic Mammal MoU - Memorandum of Understanding concerning the Conservation of the Manatee and Small Cetaceans of Western Africa and Macaronesia (www.cms.int/species/waam/index.htm)**
- **West African Elephants MoU**

Action Plans

- **Central Asian Flyway - CENTRAL ASIAN FLYWAY ACTION PLAN FOR THE CONSERVATION OF MIGRATORY WATERBIRDS AND THEIR HABITATS**
- **Sahelo-Saharan Antelope Action Plan**

Initiatives

- **Houbara Bustard**

IUCN RED List categorisation:

Key	IUCN RED list term
EX	Extinct
EW	Extinct in Wild
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
NT	Near Threatened
LC	Least Concern
LR/cd	Conservation Dependent

13.2. Appendix 2: Example of Phase 1 Stage 1

Reptile Assessment References

Species Name	Published literature directly relating species to climate change impacts and threats both observed and predicted
Migratory Species	Davis MB, Shaw RG (2001) Range shifts and adaptive responses to Quaternary climate change. Science 292: 673–679 [Link] McCarty J (2001) Ecological consequences of recent climate change. Conserv Biol 15:320–331 [Link] Robinson RA, Crick HQP, Learmonth JA, Maclean IMD and others (2009) Travelling through a warming world— climate change and migratory species. Endang Species Res 7:87–99 [Link] Root TL, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA (2003) Fingerprints of global warming on wild animals and plants. Nature 421:57–60 [Link] Sala OE, Chapin FS, Armesto JJ, Berlow E and others (2000) Global biodiversity scenarios for the year 2100. Science 287:1770 [Link] Visser ME, Both C (2005) Shifts in phenology due to global climate change: the need for a yardstick. Proc R Soc Lond B Biol Sci 272:2561–2569 [Link] Walther GR, Post E, Convey P, Menzel A and others (2002) Ecological responses to recent climate change. Nature 416:389–395 [Link]
Reptiles	Fish MR, Cote IM, Gill JA, Jones AP, Renshoff S, Watkinson AR (2005) Predicting the impact of sea-level rise on Caribbean sea turtle nesting habitat. Conserv Biol 19: 482–491 [Link] Fish MR, Cote IM, Horrocks JA, Mulligan B, Watkinson AR, Jones AP (2008) Construction setback regulations and sea level rise: mitigating sea turtle nesting beach loss. Ocean Coast Manag 51:330–341 [Link] Fuentes MMPB, Maynard JA, Guinea M, Bell IP, Werdell PJ, Hamann M (2009). Proxy indicators of sand temperature help project impacts of global warming on sea turtles. Endangered Species Research Journal. [Link] Fuentes MMPB, Limpus CJ, Hamann M, and Dawson J (2009). Potential impacts of projected sea level rise to sea turtle rookeries. Aquatic conservation: marine and freshwater ecosystems.doi:10.1002/aqc.1088 [Link] Fuentes MMPB, Hamann M, and Lukoschek V (2009). Marine Reptiles and Climate Change. In A Marine Climate Change Impacts and Adaptation Report Card for Australia 2009 (Eds. ES Poloczanska, AJ Hobday and AJ Richardson), NCCARF Publication 05/09, ISBN 978-1-921609 03-9. [Link] Fuentes MMPB, Hamann M and Limpus CJ (2010). Past, current and future thermal profiles for green turtle nesting grounds: implications from climate change. Journal of Experimental Marine Biology and Ecology 383, 56-64. [Link] Fuentes MMPB, Limpus CJ, and Hamann M (In Press). Vulnerability of sea turtle nesting grounds to climate change. Global Change Biology. doi : 10.1111/j.1365-2486.2010.02192.x [Link] Fuentes MMPB, Dawson J, Smithers S, Limpus CJ, Hamann M (In Press). Sedimentological characteristics of key sea turtle rookeries: potential implications under projected climate change. Journal of Marine and Freshwater Research. [Link] Grifn, E., Frost E., White L., Allison D. (2007) Climate Change and Commercial Fishing: A One-two Punch for Sea Turtles. [Link] Hamann M, Limpus CJ, Read MA (2007) Chapter 15 Vulnerability of marine reptiles in the Great Barrier Reef to climate change. In: Johnson JE, Marshall PA (eds) Climate change and the Great Barrier Reef: a vulnerability assessment, Great Barrier Reef Marine Park Authority and Australia Greenhouse Office, Hobart, p 465–496 Hays GC, Broderick AC, Glen F, Godley BJ (2003) Climate change and sea turtles: a 150 year reconstruction of incubation temperatures at a major marine turtle rookery. Glob Change Biol 9:642–646 Hawkes L.A., Broderick A.C; Godley M.H, (2007) Investigating the potential impacts of climate change on a marine turtle population. Global

