



Climate Change Vulnerability of Migratory Species

Species Assessments



PRELIMINARY REVIEW

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

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The Zoological Society of London (ZSL) has been conducting research for the UNEP Convention on Migratory Species (CMS) into the effects of climate change on species protected under the convention. This project report has been produced to present all findings of this study at the earliest opportunity to CMS for consideration at the forthcoming CMS ScC COP16 meeting.

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. The first major ecosystems likely to collapse as a direct result of exponential increases in atmospheric CO₂ from anthropogenic activities are coral reefs, due to combined impacts of climate change and ocean acidification. If atmospheric CO₂ is not brought back down to safe levels it is unlikely to be the last, with major impacts predicted for many species both migratory and non migratory.

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 down 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. The results of 45 case study species are presented within this report and full assessments have been made available to further inform potential next steps. 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 their 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.

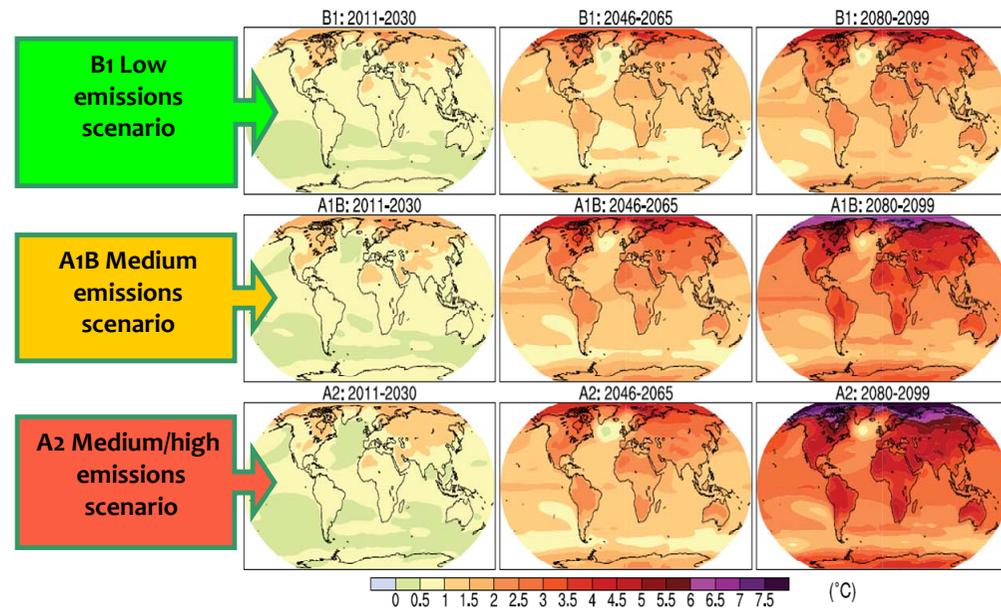
INCREASING TEMPERATURES

Without mitigation, the IPCC predicts that temperatures will be 3.4°C warmer by the end of the century³. 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 period⁴. 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 warm⁵.

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 breed⁸. Intense warming is projected for the Arctic³ with air temperatures rising between 5°C - 7°C by 2100, two times higher than 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 decline¹². 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 determination¹⁴, as are some birds¹⁵ and fish¹⁶. 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 populations¹⁷, which will affect breeding success.



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

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 latitudes³.

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 Mesopotamia¹⁹. 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 scenarios²⁰, 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 region²¹ 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 very sensitive to changes in water levels as they require low-lying islands on freshwater lakes for nesting²². Precipitation across much of this breeding habitat is expected to increase in variability³, 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 hatchlings²³. 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 hatchlings²⁴. In 2008, early monsoon flooding destroyed all nests in Katernighat, India, a primary reserve for this species.



Addax

EXTREME WEATHER

More erratic weather regimes, which increase the incidence of phenomena such as hurricanes, droughts and floods, are predicted to become more frequent²⁵. 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 heating²⁶. 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 turbulence²⁷ 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 cyclones²⁸, 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 nests²⁹. The **Mexican-free tailed bat** is also expected to suffer because the availability of its insect prey is reduced in poor weather³⁰.

Precipitation Extremes: The **West African manatee** is vulnerable to both high and low extremes in river flow³¹. Precipitation in West Africa is expected to become more extreme with more infrequent, heavy rainfall³. Optimum habitat for the manatee is deep, slow moving river waters³¹. 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 1980-1999³² levels. However, other models indicate a much greater magnitude of sea level rise by the end of the century¹⁰, with some predicting it to be in the range of 0.5m - 1.4m³³. 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 migration³⁴.

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 grounds³⁵. 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

CO₂ is the primary molecule influencing the pH of oceans³⁶. Since the 1800's, oceans have absorbed 1/3 of anthropogenic CO₂ emissions³⁷ 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 units³⁶ by 2100. Increases in atmospheric CO₂ are currently more rapid than at any point in the last 650,000 years³⁸. 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 2016⁴⁰ and both calcite and aragonite concentrations expected to be insufficient for mineralisation in Arctic waters by 2060⁴¹. 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 suffer²⁵.

Habitat Loss: Hawksbill turtles depend upon coral reef ecosystems at various stages of their life-cycle⁴⁵. The shelves and caves formed by coral reefs provide resting and sheltering areas for this species⁴⁶, whilst adult hawksbills feed almost exclusively upon reef fauna⁴⁵. By 2030-2050, reefs globally will be facing severe acidification stress²⁵. Coral reef formation depends upon aragonite, which has decreased considerably in tropical seawaters⁴⁷. When atmospheric CO₂ levels reach approximately 450ppm, the ability of coral reefs to withstand erosion and grow will be severely impeded⁴⁸. 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 ecosystems⁴⁹, 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 cycle⁵⁰. 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 system³². 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 impacts⁵¹.

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 adapt⁵² 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 basins⁵³. Changes in ocean circulation are likely to change the distributions and migration patterns of such species⁵⁴.

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 vulnerable¹. 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 occurring⁶⁰ 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}.



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 species⁶⁶. 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:	<p>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.</p> <p>Identify research gaps: Identify species which have had little or no direct research into their climate change vulnerabilities.</p> <p>Identify species with large amount of research indicating vulnerability to climate change.</p> <p>Identify species where observed changes have been directly related to climate change</p>
Methods:	<p>Table of species listed under groupings and taxon alongside related literature directly referring to climate change impacts on each (see appendix 2 for example).</p> <p>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.</p> <p>Each reference will be hyperlinked to original document.</p> <p>References showing observed changes tagged</p> <p>Species with no direct references identified</p> <p><i>This methodology is being proposed for follow on work and has been tested within this study.</i></p>
Results:	<p>Each species will have a list of peer reviewed references that directly relates this species to climate change vulnerability</p> <p>All references identifying observed changes will be tagged</p>
Outputs:	<p>Organised list of relevant references for CMS and further research use.</p> <p>Overview of species where there are research gaps and where there are disproportionately high levels of research.</p> <p>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.</p> <p>List of migratory species flagged as “concern” due to climate change impacts already being felt.</p>
Scope:	<p>An initial overview of literature is recommended for all migratory species and species listed on the CMS appendices.</p>

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. <i>This methodology is being proposed for follow on work and has been tested within this study.</i>
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. <i>This methodology has been applied to case study species presented within this report.</i>
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.

	<p>Compile information into a report identifying all potential threats, vulnerabilities as well as uncertainties and discussion of points raised.</p> <p>Provide graphical information where available.</p> <p>Liaise with species specialists and, where available, climate change specialists during production of report.</p> <p><i>This methodology has been applied to case study species presented within this report.</i></p>
Results:	See example Species Reports provided in current review
Outputs:	<p>Species reports often 4 - 10 pages each.</p> <p>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.</p> <p>Potential to feed into conservation management planning processes</p>
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 than 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 trade 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 selected species within CMS Appendix I. However the development of the assessment process is aimed at maximising ability to review species listed on all appendices under CMS 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. 39 of these ‘biological migrants’ were case studied including 7 reptile species, 14 mammal species, 4 fish species and 14 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 make up the selection of example ‘non biological 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	<i>Podocnemis expansa</i>	Potamodromous	-		LR/cd	Not provided	High	I	Pelomedusidae	Arrauschildkröte	Tortue de l'Amazone	Tortuga Arrau

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

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
16	Mammalia	Barbary Stag, Barbary Deer, Red Deer	<i>Cervus elaphus</i>	technical migrant	-		LC	Increasing		I	Cervidae	Berberhirsch	Cerf de Barbarie	Ciervo de Berbería
17	Mammalia	Blue Whale	<i>Balaenoptera musculus</i>	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	EN	Increasing	--	I	Balaenopteridae	Blauwal	Baleine bleue	Ballena azul
18	Mammalia	Bowhead Whale	<i>Balaena mysticetus</i>	interoceanic	-	X	LC	Increasing	--	I	Balaenidae	Grönlandwal	Baleine du Groenland	Ballena de Groenlandia
19	Mammalia	Cheetah	<i>Acinonyx jubatus</i>	not included	-		VU	Decreasing		I				
20	Mammalia	Common Bottlenose Dolphin	<i>Tursiops truncatus</i>	partial	ACCOBAMS, ASCOBANS		LC	Unknown	Medium	I				
21	Mammalia	Cuvier's Gazelle	<i>Gazella cuvieri</i>	data deficient	Sahelo-Saharan Antelope Action Plan	X	EN	Unknown	--	I	Bovidae	Atlasgazelle	Gazelle de Cuvier	Gacela de Cuvier
22	Mammalia	Dama Gazelle	<i>Gazella dama</i>	intracontinental	Sahelo-Saharan Antelope Action Plan	X	CR	Decreasing	--	I	Bovidae	Damagazelle	Gazelle dama	Gacela dama
23	Mammalia	Dorcas Gazelle	<i>Gazella dorcas</i>	nomadising	Sahelo-Saharan Antelope Action Plan		VU	Decreasing	Medium	I	Bovidae	Dorkasgazelle	Gazelle Dorcas	Gacela Dorcas
24	Mammalia	Fin Whale	<i>Balaenoptera physalus</i>	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	<i>Platanista gangetica</i>	potamodromous	-		EN	Decreasing		I	Platanistidae	Ganges-Delphin	Platanista du Gange	Delfín del Río Ganges
26	Mammalia	Grevy's Zebra	<i>Equus grevyi</i>	technical migrant	-		EN	Stable		I	Equidae	Grevy Zebra	Zèbre de Grevy	Cebra de Grevy
27	Mammalia	Humpback Whale	<i>Megaptera novaeangliae</i>	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	LC	Increasing	--	I	Balaenopteridae	Buckelwal	Mégaptère	Yubarta
28	Mammalia	Irrawaddy Dolphin	<i>Orcaella brevirostris</i>	potamodromous	-		VU	Decreasing		I				

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
29	Mammalia	Kouprey, Grey Ox	<i>Bos sauveli</i>	technical migrant	-		CR	Unknown		I	Bovidae	Kuprey	Kouprey	Kouprey
30	Mammalia	La Plata Dolphin, Franciscana	<i>Pontoporia blainvillei</i>	technical migrant	-		VU	Decreasing	Low	I	Platanistidae	La-Plata-Delphin	Dauphin de la Plata	Franciscana
31	Mammalia	Lowland Gorilla	<i>Gorilla gorilla</i>	nomadising	Gorilla Agreement		CR	Decreasing	High	I	Hominidae	Gorilla	Gorille	Gorila
32	Mammalia	Marine Otter	<i>Lontra felina</i>	technical migrant	-	X	EN	Decreasing	--	I	Mustelidae	Meerotter	Loutre de mer	Chungungo
33	Mammalia	Mediterranean Monk Seal	<i>Monachus monachus</i>	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, Brazilian free-tailed bat	<i>Tadarida brasiliensis</i>	intercontinental	-	X	LC	Stable	--	I	Molossidae	Brasilianische Bulldogfledermaus	Chauve-souris à queue-libre du Mexique	Rabudo mejicano
35	Mammalia	Mountain Gorilla, Eastern Gorilla	<i>Gorilla beringei</i>	nomadising	Gorilla Agreement		EN	Decreasing	High	I				
36	Mammalia	NARWHAL	<i>Monodon monoceros</i>	intraoceanic	-	X	NT	Unknown	--	II				
37	Mammalia	North Pacific Right Whale	<i>Eubalaena japonica</i>	interoceanic	-	X	EN	Unknown	--	I				
38	Mammalia	Northern Atlantic Right Whale, Biscayan Right Whale	<i>Eubalaena glacialis</i>	interoceanic	-	X	EN	Unknown	--	I	Balaenidae	Nordkaper	Baleine de Biscaye	Ballena franca
39	Mammalia	Scimitar-horned Oryx	<i>Oryx dammah</i>	intracontinental	Sahelo-Saharan Antelope Action Plan		EW			I	Bovidae	Säbelantilope	Oryx gazelle	Orix cimitarra
40	Mammalia	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	<i>Balaenoptera borealis</i>	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	EN	Unknown	--	I	Balaenopteridae	Seiwal	Baleinoptere de Rudolphi	Rorcual norteño

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
41	Mammalia	Short-beaked Common Dolphin	<i>Delphinus delphis</i>	intraoceanic	ACCOBAMS, ASCOBANS, Pacific Island Cetaceans MoU, West African Aquatic Mammal MoU	X	LC	Unknown	--	I				
42	Mammalia	Slender-horned Gazelle, Rhim	<i>Gazella leptoceros</i>	nomadising	Sahelo-Saharan Antelope Action Plan		EN	Decreasing	Medium	I	Bovidae	Dünengazelle	Gazelle leptocère	Gacela de astas delgadas
43	Mammalia	Snow Leopard	<i>Uncia uncia</i>	nomadising	-	X	EN	Decreasing	--	I	Felidae	Schnee leopard	Panthère des neiges	Pantera de las nieves
44	Mammalia	South Andean Deer, Patagonian Huemul	<i>Hippocamelus bisulcus</i>	technical migrant	-		EN	Decreasing		I	Cervidae	Südandenhirsch	Cerf des Andes méridionales	Huemul
45	Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	interoceanic	-	X	LC	Increasing	--	I	Balaenidae	Südkaper	Baleine australe	Ballena franca austral
46	Mammalia	Southern River Otter	<i>Lontra provocax</i>	technical migrant	-		EN	Decreasing		I	Mustelidae	Südlicher Flussotter	Loutre du Chili	Huillín
47	Mammalia	Sperm Whale	<i>Physeter macrocephalus</i>	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	X	VU	Unknown	--	I	Physeteridae	Pottwal	Cachalot	Ballena esperma
48	Mammalia	Vicugna)	<i>Vicugna vicugna</i>	nomadising	-		LC	Increasing	Low	I	Camelidae	Vikunja	Vigogne	Vicuña
49	Mammalia	West African Manatee	<i>Trichechus senegalensis</i>	intracontinental	West African Aquatic Mammal MoU	X	VU	Unknown	--	I				
50	Mammalia	Wild or Bactrian camel	<i>Camelus bactrianus</i>	NONE PROVIDED	-		CR	Decreasing	High	I	Camelidae			Camello Bactriano
51	Mammalia	Wild Yak, Yak (Domestic species)	<i>Bos grunniens (Bos mutus)</i>	technical migrant	-		VU	Decreasing	High	I	Bovidae	Wildyak	Yack sauvage	Yak
52	Aves	Amsterdam Albatross	<i>Diomedea amsterdamensis</i>	intraoceanic	ACAP		CR	Decreasing	Medium	I	Diomedidae	Amsterdimalbatros	Albatros d'Amsterdam	Albatros de la Amsterdam

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
53	Aves	Andean Flamingo	<i>Phoenicopterus andinus</i>	intracontinental	High Andean Flamingo MoU	X	VU	Decreasing	--	I	Phoenicopteridae	Andenflamingo	Flamant des Andes	Parina grande
54	Aves	Aquatic Warbler	<i>Acrocephalus paludicola</i>	intercontinental	Aquatic warbler MoU	X	VU	Decreasing	--	I	Muscicapidae	Seggenrohrsänger	Phragmite aquatique	Carricerín
55	Aves	Audouin's Gull	<i>Larus audouinii</i>	partial	-		NT	Decreasing	Low	I	Laridae	Korallenmöwe	Goéland d'Audouin	Gaviota de Audouin
56	Aves	Baikal Teal	<i>Anas formosa</i>	intracontinental	-		VU	Decreasing	Low	I	Anatidae	Gluckente	Sarcelle élégante	Cerceta del Baikal
57	Aves	Balearic Shearwater	<i>Puffinus mauretanicus</i>	interoceanic	-	X	CR	Decreasing	--	I				
58	Aves	Basra Reed-warbler	<i>Acrocephalus griseldis</i>	intercontinental	-	X	EN	Decreasing	--	I				
59	Aves	Bermuda Petrel	<i>Pterodroma cahow</i>	intraoceanic	ACAP	X	EN	Increasing	--	I	Procellariidae	Bermudasturmvogel	Pétrel des Bermudes	Petrel cahow
60	Aves	Black-faced Spoonbill	<i>Platalea minor</i>	intracontinental	-		EN	Decreasing	High	I	Threskiornithidae	Schwarzgesichtlöföfler	Petite Spatule	Espátula menor
61	Aves	Black-necked Crane	<i>Grus nigricollis</i>	intracontinental	-		VU	Decreasing		I	Gruidae	Schwarzhalskranich	Grue à cou noir	Grulla cuellinegra
62	Aves	Blue Swallow	<i>Hirundo atrocaerulea</i>	intracontinental			VU	Decreasing		I	Hirundinidae	Stahlschwalbe	Hirondelle bleue	
63	Aves	Broad-billed Sandpiper	<i>Limicola falcinellus</i>	intercontinental	-		LC	Not provided	Low	I				
64	Aves	Buff-breasted Sandpiper	<i>Tryngites subruficollis</i>	intercontinental	-		NT	Decreasing	Low	I	Scolopacidae	Grasläufer	Bécasseau roussâtre	Correlimos canelo
65	Aves	Chestnut Seedeater	<i>Sporophila cinnamomea</i>	intracontinental	-		VU	Decreasing		I	Emberizidae		Sporophile cannelle	Capuchino corona gris
66	Aves	Chinese Crested Tern	<i>Sterna bernsteini</i>	intracontinental	-		CR	Decreasing	Low	I	Laridae	Bernsteinseeschwalbe	Sterne d'Orient	Charrán chino
67	Aves	Chinese Egret	<i>Egretta eulophotes</i>	intracontinental	-		VU	Decreasing	Low	I	Ardeidae	Schneereiher	Aigrette de Chine	Garceta china
68	Aves	Cock-tailed Tyrant	<i>Alectrurus tricolor</i>	migrantory	-		VU	Decreasing		I	Tyrannidae		Moucherolle petit	Yetapá chico

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
69	Aves	Dalmatian Pelican	<i>Pelecanus crispus</i>	partial	AEWA		VU	Decreasing	Low	I	Pelecanidae	Krauskopfpelikan	Pélican frisé	Pelicano ceñudo
70	Aves	Dark-rumped Petrel, Galapagos Petrel, Galápagos petrel	<i>Pterodroma phaeopygia</i>	intraoceanic	-		CR	Decreasing	Medium	I	Procellariidae	Galapagossturmvogel	Pétrel des HawaÛ	Petrel Hawaiiano
71	Aves	Dark-rumped Petrel, Hawaiian Petrel, Uau	<i>Pterodroma sandwichensis</i>	intraoceanic	-		VU	Decreasing		I	Procellariidae	Hawaiisturmvogel	Pétrel à croupion sombre	Petrel hawaiano
72	Aves	Eastern Imperial Eagle, Asian Imperial Eagle, Imperial Eagle	<i>Aquila heliaca</i>	intercontinental	Raptors MoU		VU	Decreasing	High	I	Accipitridae	Kaiseradler	Aigle impérial	Águila imperial oriental
73	Aves	Egyptian Vulture	<i>Neophron percnopterus</i>	partial	Raptors MoU		EN	Decreasing	High (choose)	I				
74	Aves	Eskimo Curlew	<i>Numenius borealis</i>	intercontinental	-	--	CR	Not provided	--	I	Scolopacidae	Eskimo-Brachvogel	Courlis esquimau	Zarapito boreal
75	Aves	Ferruginous Pochard, Ferruginous Duck	<i>Aythya nyroca</i>	intercontinental	AEWA		NT	Decreasing	Low	I	Anatidae	Moorente	Fuligule nyroca	Porrón pardo
76	Aves	Great bustard	<i>Otis tarda</i>	partial	Great Bustard MoU		VU	Decreasing	High	I	Otididae	Großtrappe	Grande Outarde	Avutarda euroasiática
77	Aves	Greater Spotted Eagle, Spotted Eagle	<i>Aquila clanga</i>	intercontinental	Raptors MoU		VU	Decreasing	Low / Medium	I	Accipitridae	Schelladler	Aigle criard	Águila moteada
78	Aves	Grey-cheeked Parakeet	<i>Brotogeris pyrrhopterus</i>	possibly migratory			EN	Decreasing		I	Psittacidae	Feuerflügelsittich	Toui flamboyant	Catita macarena
79	Aves	Henderson Petrel	<i>Pterodroma atrata</i>	NON PROVIDED	-		EN	Decreasing	2	I				

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
80	Aves	Hooded Crane	<i>Grus monacha</i>	intracontinental	-		VU	Decreasing		I	Gruidae	Mönchskranich	Grue moine	Grulla capachina
81	Aves	Houbara Bustard	<i>Chlamydotis undulata</i>	partial	-		VU	Decreasing	Low	I	Otididae	Kragentrappe	Outarde houbara	Avutarda hubara
82	Aves	Humboldt Penguin	<i>Spheniscus humboldti</i>	intraoceanic	-	X	VU	Decreasing		I	Spheniscidae	Humboldtpinguin	Manchot de Humboldt	Pingüino de Humboldt
83	Aves	Japanese Murrelet, Crested Murrelet	<i>Synthliboramphus wumizusume</i>	intracontinental	-		VU	Decreasing		I	Alcidae	Japanalk	Guillemot du Japon	Mérgulo japonés
84	Aves	Japanese Night Heron	<i>Gorsachius goisagi</i>	intracontinental	-		EN	Decreasing		I	Ardeidae	Rotscheitelreiher	Bihoreau goisagi	Martinete japonés
85	Aves	Kirtland's Warbler	<i>Dendroica kirtlandii</i>	intercontinental	-		NT	Increasing		I	Parulidae	Kirtlands Waldsänger	Paruline de Kirtland	Silbador de Kirtland
86	Aves	Lesser Kestrel	<i>Falco naumanni</i>	intercontinental	Raptors MoU		VU	Decreasing	High	I	Falconidae	Rötelfalke	Faucon crécerellette	Cernícalo primilla
87	Aves	Lesser White-fronted Goose	<i>Anser erythropus</i>	intercontinental	AEWA, Action Plan		VU	Decreasing	Low	I	Anatidae	Zwerggans	Oie naine	Ánsar chico
88	Aves	Madagascar Pond-heron	<i>Ardeola idae</i>	intracontinental	AEWA		EN	Decreasing	Low	I				
89	Aves	Manchurian Crane, Japanese Crane, Red-crowned crane	<i>Grus japonensis</i>	intracontinental	-		EN	Decreasing		I	Gruidae	Mandschurenkranich	Grue du Japon	Grulla de Manchuria
90	Aves	Marbled Teal	<i>Marmaronetta angustirostris</i>	partial	AEWA		VU	Decreasing	Low	I	Anatidae	Marmelente	Marmaronette marbrée	Cerceta pardilla
91	Aves	Marsh Seedeater	<i>Sporophila palustris</i>	intracontinental	-		EN	Decreasing		I	Emberizidae		Sporophile des marais	Capuchino pecho blanco
92	Aves	Olog's Gull	<i>Larus atlanticus</i>	range extension	-		VU	Decreasing		I	Laridae	Ologmöwe	Goéland d'Olog	Gaviota de Olog
93	Aves	Oriental White Stork	<i>Ciconia boyciana</i>	intracontinental	-		EN	Decreasing	Low	I	Ciconiidae	Schwarzschnabelstorch	Cigogne orientale	Cigüeña oriental

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
94	Aves	Pallas Fish Eagle, Pallas's fish-eagle	<i>Haliaeetus leucoryphus</i>	partial	Raptorss MoU	X	VU	Decreasing	--	I	Accipitridae	Bindenseeadler	Pygargue de Pallas	Pigargo de Pallas
95	Aves	Peruvian diving petrel	<i>Pelecanoides garnotii</i>	intraoceanic	-		EN	Decreasing	Medium	I	Pelecanoididae	Garnot-Lummensturmvogel	Puffinure de Garnot	Potoyunco peruano
96	Aves	Peruvian Tern	<i>Sterna lorata</i>	data deficient	-		EN	Decreasing		I				
97	Aves	Pink-footed Shearwater	<i>Puffinus creatopus</i>	interoceanic	-		VU	Unknown		I	Procellariidae	Rosafuß-Sturmtaucher	Puffin à pieds roses	Pardela patirrosa
98	Aves	Puna Flamingo	<i>Phoenicopterus jamesii</i>	intracontinental	High Andean Flamingo MoU	X	NT	Decreasing	--	I	Phoenicopteridae	Jamesflamingo	Flamant de James	Parina chica
99	Aves	Red Knot (Rufa)	<i>Calidris canutus (rufa)</i>	intercontinental	AEWA		LC	Not provided	Low	I				
100	Aves	Red-breasted Goose	<i>Branta ruficollis</i>	intercontinental	AEWA	X	EN	Decreasing	--	I	Anatidae	Rothalsgans	Bernache à cou roux	Barnacla cuelliroja
101	Aves	Relict Gull	<i>Larus relictus</i>	intracontinental	-	X	VU	Decreasing	--	I	Laridae	Gobi-Schwarzkopfmöwe	Mouette relique	Gaviota de Mongolia
102	Aves	Ruddy-headed Goose	<i>Chloephaga rubidiceps</i>	partial	Ruddy-headed goose MoU		LC	Not provided	High	I	Anatidae	Rotkopfgans	Ouette à tête rousse	Cauquén cabeza colorada
103	Aves	Rufous-rumped Seedeater	<i>Sporophila hypochroma</i>	migrantory	-		NT	Decreasing		I	Emberizidae		Sporophile à croupion roux	Capuchino castaño
104	Aves	Saffron-cowled Blackbird	<i>Agelaius flavus</i>	migrant	-		VU	Decreasing		I	Icteridae	Gelbhaubenstärting	Carouge safran	Tordo amarillo
105	Aves	Saunders's Gull, Chinese Blackheaded Gull	<i>Larus saundersi</i>	local migrant	-		VU	Decreasing		I	Laridae	Kappenmöwe	Mouette de Saunders	Gaviota de Saunders
106	Aves	Short-tailed Albatross, Steller's Albatross	<i>Diomedea albatrus</i>	interoceanic	ACAP	X	VU	increasing	--	I	Diomedidae	Kurzschwanzalbatros	Albatros à queue courte	Albatros colicorto
107	Aves	Siberian Crane	<i>Grus leucogeranus</i>	intracontinental	AEWA, Siberian crane MoU	X	CR	Decreasing	--	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	<i>Numenius tenuirostris</i>	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)	<i>Vanellus gregarius</i>	intercontinental	AEWA	X	CR	Decreasing	--	I	Charadriidae	Steppenkiebitz	Vanneau sociable	Avefría sociable
110	Aves	Spanish Imperial Eagle, Adalbert's Eagle, Spanish Eagle	<i>Aquila adalberti</i>	partial	Raptors MoU		VU	Increasing	Low	I	Accipitridae	Spanischer Kaiseradler	Aigle ibérique	Águila imperial ibérica
111	Aves	Spoon-billed Sandpiper	<i>Eurynorhynchus pygmeus</i>	intracontinental	-		CR	Decreasing	Low	I	Scolopacidae	Löffelstrandläufer	Bécasseau spatule	Correlimos cuchareta
112	Aves	Spotted Greenshank, Nordmann's Greenshank	<i>Tringa guttifer</i>	intracontinental	-		EN	Decreasing	High	I	Scolopacidae	Tüpfelgrünschenkel	Chevalier tacheté	Archibebe motaedo
113	Aves	Steller's Eider	<i>Polysticta stelleri</i>	intercontinental	AEWA	X	VU	Decreasing	--	I	Anatidae	Scheckente	Eider de Steller	Eider menor
114	Aves	Steller's Sea-eagle	<i>Haliaeetus pelagicus</i>	intracontinental	Raptors MoU		VU	Decreasing	Medium	I	Accipitridae	Riesenseeadler	Pygargue empereur	Pigargo gigante
115	Aves	Strange-tailed Tyrant	<i>Alectrurus risora</i>	intracontinental	-		VU	Decreasing		I	Tyrannidae		Moucherolle à queue large	Yetapá de collar
116	Aves	Streaked Reed-warbler	<i>Acrocephalus sorghophilus</i>	intracontinental	-		VU	Decreasing		I				
117	Aves	Swan Goose	<i>Anser cygnoides</i>	intracontinental	-	X	VU	Decreasing	--	I	Anatidae	Schwanengans	Oie cygnoïde	Ánsar ciscal
118	Aves	Syrian Serin	<i>Serinus syriacus</i>	range extension	-		VU	Decreasing	High	I	Fringillidae	Zederngirlitz	Serin syriaque	Serín de Siria
119	Aves	Waldrapp, Hermit Ibis, Northern Bald Ibis	<i>Geronticus eremita</i>	partial	AEWA		CR	Decreasing	Low	I	Threskiornithidae	Waldrapp	Ibis chauve	Ibis eremita
120	Aves	White Pelican, Great White Pelican	<i>Pelecanus onocrotalus</i>	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	<i>Larus leucophthalmus</i>	range extension	AEWA		NT	Stable	Low	I	Laridae	Weißaugenmöwe	Goéland à iris blanc	Gaviota de Adén piquirroja
122	Aves	White-headed Duck	<i>Oxyura leucocephala</i>	partial	AEWA		EN	Decreasing	Low	I	Anatidae	Weißkopfruderente	Érismature à tête blanche	Malvasia
123	Aves	White-naped Crane	<i>Grus vipio</i>	intracontinental	-	X	VU	Decreasing	--	I	Gruidae	Weißsnacken-Kranich	Grue à cou blanc	Grulla de cuello blanco
124	Aves	White-tailed eagle; Grey Sea Eagle	<i>Haliaeetus albicilla</i>	partial	Raptors MoU	X	LC	Not listed	--	I	Accipitridae	Seeadler	Pygargue à queue blanche	Pigargo europeo
125	Aves	Whitewinged Flufftail	<i>Sarothrura ayresi</i>	intracontinental	AEWA		EN	Decreasing	Low	I	Rallidae	Spiegelralle	Râte à miroir	Polluela especulada
126	Aves	Zelich's Seedeater	<i>Sporophila zelichi</i>	possibly migratory	-		CR	Decreasing		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 these** 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 than 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 rationale 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:						
<p>Resilience to change</p> <ul style="list-style-type: none"> >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?
<p>Further Information</p> <ul style="list-style-type: none"> ▪ 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.

<p>Dispersability</p>	<p>High ability to disperse to new areas and shift migration patterns. No natural barriers to migration to new or more suitable range/habitats.</p>	<p>Some ability to disperse to new areas and shift migration patterns. Minimal natural barriers to migration to new or more suitable range/habitats.</p>	<p>Moderate ability to disperse to new areas and shift migration patterns. Some natural barriers to migration to new or more suitable range/habitats.</p>	<p>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.</p>	<p>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.</p>	<p>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?</p>
<p>Reproduction rate and resilience: Climate related changes to fecundity or reproductive success</p>	<p>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.</p>	<p>Good reproduction and little climate-related reduction of fecundity or reproductive success expected. Displays reproductive resilience to potential climate change impacts.</p>	<p>Average reproduction rate. Some climate-related reduction of fecundity or reproductive success expected. Non optimal environmental tolerances experienced with some impacts on reproductive success.</p>	<p>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.</p>	<p>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.</p>	<p>The biological aspects of dispersability should be considered. Are specific metapopulations at greater risk?</p>
<p>Further Information</p> <ul style="list-style-type: none"> ▪ 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) 						

<ul style="list-style-type: none"> ▪ 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 foodweb 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 foodweb 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 mutualisms important, as is the relative reliance upon those mutualisms
Further Information <ul style="list-style-type: none"> ▪ 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 <ul style="list-style-type: none"> ▪ 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 than 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 effective 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 CO₂ threshold past which this species will not survive? If a reference to a specific threshold exists, this is an 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 than 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 the 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 provided 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?

<p>Evidence of adaptation in the past</p>	<p>Evidence of rapid migration and adaptation response to climatic changes in the recent past. Culturally driven migration rather than genetically driven migration.</p>	<p>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.</p>	<p>Some migration and adaptation response to climatic changes in the past.</p>	<p>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.</p>	<p>No evidence of migration or adaptation response to climatic changes. Genetically driven migration rather than culturally driven migration.</p>	<p>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.</p>
<p>Dispersability</p>	<p>High ability to disperse to new areas and shift migration patterns. No natural barriers to migration to new or more suitable range/habitats.</p>	<p>Some ability to disperse to new areas and shift migration patterns. Minimal natural barriers to migration to new or more suitable range/habitats.</p>	<p>Moderate ability to disperse to new areas and shift migration patterns. Some natural barriers to migration to new or more suitable range/habitats.</p>	<p>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.</p>	<p>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.</p>	<p>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?</p>
<p>Reproduction rate and resilience: Climate related changes to fecundity or reproductive success</p>	<p>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.</p>	<p>Good reproduction and little climate-related reduction of fecundity or reproductive success expected. Displays reproductive resilience to potential climate change impacts.</p>	<p>Average reproduction rate. Some climate-related reduction of fecundity or reproductive success expected. Non optimal environmental tolerances experienced with some impacts on reproductive success.</p>	<p>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.</p>	<p>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.</p>	<p>The biological aspects of dispersability should be considered. Are specific metapopulations at greater risk?</p>