	Change Biology 13, 923–932, [Link] Hawkes, L.A., Broderlick, A.C., Godfrey, M.H., Godley, B.J. (2009) Climate change and marine turtles. Endang Species Res. 7: 137-154 [Link] Janzen FJ (1994) Climate change and temperature-dependent sex determination in reptiles. Proc Natl Acad Sci USA 91:7487–7490 [Link] Rage, J.C. (1998) Latest cretaceous extinctions and environmental sex determination in reptiles, Bull. Soc. Géolog. Fr., 169, 479–483. Schwanz LE, Janzen FJ (2008) Climate change and temperature- dependent sex determination: can individual plasticity in nesting phenology prevent extreme sex ratios? Physiol Biochem Zool 81:826–834 [Link]
Gharial, Indian Gavial	No direct references found Bickford D., S. D. Howard, D. J. J. Ng , J. A. Sheridan (2010) Impacts of climate change on the amphibians and reptiles of Southeast Asia, Biodivers Conserv 19:1043–1062 [Link]
Green Turtle	Pike DA (in press) Do green turtles modify their nesting seasons in response to environmental temperatures? Chelonian Conserv Biol Spotila, J.R., Standora, E.A., Morreale, S.J., & Ruiz, G.J. (1987) Temperature dependent sex determination in the green turtle (Chelonia mydas): Effects on the sex ratio on a natural nesting beach, Herpetologica, 43, 74–81.
Hawksbill Turtle	Glen F, Mrosovsky N (2004) Antigua revisited: the impact of climate change on sand and nest temperatures at a hawksbill turtle (Eretmochelys imbricata) nesting beach. Glob Change Biol 10:2036–2045 [Link]
Leatherback Turtle	McMahon CR, Hays GC (2006) Thermal niche, large-scale movements and implications of climate change for a critically endangered marine vertebrate. Glob Change Biol 12:1330–1338 [Link]
Loggerhead Turtle	Chaloupka MY, Kamezaki N, Limpus CJ (2008) Is climate change affecting the population dynamics of the endangered Pacific loggerhead sea turtle? J Exp Mar Biol Ecol 356:136–143 [Link] Hawkes LA, Broderick AC, Coyne MS, Godfrey MH, Godley BJ (2007a) Only some like it hot—quantifying the environmental niche of the loggerhead sea turtle. Divers Distrib 13:447–457 [Link] Hawkes LA, Broderick AC, Godfrey MH, Godley BJ (2007b) Investigating the potential impacts of climate change on a marine turtle population. Glob Change Biol 13:923–932 [Link] Mrosovsky, N (1988) Pivotal temperatures for loggerhead turtles (Caretta caretta) from northern and southern nesting beaches, Canadian Journal of Zoology, 66: 661-669. [Link] Saba VS, Spotila JR, Chavez FP, Musick JA (2008) Bottom-up and climatic forcing on the worldwide population of leatherback turtles. Ecology 89:1414–1427 [Link] Weishampel JF, Bagley DA, Ehrhart LM (2004) Earlier nesting by loggerhead sea turtles following sea surface warming. Global Change Biol 10:1424–1427 [Link]