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 foodweb 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 foodweb 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 mutualisms important, as is the relative reliance upon those mutualisms
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 rationale 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 Gaviel	<i>Gavialis gangeticus</i>	potamodromous	-	CR	Decreasing	I	Gavialidae	Ganges-Gaviel	Gaviel du Gange	Gaviel del Ganges
2	Reptilia	Green Turtle	<i>Chelonia mydas</i>	interoceanic	IOSEA MoU	EN	Decreasing	I	Cheloniidae	Pazifische Suppenschildkröte	Tortue verte	Tortuga verde
3	Reptilia	Hawksbill Turtle	<i>Eretmochelys imbricata</i>	intraoceanic	IOSEA MoU	CR	Decreasing	I	Cheloniidae	Echte Karettschildkröte	Tortue imbriquée	Tortuga carey
4	Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	<i>Lepidochelys kempii</i>	intraoceanic	IOSEA MoU	CR	Not provided	I	Cheloniidae	Atlantische Bastardschildkröte	Tortue de Ridley	Tortuga lora
5	Reptilia	Leatherback Turtle,	<i>Dermochelys coriacea</i>	interoceanic	IOSEA MoU	CR	Decreasing	I	Dermochelyidae	Lederschildkröte	Tortue luth	Tortuga laud
6	Reptilia	Loggerhead Turtle	<i>Caretta caretta</i>	interoceanic	IOSEA MoU	EN	Not provided	I	Cheloniidae	Unechte Karettschildkröte	Caouanne	Tortuga boba
7	Reptilia	Olive Ridley	<i>Lepidochelys olivacea</i>	intraoceanic	IOSEA MoU	VU	Decreasing	I	Cheloniidae	Bastardschildkröte	Tortue batarde	Tortuga olivacea
8	Pisces	Basking Shark	<i>Cetorhinus maximus</i>	oceanodromous	Sharks MoU	VU	Decreasing	I				
9	Pisces	Common Sturgeon	<i>Acipenser sturio</i>	anadromous	-	CR	Decreasing	I				
10	Pisces	Giant Catfish	<i>Pangasius gigas</i>	potamodromous	-	CR	Decreasing	I	Pangasiidae	Riesenwels	Silure de verre géant	Siluro gigante
11	Pisces	Great White Shark, White Shark	<i>Carcharodon carcharias</i>	oceanodromous	Sharks MoU	VU	Unknown	I	Lamnidae	Weißer Hai	Mangeur d'hommes	Tiburón antropófago
12	Mammalia	Addax	<i>Addax nasomaculatus</i>	intracontinental	Sahelo-Saharan Antelope Action Plan	CR	Decreasing	I	Bovidae	Mendesantilope	Addax à nez tacheté	Adax
13	Mammalia	Blue Whale	<i>Balaenoptera musculus</i>	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	<i>Balaena mysticetus</i>	interoceanic	-	LC	Increasing	I	Balaenidae	Grönlandwal	Baleine du Groenland	Ballena de Groenlandia
15	Mammalia	Cuvier's Gazelle	<i>Gazella cuvieri</i>	data deficient	Sahelo-Saharan Antelope Action Plan	EN	Unknown	I	Bovidae	Atlasgazelle	Gazelle de Cuvier	Gacela de Cuvier
16	Mammalia	Dama Gazelle	<i>Gazella dama</i>	intracontinental	Sahelo-Saharan Antelope Action Plan	CR	Decreasing	I	Bovidae	Damagazelle	Gazelle dama	Gacela dama
17	Mammalia	Humpback Whale	<i>Megaptera novaeangliae</i>	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	LC	Increasing	I	Balaenopteridae	Buckelwal	Mégaptère	Yubarta
18	Mammalia	Marine Otter	<i>Lontra felina</i>	technical migrant	-	EN	Decreasing	I	Mustelidae	Meerotter	Loutre de mer	Chungungo
19	Mammalia	Mexican Free-tailed Bat, Brazilian free-tailed bat	<i>Tadarida brasiliensis</i>	intercontinental	-	LC	Stable	I	Molossidae	Brasilianische Bulldogfledermaus	Chauve-souris à queue-libre du Mexique	Rabudo mejicano
20	Mammalia	NARWHAL	<i>Monodon monoceros</i>	intraoceanic	-	NT	Unknown	II				
21	Mammalia	North Pacific Right Whale	<i>Eubalaena japonica</i>	interoceanic	-	EN	Unknown	I				
22	Mammalia	Northern Atlantic Right Whale, Biscayan Right Whale	<i>Eubalaena glacialis</i>	interoceanic	-	EN	Unknown	I	Balaenidae	Nordkaper	Baleine de Biscaye	Ballena franca
23	Mammalia	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	<i>Balaenoptera borealis</i>	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	<i>Delphinus delphis</i>	intraoceanic	ACCOBAMS, ASCOBANS, Pacific Island Cetaceans MoU, West African Aquatic Mammal MoU	LC	Unknown	I				
25	Mammalia	Snow Leopard	<i>Uncia uncia</i>	nomadising	-	EN	Decreasing	I	Felidae	Schneeleopard	Panthere des neiges	Pantera de las nieves
26	Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	interoceanic	-	LC	Increasing	I	Balaenidae	Südkaper	Baleine australe	Ballena franca austral
27	Mammalia	Sperm Whale	<i>Physeter macrocephalus</i>	interoceanic	ACCOBAMS, Pacific Island Cetaceans MoU	VU	Unknown	I	Physeteridae	Pottwal	Cachalot	Ballena esperma
28	Mammalia	West African Manatee	<i>Trichechus senegalensis</i>	intracontinental	West African Aquatic Mammal MoU	VU	Unknown	I				
29	Aves	Andean Flamingo	<i>Phoenicopterus andinus</i>	intracontinental	High Andean Flamingo MoU	VU	Decreasing	I	Phoenicopteridae	Andenflamingo	Flamant des Andes	Parina grande
30	Aves	Aquatic Warbler	<i>Acrocephalus paludicola</i>	intercontinental	Aquatic warbler MoU	VU	Decreasing	I	Muscicapidae	Seggenrohrsänger	Phragmite aquatique	Carricerin
31	Aves	Balearic Shearwater	<i>Puffinus mauretanicus</i>	interoceanic	-	CR	Decreasing	I				
32	Aves	Basra Reed-warbler	<i>Acrocephalus griseldis</i>	intercontinental	-	EN	Decreasing	I				
33	Aves	Bermuda Petrel	<i>Pterodroma cahow</i>	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	<i>Platalea minor</i>	intracontinental	-	EN	Decreasing	I	Threskiornithidae	Schwarzgesichtlöffler	Petite Spatule	Espátula menor
35	Aves	Humboldt Penguin	<i>Spheniscus humboldti</i>	intraoceanic	-	VU	Decreasing	I	Spheniscidae	Humboldtpinguin	Manchot de Humboldt	Pingüino de Humboldt
36	Aves	Pallas Fish Eagle, Pallas's fish-eagle	<i>Haliaeetus leucoryphus</i>	partial	Raptorss MoU	VU	Decreasing	I	Accipitridae	Bindenseeadler	Pygargue de Pallas	Pigargo de Pallas
37	Aves	Puna Flamingo	<i>Phoenicopterus jamesii</i>	intracontinental	High Andean Flamingo MoU	NT	Decreasing	I	Phoenicopteridae	Jamesflamingo	Flamant de James	Parina chica
38	Aves	Red-breasted Goose	<i>Branta ruficollis</i>	intercontinental	AEWA	EN	Decreasing	I	Anatidae	Rothalsgans	Bernache à cou roux	Barnacla cuelliroja
39	Aves	Relict Gull	<i>Larus relictus</i>	intracontinental	-	VU	Decreasing	I	Laridae	Gobi-Schwarzkopfmöwe	Mouette relique	Gaviota de Mongolia
40	Aves	Short-tailed Albatross, Steller's Albatross	<i>Diomedea albatrus</i>	interoceanic	ACAP	VU	increasing	I	Diomedidae	Kurzschwanzalbatros	Albatros à queue courte	Albatros colicorto
41	Aves	Siberian Crane	<i>Grus leucogeranus</i>	intracontinental	AEWA, Siberian crane MoU	CR	Decreasing	I	Gruidae	Schneekranich	Grue de Sibérie	Grulla siberiana
42	Aves	Sociable Plover, Sociable Lapwing	<i>Vanellus gregarius</i>	intercontinental	AEWA	CR	Decreasing	I	Charadriidae	Steppenkiebitz	Vanneau sociable	Avefría sociable
43	Aves	Steller's Eider	<i>Polysticta stelleri</i>	intercontinental	AEWA	VU	Decreasing	I	Anatidae	Scheckente	Eider de Steller	Eider menor
44	Aves	Swan Goose	<i>Anser cygnoides</i>	intracontinental	-	VU	Decreasing	I	Anatidae	Schwanengans	Oie cygnoïde	Ánsar ciscal
45	Aves	White-naped Crane	<i>Grus vipio</i>	intracontinental	-	VU	Decreasing	I	Gruidae	Weißnacken-Kranich	Grue à cou blanc	Grulla de cuello 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)

7.3. Case Study Assessment Results

7.3.1. REPTILES

Climate Change Vulnerability of Migratory Species						  		
Species Assessment								
Indian Gharial, <i>Gavialis gangeticus</i>								
Impacting factor	Severity of impacting factor					Conclusion	Overall Score	
	1	2	3	4	5			
Vulnerability of habitat/s	<p>Gharials are adapted to an aquatic lifestyle in the calmer areas of deep, fast-moving rivers - Ganges, San and other rivers of North India (Choudhury et al., 2007). Sandbanks on these rivers are exposed seasonally, sometimes in different areas as the banks are moulded by the river over time. The highest concentrations of where Gharials are found are areas where there is favourable habitat present - sites where water is over 2m deep adjoining wide sand beaches or where rivers form large bends with pools of deep calm water inhabited by the gharial's prey (Ballouard & Cadi, 2005). They generally only leave the water to bask and nest, both of which usually occur on sandbanks. Mating occurs during January and February and nesting from March to May which corresponds to the dry, low water season. They use sandy banks to excavate nest chambers above the flood line - Indian Gharial nest in seasonally exposed sandbanks along slow moving sections of large to medium sized rivers (Whitaker, 2007). The major threat to the Gharial habitat is to the inundation of breeding sites on sandbanks by rising flood lines from increased precipitation during monsoon – however monsoon season in India is after June and the Gharials nest from March to May corresponding with the low dry season. It is unlikely that climate change will have any significant impact on this species; it may possibly push their nesting time earlier if monsoon season is extended or they may be a threat with inundation from rising sea levels or changes in river course but this is unlikely to be a major factor. However, some studies have shown that monsoons are a cause of high mortality in Gharial populations (Ballouard & Cadi, 2005); therefore if the monsoon season was to alter in its timing to correspond with nesting periods, this could be very dangerous for this species.</p>					<p>The threat to this species from climate change is uncertain due to the lack of confidence in river flow predictions from the GCMs. Sandbanks may become less available for nesting and basking if flood lines increase by increased precipitation, sea level rise and glacial melt. Once the glaciers have melted river flows will be greatly reduced.</p>		3

	<p>The projected intensity of the Indian subcontinent monsoon is poorly simulated by many models (Christensen et al., 2007).</p> <p>Because gharials only come onto sandbanks to bask and nest, increasing water levels may reduce the area of protected sandbanks available and push them closer to human contact. The Narayani and Rapti rivers in Nepal are fed by the Himalayas and local rainfall respectively and therefore depend on the climate of the Himalayas (Ballouard & Cadi 2005). It is posited that the accelerated melting of glaciers will cause an increase in river levels over the next few decades, initially leading to higher incidence of flooding and land-slides (IPCC, 2001a). But, in the longer-term, as the volume of ice available for melting diminishes, a reduction in glacial runoff and river flows can be expected (Chamling, 2005). The mean temperature increases for the period 2071 to 2100 relative to the period 1961 to 1990 is about 4°C for SRES A2 and about 3°C for SRES B2. The projected change above the baseline average is 1.2°C for 2030, 1.7°C for 2050 and 3.0°C for 2100. This analysis also agrees with the IPCC analysis on the projection of precipitation change i.e. less significant change and high standard deviation among the model results, and precipitation may increase by up to 12% (Chamling, 2005). The effect of climate change on stream flow varies regionally and between climate scenarios, largely following projected changes in precipitation. In South Asia, HadCM3 shows increase in annual runoff ranging from 0 to 150 mm/yr by the year 2050, relative to average runoff for the period 1961-1990, while the older version HadCM2 projects show a decrease of up to 250 mm/yr. These climate models are unable to highlight the details on seasonal variations in runoff, although it is generally suggested that due to higher evaporation and decrease in glacier mass, the low flows are likely to decrease (IPCC, 2001a). Drought periods may reduce water levels and restrict Gharials to areas where river flow and depth is adequate, exposing Gharials to humans, pollutants will be less diluted and salinity may increase with increasing sea levels.</p>		
<p>Ecological flexibility</p>	<p>Specialisation: The Indian Gharial is found only in the north of the Indian subcontinent. Historically its range extended from the Indus River (Pakistan) in the west to the Irrawaddy (Myanmar) in the east. It is now limited to just 8 fragmented subpopulations in India and Nepal (Choudhury et al 2007), occupying just 2% of its previous range (Whitaker 2007). There are only a handful of breeding populations remaining, the largest of which is found in the Chambal River in India (Choudhury et al 2007). A few non-breeding populations are also scattered through India and Nepal (Britton 2009).</p> <p>The Indian Gharial is well adapted to its deepwater habitat in large, fast flowing</p>	<p>The Indian Gharial has a fairly generalist diet but its range and habitat requirements are much more specialised, particularly for nesting. It is a large species which can take over 10 years to reach sexual maturity, but subsequently can reproduce annually.</p>	<p>4</p>

rivers (Britton 2009). It favours slower flowing areas where the current is reduced, for example on bends (Ross 1998). This is a highly aquatic species (IRCF), its morphology providing great manoeuvrability in the water (Whitaker 2007). It is not very mobile on land (Whitaker & Basu 1982), but must leave the water to bask and nest on sandbanks (Britton 2009). All crocodylians must maintain their body temperature within narrow limits by basking in the sun or seeking shade (Ross 1998). Gharials use seasonally exposed sandbanks along the river for nesting (Choudhury et al 2007). Nests are traditionally laid on the same beaches year after year (Choudhury et al 2007) but there are records of artificially created banks being used successfully (IRFC). There are a number of wild populations that are thought to be non-breeding, illustrating its high degree of specialisation.

Juvenile Gharials feed on a variety of invertebrate organisms, mostly insects, but may also take other prey items such as small frogs (Britton 2009). As they reach adulthood their diet becomes almost exclusively fish (Britton 2009). They are very effective ambush predators (Ross 1998) with specialised jaw and teeth morphology (Britton 2009). Although their diet is fairly generalist, their specific and highly seasonal habitat requirements mean Gharials are threatened by the impacts of climate change.

Evidence of adaptation in the past: No information available

Reproductive rate: One of the largest species of crocodylians, the Gharial must grow to a considerable size before becoming sexually mature. Some estimates of female maturity suggest around 7 years of age (Whitaker 2007), whereas others indicate over 10 years (Britton 2009). It is thought that males must grow to around 4m before maturing which may take 15-18 years (Whitaker 2007). Gharials congregate during the dry season when males guard territory in which several females live (Whitaker 2007). Mating occurs between November and January and nesting from March to May (Britton 2009). Unlike other crocodylians, Gharials in captivity reproduce every year (Choudhury et al 2007). It has been said that this high reproductive frequency may compensate for a relatively low reproductive investment per nesting (Thorbjarnarson 1996). Females typically lay 20-50 eggs (Ross 1998, Hussain 1999, Britton 2009) in a hole in the sandbank, dug 1-5m from the waterline (Whitaker & Basu 1982). Incubation lasts 2-3 months depending on temperature (GCA 2008), and significant deviation from optimum (30-34°C) can lead to defects or death of embryos (GCA 2008). Females protect young around the nest area for some time after hatching (Britton 2009), but hatchling mortality can be extremely high – over 90% in the first year (Hussain 1999). Predation and

	<p>raising waters during the monsoon are significant causes of mortality (GCA 2008). Although the Gharial reproduces every year and has a fairly high reproductive rate, its late maturity and high juvenile mortality mean its populations are not very resilient.</p> <p>Dispersal: The Gharial is a strong, powerful swimmer, well adapted to moving in the aquatic environment (Whitaker 2007). There is, however, little information on the distances covered by Gharials. On land it is unable to stand, moving short distances by sliding on its belly (Whitaker & Basu 1982).</p> <p>Climate related changes to fecundity: Like all crocodilians the Indian Gharial exhibits temperature dependent sex determination (TSD). Studies in other crocodilian species have shown slow development of eggs (below 31°C) produces females, constant incubation at 32°C produces males, and above 33°C reverts back to producing females (GCA 2008). However, in the Australian freshwater crocodile all constant incubation temperature produce females and gradually increasing temperatures tend to produce males (GCA 2008). The critical temperatures for sex determination in the Gharial is not known, but as in other reptile species, global warming is likely to have a profound impact on offspring sex ratios (Janzen 1994). 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 (IPCC2007). A rapid evolutionary response would be necessary for species to ‘catch up’ (Hulin et al 2008). A number of responses are possible:</p> <ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in some groups in the past (Janzen and Krenz 2004), but is unlikely to be possible in a short space of time. - Displacement of the pivotal temperatures. - Females altering nesting behaviour. Nesting sites with slightly different characteristics could be selected. - Phenological shifts of the breeding season, although it is likely that this would be limited to the dry season. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>		
<p>Changing dynamics of species interactions</p>	<p>Young gharials eat insects, larvae, tadpoles, small fish and small frogs (Piper, 2007). As they grow older and their snout becomes thinner and longer, they feed almost solely on fish. Their snout morphology is perfectly adapted for a piscivorous diet; their long, narrow jaws offer very little resistance to water when they use quick swiping motions to snap up fish. Their many needle-like teeth are ideal for</p>	<p>While juvenile Gharials feed on a range of small aquatic or semi-aquatic animals, adult Gharial feed predominantly on fish, for which they are</p>	<p>3</p>

	<p>keeping hold of their struggling, slippery prey (Piper, 2007). Gharial snouts are primarily adapted for eating fish, and are too thin and delicate to grab larger prey.</p> <p>Climate change is expected to have many effects on freshwater ecosystems, for example decreased dissolved oxygen levels, increased toxicity of pollutants, and increased water temperatures (Ficke, Myrick & Hansen, 2007). In lotic systems, increased groundwater temperatures and changed hydrologic regimes may affect habitat quality for fishes. In lentic systems, eutrophication may increase in severity or could be offset, and stratification is likely to become much stronger. This could change habitat quality and availability, resulting in disrupted food webs. Fish physiology is intricately linked to temperature, and fish are adapted to cope with specific habitat niches and hydrologic regimes. Therefore, their physiology and life histories will be affected by any changes caused by climate change. Fish communities will be affected as range shifts will likely occur on a species level, (rather than at a community level), and this will add new biotic pressures to freshwater communities (Ficke, Myrick & Hansen (2007)).</p> <p>The Gharial, <i>Gavialis gangeticus</i>, the saltwater crocodile, <i>Crocodylus porosus</i>, and the mugger or marsh crocodile, <i>C. palustris</i> may all be found together in the same habitat. Gharial may compete with these crocodilians for resources, such as prey and nesting areas. Climate change is likely to have negative impacts on these reptile competitors, as changing temperatures will have similar effects on all three species (e.g. impacts on fecundity due to temperature dependent sex determination, decrease in suitable nesting habitat etc).</p> <p>Monitor lizards, mongooses and jackals are known to eat Gharial eggs (WWF). However, it is unclear what affects climate change will have on these predators.</p>	<p>specially adapted. Fish and other freshwater organisms are likely to be negatively affected by climate change, potentially leading to disruption of the food web. The gharials crocodilian competitors are also likely to be negatively affected by climate change. It is unclear how predators of eggs and hatchlings will be affected.</p>	
<p>Interactions with other processes</p>	<p>The Indian gharial faces severe threats of extinction. Its status has been changed from endangered to critically endangered (IUCN, 2009). Its current population has declined by 58% from 436 breeding adults in 1997 to about 182 in 2006 (Rao et al, 1995). The main threat to the Indian Gharial comes from its habitat degradation resulting from intense anthropogenic activities. Construction of dams, irrigation projects, human encroachment, sand mining and artificial embankments have all encroached on its habitat, reducing its domain to just 2% of its former range (Rao et al, 1995). Fishing and hunting activities have also been responsible for the decline of its population numbers alongside pollution which was responsible for contraction of adult populations in 2008 (IUCN, 2009). Another important reason asserted for the critical decline in the numbers of the Indian gharial is the practice of illegal fishing and trade among locals for its skin,</p>	<p>Water level rise due to climate change could push Gharials closer to human contact. As fish populations are impacted by climate change anthropogenic competition for this important source of food for Gharials could increase. Predicted increases in drought event frequencies could increase exposure to higher levels of pollutants impacting</p>	<p>5</p>

	<p>egg, meat and bio medicinal purposes and for trophies (Rao et al, 1995; Whitaker, 2007). Gharials often get caught in fishing nets, their long slender snouts entangled which makes them difficult to breathe and may drown. Others die of starvation as they are unable to disentangle themselves from the fishing nets. Expansion of the riverbank area for agricultural purposes throughout the gharial range has also resulted in habitat degradation. This has pushed the riverbank area as well as the nesting and basking areas of the gharial. Sometimes gharials die as they are caught and killed in long lines of hooks set for turtle poaching or in noose traps designed to catch ducks (IRCF, 2001). Overfishing also threatens the survival of the gharial as they are deprived of adequate prey base. Contrarily, gharials are sometimes held responsible for the diminishing fish populations and therefore subjected to retribution killing by fishermen as they are considered a threat to their livelihoods. Post mortem reports from the Environmental News Network revealed that the gharials were severely affected by a form of self-debilitating gout at the National Chambal Sanctuary (The Indian, 2008). Early results showed the presence of heavy metals –lead and cadmium leading to immune-suppression or reduction the body’s ability to fight pathogens and thereby making their body susceptible to infections (The Indian, 2008). Recent threat to the species is a widespread mortality due to gout. Since 2007 over 110 gharials have succumbed to gout. This may be caused by the introduction of Tilapia into the Yamuna river. It is believed that these fish carry a toxin that effects gharials, but the composition of the toxin and how it enters the river is still being researched (Animal Diversity Web 2008).</p>	<p>on the health of Gharials.</p>	
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Green Turtle, *Chelonia mydas*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Habitats include warm open sandy beaches for nest sites, juveniles to migrating adults occur in oceanic and pelagic zone and forage in neritic zones (Seminoff et al 2004). Adults of both sexes are presumed to migrate between nesting and foraging habitats along corridors adjacent to coastlines and reefs. Green turtles are particularly vulnerable to climate change as their life history traits are strongly associated with environmental variables and they nest in coastal areas subject to sea level rise and cyclonic activity (Fuentes, 2009). Hurricanes are particularly destructive on their nests due to sand accretion, high rainfall and intense wave action (Hirth, 1997). Rising sea levels will mean beaches for breeding sites where the turtles breed may not exist in the future.</p> <p>Rookery beaches are at risk of becoming too hot and being flooded with sea water or washed away entirely (Howard, 2009). 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 the green turtle.</p> <p>The largest green sea turtle nesting grounds in the world occur in the Great Barrier Reef and the Torres Strait - it is estimated that 38% of available nesting areas across all rookeries used by this population will be inundated as a result of sea level rise which may severely reduce the population of this already threatened species (Fuentes 2009). Impacts of climate change on Australia include; altered atmospheric wind circulation, altered run off, sea level rise, altered nutrient supply and stratification (mixed layer depth), warmer sea temperatures and altered ocean circulation of currents. Increased dissolved CO₂ will also cause ocean acidification. Increased wind intensities may suppress ocean upwelling's, the EAC will strengthen and increase flow southward (Hobday et al 2006). The Florida coast in the USA is also considered a primary nesting area and also face the same threats from sea level rise and storm wave intensities.</p>					<p>Future populations of green turtles are at high risk from sea level rise and increased temperatures as well as changing ocean currents. This together with human influences on nesting beaches makes them highly vulnerable.</p>	5

<p>Ecological flexibility</p>	<p>Specialisation: The Green Turtle is found in tropical and subtropical oceans worldwide (NOAA). They nest on the sandy beaches of islands and continents between 30°N and 30°S (Witherington 2006a), often in huge numbers (Bonin 2004). Different life stages of this species inhabit different environments (Seminoff 2004 IUCN). Little is known of the movements of young Green turtles post hatching, but it is thought they begin an oceanic phase which lasts at least 3-5 years (Zug and Glor 1998). Following this period the turtles move back into neritic waters where they maintain occupy distinct home ranges as they grow to maturity (Makowski 2006). Both female and male adults migrate 1000s of kilometres between temperate feeding grounds and tropical breeding grounds (Seminoff 2004). Females exhibit strong natal homing (Meylan et al 1990) indicating limited flexibility in migratory patterns. Despite regular long distance migrations, Green turtles also exhibit extensive periods of residency and often show high fidelity to specific features in their environment (Witherington 2006a). They have, for example they lodge themselves into corals, sponges, rocky ledges and soft mud close to foraging areas to rest without drifting on the current (Witherington 2006a). These specialised habitats may not be maintained in a changing environment.</p> <p>Juvenile Green turtles are likely to remain near the water surface during their pelagic dispersal period, drifting on currents and feeding on a variety of plant and animal material associated with convergence zones (Witherington 2006a). As they mature and return to coastal waters their diet shifts and becomes almost entirely vegetarian. They forage for benthic microalgae and sea grasses, usually in waters less than 10m in depth (Witherington 2006a). They do not graze at random over sea grass meadows, but maintain 'grazing plots' of young leaves by constant re-cropping (Bjorndal 1980). They occasionally ingest small animals such as jellyfish, crustaceans and molluscs (Bonin et al 2006). This is the only species of sea turtle known to bask on sandy beaches during the day, probably to supplement their Vitamin D deficient diet (Garnett 1985). Although Green turtles consume a variety of organisms, sea grass meadows represent the primary food source for the adult stage. This leaves them vulnerable to changes in the distribution and extent of these important ecosystems which are likely to be impacted by climate change. However, it has been suggested that this species is able to utilise alternate oceanic feeding habitats (>200m water depth), and thus respond to disruption (Hatase 2006).</p> <p>Evidence of adaptation in the past: Reproductive rate: Adult females reproduce every 2-4 years (Witherington 2006b), laying 2-5 clutches of 100-150 eggs in one</p>	<p>The Green Turtle is a very specialised species. Although they migrate long distances, they exhibit extensive periods of residency, often showing high fidelity to specific features in their environment. Females also exhibit strong natal homing. Adults feed primarily on sea grass meadows and are thus very dependent on these important ecosystems.</p> <p>This species takes up to 50 years to reach sexual maturity, and females reproduce every 2-4 years once mature. This makes them very vulnerable to threats.</p> <p>As in many reptiles sex determination is temperature dependent, meaning populations may be vulnerable to skewed sex ratios in a changing climate.</p>	<p style="text-align: center;">5</p>
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	<p>season (Witherington 2006a). Age at sexual maturity estimated to be 35-40 years, and even in excess of 50 years in some populations (Balazs and Chaloupka 2004). A reproductive longevity has been estimated at around 20 years but this is not confirmed (NOAA). This extremely slow development makes green turtles very vulnerable to threats from climate change, and limits their ability to adapt.</p> <p>Dispersal: Adult Green turtles are known to travel 1000s of kilometres during breeding migrations, along coastlines and reefs, and possibly spanning the open ocean (Witherington 2006a). Hatchlings are also able to travel great distances, moved by currents during their pelagic phase (Seminoff 2008).</p> <p>Climate related changes to fecundity: Like many other reptiles sea turtles exhibit temperature dependent sex determination (TSD). An incubation temperature of around 29°C produces a 50:50 sex ratio, with lower temperatures resulting in male production, and higher temperatures producing females (Spotila 1987). Global warming is therefore expected to have a profound impact on the offspring sex ratio of turtle populations, with higher temperatures leading to feminization (Janzen 1994). 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 (IPCC2007). A rapid evolutionary response would be necessary for species to 'catch up' (Hulin et al 2008). A number of responses are possible:</p> <ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in the past (Janzen and Krenz 2004), but is unlikely to occur in a short space of time. - Displacement of the pivotal temperature to a higher threshold. - Females altering nesting behaviour. Cooler places on the same beach could be selected, for example under vegetation or near to water (Kamel and Mrosovsky 2005) or females could dig deeper holes to lay in. Alternatively imperfect natal homing may allow nesting beaches to shift to higher latitudes. - Phenological shifts of the breeding season to cooler times of year. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>		
<p>Changing dynamics of species interactions</p>	<p>Adult green turtles are almost exclusively herbivorous, foraging primarily on sea grasses and algae (NOAA Fisheries, 2009). Sea grasses are a vital habitat and source of food for a large number of marine species. However, in recent decades mass mortality of sea grass beds has become increasing widespread with explanations for these losses including increases in sedimentation, turbidity or disease (as cited by Jackson et al. 2001). Deterioration of the sea grass ecosystem is thought to have begun centuries ago with the steady removal of large herbivorous vertebrates such as green turtles (Jackson et al., 2001). Grazing by</p>	<p>Climate change is predicted to affect both the health and distribution of sea grasses (green turtles primary food source).</p>	<p>3</p>

	<p>green turtles increases the productivity and nutrient content of sea grass beds, benefiting the ecosystem (Oceana, 2009). In the absence of grazing, sea grasses grow long, shading the seabed and decompose, encouraging slime moulds that cause turtlegrass wasting disease, a problem that has occurred in Florida Bay (Jackson et al. 2001).</p> <p>Reviews assessing the potential effects of global climate change on the world's sea grasses predict that growth rates of sea grass will be severely affected by temperature stress, sea level rise and changing tidal circulation (Short & Neckles, 1999). The distribution of sea grasses will shift as plants relocate in order to stay within their tolerance zones (Short & Neckles, 1999). A redistribution of existing foraging habitats would consequently affect green turtles and other sea grass-dependant species. Following several years in the oceanic zone, young turtles forage and grow in these coastal areas, upon reaching sexual maturity, they undertake breeding migrations every few years between their feeding grounds and nesting areas (IUCN, 2009).</p> <p>In previous years when green turtles were abundant, it is thought that there would have been considerable intra-specific grazing competition for sea grasses and algae (Meyland, 2006). Bjorndal et al., (2000) has demonstrated that green turtle growth rates are negatively correlated with abundance, suggesting that they do compete for food resources where populations are high.</p> <p>Turtles have the potential to reproduce abundantly, however relatively few turtles survive their first year of life (WWF, 2009). Nests can be lost to natural predators such as mammals, crabs, seabirds and even ants. Nest predation by wild canids is a significant problem for green turtles in Turkey (Brown and Macdonald, 1995). Hatchlings are also vulnerable to predation by mammals, sea birds and crabs as they make their way to the sea. When they reach the shallows, many more hatchlings will be taken by carnivorous fish. Predation continues to be high while turtles are young. As adults, the only significant natural predator to sea turtles are sharks (MarineBio, 2009). In Shark Bay, Australia, green turtles graze in microhabitats in a condition-dependent manner when under threat of predation by tiger sharks. Turtles in a poor body condition choose higher risk but more profitable grazing areas than turtles in a good body condition (Heithaus et al. 2007)</p>		
Interactions with other processes	<p>Anthropogenic practices such as construction work of buildings, beach protection and sand extraction has made the green turtle an extremely vulnerable species. Threats occurring from increased industrial effluents in water is also polluting the</p>	<p>Green turtle species are at high risk due to poaching of turtle eggs and adult and juvenile</p>	5

	<p>habitat of the species. Habitat disturbance also occurs in the presence of boating traffic and pollution from coastal construction leading to changes in the nesting patterns of green turtles. Occasionally, young green turtles are drawn away from the water due to disturbance caused by noise and light sources. Alongside this, green turtles have also become vulnerable due to a certain type of disease occurring among the species known as fibropapillomatosis. Researchers believe that this is mainly caused by the increase in chemicals and toxins within water causing the outbreak of this deadly disease (IUCN Red List 2009). Another major cause of threat is the exploitation of green turtle eggs and adult and juvenile turtles on nesting areas. High mortality rates are also associated with accidental killing in fishing nets, dynamite fishing, shrimp trawling and long lining (IUCN Red List 2009).</p>	<p>turtles for their meat. Increasing sea levels combined with anthropogenic encroachment will greatly limit suitable nesting beaches. Current anthropogenic impacts are so great that they will likely significantly limit Green Turtles resilience to climate change and ability to adapt.</p>	
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Hawksbill turtle, <i>Eretmochelys embricata</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
Vulnerability of habitat/s	1	2	3	4	5	Two of the Hawksbill's most important habitats are predicted to be seriously degraded. Sea level rise is expected to degrade and destroy a number of beaches that the Hawksbill uses for nesting. Whist ocean acidification is likely to seriously damage coral reefs which are very important foraging habitats. Meanwhile, other processes are likely to	5
	<p>At different stages in their life, Hawksbills inhabit the open ocean, various coastal habitats and beaches, through out the tropics and sub-tropics. This means that the effects of climate change on the oceans and coastal areas will affect the habitat of Hawksbill turtles (Mortimer and Donnelly, 2008). Sea level change has the potential to remove a large number of beaches from coastal areas. In fact, a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds (Fischlin et al, 2007). 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 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 number of available habitats</p>						

	<p>where Hawksbills can nest. Climate change will also affect the beaches themselves. Even the beaches that do not become inundated are likely to get hotter as global temperatures rise, changing the nature of the beach habitat. The magnitude of global temperature change is dependent on emissions scenarios; however the warming is likely to be within the range of 1.1-6.4 degrees centigrade (Solomon et al, 2007). 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, to the rates of chemical reactions, which will affect the habitat of the Hawksbill turtle. 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 ocean 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 processes such as species abundance and chemical processes, which will change the Hawksbills habitat. Changes in PH from CO2 dissolving 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 affect the Hawksbill's habitat, for example by altering the structure and diversity of coral reef systems, where they survive (Meehl et al, 2007).</p>	<p>effect the wider ocean, negatively impacting upon other areas which Hawksbills reside in.</p>	
<p>Ecological flexibility</p>	<p>Specialisation: The Hawksbill is considered to be the most tropical of the sea turtles, and is usually restricted to tropical and sub-tropical waters between 300N and 300S (Witzell 1983). It is found in the Pacific, Atlantic and Indian Oceans but usually at low densities (Meylan and Redlow 2006). Like other turtles they are highly migratory and use a wide range of different locations and habitats during their lifetimes (Witzell 1983). Adults migrate long distances between breeding and foraging grounds (Mortimer & Donnelly 2008), and genetic analysis has indicated that females return to their natal tropical sandy beach to reproduce (Bowen and Karl 1997). Post hatching, Hawksbills enter a pelagic development phase of which we know little. It is believed they drift in ocean currents, foraging within surface weed lines (Witherington 2006) before returning to coastal seas sized roughly 20-24cm (Meylan 1988). These juveniles feed on a wide variety of invertebrate animals and algae in shallow neritic waters before specialising on sponges as adults (Witherington 2006). This unusual food type is the primary food source of the adult Hawksbill (Meylan 1988) and strongly influences its distribution, with sponges typically requiring hard substrate for attachment and well aerated waters for nutrition (Meylan and Redlow 2006). This species is thus usually associated with coral reefs where it also finds a number of caves, ledges and crevices in which individuals wedge themselves to rest (Witherington 2006). Between migratory</p>	<p>Adult Hawksbill turtles are primarily specialist spongivores. They are limited to the topical waters, relying heavily on coral reef habitats. Little is known about the ecology of the pelagic developmental stage.</p> <p>They are thought to reach sexual maturity at 20-40 years or age and are often reproductively active for decades. Although they produce multiple clutches of reasonable size, juvenile mortality is high.</p> <p>As in many reptiles sex</p>	<p>4</p>