13.3. Appendix 3: Example of Preliminary Identification of Species Specialists

	Specialist Name	Email Address
Reptiles		
Gharial, Indian Gavial	B. C. Choudhury	bcc@wii.gov.in
Green Turtle	Jeffrey Seminoff	Jeffrey.Seminoff@noaa.gov
Hawksbill Turtle	Jeanne Mortimer	mortimer@.ufl.edu
Leatherback Turtle,	Richard Reina	richard.reina@sci.monash.edu.au
Loggerhead Turtle	Brian Bowen	bbowen@hawaii.edu
Olive Ridley	Pamela Plotkin	plotkin@etsu.edu
Birds		
Amsterdam Albatross	Henri Weimerskirch	henri.weimerskirch@la-reunion.ird.fr
Aquatic Warbler	Franziska Tanneberger	tanne@uni-greifswald.de
	Cosima Tegetmeyer	cosima.tegetmeyer@uni-greifswald.de
Balearic Shearwater	Daniel Oro	d.oro@uib.es
Basra Reed-warbler	Bruno Walther	bruno@diversitas-international.org
Black-faced Spoonbill	Jiann-Pyng Wang	wangcp@mail.ncku.edu.tw
Black-necked Crane	Xiaojun Yang	yangxj@mail.kiz.ac.cn
Blue Swallow	Steven Evans	stevene@ewt.org.za
Broad-billed Sandpiper	Wlodzimierz Meissner	w.meissner@univ.gda.pl
Buff-breasted Sandpiper	JOEL G. JORGENSEN	joel.jorgensen@ngpc.ne.gov
Chinese Egret	Natalia M. Litvinenko	litvinenko@mail.primorye.ru
Ferruginous Pochard, Ferruginous Duck	Nikolai Petkov	nicky.petkov@bspb.org
Greater Spotted Eagle, Spotted Eagle	Ülo Väli	ulo.vali@ebc.uu.se
Humboldt Penguin	F. Hernán Vargas	hvargas@fondoperegrino.org
Japanese Night Heron	Kazuto KAWAKAMI	kazzto@ffpri.affrc.go.jp
Lesser Kestrel	Jean-Pierre Biber	Jean-Pierre.Biber@natcons.ch
Lesser White-fronted Goose	Ingar Jostein Øien	ingar@birdlife.no
Madagascar Pond-heron	James A. Kushlan (Only IUCN recommendation)	Jkushlan@earthlink.net
Manchurian Crane, Japanese Crane	Dr. Ding Changqing (worth enquiring first)	cqding@mx.cei.gov.cn
Marbled Teal	Andy J Green	ajgreen@ebd.csic.es
Olrog's Gull	Pablo Yorio	yorio@cenpat.edu.ar
Peruvian Tern	Carlos B. Zavalaga	cbz3724@uncw.edu
Red Knot	Theunis Piersma	theunis@nioz.nl
Red-breasted Goose	John Quinn	john.quinn@zoo.ox.ac.uk
Short-tailed Albatross, Steller's Albatross	Rob Suryan	rob.suryan@oregonstate.edu
Siberian Crane	Guofeng Wu	guofeng.wu@whu.edu.cn

Spoon-billed Sandpiper	Christoph Zockler	cz@arccona.com
Spotted Greenshank, Nordmann's Greenshank	Mark Barter	markbarter@optusnet.com.au
Steller's Eider	Paul Flint	paul_flint@usgs.gov
Steller's Sea-eagle	Mutsuyuki Ueta	mj-ueta@netlaputa.ne.jp
Swan Goose	Mark Barter	markbarter@optusnet.com.au
White-naped Crane	Hiroyoshi Higuch	higuchi@es.a.u-tokyo.ac.jp
Mammals		
Addax	John Newby	scf@bluewin.ch
Blue Whale	Trevor Branch	tbranch@u.washington.edu
Bowhead Whale	Todd O'Hara	tmohara@alaska.edu
Cuvier's Gazelle	David Mallon	d.mallon@zoo.co.uk
Dama Gazelle	François Lamarque	f.lamarque@oncfs.gouv.fr
Humpback Whale	Marianne Rasmussen	mhr@hi.is
Mexican Free-tailed Bat	Gary F. McCracken	gmccrack@utk.edu
North Pacific Right Whale	Sue Moore	sue.moore@noaa.gov
Northern Right Whale, Biscayan Right Whale	Bruce Mate	bruce.mate@oregonstate.edu
Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	Koji Matsuoka	matsuoka@cetacean.jp
Short-beaked Common Dolphin	Ana Cañadas Carbó	alnitak.ana@cetaceos.com
Southern Right Whale	Peter Best	pbest@iziko.org.za
Sperm Whale	Malcolm Clarke	dotmacclarke@yahoo.co.uk
West African Manatee	Fabricio Santos (tbc)	fsantos@icb.ufmg.br
Fish		
Basking Shark	David Sims	dws@mba.ac.uk
Common Sturgeon	Frank Kirschbaum	kirschbaum@staff.hu-berlin.de
Giant Catfish		zshogan@ucdavis.edu.
Great White Shark, White Shark	Michael Domeier	ml.domeier@gmail.com