	<p>movements Hawksbills show high residency, with individuals being observed year after year under the same reef ledge (Witherington 2006). Different populations show differing degrees of specialisation, with Indo-Pacific populations being more omnivorous (Mortimer & Donnelly 2008) and consuming other reef dwellers such as sea cucumbers, molluscs, anemones, sea urchins, crabs and algae (Witherington 2006). Caribbean Hawksbills have been seen to be highly selective foragers, favouring only a few species of sponge (Leon and Bjorndal 2002). The specialist habitat and food requirements of the Hawksbill make it vulnerable to changes in availability and distribution of key marine systems, particularly coral reefs.</p> <p>Reproductive rate: Females breed every 2-4 years (Witherington 2006), producing an average of 5 clutches of 140-170 eggs at two week intervals throughout the season (Richardson 1999). The incubation period is roughly 60 days (Witherington 2006), but this can vary with temperature (Godfrey 1999). It is estimated that Hawksbills reach reproductive maturity between 20 and 40 years (Meylan and Donnelly 1999). Like most sea turtles the species is long lived (Mortimer and Donnelly 2008) and reproductive longevity of up to 20 years has been recorded (Limpus 1992). Based on data from the Caribbean, Richardson et al (1999) estimated an adult female must be allowed to reproduce for at least 9 years to replace herself, and some animals must continue to be reproductively active for decades more to balance the early mortality of other individuals. This leaves Hawksbills demographically vulnerable to a variety of threats.</p> <p>Dispersal: Hawksbills are capable of extensive migrations of 1000s of kilometres (Caribbean Conservation Corporation 2009). Small pelagic juveniles drift on ocean currents but are seldom known to cross entire ocean basins (Witherington 2006). Hawksbills are able to move between disparate areas of reef and also travel long distances to breeding grounds, but are perhaps less mobile than other sea turtle species.</p> <p>Climate related changes to fecundity: Like many other reptiles sea turtles exhibit temperature dependent sex determination (TSD). An incubation temperature of 29.20C produces a 50:50 sex ratio, with lower temperatures resulting in male production, and higher temperatures producing females (Mrosovsky 1992). Global warming is therefore expected to have a profound impact on the offspring sex ratio of turtle populations, with higher temperatures leading to feminization (Janzen 1994). 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 (IPCC2007). A rapid evolutionary response would be necessary for</p>	<p>determination is temperature dependent, meaning populations may be vulnerable to skewed sex ratios in a changing climate.</p>	
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	<p>species to 'catch up' (Hulin et al 2008). A number of responses are possible:</p> <ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in the past (Janzen and Krenz 2004), but is unlikely to be possible in a short space of time. - Displacement of the pivotal temperature to a higher threshold. - Females altering nesting behaviour. Cooler places on the same beach could be selected, for example under vegetation or near to water (Kamel and Mrosovsky 2005) or females could dig deeper holes to lay in. Alternatively imperfect natal homing may allow nesting beaches to shift to higher latitudes. - Phenological shifts of the breeding season to cooler times of year. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>		
<p>Changing dynamics of species interactions</p>	<p>While they are known to be omnivorous, the main food of hawksbill turtles are sponges. Sponges make up 70 – 95% of the diets of <i>E. imbricata</i> populations in the Caribbean. However like many spongivores, <i>E. imbricata</i> feed only on a few specific species, ignoring many others. The Caribbean hawksbill populations were found to feed mainly on sponges from the class Demospongiae, specifically ones belonging to the orders Astrophorida, Spirophorida and Hadromerida (Meylan 1988). Select sponge species known to be eaten by <i>E. imbricata</i> include <i>Geodia gibberosa</i> (Virginia Department of Game & Inland Fisheries, 2009). Aside from sponges, hawksbills also feed on algae and cnidarians such as jellyfish and sea anemones (MarineBio, 2009). Occasionally the hawksbill is also feeds on the dangerous jellyfish-like hydrozoan, the Portuguese Man o' War (<i>Physalia physalis</i>). Some of the sponges eaten by hawksbills, such as <i>Aaptos aaptos</i>, <i>Chondrilla nucula</i>, <i>Tethya actinia</i>, <i>Sphaciospongia vesparium</i> and <i>Suberites domuncula</i>, are highly toxic and often lethal to other organisms. Hawksbills are one of few animals capable of eating siliceous organisms, and are known to choose sponge species that have a significant amount of siliceous spicules, such as <i>Ancorina</i>, <i>Geodia</i>, <i>Ecionemia</i> and <i>Placospongia</i> (Meylan 1988). They also feed on other invertebrates, such as jellyfish and comb jellies (Virginia Department of Game & Inland Fisheries, 2009). Sea sponges appear to be susceptible to the effects of climate change (Webster et al., 2008). Inside the tissues of several sponge species lives a complex community of microbes. Microbes such as cyanobacteria provide food for the sponge through a symbiotic relationship. This symbiotic relationship breaks down at 33°C, therefore these sponges are at risk from higher sea surface temperatures. The temperature threshold is the same as that which corals experience bleaching, which also results from a breakdown in the symbiotic relationship between the host and its microbes. As a high percentage of the Hawksbill turtles diet is made up of sponges,</p>	<p>Sponges are a primary food source for Hawksbill turtles, and may make up to 95% of an animals diet. Sponges will be negatively affected by rising sea surface temperatures, which will impact food availability for <i>E. imbricata</i>. Climate change is expected to effect the distribution of sharks, which are the main predators of adult turtles. This may also impact Hawksbill turtle numbers. There are no known affects of climate change on cleaning symbiosis.</p>	<p>4</p>

	<p>it is likely that rising sea temperatures will negatively affect food availability.</p> <p>Like all turtles, Hawksbill turtles have a hard protective shell to help protect against predators. However, adult turtles are still consumed by humans, sharks, crocodiles, large fish and octopi, although the only significant natural predator of adult sea turtles are sharks. It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution as well (Hearn et al., 2009). Nests and hatchlings are commonly lost as a result of predation by dogs, raccoons, rats, crabs, seabirds, humans and even ants (MarineBio, 2009).</p> <p>It has been documented that there is a cleaning symbiosis between Hawksbill turtles and the shrimp <i>Stenopus hispidus</i> (Sazima et al., 2004), and that Hawksbill</p>		
<p>Interactions with other processes</p>	<p>Hawksbill population is subjected to a lot of exploitation which has made the species critically endangered. Their habitat is subjected to a lot of disturbance caused by tourism activities and construction work in beaches including beach lighting. Beach lights play a negative role in the nesting patterns of turtles. Additionally they are poached for their eggs along with their shells commonly known as 'tortoise shell' used for hair decoration, ornaments and other decorative purposes. Death from incidental capture in fishing nets, shark control program gear, death from ingestion of synthetic material boat strike; predation of eggs and hatchlings; unsustainable indigenous hunting of adults and collection of eggs; hunting of immature adult turtles for tortoiseshell; Flushing of industrial effluents and toxins into marine waters has also led to the increased occurrence of disease among hawksbill turtle.</p>	<p>High level of anthropogenic threats will greatly reduce the Hawksbill turtle's resilience to climate change and ability to adapt.</p>	<p>5</p>
		<p>HIGH VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Kemp's Ridley, *Lepidochelys kempii*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>At different times during their life cycle, Kemp's Ridley Turtles inhabit; the Atlantic Ocean, coastal areas around the Gulf of Mexico and beaches in Mexico and Texas, with the most important habitats being beaches and coastal areas (Collard and Ogren, 1990).</p> <p>Sea level change has the potential to remove a large number of beaches from coastal areas. In fact, a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds (Fischlin et al, 2007). 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 has the potential to greatly reduce the number of available habitats where Kemp's Ridelys can nest.</p> <p>Climate change will also affect the beaches themselves. Even the beaches that do not become inundated are likely to get hotter as global temperatures rise, changing the nature of the beach habitat. Warming around the continental edges of South Eastern North America is likely to be in the range of 2-3 degrees over the next century, thus warming the beaches by about this magnitude (Christensen et al, 2007). From 1961 to 2003, global 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. This will have ramifications on a wide variety of ocean processes, from the ranges of species, to the rates of chemical reactions, which will affect the habitat of juvenile Kemp's Ridley Turtles.</p> <p>Over the majority of North America precipitation is predicted to increase by up to 30% (Christensen et al, 2007). This is likely to increase the sediment flux in rivers such as the Mississippi, which will then deposit more sediment in delta habitats. As</p>					<p>The largest single threat to Kemp's Ridley Turtles is sea level rise. A sea level rise within the predicted range is likely to destroy or degrade important nesting beaches as well as some coastal foraging habitats. Other factors such as increased ocean and air temperatures as well as ocean acidification are likely to indirectly affect the coastal habitats. These and other factors such as changes to ocean circulation will also affect the wider ocean where, juveniles can be found for two years of their maturity cycle and adults can sometimes be observed.</p>	4

	<p>sedimentation rates have been falling in the Mississippi delta because of water impoundment, increased rainfall may offset the loss of sediment input into delta environments, however they are likely to be inundated by sea level change (Walling and Fang, 2003).</p> <p>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 ocean 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 processes such as species abundance and chemical processes, which will change the Kemp's Ridley juvenile's habitat.</p> <p>Changes in pH from CO₂ dissolving in the oceans are likely to have a large effect on the entire ocean system, and particularly coastal habitats. pH is expected to decrease by 0.3 to 0.4 units by 2100. This will affect the Kemp's Ridley's habitat, for example by altering the species composition of the shallow soft bottomed environments on which they rely (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: The distribution of the Kemp's Ridley turtle is limited to the western north Atlantic and Gulf of Mexico. They were known to forage along large parts of the North American coast, up to New England (UNEP), but they are thought to be intolerant of temperatures below 10°C (Bonin 2006). As with most turtle species the post-hatching phase is pelagic and not well understood. Many hatchlings drift on currents in the Gulf of Mexico and are associated with sargassum flotillas, and some are swept out into the Atlantic (US FWA). Sub-adults then recruit to neritic waters where they spend the remainder of their lives (Schmid & Barichivich 2006), rarely venturing into waters more than 50m deep (NOAA). The distribution of sub-adults throughout the Gulf of Mexico and Atlantic coast of the USA indicates Kemp's Ridelys developmental habitats are fairly flexible (NMFS & FWS 2007). Individuals migrate between breeding and feeding grounds along the North American Atlantic coast. Females particularly exhibit short term fidelity to specific sites (Schmid & Barichivich 2006) suggesting directed migration as opposed to the wanderings seen in Olive Ridelys (NOAA). This leaves them more vulnerable to an altered environment.</p> <p>Adult and sub adult Kemp's Ridelys are known to be benthic foragers, feeding primarily on decapod crustaceans (Shaver 1991, Burke 1994). Juveniles are thought to feed closer to the surface on a variety of organisms (Shaver 1991). Benthic foraging utilizes mainly the sea grass meadows and mud bottoms of coastal</p>	<p>The Kemp's Ridley turtle eats a variety of organisms, but these are often associated with specific habitat types or substrates. They have shown high residency in certain areas, and migrations are thought to be directed. The highly specialised Arribada nesting strategy leaves the Kemp's Ridley vulnerable to threats from climate change. They take a considerable time to reach sexual maturity but breed annually, unlike most other turtle species.</p>	<p>4</p>

marshes, and also the live bottoms with macroalgae and sessile invertebrates found near oyster reefs (Schmid & Barichivich 2006). Adults are almost entirely carnivorous (Bonin 2006).

Kemp's Ridleys exhibit a highly specialised breeding strategy. Nearly all nesting occurs on a single 20km section of beach near Rancho Nuevo, Tamaulipas on the Gulf coast of Mexico (UNEP). Hundreds of turtles synchronously come ashore to nest in Arribadas during daylight (Schmid & Barichivich 2006). The high specificity of this strategy means Kemp's Ridley turtles are unlikely to be able to cope with changes in their environment, particularly since the cues for these arribadas are still unknown (NOAA). However, occasional solitary nesting has been recorded (NOAA) indicating potential flexibility in reproductive behaviour.

Evidence of adaptation in the past: No information available

Reproductive rate: Kemp's Ridleys are the smallest sea turtle species. Estimates of age at sexual maturity vary (Chaloupka & Zug 1997, Shaver & Wibbels 2007, Zug et al 1997), but available data indicates between 10 and 17 years (Snover et al 2007). Breeding takes place almost exclusively in arribadas. Females usually nest on 1 or 2 year cycles, laying clutches of around 110 eggs (UNEP). Nesting occurs 1 to 4 times within a season at intervals of 10-28 days (US FWA) and incubation is similar to other turtle species at 50-60 days (NOAA). Although Kemp's Ridleys may breed annually, their fairly late age of maturity and highly specific arribada nesting strategy leaves them vulnerable.

Dispersal: Extensive migrations up and down the east coasts of North America indicate high dispersal capabilities, although these are likely limited to neritic waters. Juvenile individuals recorded in the eastern Atlantic (Bolton & Martins 1990) are thought to have been carried on oceanic currents during the pelagic development stage. The success of these individuals is unknown.

Climate related changes to fecundity: Like many other reptiles, sea turtles exhibit temperature dependent sex determination (TSD). An incubation temperature of around 29°C produces a 50:50 sex ratio, with lower temperatures resulting in male production, and higher temperatures producing females (Spotila 1987). Global warming is therefore expected to have a profound impact on the offspring sex ratio of turtle populations, with higher temperatures leading to feminization (Janzen 1994). 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

	<p>million years (IPCC2007). A rapid evolutionary response would be necessary for species to 'catch up' (Hulin et al 2008). A number of responses are possible:</p> <ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in the past (Janzen and Krenz 2004), but is unlikely to be possible in a short space of time. - Displacement of the pivotal temperature to a higher threshold. - Females altering nesting behaviour. Cooler places on the same beach could be selected, for example under vegetation or near to water (Kamel and Mrosovsky 2005) or females could dig deeper holes to lay in. Alternatively imperfect natal homing may allow nesting beaches to shift to higher latitudes. - Phenological shifts of the breeding season to cooler times of year. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>		
<p>Changing dynamics of species interactions</p>	<p>Juvenile Kemp's Ridley turtles are known to forage surface waters during an early pelagic stage, where they are documented to feed on Sargassum seaweed, as well as species associated with Sargassum such as pelagic mollusc species (MarineBio, 2009). However, it has also been recorded that the diets of juveniles may be made up largely of crabs (e.g. Burke, Standora, and Morreale, 1993). When turtles reach around 20cm in carapace length, they move to relatively shallow benthic foraging areas, and feed mainly on crabs at this post-pelagic stage. It has also been documented that some animals may also consume items discarded from shrimp trawls (Shaver, 1991). Fish, jellyfish, echinoderms, crustaceans, gastropod and cephalopod molluscs are also among recorded prey items (UNEP-WCMC).</p> <p>Crabs, the main prey species for adult Kemp's Ridley turtles, are likely to be affected by changing water temperatures and ocean acidification, undergoing shifts in range and changes in abundance. A decrease in ocean pH will have negative consequences for oceanic calcifying organisms, such as crabs, as they are dependent on the availability of calcium and bicarbonate ions for the mineralization of their exoskeletons (The Royal Society, 2005). This would lead to a decrease in populations. However, there has also been findings that some crab species are increasing in abundance as a result of climate change. For example, certain species of crab in the north sea are undergoing a population increase, as Cod (<i>Gadus sp.</i>) which feed on the crabs are declining as a result of decreasing food availability for cod larvae caused by climate change (Kirby, Beaugrand and Lindley, 2009). Also, Blue Crabs (<i>Callinectes sapidus</i>) south of Chesapeake Bay are expected to experience a population increase, as warmer temperatures means that winter hibernation will be unnecessary, therefore crabs can complete their</p>	<p>Adult Kemp's Ridley turtles prey mainly on crabs, a food source also exploited by juveniles. Crabs are likely to be affected by changing water temperatures and ocean acidification, undergoing shifts in range and changes in abundance. Climate change is expected to effect the distribution of sharks, which are the main predators of adult turtles. This may also impact Kemp's Ridley turtle numbers. There are no known affects of climate change on cleaning symbiosis.</p>	<p style="text-align: center;">3</p>

	<p>lifecycle within just one year, instead of having to wait until the following year (Goldman, 2006).</p> <p>Like all turtles, Kemp's Ridley turtles have a hard protective shell to help protect against predators. The most significant natural predator of adult sea turtles are sharks. It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution as well (Hearn et al., 2009).</p> <p>It is likely that Kemp's Ridley turtles form a cleaning symbiosis with certain species of reef fishes, and it has been documented that there was a cleaning symbiosis between captive Kemp's Ridley turtles and Porkfish (Moll, Michaels, Henson, Roberts, 1995). However, the impact of climate change on such interactions is unknown.</p>		
Interactions with other processes	<p>The Kemp Ridley turtles like many of the marine turtles have been critically endangered due to anthropogenic activities. These detrimental activities include construction work, human encroachment onto breeding sites, developmental work and disturbance from tourist activities and offshore artificial lighting (IUCN, 2009). Kemp ridley turtles are extremely vulnerable to natural and human impacts such as hurricanes and oil spills and any such disturbance can affect their habitat space, Rancho Nuevo, and this can affect their breeding pattern (WWF Fact sheet, 2008). Degradation of foraging and habitat grounds also occurs from the channelization of inshore areas (FWS and NMFS 1992). Another primary threat comes to this species is from the massive harvesting of eggs and meat by humans as they are valued for their aphrodisiac properties. Mortality rates also went up because of accidental death in fishing trawls and shrimp trawlers (WWF, 2008). These trawls usually operate in the breeding grounds of the turtles or where they feed themselves. Human population growth and large scale development work has also been instrumental in the growing threats to the k.ridley turtles especially in and around their nesting beaches (FWS and NMFS 1992).</p>	<p>Kemp ridley turtles have critically endangered because of the large scale poaching for eggs and meat. Accidental death by being caught in the fishing trawls is another factor responsible for the death of the kemp ridley turtles. Habitat disturbance from human interference such as development and construction work in and around the nesting grounds of k. ridley turtles has also caused them to change their nesting and foraging patterns.</p>	5
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Leatherback Turtle, *Dermochelys coriacea*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Leatherback Turtle has a global distribution ranging throughout ocean waters up to the 15 degree isotherm, however they have been observed in temperatures below 10 degrees centigrade (McMahon and Hays, 2006; Sarti Martinez, 2000). They are most often pelagic; however there have been many observations of leatherbacks in coastal waters. Tropical beaches are one of the most important habitats for the species as they provide nesting sites (Sarti Martinez, 2000).</p> <p>Sea level change has the potential to remove a large number of beaches from coastal areas. In fact, a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds (Fischlin et al, 2007). 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 rates of sea level rise were not incorporated into the projections, the IPCC predictions are very conservative (Kerr, R.A. 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 number of available habitats where leatherbacks can nest.</p> <p>Climate change will also affect the beaches themselves. Even the beaches that do not become inundated are likely to get hotter as global temperatures rise, changing the nature of the beach habitat. The magnitude of global temperature change is dependent on emissions scenarios; however the warming is likely to be within the range of 1.1-6.4 degrees centigrade (Solomon et al, 2007). From 1961 to 2003, global 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. This will have ramifications on a wide variety of ocean processes, from the ranges of species, to the rates of chemical reactions, which will affect the habitat of leatherbacks.</p>					<p>Sea level rise represents a great threat to tropical beaches and therefore leatherback's nesting habitats. Changes in temperature pH and salinity will also affect the structure of the ocean and species distribution. However these changes will be somewhat buffered by the leatherback's huge range.</p>	4