13.4. Appendix 4: Further Project Outputs – Policy Brochure

Executive Summary: The Zoological Society of London (ZSL) is conducting research for the UNEP Convention on Migratory Species (CMS) into the effects of climate change on species protected by CMS. Species have been identified as having a high, medium or low vulnerability to the threat of climate change and have been categorised on the basis of a standardised assessment process. This leaflet summarises the emerging results from an assessment of CMS Appendix I species, in order to provide guidance to policy makers at the earliest opportunity. Results highlight a number of processes by which greenhouse gas emissions and climatic changes will increasingly threaten migratory species; all species assessed will be affected by these impacts. A broad set of biological, geographical and socio-economic factors will influence species vulnerability. Identifying these factors and developing further conservation management practices will be essential for the short term future of these species. In the long term, the reduction of greenhouse gas emissions is vital if we are to avoid unmanageable levels of climate change.

Assessment background and overview

CMS aims to conserve terrestrial, aquatic and avian migratory species throughout their range. Due to the urgent need to address climate change, the number of decisions responding to this threat has markedly increased within biodiversity-related treaties including the Convention on Biodiversity, the Ramsar Convention on Wetlands and CMS. CMS Parties have made several decisions that prioritise actions to reduce climate change impacts on migratory species. Most recently in 2008, Resolution 9.7 called upon Parties to mitigate climate change and aid adaptation of species to these changes. Section 2 of the resolution requests that research be undertaken to identify which Appendix I species are most vulnerable to climate change, with further research into Appendix II species to follow. Fulfilment of this part of Resolution 9.7 forms the basis of this study.

Investigations to date show that migratory species are particularly sensitive to climatic disturbances and corresponding impacts, including habitat loss/alteration and changes to the composition of biological communities[1,2]. Their vulnerability stems from the large energy investment they make to migrate to high quality habitats, often timing their arrival to coincide with the optimum abundance of resources at their destination.

This study, commissioned by the UNEP/CMS Secretariat, aims to identify how climate change is likely to affect individual migratory species, and the degree of threat that they face. The first wave of assessments have focused on species that undergo cyclic and predictable long-distance migrations, with the final study due to be completed in summer 2010. Almost half of Appendix I species have been assessed to date. Of these species, around half are marine, 38% are freshwater and 13% are terrestrial. Results show that climate change will have negative impacts on populations of all these species.

With carbon dioxide emissions already reaching 387ppm and causing significant and irreversible ecosystem change, it is evident that emphasis needs to be placed not only upon mitigation of greenhouse gas emissions, but also on maximising the adaptive potential of migratory species populations.

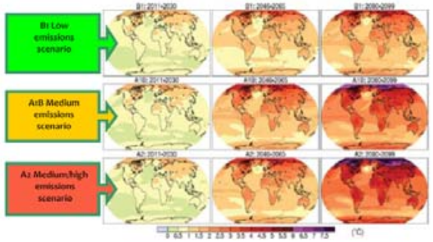

Mexican-free tailed bats

Threats to CMS Appendix I Migratory Species

A broad range of climate change processes will affect migratory species populations. These are outlined below, with examples of significant impacts on species identified in assessments to date.

INCREASING TEMPERATURES

Without mitigation, the IPCC predicts that temperatures will be 3.4°C warmer by the end of the century[3]. However, more recently the UK Met Office has indicated that temperatures are likely to increase by more than 5.5°C within the same time period[4]. Mitigation efforts will be able to reduce this predicted warming. However, due to inertia in the system, even if emissions were halted immediately the climate would continue to warm[5].