	<p>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 ocean 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 chemical processes and the assemblages of biological communities, which will change the leatherback's habitat, and the distribution of prey species.</p> <p>Changes in pH from CO₂ dissolving in the oceans are likely to have a large effect on the entire ocean system, particularly open ocean food webs that rely on plankton (Orr et al, 2005). pH is expected to decrease by 0.3 to 0.4 units by 2100. This will affect the leatherbacks habitat, for example by altering the structure and diversity of the open ocean and coastal habitats (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: The Leatherback turtle has the widest distribution of all the sea turtles, and in fact of all reptile species (Witherington 2006). It is predominantly a pelagic species (Snover and Rhodin 2008) but has also been documented to feed in neritic waters (James 2005). It is found in tropical, temperate and into sub-arctic waters worldwide from British Columbia and Newfoundland in the north to the Cape of Good Hope, South Africa and New Zealand (Witherington 2006). Nesting occurs on tropical sandy beaches, and females prefer those that are gently sloping and free from rocks (The Leatherback Trust). They show some fidelity to their natal beach, but not to the same degree as many other sea turtles (Dutton 1999). Not a great deal is known about the movements of hatchlings, but juveniles are thought to remain in warm waters over 26°C (Ekert 2002). Adults have a very wide temperature tolerance, and partial endothermy (Snover and Rhodin 2008) enables them to migrate to sub-arctic feeding areas (James 2005) and dive to great depths (James 2006). These factors indicate the leatherback may be better positioned to cope with the threats of climate change than other turtles.</p> <p>Leatherbacks are highly specialised feeders, consuming only gelatinous plankton such as jellyfish, salps and comb jellies (NOAA). They are anatomically well adapted to this diet, and thus climate change induced alterations to the distribution of their prey may affect them adversely (NOAA 5 year review). However, their wide foraging tendencies should enable them to cope with some degree of change.</p> <p>Evidence of adaptation in the past: No information available</p> <p>Reproductive rate: Adult leatherback turtles are huge, weighing 250-900kg (Spotila 2004). However, age at sexual maturity has been estimated to be 13-14</p>	<p>The leatherback turtle is a very widely distributed species found in tropical, temperate and into sub-arctic waters worldwide. It is predominantly pelagic with a wide temperature tolerance, travelling huge distances through the open ocean in search of gelatinous prey. They are wandering migrants, nesting on tropical beaches with some natal homing, but not to the same degree as other turtle species.</p> <p>Adults take 13-14 years to reach sexual maturity, and females only breed every 2-4 years meaning longevity is important. They exhibit relatively high fecundity, but juvenile mortality is high.</p> <p>As in many reptiles sex determination is temperature</p>	<p>3</p>

	<p>years (Zug and Parham 1996) meaning juveniles must grow extremely rapidly. Females breed every 2-4 years, and lay 4-9 clutches within each breeding season with 9-10 day intervals (Witherington 2006). Average clutch size is 50-70 fertile eggs (Spotila). Although they exhibit relatively high fecundity, mortality of eggs and juveniles is naturally very high. Their long life expectancy, discrete multiple breeding seasons and overlapping generations makes them their populations of low resilience and vulnerable to threats (REF).</p> <p>Dispersal: Leatherbacks migrate huge distances between feeding and breeding grounds, sometimes undertaking trips of around 10000km (James 2005). They have also been found to utilize broad expanses of ocean, and do not stick to common paths (James 2005) indicating their dispersal abilities are high.</p> <p>Climate related changes to fecundity: Like many other reptiles sea turtles exhibit temperature dependent sex determination (TSD). An incubation temperature of 29.50C produces a 50:50 sex ratio, with lower temperatures resulting in male production, and higher temperatures producing females (Spotila 2004). Global warming is therefore expected to have a profound impact on the offspring sex ratio of turtle populations, with higher temperatures leading to feminization (Janzen 1994). 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 (IPCC2007). A rapid evolutionary response would be necessary for species to 'catch up' (Hulin et al 2008). A number of responses are possible:</p> <ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in the past (Janzen and Krenz 2004), but is unlikely to be possible in a short space of time. - Displacement of the pivotal temperature to a higher threshold. - Females altering nesting behaviour. Cooler places on the same beach could be selected, for example under vegetation or near to water (Kamel and Mrosovsky 2005) or females could dig deeper holes to lay in. Alternatively imperfect natal homing may allow nesting beaches to shift to higher latitudes. - Phenological shifts of the breeding season to cooler times of year. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>	<p>dependent, meaning populations may be vulnerable to skewed sex ratios in a changing climate.</p>	
<p>Changing dynamics of species</p>	<p>The leatherback has the largest global range of all the sea turtles and they appear to migrate huge distances between feeding and nesting areas. The leather back is omnivorous, it is known to feed on sea urchins, squid, crustaceans, tunicates, blue-green algae and seaweed (MarineBio, 2009). However, its primary (and preferred)</p>	<p>The predicted effects of climate change on leatherback prey species (primarily jellyfish) do not appear to be</p>	<p>2</p>

<p>interactions</p>	<p>food source is jellyfish, for which it will travel many hundreds of miles. Every year some individuals of the Pacific population will cross the entire Pacific Basin to feed in the nutrient-rich waters of the California Current where there are large congregations of jellyfish (Oceana, 2007). Similarly, in the Atlantic Ocean turtles in French Guiana travel north or east to reach areas of abundant jellyfish in the middle of the Atlantic (Bonin et al. 2006)</p> <p>The leatherbacks appetite for jellyfish is a significant cause of mortality for the species due to individuals mistaking plastic bags for prey and ingesting the plastic which consequently either kills or causes internal injuries to the turtles digestive system (Oceana, 2007). It is thought that leatherbacks can remove considerable numbers of jellyfish when encountering dense aggregations, perhaps as much as their own weight on a daily basis (Mrosovsky, 2009). Declines in leatherback population numbers would significantly reduce the levels of predation on jellyfish which in turn could have cascading effects on food chains (Mrosovsky, 2009). The proliferation of jellyfish (which feed on fish larvae) would impact fish populations and have a negative impact on commercial fish stocks (Gulko and Eckert 2003). In addition to their effects on ecosystems, jellyfish ‘blooms’ are reported to cause variety of destructive problems (Hay, 2006).</p> <p>Information detailing leatherback jelly fish prey species is not widely available. The predicted effects of climate change on jellyfish populations include shifts in distribution, longer seasonal occurrence and ‘blooms’ of temperate-boreal species (Purcell, 2005) these consequences would not have a detrimental effect on leatherback turtles.</p> <p>It has been suggested that the increasing demand for jellyfish by Asian markets (Hsieh et al., 2001) could impact leatherback populations, but to what extent remains unknown. If leatherbacks were to ingest more plastic bags as a result of prey species becoming scarcer then commercial harvesting of jellyfish could impact greatly (Mrosovsky, 2009).</p> <p>Turtles have the potential to reproduce abundantly, however relatively few turtles survive their first year of life (WWF, 2009). Nests can be lost to natural predators such as mammals, crabs, seabirds and even ants. Hatchlings are also vulnerable to predation by mammals, sea birds and crabs as they make their way to the sea. When they reach the shallows, many more hatchlings will be taken by carnivorous fish. Predation continues to be high while turtles are young (MarineBio, 2009). Adult leatherbacks are sometimes attacked by killer whales (Orcinus orca). Fertl & Fulling (2007) have reported several cases of killer whales preying on sea turtles. Although predation by killer whales is likely to be opportunistic, attacks could have</p>	<p>detrimental to the extent they would impact their diet significantly. The effects of over-harvesting jellyfish and ingestion of plastic on leatherback populations is as yet unknown.</p>	
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	a significant impact on the already severely depleted Pacific populations of leatherbacks (Pitman and Dutton, 2004).		
Interactions with other processes	<p>Anthropocentric factors are largely responsible for the decline in the numbers of the leatherback turtles. Tourism and development activities have affected the leatherback turtles by disturbing their habitats and nesting grounds. Poaching and hunting of turtles for meat, eggs and oil is another cause of threat for the species (WWF Fact sheet, 2006). Additionally, habitat loss and disturbance of breeding grounds through human interference such as marine construction activity and sand mining have caused considerable damage to the breeding pattern of nesting turtles and often lead to the death of adult and young hatchling turtles (WWF Fact sheet, 2006). Deaths also occur from being entangled inside the sea or hooked externally to the fishing line (James et al, 2005). Leatherback turtles are also susceptible to a kind of disease called fibropapillomas, a tumour causing disease which restricts their mobility and damages their vision (NMFS, 2007). The disease is mostly caused as a result of toxins and chemicals released in the ocean from industrial effluents and construction activities in the coastal areas which is usually the nesting ground of the leatherback turtles (NMFS, 2007). The occurrence of tumour not only impairs their vision but also restricts their mobility and making them vulnerable to predators (NMFS, 2007).</p>	<p>The main cause of threats to the leatherback turtles is the influence of anthropogenic activities. Much of it has caused habitat disturbance especially of the nesting leatherback turtles. Artificial beach lighting was also responsible for causing disturbance to young hatchlings. Marine construction activity and tourism have added on to this disturbance. Poaching is another important factor which has endangered the leatherback turtles as they are hunted for their meat, eggs and oil. Additionally, the drainage of industrial toxins into the sea has affected leatherback turtles as they developed a kind of tumour called fibropapillomas which impairs their vision and restricts their mobility making them susceptible to predators. All these anthropogenic threats will limit the species resilience to climate change impacts.</p>	5
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Loggerhead Turtle, *Caretta caretta*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Loggerhead Turtles' range extends through tropical, sub-tropical and temperate waters. Like many turtle species the parts of the range which Loggerheads use depends on their position in their maturity cycle (Encalada et al, 2008). After hatching, juveniles inhabit the surface waters of the open ocean for 15 years or more (Monzón-Argüello et al, 2009; Department of the Environment, Water, Heritage and the Arts, 2009). After this they inhabit various benthic waters including rocky or coral reefs, mud flats, sand flats, estuaries and sea grass meadows (Department of the Environment, Water, Heritage and the Arts, 2009). Sub-tropical and warm temperate beaches are also very important as Loggerheads use them as nesting sites (Mrosovsky, 1988).</p> <p>Sea level change has the potential to remove a large number of beaches from coastal areas. In fact, a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds (Fischlin et al, 2007). 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 has the potential to greatly reduce the number of available sub-tropical and warm temperate beach habitats where loggerheads can nest.</p> <p>Climate change will also affect the beaches themselves. Even the beaches that do not become inundated are likely to get hotter as global temperatures rise, changing the nature of the beach habitat. The magnitude of global temperature change is dependent on emissions scenarios; however the warming by 2100 is likely to be within the range of 1.1-6.4 degrees centigrade (Solomon et al, 2007). From 1961 to 2003, global 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</p>					<p>Sea level rise is likely to be a great threat to Loggerheads almost certainly destroying or degrading nesting habitats. Wider ocean processes such as, ocean temperature, circulation and acidification probably will be effected the habitats of juveniles. Benthic habitats will also be degraded in many ways including changes to species abundances. with the effects of acidification on coral reefs acting as a good example</p>	4

	<p>in line with air temperature. This will have ramifications on a wide variety of ocean processes, from the ranges of species, to the rates of chemical reactions, which will affect the habitat of juvenile Loggerhead Turtles.</p> <p>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 ocean 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 processes such as species abundance and chemical processes, which will change the Loggerhead juvenile's habitat.</p> <p>Changes in pH from CO₂ dissolved in the oceans are likely to have a large effect on the entire ocean system, and particularly coastal habitats. pH is expected to decrease by 0.3 to 0.4 units by 2100. This will affect the Loggerheads habitat, for example by altering the species composition of shallow soft bottomed environments, and coral reefs, where they survive (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: Loggerhead turtles have a circumglobal distribution, being present throughout the temperate and tropical waters of the Pacific, Atlantic and India Oceans (DEWHA 2009). They are able to maintain body temperatures higher than that of the surrounding water meaning they can tolerate colder areas (Bonin) as far north as Newfoundland and Alaska (NOAA). There are also reports of loggerheads burying themselves in soft sediment and even entering hypothermic torpor in order to cope with particularly cold periods in temperate regions (Witherington et al 2006).</p> <p>C. caretta is less tropical than many other turtle species with the majority of nesting beaches in the sub-tropics, occurring between 19°-36° north and south of the equator (Witherington et al 2006). They favour wide, sandy beaches for nesting, backed by low dunes and fronted by a flat, sandy approach from the water (Conant et al 2009). Beaches on the western rims of the Atlantic and Indian Oceans are important for their large aggregations of nesting loggerheads (NOAA). Appropriate sand temperatures (25°-33°C) (DEWHA 2009, Limpus 2008) and humidity levels (Conant et al 2009) are necessary for successful incubation of the eggs.</p> <p>Post-hatching, juvenile loggerheads enter an extended pelagic phase which they spend far out to sea, often associated with floating Sargassum at convergence zones (Musick & Limpus 1996). They are principally low energy float-and-wait</p>	<p>C. caretta is a widely distributed species, tolerant of varying temperatures. They nest throughout the sub-tropics, although this is concentrated in areas of the western north Atlantic and Indian Oceans. Both adults and juveniles are thought to be generalist, opportunistic foragers. Whilst they are adaptable in their mode of life, adults migrate huge distances between nesting and feeding grounds, to which they show a high degree of fidelity, and they are also have very slow maturation. Loggerheads take around 30 years to reach sexual maturity, making them very vulnerable.</p>	<p>3</p>

	<p>foragers during this period, feeding on a variety of animal and plant material near the surface (Witherington 2002). The duration of this phase varies between individuals but can be up to 15 years (Limpus 2008). Loggerheads then recruit to the neritic zone where they continue to develop and remain throughout adulthood (Conant et al 2009). Adults undertake extensive migrations over continental shelves, and also crossing oceanic waters (NOAA). They show high fidelity to breeding and feeding grounds, and also to individual migration paths (Limpus 2008).</p> <p><i>C. caretta</i> forages in a wide variety of tidal and sub tidal habitats including coral and rocky reefs, sea grass meadows, and soft bottomed sand or mud areas (Limpus 2008). They are primarily carnivorous, with their strong jaw specialised for feeding on hard-bodied, slow moving invertebrate prey. However, they are varied in their foraging behaviours and can take broad spectrum of other prey (Limpus 2008). Although regarded as neritic, benthic foraging specialists some adults may periodically move into the pelagic zone. Populations breeding in Japan and west Africa are known to utilize oceanic foraging habitats, though these individuals are significantly smaller than neritic feeders, and the fitness consequences of this strategy are unknown (Conant et al 2009).</p> <p>Evidence of adaptation in the past: No information available</p> <p>Reproductive rate: Loggerhead turtles are thought to take around 30 years to reach sexual maturity. Once mature females breed every 2-3 years, laying 3-5 clutches of around 110 eggs in each breeding season (Conant et al 2009). They remain in the same region for the entire nesting period during which time they do not feed, relying on stored fat (Limpus 2008). Genetic studies have shown females return to their region of birth to lay (Limpus 2008).</p> <p>Dispersal: <i>C. caretta</i> is capable of dispersing great distances (NOAA). Pelagic juveniles can be carried on oceanic currents, and successful trans-Atlantic crossings occur (Musick & Limpus 1996). Adults migrate 1000s of km in both coastal and oceanic waters, even across ocean basins (DEWHA 2009, NOAA).</p> <p>Climate related changes to fecundity: Like many other reptiles sea turtles exhibit temperature dependent sex determination (TSD). An incubation temperature of 28.6°C produces a 50:50 sex ratio, with lower temperatures resulting in male production, and higher temperatures producing females (Hawkes et al., 2007; Limpus 2008). Global warming is therefore expected to have a profound impact on</p>		
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	<p>the offspring sex ratio of turtle populations, with higher temperatures leading to feminization (Janzen 1994). 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 (IPCC2007). A rapid evolutionary response would be necessary for species to ‘catch up’ (Hulin et al 2008). A number of responses are possible:</p> <ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in the past (Janzen and Krenz 2004), but is unlikely to be possible in a short space of time. - Displacement of the pivotal temperature to a higher threshold. - Females altering nesting behaviour. Cooler places on the same beach could be selected, for example under vegetation or near to water (Kamel and Mrosovsky 2005) or females could dig deeper holes to lay in. Alternatively imperfect natal homing may allow nesting beaches to shift to higher latitudes. - Phenological shifts of the breeding season to cooler times of year. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>		
<p>Changing dynamics of species interactions</p>	<p>Loggerheads have a broad diet that is primarily carnivorous. They have evolved powerful jaws that enable them to easily crush the hard shells of crustaceans and molluscs (IUCN, 2009). Shellfish species require carbonate found in the ocean to produce and replenish their calcium carbonate shells. It is thought that ocean acidification (increasing carbonic acid and reducing available carbonate) could leave crustaceans and molluscs more vulnerable to predation by other species (Griffin et al. 2007). Loggerheads could potentially face food resource competition from a variety of new predators that may be able to exploit important prey species.</p> <p>As major predators of invertebrates, loggerhead turtles could affect community structure in benthic habitats. Predation by loggerheads is thought to be a major mortality factor for saucer scallops around Bundaberg, Australia and for queen conch in the Bahamas (Lutz et al., 2003.)</p> <p>Few studies have explored the extent of competition between species of sea turtle and between sea turtles and other species. However, it is thought in general, the differences in diet and foraging habitats of sea turtle species minimise competition for food resources between sea turtles (Lutz et al., 2003.) Food resources are shared in some areas, for example, diet overlap has been reported for juvenile Kemp's ridleys and loggerheads around Long Island, New York. However, this competition is reduced as adults when these two species show habitat and diet</p>	<p>Climate change may affect the vulnerability loggerhead prey species - increasing competition for food resources. Foraging habitats are also being adversely affected - changing ecosystem dynamics.</p>	<p>3</p>