Annual mean surface warming (°C) for three emissions scenarios (A1, A1B, A2) and three time periods. Temperatures are relative to the average of the period 1980 to 1999. Source: IPCC 2007 WGI

Vital Habitats Due to the Melting of Sea Ice: Polar marine mammals will suffer due to a decline in protective and breeding habitats. The **bowhead whale**[6] and the **narwhal**[7] (Appendix II) require the Arctic sea ice to provide them with protection, whilst other species such as the **ringed seal** (not yet listed by CMS) rely upon this habitat to breed[8]. Intense warming is projected for the Arctic[3], with ice free summers expected by 2025-2040[9,10].

Collapsing Food Webs Linked to Changes in Zooplankton Abundance: Baleen whales, a number of fish (e.g. **basking shark**)[11] and bird species (e.g. **Humboldt penguin, Balearic shearwater, Bermuda petrel, short-tailed albatross**) are reliant on abundant zooplankton either directly, or to nourish their prey: krill, fish and cephalopod populations. These species will be negatively affected by changes in marine ecosystems and food-webs as increasing sea temperatures cause zooplankton abundance to decline[12]. Algae, a vital nutrient within the Arctic ecosystem, is also predicted to decline as this grows beneath the sea ice. Numerous cetaceans that feed in the Arctic such as the **bowhead whale**[13] and three **right whale** species will be affected as krill abundances decline.

Changing Sex Ratios: Many reptiles are reliant on temperature sex determination[14], as are some birds[15] and fish[16]. Temperatures of 29.2°C produce a 50:50 sex ratio in sea turtle populations; including the **green turtle, hawksbill turtle, leatherback turtle, loggerhead turtle and the olive ridley turtle**. Higher temperatures will lead to the feminisation of populations[17], which will affect breeding success.

CHANGES IN PRECIPITATION

An increase in temperature will intensify the hydrological regime whilst increasing the spatial variability of precipitation. The overall projected patterns show a reduction of rainfall in the subtropics and an increase in rainfall near the equator and at high latitudes[3].

Reducing Wetland Habitats for Breeding and Feeding: Many bird species are particularly dependent on wetland habitats during vital stages of their life cycles. Reduced precipitation in these areas will negatively impact many species including the **Andean flamingo, aquatic warbler** and **red-knot.** Decreased precipitation coupled with increased evaporation rates has been identified as a key threat that will cause a reduction in the number of wetland stop-over habitats available to the **swan goose** and the **white-naped crane**[18]. To breed, the **Basra reed warbler** requires aquatic vegetation in or around shallow water, on marshlands and in river basins across Mesopotamia[19]. This habitat is under threat from drought, alongside increased human pressures from water extraction. Water resources for this region are already in decline, and models show a stark decrease in the availability of water from the moderate to the high warming scenarios[20], highlighting the importance of climate change mitigation.

Reducing Grazing Habitat for Terrestrial Mammals: Terrestrial mammals such as the **addax, Cuvier's gazelle** and **dama gazelle** are already adapted to very dry climates. However, a number of models are predicting prolonged periods of drought in the North African region[21] which will further increase pressures on both wild and domestic animals through declines in grazing habitats.


Addax

Variation in Rainfall Affecting Breeding Success: More variable rainfall is likely to affect the breeding success of birds, especially those nesting in close proximity to water. **Relict gulls** for instance, are very sensitive to changes in water levels as they require low-lying islands on freshwater lakes for nesting[22]. Precipitation across much of this breeding habitat is expected to increase in variability[3], further reducing the low breeding success of the species. Aquatic reptiles such as the **Kemp's ridley turtle** utilise freshwater beaches for egg-laying. Heavy rainfall from storms has the potential to rapidly cool the sand and nest temperature, increasing mortality in hatchlings[23]. The crocodile-like **gharial** is also vulnerable to variations in rainfall. High water levels and faster river flows can destroy nest sites and cause higher mortality, particularly in hatchlings[24]. In 2008, early monsoon flooding destroyed all nests in Katerniaghat, India, a primary reserve for this species.

EXTREME WEATHER

More erratic weather regimes, which increase the incidence of phenomena such as hurricanes, droughts and floods, are predicted to become more frequent[25]. This is likely to increase the vulnerability of many species in the future. Half of the CMS Appendix I species studied to date have been identified as vulnerable to increased incidences of extreme weather, mainly through direct impacts on mortality rates.


West African manatee

Extremes in Temperature: Species which utilise freshwater habitats appear to be much more vulnerable to extreme weather events when compared with marine species, as they are more restricted in their movement and the smaller water bodies they inhabit heat up more rapidly. Extreme temperatures have been known to cause mortality in the **West African manatee** as sections of river can become isolated from the main flow, leaving pools or channels vulnerable to intense heating[26]. Other species such as the **Ganges River dolphin** are also vulnerable to these changes.

Increased Storm Frequency and Intensity: The diet of marine mammals has been shown to be impacted by increased incidence and intensity of storms. Storms can affect zooplankton concentration, thereby disrupting the diet of many marine species. Krill, upon which the **blue whale** depends, have been documented to be affected by tropical cyclones and increased surface turbulence[27] and it is likely that this will also negatively affect other baleen whales and the **basking shark.** The nesting beaches of marine turtles are expected to be damaged by the increased occurrence and intensity of hurricanes and tropical cyclones[28], with **green turtles** being particularly vulnerable as they use beaches prone to storms during peak hurricane season. The storm surges generated have the potential to destroy large numbers of nests[29]. The **Mexican-free tailed bat** is also expected to suffer because the availability of its insect prey is reduced in poor weather[30].

Precipitation Extremes: The **West African manatee** is vulnerable to both high and low extremes in river flow[31]. Precipitation in West Africa is expected to become more extreme with more infrequent, heavy rainfall[3]. Optimum habitat for the manatee is deep, slow moving river waters[31]. Drought leaves them vulnerable to isolation in channels and to the loss of navigable habitat.

Flooding events cause fast flowing water, and can lead to entrapment when the waters recede.

SEA LEVEL RISE

By 2100, the IPCC predict sea levels will rise by 0.18m-0.59m compared to 1980-1999[32] levels. However, other models indicate a much greater magnitude of sea level rise by the end of the century[10], with some predicting it to be in the range of 0.5m - 1.4m[33]. This will have an impact on numerous migratory species utilising coastal habitats.

Loss of Low-Lying Coastal Habitats: The **swan goose** for instance, will lose large amounts of its important wintering grounds located on coastal mudflats and estuaries. This will greatly reduce the winter feeding capacity of the species, as there will be less prey available, reducing the amount of energy available for their annual migration[34].

Loss of Nesting Sites: Of species listed on CMS Appendix I, sea turtle populations are likely suffer the most from sea level rise. The IPCC predicts that a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds[35]. If sea levels rise significantly higher than this over the next century, which is expected, many more vital nesting sites will be threatened.

OCEAN ACIDIFICATION

CO_2 is the primary molecule influencing the pH of oceans[36]. Since the 1800's, oceans have absorbed 1/3 of anthropogenic CO_2 emissions[37] and the average oceanic pH has dropped by 0.10 units, equivalent to a 30% decrease. If unmitigated, oceanic pH is likely to decrease by a further 0.4 units[36] by 2100. Increases in atmospheric CO_2 are currently more rapid than at any point in the last 650,000 years[38]. A reduction in pH will have impacts on the entire oceanic system, with high latitude cold water oceans affected earlier and more severely than warm water oceans.

Impacts on Food-Webs: Many species including corals, snails and krill are dependent on aragonite and calcite concentrations in the water. As oceans acidify, these minerals will become less abundant and species will struggle to mineralise their exoskeletons. Severe impacts will be felt within polar regions, with aragonite undersaturation expected to occur as early as 2016[40] and both calcite and aragonite concentrations expected to be insufficient for mineralisation in Arctic waters by 2060[41]. This will have serious consequences for the entire ecosystem, as species dependent on these minerals form the basis of food webs in these regions. As zooplankton composition and abundance is expected to change[39,42,43,44], species directly or indirectly dependent on these (e.g. whales, dolphins) are likely to suffer[25].