	<p>partitioning (Lutz et al., 2003.)</p> <p>Turtles have the potential to reproduce abundantly, however relatively few turtles survive their first year of life (WWF, 2009). Nests can be lost to natural predators such as raccoons, dogs, crabs, seabirds and even ants. Hatchlings are vulnerable to predation by mammals, sea birds and crabs as they make their way to the sea. When they reach the shallows, many more hatchlings will be taken by carnivorous fish. Predation continues to be high while turtles are young. As adults, the only significant natural predator to sea turtles are sharks (MarineBio, 2009).</p> <p>Loggerheads provide a home for a vast array of plants and animals that attach to their shells. It is reported that over 100 species of animals and 37 types of algae live on the backs of loggerheads. This extra load increases drag whilst swimming and the only suggested benefit to the turtle from these associations are a degree protection from camouflage (Spotila, J.R. 2004).</p> <p>Sea turtles use coastal marine ecosystems such as coral reefs and sea grass beds as foraging habitats (Eckert et al. 1999). Climate change is having increasingly negative effects on the habitats that support the prey species of turtles. Growth rates of seagrass are predicted to be severely affected by temperature stress, sea level rise and changing tidal circulation (Short & Neckles, 1999). Ocean acidification is already having devastating effects on coral reefs (Jones et al., 2004; Buddemeier et al., 2004).</p>		
<p>Interactions with other processes</p>	<p>This highly migratory species is subjected to a lot of threats caused by intense anthropogenic activities. Most of the habitat loss and disturbance is caused by tourism activities, coastal vehicles and development activities around coastal areas which coincide with the nesting grounds of turtles. Pollution, nesting habitat degradation including degradation of feeding sites from industrial effluents, waste disposal have harmed the loggerhead turtles near to the point of extinction. Industrial effluents are also cause damage to the feeding grounds of these turtles which are usually the sea grass meadows and coral reefs under the sea (IUCN, 2009). Unsustainable fishing practices is also another factor causing incidental deaths of numerous loggerhead turtles. Strong recommendations have been made for the elimination of shallow sets to substantially reduce the incidental catch of loggerhead turtles (Polovina et al, 2004). Poaching, in addition, for eggs, meat and turtle oil has increased the exploitation of nesting grounds of turtles.</p>	<p>Loggerhead turtles are one of the most threatened turtle species because of harmful anthropogenic activities. Added to this is the heavy poaching activity and deaths caused by unsustainable fishing practices.</p>	<p>5</p>
		<p>HIGH VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Olive Ridley, *Lepidochelys olivacea*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Olive Ridley occurs throughout tropic waters and in some sub-tropical waters, mainly within the 20 degree isotherm. Like most sea turtles, soon after hatching juveniles enter the deep ocean transported by currents, they remain there until they are mature. Adults, mainly inhabit neritic waters; however they are often observed in oceanic waters as well. Olive Ridley's nest on a variety of tropical beaches, sometimes in great numbers, sometimes solitarily. This means that different beaches may be more or less important to the species as a whole (Abreu-Grobois and Plotkin, 2008).</p> <p>Sea level change has the potential to remove a large number of beaches from coastal areas. In fact, a sea level rise of 0.5m will eliminate 32% of sea turtle nesting grounds (Fischlin et al, 2007). 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 has the potential to greatly reduce the number of available habitats where Olive Ridleys can nest.</p> <p>Climate change will also affect the beaches themselves. Even the beaches that do not become inundated are likely to get hotter as global temperatures rise, changing the nature of the beach habitat. The magnitude of global temperature change is dependent on emissions scenarios; however the warming is likely to be within the range of 1.1-6.4 degrees centigrade (Solomon et al, 2007). 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, to the rates of chemical reactions and nutrient cycles. For example, El Niño changes migratory patterns of Olive Ridleys, the future of El</p>					<p>The greatest threat to the habitats of Olive Ridleys comes in the form of sea level rise, which could destroy or degrade a large number of nesting beaches. Other effects of climate change will also affect the habitats Olive Ridleys, such as changes to ocean circulation and pH. therefore climate change will degrade a key habitat substantially, and the rest of the turtles range to a lesser extent as well.</p>	4

	<p>Niño is uncertain (National Oceanic and Atmospheric Administration and National Marine Fisheries, 2007; Christensen, 2007) but it shows that changes to the ocean will affect the habitat of the Olive Ridley.</p> <p>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 ocean 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 processes such as species abundance and chemical processes, which will change the habitat of Olive Ridleys.</p> <p>Changes in pH from CO₂ dissolved in the oceans are likely to have a large effect on the entire ocean system, and particularly neritic habitats. pH is expected to decrease by 0.3 to 0.4 units by 2100. This will affect the Olive Ridley's habitat, for example by altering the structure and diversity of neritic waters, where they spend most of the time (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: Olive Ridley turtles have a circumtropical distribution in waters with a sea surface temperature of 23-28°C (Polovina, 2004). They can be found nesting on sandy beaches in many parts of the tropics (Abreu-Grobois & Plotkin, 2008). They are more pelagic than other hard-shelled marine turtle species and have been found 4000km out to sea (NOAA 5 year review). They migrate great distances between tropical breeding sites and open ocean foraging grounds (Plotkin, 1995). They have been recorded in waters up to 3km deep (Plotkin 1994) and are known to dive well below 40m to forage for extended periods (McMahon et al 2007). Olive Ridleys have less specialised feeding habits than most marine turtles, feeding opportunistically on a variety of algae and invertebrates. They commonly feed on subsurface pyrosomes and salps, but also take surface organisms such as <i>Janthina</i> species (Polovina 2004). Their wide dispersal through pelagic waters does not appear to follow distinct migration corridors, and pathways vary annually (Plotkin 1994). These factors indicate Olive Ridleys may be able to cope with changes in their environment more readily than other marine turtle species.</p> <p>The Olive Ridley is, however, vulnerable because of its reproductive behaviour. They are renowned for their extraordinary arribada nesting's in which hundreds of thousands of female Ridleys come ashore to lay on a handful of beaches in just a few days (Abreu-Grobois & Plotkin 2008). These synchronised mass nesting's occur on a limited number of beaches worldwide, on certain parts of the Pacific coast of Central America and three beaches in India (NOAA). The triggers for these events</p>	<p>Olive Ridleys are more generalist than other marine turtle species. They inhabit both pelagic and neritic waters and their extensive migrations do not follow fixed paths. They are opportunistic omnivores, feeding on a variety of organisms. However, some populations exhibit the highly specialised synchronous mass nesting behaviour known as arribada.</p> <p>Olive Ridleys reach sexual maturity around 13 years of age, and commonly breed in successive years. This means their reproductive rate is likely to be higher than other sea turtles, but hatchling mortality is thought to be extremely</p>	<p>4</p>

	<p>are still unknown (NOAA) but it seems likely even small changes in the environment could disrupt this delicate cycle. Olive Ridleys also exhibit solitary nesting behaviour, and some females have been known to favour a mixed strategy (Bernardo and Plotkin 2007). These individuals also exhibit less nest site fidelity and may be better equipped to deal with climatic changes.</p> <p>Evidence of adaptation in the past: Not found</p> <p>Reproductive rate: Zug et al (2006) estimated the average age at sexual maturity for Olive Ridley turtles to be 13 years. Reproductive rate varies with the different mating strategies. Unlike other sea turtles it is common for this species to nest in successive years (NOAA 5 year review). Females usually lay 1-3 clutches of 100-110 eggs per season (Pritchard and Plotkin 1995). Solitary nesters show some nest site fidelity but may use multiple beaches during one season, re-nesting at 14 day intervals (NOAA 5 year review). Arribada females are faithful to their nesting beach and return every 28 days (Abreu-Grobois & Plotkin, 2008). Incubation takes 45-62 days (Bonin, 2006) meaning nests can overlap in time. Arribada nesters tend to lay larger clutches, probably to compensate for the high density-dependent mortality experienced with this strategy (Cornelius et al., 1991). The Olive Ridley has a higher reproductive rate than most other sea turtle species. However, age at sexual maturity is still significant, as is hatchling mortality, particularly in arribada nesters. Little is known about recruitment rates, but it seems likely that juvenile mortality is very high.</p> <p>Dispersal: Like all marine turtles, Olive Ridleys are migratory and are capable of travelling extensive distances. Although they are known to swim thousands of kilometres it is thought that they do not move between ocean basins or cross from one ocean boarder to another (Abreu-Grobois & Plotkin, 2008).</p> <p>Climate related changes to fecundity: Like many other reptiles, sea turtles exhibit temperature dependent sex determination (TSD). An incubation temperature of around 29°C produces a 50:50 sex ratio, with lower temperatures resulting in male production, and higher temperatures producing females (Spotila 1987). Global warming is therefore expected to have a profound impact on the offspring sex ratio of turtle populations, with higher temperatures leading to feminization (Janzen 1994). 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 (IPCC2007). A rapid evolutionary response would be necessary for species to 'catch up' (Hulin et al 2008). A number of responses are possible:</p>	<p>high, particularly on arribada beaches.</p> <p>As in many reptiles sex determination is temperature dependent, meaning populations may be vulnerable to skewed sex ratios in a changing climate.</p>	
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	<ul style="list-style-type: none"> - TSD lost in favour of Genetic Sex Determination. This probably has occurred in the past (Janzen and Krenz 2004), but is unlikely to be possible in a short space of time. - Displacement of the pivotal temperature to a higher threshold. - Females altering nesting behaviour. Cooler places on the same beach could be selected, for example under vegetation or near to water (Kamel and Mrosovsky 2005) or females could dig deeper holes to lay in. Alternatively imperfect natal homing may allow nesting beaches to shift to higher latitudes. - Phenological shifts of the breeding season to cooler times of year. <p>All of these potential responses would require either heritable behavioural or physiological variation among individuals in the population, or adaptive plasticity of a phenotypic trait (Hulin et al 2008).</p>		
Changing dynamics of species interactions	<p>The Olive Ridley turtle is an omnivore, and their diet includes fish and fish eggs, molluscs (e.g. gastropods and pelecypods), algae, tunicates (e.g. pyrosoma and salpa), crustaceans, bryozoans, sea urchins, jellyfish, sipunculids, and ascidians (Bjorndal, 1996). These omnivorous turtles likely consume a wide variety of prey and are probably fairly opportunistic with a wider dietary range compared to some other sea turtle species.</p> <p>Although extreme changes to benthic communities are likely under warmer climate conditions, omnivorous species are likely to have a greater adaptive ability and are probably less likely to suffer shortages of prey, compared to species with a specialist diet (Hawkes, Broderlick, Godfrey & Godley (2009)).</p> <p>Like all turtles, Olive Ridley turtles have a hard protective shell to help protect against predators. The most significant natural predator of adult sea turtles are sharks. It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution as well (Hearn et al., 2009). There are many predators of eggs and hatchlings which may include mammals (including jaguars, cougars and jackals), birds and crabs (Richardson, 1997). The effects of climate on nest and hatchling predation is unclear.</p>	<p>The Olive Ridley is a generalist omnivore that preys on a wide variety of species. Although climate change is likely to have a great impact on ocean ecosystems, the Olive Ridley turtle will be less likely to suffer prey shortages, and will be more likely to adapt compared to other sea turtle species. Climate change is expected to effect the distribution of sharks, which are the main predators of adult turtles. The impacts of climate change on nest and hatchling predation is unclear.</p>	2
Interactions with other processes	<p>Anthropogenic activities are largely responsible for the threat to the habitat of the olive ridleys along with the slow growth rate of the olive ridley turtles (WWF Factsheet). Construction of turtle habitat results from the construction of new aqua-culture ponds, fishing harbours and tourist activities. Growth of coastal villages in some parts of India, Mexico have also resulted in the loss of habitat for the olive ridley turtles. These impacts lead to the loss of nesting habitats along with light pollution and increase in industrial sewage. Incidental catching in fishing</p>	<p>Despite the large number of Olive Ridley turtles there has been a general decline in the population numbers due to anthropogenic factors which continue to affect its habitat. This includes where nesting</p>	4

	<p>hooks and gill nets have also created a certain loss of olive ridley turtles (Poiner and Harris, 1996). Poaching is another rampant activity. Olive ridley turtles are poached for their meat, leather and eggs. These eggs are consumed for their aphrodisiac properties especially in Mexico and Latin American countries. Exploitation was often intense in the past with harvest estimates exceeding more than 100,000 adult turtles per season (Richardson, 1997). Oil spills also cause respiratory damage to sea turtles causing malfunctioning of skin and salt glands. Interference with normal metabolism and gut function is also caused by accidental swallowing of metals pellets and plastic and styrofoam pieces and balloons.</p>	<p>turtles are disturbed or eggs are poached for consumption purposes. Olive ridley turtles are also poached for their skin and meat. Overall, trend is a declining population size. High anthropogenic threat factors will limit this species resilience to climate change.</p>	
			HIGH VULNERABILITY

7.3.2. MAMMALS

Climate Change Vulnerability of Migratory Species							
Species Assessment							
<i>Addax, Addax nasomaculatus</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>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 by at 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.</p> <p>The median A1B model predicts a modest reduction in annual precipitation over the same period, although the amount of uncertainty that the climate models' prediction is large (Christensen, 2007)</p> <p>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</p>					<p>Uncertainty is a major factor in the Sahelo climatic projections. Desertification is a major risk, but a very wide variation is apparent in the future climatic conditions predicted by the IPCC's GCMs. More work is required to remove some of this uncertainty so adequate mitigation and adaptation strategies can be established.</p>	4*

	<p>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.</p> <p>*more research is needed to reduce uncertainty in the Sahelo/Saharan region*</p>		
Ecological flexibility	<p>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 Wachter, 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-Saharan 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).</p> <p>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).</p> <p>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 Wachter 2008).</p>	<p>Species shows quite a high degree of specialisation, but in this case it is specialised to withstand very harsh environments. The reproduction rate is good, and there are no reported climate related disruptions to reproduction</p>	2
Changing dynamics of species interactions	<p>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 up which this species relies is diverse, but is heavily linked to rainfall.</p>	<p>No known increase in threats from predators, however the vegetation on which this species relies are dependent on rainfall. Currently rainfall prediction in the Sahel have a high level of uncertainty.</p>	3
Interactions with other processes	<p>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,</p>	<p>The habitat loss and fragmentation due to</p>	4

	<p>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 (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.</p> <p>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)</p>	<p>increasing anthropogenic pressures, along with a risk of higher rates of exploitation pose a large threat to this species. As the agricultural output of the region faces difficulty the conflict for resources is likely to grow. Direct exploitation in regions with food shortages are almost inevitable in areas with little infrastructure with which to ensure this species is sufficiently protected</p>	
	HIGH VULNERABILITY		

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Blue whale, <i>Balaenoptera musculus</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Of the three habitats the blue whale frequents, both polar feeding grounds, and tropical calving grounds could be severely affected by warming sea temperatures (Mate et al. 2006). Predictions of polar sea warming of up to 3°C affects the reproduction ability of krill and could result in krill depletion and/or movement resulting in a reduction the reproduction rates of the blue whale and their overall fecundity (Kawaguchi et al. 2006). Warming tropical seas are causing a reduction in krill growth rates during calving periods, thus forcing the blue whale to seek slightly cooler calving grounds along the Californian, Costa Rican and Galapagos coastline - this shift may lead to higher killer incidents and subsequent infant mortality incidents</p>					<p>Krill will adapt to warming temperatures by moving further towards the poles, subsequently resulting in whales moving further polewards. Overall blue whale feeding patterns are being changed in all habitats. Whale breeding is being affected by warming waters, and risk of infant mortality is rising in conjunction with this.</p>	4