Coral reef ecosystem

Habitat Loss: **Hawksbill turtles** depend upon coral reef ecosystems at various stages of their life-cycle[45]. The shelves and caves formed by coral reefs provide resting and sheltering areas for this species[46], whilst adult hawksbills feed almost exclusively upon reef fauna[45]. By 2030-2050, reefs globally will be facing severe acidification stress[75]. Coral reef formation depends upon aragonite, which has decreased considerably in tropical seawaters[47]. When atmospheric CO_2 levels reach approximately 450ppm, the ability of coral reefs to withstand erosion and grow will be severely impeded[48]. This combined with increased temperature stress and storm frequency will cause the collapse of coral reef ecosystems globally, possibly within the next 30 years. Considering that coral reefs are the most biodiverse marine ecosystems harbouring up to 3 million species, with more than 1/4 of all marine fish species, the **"Coral Reef Crisis"** is currently proving to be the most urgent threat to biodiversity from climate change. Further degradation could precipitate a 'domino-effect' across marine ecosystems[49], which is likely to have severe implications for many CMS species.

OCEAN CIRCULATION

Marine primary production is the basis of ocean ecosystems and a key component of the carbon cycle[50]. By increasing water temperatures and freshwater discharge from melting ice sheets, climate change will affect nutrient supplies and is likely to change the ocean circulation system[51]. All marine species assessed were found to be vulnerable to these changes; however there is currently still a high spatial and temporal uncertainty as to the extent and magnitude of these impacts[51].

Changes in Food Distribution and Abundance: Ocean circulation affects species abundances, through nutrient upwellings and more directly by transporting species and providing resources for specific oceanic habitats. Numerous species (e.g. **humpback whale**[13], **basking shark**[11]) are likely to be affected by changing ocean circulations as these will affect prey distribution. Migration routes will have to adapt[52] if species are to survive.


Humpback whale

Altering Migrations: Many species depend upon ocean currents to aid movement, with a number of turtle species using ocean currents to migrate. During their juvenile phase, **hawksbill turtles**[54] and **loggerhead turtles**[55] float on ocean currents until they mature. Turtle hatchlings instinctively swim towards local surface currents to help transport them across ocean basins[53]. Changes in ocean circulation are likely to change the distributions and migration patterns of such species[54].

SPATIAL AND TEMPORAL RESPONSES

Species have varied responses to climate change. Some species are already adapting the timings of their annual cycles due to a changing climate, whilst others are altering the locations of their migration or foraging habitats. Such individual and dynamic responses will inevitably interfere with species interactions.

Biome Shifts: Migratory species rely on a number of isolated high quality habitats during their annual cycle. Any disturbance or alteration to a required habitat can leave a species vulnerable[1]. As temperatures rise, the distances between suitable habitats can increase. This threat is particularly pronounced when geological features or human developments limit suitable habitats, when there are barriers to migration, or when food abundances occur in different locations to traditional migratory routes. The distance between the breeding and feeding sites of the **Balearic shearwater** is increasing due to shifts in prey abundances, linked to changing sea surface temperatures[56,57,58,59]. The extra energy required for this migration increases the species vulnerability.

Phenological Shifts: Species display varying phenological responses to climate change, which can lead to mismatches in predator prey interactions. For example, due to increasing sea surface temperatures, changes in **loggerhead turtle** nesting times are occurring[60] which could alter predation on hatchlings.


Loggerhead turtle hatching

Mismatches also occur when food requirements and abundances do not coincide[52,61]. Energy-intensive migrations are timed with critical life stages, including reproduction cycles and growth of individuals, linking them to periods of peak resource availability. Mistiming of these events could have severe consequences for many species.

Habitat Loss: Biome shifts will result in the reduction of certain habitats. For example, tundra habitat cannot advance polewards as temperatures rise due to its position at the northern extent of the Eurasian landmass. These higher temperatures are causing forests to invade areas which were originally treeless tundra[62,63], greatly reducing suitable habitat area for some species. The **Siberian crane** for example is currently affected by these changes as the open tundra that it requires to nest disappears[64,65].

EXACERBATION OF EXISTING THREATS

The majority of the species assessed by this study are already at high risk from anthropogenic pressures. There is evidence that past climatic change increased overexploitation of certain species[66]. The negative socio-economic impacts of current climate change on humans will ultimately result in increased anthropogenic pressures on species and natural systems. For example, harvested species are likely to be even more heavily exploited. Wetland habitats will be starved of water as it becomes increasingly diverted for human use, threatening species such as the **Basra reed warbler**[67]. Sea level rise will encourage the construction of coastal defences, which are likely to negatively impact species reliant on coastal habitats, including sea turtle species and the **West African manatee**[68].

Climate change has the capacity to act synergistically with current anthropogenic threats, so that species are not only dealing with the direct impacts of climate change, but also consequences of climate change impacts on humans. Current anthropogenic threats also weaken a species ability to cope with climate change. Building resilience into species populations, and the habitats on which they depend by reducing conventional threats such as pollution, habitat fragmentation and overexploitation will improve species ability to adapt.

Preliminary Recommendations

Monitoring and Further Research Needs: Little is known about migratory species capacity for adaptation to climate change. If we are to gain a solid understanding of the impacts of climate change on migratory species, intensive monitoring and research is needed. Thorough assessment is not only required for species already protected by CMS, but also for those not currently listed in the Appendices. This knowledge is vital to identify key limiting factors, the 'weakest link', upon which each species survival hinges, and to provide essential building blocks for policy guidance. Further literature on the interactions between climate change and migratory species populations is being gathered and made available online to inform policy and management decisions: www.bioclimate.org

Managing Changing Environments: The advantage that migratory species have in comparison with most non-migratory taxa is their ability to move over large distances. To facilitate this movement, it is vital to improve the connectivity of habitats critical to population survival currently and in the future. CMS is already involved in developing critical site networks and tools such as the African-Eurasian Waterbird Agreement's Wings Over Wetlands Project (www.wingsoverwetlands.org). There is an urgent need to identify and protect further critical site networks with species range shifts in mind. By maintaining viable habitats and reducing current threats, stakeholders may be able to improve the resilience of some species to cope and adapt to climate change.

Difficulty of Adaptation and Importance of Mitigation: The large extent of many migratory species ranges will make the design of adaptation strategies, aimed at minimising climate change impacts, very challenging. For instance, the **Siberian crane's** global population consists of roughly 3000 individuals, which nest over an area of 26,000km². Even if adaptation is facilitated, such as by shifting migratory routes with imprinting and microlight plane guidance (e.g. Flight of Hope project), these measures require a large investment both in terms of time and money.


Siberian Cranes

Unfortunately, even high levels of investment will not ensure viable populations if emissions surpass critical thresholds, as many of the threats highlighted in this study will be difficult to control and adapt to once levels are breached. Furthermore, populations currently dependent on habitats located on the most northerly or southerly ends of landmasses, as well as those close to mountain tops, are particularly vulnerable since migration to follow their climatic niche is not an option. There is potential for the translocation of species to new areas through assisted colonisation/migration, but this again is costly and should only be used as a last resort once adequate research has been done on the long term affects of such drastic intervention.

On a species by species basis, provisions to aid adaptation could be feasible in the short to medium term, but it is clear that for a multitude of species such actions will be too costly and ultimately not sufficient to ensure their survival, especially if rapid levels of climate change are allowed to occur. It is therefore vital that a **dual approach** be taken where; **proactive adaptation measures** are applied to species already threatened by committed levels of climate change alongside **considerable and rapid emissions abatement** to limit further impacts. This is the only cost effective and practical way to safeguard migratory species into the future.

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13.5. Appendix 5: Further Project Outputs - Posters / Banners

1. Policy Poster / Banner: **"Climate Change Impacts on Migratory Species: Uncertain Destinations"**

2. Case Study Poster / Banner: **"Migrating Towards an Uncertain Future: The Hawksbill turtle (*Eretmochelys imbricata*)"**