Ecological flexibility	There has been no evidence to show blue whales have changed dietary habits in the past. They have adapted to higher frequency of tropical storms by feeding at greater depths, and in some instances have begun breeding and feeding off the coasts of Costa Rica and California, rather than pursuing their usual migratory patterns (Davis, 2002). Blue whales have also displayed an increase in population figures in the most depleted stocks, but there is no evidence of any increase in breeding rates after the mass depletions of the 1900-1960's (Best, 1993).	Blue whales have shown the ability to adapt in some aspects regarding changes in tropical sea temperatures, however, the dramatic predicted changes in polar sea temperatures and levels will have a greater damaging effect. Their apparent inability to change their diet leaves them vulnerable to predicted changes in krill stocks	4
Changing dynamics of species interactions	Blue whales feed solely on krill, and the mass migrations and depletions that are predicted to hit krill stocks (Fabry et al., 2008) may not happen for several decades, but when temperatures rise significantly, the effect will be profound. Krill life cycles rely on the freezing of sea-ice and its subsequent thawing for food supply - continued reductions in sea-ice levels will have negative impacts on krill stocks.	Mass krill migrations/depletions have not yet been caused so it is impossible to determine the impact a depletion or migration of krill will have, however removal or reduction of their primary food source is likely to be severely damaging to blue whale populations	4
Interactions with other processes	Noise pollution created in shallow waters by increasing boat haulage is a threat to blue whales - and the added ambient noise can skew songs and calls they make to potential mates - rises in haulage traffic has accounted for an increase in ocean ambient noise of 2.5-3 dB per decade since 1964 (McDonald et al. 2006). There have been no recorded papers on incidents of this, and the effect of haulage is thought to be minimal due to current trade/migration routes not coinciding. Protection levels on the blue whale remain successful, and reports of whaling are rare. Occasional accidents through nets and snares still occur, but are also rare	Protection of individual blue whales is expansive and effective. All global populations are increasing, and accidental deaths caused through anthropogenic causes are rare.	1
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Bowhead Whale, *Balaena Mysticetus*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>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 planktonic organisms including copepods, amphipods, euphausiids (Reilly et al, 2009). This means that the impacts of climate change on high latitude arctic waters and sea ice, will affect the habitats of Bowhead Whales.</p> <p>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 (Christensen et al, 2007). This will have large effects on Arctic waters and sea-ice. This magnitude of warming is likely to greatly reduce the thickness and extent of sea ice. In fact by 2100, some models predict that Arctic sea ice will be seasonal (Meehl et al, 2007). Reduced sea ice cover will affect many mechanisms in the Arctic and the circumpolar ocean, such as food abundance (Tynan and DeMaster, 1997). 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 (Robinson et al, 2005).</p> <p>From 1961 to 2003, global 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.</p> <p>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</p>					<p>The main threat to Bowhead Whales is the likely to be reduction in the extent of sea ice as their range focuses on the boundary between sea ice and open ocean. Other processes in the ocean will also affect Bowhead Wales Whales, for example ocean acidification.</p>	5

	<p>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 Bowhead Whales' habitat.</p> <p>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 Bowhead Whales, for example by altering the species composition of oceanic Arctic environments, particularly plankton abundance (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: 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 arctic conditions (Harrington 2008), and it is the only baleen whale to remain in these cold waters throughout its lifecycle (Carroll, G). They are highly migratory, and seasonal distribution is strongly influenced by pack ice (Reilly 2008). They usually remain close to the southern boundary of the winter ice, and move northward as the ice recedes during spring (Kovacs & Lydersen).</p> <p>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). 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, G). Bowheads feed at all depths throughout the water column, and are known to use a variety of strategies to increase their feed efficiency, such as swimming in formation in groups and feeding under ice (Carroll,G). 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 arising from oceanographic features such as upwelling and fronts (Laidre 2008).</p> <p>Evidence of adaptation in the past: Radiocarbon-dating of Bowhead remains indicates this species has experienced extensive expansions and contractions in its range in the last 10000 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.</p>	<p>The bowhead whale is an Arctic specialist, spending its entire lifecycle around the southern limit of the pack ice in high northern latitudes. It is highly migratory, travelling long distances with the changing seasons. It is a generalist feeder, filtering the water for zooplankton prey. Previous range alterations suggest some ecological flexibility. Like many Arctic species, the bowhead whale is very long lived, taking at least 20 years to reach sexual maturity and reproducing slowly.</p>	<p>3</p>

	<p>Reproduction: Bowhead whales are massive, with adults known to grow over 20m in length (UNEP-WCMC). Estimates of age at sexual maturity vary, but it is thought to take at least 20 years (Reilly 2008). Calves are born every 3-4 years, but occasionally intervals can be as long as 7 years (American Cetacean Society). A single calf is born after a gestation period of 13-14 months, and lactation is thought to last over a year (Kovacs & Lydersen). Some studies indicate Bowhead can live well in excess of 100 years (George et al 1999) making them among the oldest living mammals.</p> <p>Dispersal: 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, G). 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).</p> <p>Climate related changes to fecundity: n/a</p>		
<p>Changing dynamics of species interactions</p>	<p>Small to medium-sized crustaceans, such as 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 bowhead's 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).</p> <p>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 affect 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</p>	<p>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). A decrease in the frequency of winters with extensive sea-ice development would also mean that the frequency of krill recruitment would increase, and the krill population would be expected to decline (UNEP-GRID, accessed 2009). 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,</p>	<p>4</p>

	<p>population would decline (UNEP-GRID, accessed 2009). This would have a significant impact on the bowhead whale populations, which depend on krill for their main source of food (UNEP-GRID, accessed 2009).</p> <p>The degree to which climate change will likely affect bowhead populations, by altering the food web is still uncertain at this time, and may bring about a positive or a negative effect (COSEWIC, 2005).</p> <p>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).</p>	<p>and survivorship of the whales (COSEWIC, 2005).</p> <p>The degree to which climate change will likely affect bowhead populations, by altering the food web is still uncertain at this time, and may bring about a positive or a negative effect (COSEWIC, 2005).</p>	
Interactions with other processes	<p>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.</p>	<p>Much of the threat to bowhead whales comes from overhunting and whaling activities. The threat from hunting is presently moderate. Other anthropogenic activities such as accidental catch in fishing gears, accumulation of chemicals and toxins in the body of the whale has also led to significant threats to the bowhead species.</p>	3
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Cuviers Gazelle, *Gazella Cuvieri*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Gazella Cuvieri's habitat ranges from sea-level to 2,600m in altitude. It is endemic to the Atlas and Anti-Atlas mountains of the Maghreb countries of Morocco, Algeria and Tunisia (Cuzin, 2003). This range encompasses open semi-arid Mediterranean forests and steppes, and it is generally to be found in hills and low mountains, on slopes as steep as 45° (Cuzin, 2003). Cuvieri's Gazelle is a grazer and a browser, feeding on herbs and shrubs in the summer months, but on grasses in the winter. It utilises water from plants and dew, however needs to visit watering holes regularly (AZA Antelope TAG,2003).</p> <p>Figure 1 (below) shows the temperature projections for the Mediterranean region at the end of this century. The IPCC Forth Assessment Report project a temperature rise for the Mediterranean region is in the range of 2.2-5.1°C (Christensen et al. 2007). This increased temperature rise accompanied with higher CO₂ levels is expected to increase the shrub cover in northern Africa, so long as rainfall does not decrease (Cheddadi et al., 2001). However, as Figure 2 shows, a 20% drying in the annual mean precipitation is typical along the African Mediterranean coast in A1B scenario by the end of the 21st century (Christensen et al. 2009).</p> <p>An increase in the mean annual temperature of the north African Mediterranean climate coupled with a reduction in mean annual precipitation levels and an are likely to reduce grazing, browsing and watering opportunities for this species. It has the potential to migrate to other areas, however the quantity of suitable habitat and in their range is now substantially fragmented or degraded (Le Houerou, 1986; Cuzin, 2003) meaning unassisted migration into areas with adequate water and food which are not already inhabited or utilised by humans is unlikely.</p>					<p>The habitat of this species is likely to be altered by climate change, however the confidence in precipitation variations for this part of the world this century are quite uncertain. With a substantial increase in temperature and a significant drop in rainfall (predicted as the most likely outcome by the IPCC), this species will have reduced watering and feeding opportunities.</p>	3
Ecological flexibility	<p>Degree of Specialisation: The Cuviers gazelle is endemic to the mountains and hills of the Atlas and neighbouring ranges of north-west Africa, and occurs from sea level to an altitude of 2.600m (Mallon & Cuzin, 2008). It inhabits open semi-arid</p>					<p>The Cuviers gazelle lives mainly in hills and low mountains, as well as very steep slopes</p>	

	<p>Mediterranean forests, maquis and steppes (Mallon & Cuzin, 2008). It avoids heavy snow cover areas and lives mainly in hills and low mountains, as well as very steep slopes of up to 450 (Beudels et al. 2005). In the Saharan part of the gazelles range it appears to be limited to <i>Argania spinosa</i> and <i>Acacia</i> spp. woods (Beudels et al. 2005). The gazelles need to drink regularly and feed mainly on young alpha shoots (<i>Stipa tenacissima</i>) and other grasses, the young leaves of leguminous plants and Holm Oak's acorns (<i>Quercus ilex</i>) (Beudels et al. 2005).</p> <p>Evidence of past adaptation: Insufficient data.</p> <p>Reproduction rate: The gazelles give birth between April and May, usually to a single calf, after a 170 day (approx.) gestation period (Beudels et al. 2005).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: The gazelles live in small groups of 5-6 individuals or are solitary (Beudels et al. 2005). Their movements are highly variable, some may be sedentary, attitudinally migrant, migratory or nomadic (Mallon & Cuzin, 2008) and individuals from the same population may exhibit different movement patterns (Mallon & Cuzin, 2008). Recent studies have shown that the gazelles are highly mobile and can rapidly recolonise sites occupied in the past (Beudels et al. 2005).</p>	<p>(Mallon & Cuzin, 2008). Unlike most other species of gazelle they need to drink regularly (Beudels et al. 2005).</p> <p>The gazelles give birth between April and May, usually to a single calf (Beudels et al. 2005). Recent studies have shown that the gazelles are highly mobile and can rapidly recolonise sites occupied in the past (Beudels et al. 2005). However, in terms of food availability, the vast majority of natural forests have been destroyed and it is uncertain as to whether or not the gazelles will adapt to pine plantations (Beudels et al. 2005).</p>	
<p>Changing dynamics of species interactions</p>	<p>Cuvier's gazelle is a browser and grazer. Juveniles are occasionally depredated by jackals, but most natural predators of adult Cuvier's gazelle have been extirpated, and replaced by human threats (Sellami and Bouredjili, 1991). There is no known increase in threats from predators, although this is a possibility due to species range shifts. In Morocco, Cuvier's gazelle has an overlapping range with Dorcas gazelle (<i>Gazella dorcas</i>).</p>	<p>No known increase in threats from predators. There is potential for the range of this species to overlap with the Dorcas gazelle, however the affect of this is as yet unknown.</p>	<p>2</p>
<p>Interactions with other processes</p>	<p>The declining number of the Cuvier gazelle is mainly from the anthropogenic activities. The Cuvier gazelle is less tolerant to disturbance compared to the other gazelle species (Beudels et al, 2005). An important reason assigned for the decline of the Cuvier gazelle is the degradation of its habitat. For instance, the transformation of woody forest areas into agricultural lands has driven the Cuvier gazelle to extinction as they were left with little grazing territory. The increasing demand for pastureland for livestock grazing and continued deforestation activity for agriculture and charcoal has accelerated the decline of their territory. This was one of the main causes behind the decline of its numbers especially in Morocco. Land clearance for the growth of plantations of pine trees has endangered the Cuvier gazelle and there is insufficient evidence to conclude whether gazelles are</p>	<p>Habitat destruction from human activities such as land conversion into agricultural areas and grazing pastures for livestock has resulted in a loss of habitats for the Cuvier gazelle. Hunting for trophy, meat and skin has also been another important factor for the destruction of the Cuvier gazelle. These are on-going</p>	<p>4</p>

	capable of adapting to these pine tree plantations (Beudels et al, 2005). Recent studies have also shown that excessive hunting for skin, meat and trophy hunting has played an important role in the decline of the species. Another potential source of threat is the predation of the young Cuvier gazelle by dogs (Cuzin, 2003 as cited in Beudels et al, 2005).	threats	
			HIGH VULNERABILITY

Climate Change Vulnerability of Migratory Species								
Species Assessment								
Dama Gazelle, <i>Nanger dama</i>								
Impacting factor	Severity of impacting factor					Conclusion	Overall Score	
	1	2	3	4	5			
Vulnerability of habitat/s	<p>Nanger dama is found in arid areas, usually in sparse vegetation (Massicot, 2004). They make long seasonal migrations to the Saharan pastures and plateaus in the wet-season, and return to the open shrublands of the Sahel during the dry season (Atkins, 2003).</p> <p>Under the most conservative emissions scenarios, the mean temperatures in the Sahel region by 2080 and 2099 in comparison to the 1980-1999 mean temperatures are projected to increase by at 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.</p> <p>The median A1B model predicts a modest reduction in annual precipitation over the same period, although the amount of uncertainty that the climate models' prediction is large.</p> <p>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. The Dama gazelle is specialised to deal with harsh conditions, but a more variable climate with increased extreme weather events would seriously risk the viability of the present habitat in which the Dama gazelle resides.</p>					<p>Uncertainty is a major factor in the Sahelo climatic projections. Desertification is a major risk, but a very wide variation is apparent in the future climatic conditions predicted by the IPCC's GCMs. More work is required to remove some of this uncertainty so adequate mitigation and adaptation strategies can be established.</p>		4*
Ecological	Degree of specialisation: The Dama gazelle inhabits Sahelian grasslands, sparsely					Dama gazelle inhabits Sahelian		2



<p>flexibility</p>	<p>wooded savannah and sub-desert steppes, and is known to favour Acacia woodlands and their accompanying flora (Newby et al. 2009, Beudels et al. 2005). However, in certain parts of its range it was found in areas where Acacia was absent but dense shrub cover was present, and is thought to feed on <i>Argania spinosa</i> foliage instead (Beudels et al.2005).</p> <p>The gazelle is a highly drought resistant desert/semi-desert species, with the majority of its water obtained from its plant food, such as the wild melon <i>Colocynthis vulgaris</i>. In times of drought it will also consume rough desert grasses (Beudels et al. 2005).</p> <p>The gazelle is both a browser and a grazer, with a fairly mixed diet consisting of gramineous or non-graminid herbaceous plants and the foliage of ligneous species, which play an important role in its ecological requirements (Beudels et al. 2005). It appears that the presence and density of trees is a key factor determining the distribution of the gazelle (Beudels et al. 2005).</p> <p>Evidence of past adaptation: Insufficient data.</p> <p>Reproduction rate: Females reach sexual maturity at 9-12months, males at 18-24 months and are thought to have a 12 year life span. Breeding takes place between March and June and after a six month gestation period females give birth to only one young (Huffman, 2006).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: The Dama gazelle is a highly nomadic species, which covers large areas in search of food. They also undertake large seasonal migrations, moving north in the rainy season into the Sahara desert and retreating south into the Sahel during the dry season (Beudels et al. 2005). During the dry season the gazelles occur singly or in groups of 10-15, compared to the rainy season where herds could include several hundred individuals (Beudels et al. 2005).</p>	<p>grasslands, sparsely wooded savannah and sub-desert steppes, and is known to favour Acacia woodlands and their accompanying flora (Newby et al. 2009, Beudels et al. 2005). They are a highly drought resistant desert/semi-desert species (Beudels et al. 2005).</p> <p>It appears that the presence and density of trees is a key factor determining the distribution of the gazelle (Beudels et al. 2005).</p> <p>Breeding takes place between March and June, with females giving birth to only one young (Huffman, 2006).They are a highly nomadic species, which cover large areas in search of resources(Beudels et al. 2005).</p>	<p style="background-color: #90EE90;"></p>
<p>Changing dynamics of species interactions</p>	<p>The Dama Gazelle is both a browser and grazer, feeding on gramineous and non-graminid herbaceous plants as well as the foliage of ligneous species (Beudels et al. 2005).</p> <p>The species that the Dama Gazelle feeds on includes <i>Acacia senegal</i>, <i>Acacia raddiana</i>, <i>Acacia erhenbergiana</i>, <i>Maerua crassifolia</i>, <i>Capparis decidua</i>, <i>Capparis corymbosa</i>, <i>Cadaba farinosa</i>, <i>Boscia senegalensis</i>, <i>Guiera senegalensis</i>, <i>Grewia</i></p>	<p>The Dama Gazelle is both a browser and grazer, and this flexibility may enable this species to adapt more easily to changes in food supply (as long as enough water can be obtained from the plants they</p>	<p style="background-color: #FFA500; text-align: center;">3</p>

	<p>villosa, Grewia tenax, Balanites aegyptiaca, Chrozophora senegalensis, Leptadenia pyrotechnica, and Commiphora quadricenta, Limeum viscosum, Monsonia senegalensis, Boerhavia repens, Cucumis melo, Tephrosia lupinifolia, Tephrosia obcordata, Indigofera aspera, Tribulus terrester, Tribulus ochroleucus, Borreria radiata, Blepharis linariifolia, Commelina forskalae, Eleusine flagellifera, Cyperus gemenicus, Aristida mutabilis, Aristida pallida, Schmidtia pappophoroides, and Panicum turgidum. The water needs of the Dama Gazelle are met mainly by consuming plants with a high water content, for example the wild melon Colocynthis vulgaris (Newby, 1974; Beudels et al. 2005).</p> <p>The Dama Gazelle may share its habitat and compete for resources with other herbivores such as the Dorcas Gazelle. It is likely that climate change will affect the dynamics and distribution of Dama Gazelle habitat, therefore affecting the abundance and distribution of food resources. This increases the likelihood that climate change will affect the distributions of potential competitors, for example other herbivore species. However, as Dama Gazelle is both a browser and grazer, this species may be more able to adapt (providing water needs can be met by the availability of plants with a high water content), and may be less likely to suffer shortages of food than a species with a more selective diet.</p> <p>Dama Gazelle populations have many predators including Cheetahs, Leopards, Lions, Black-backed Jackals, Golden Jackals, Cape hunting dogs, Hyenas and even pythons. Climate change is likely to affect the distribution and ranges of these predators, which may bring more predators into contact with this gazelle species, which could in turn affect Dama Gazelle numbers.</p> <p>The affect that climate change will have on Dama Gazelle habitat is not clear, with different models predicting different effects. It is unclear whether rising temperatures will lead to greater desertification, or whether increased rainfall will lead to an increase in vegetation. Whichever outcome, the result is likely to affect food webs and influence the distribution and abundance of Dama Gazelle predators and competitors.</p>	<p>consume). Climate change is likely to affect their habitat, and therefore the vegetation that they feed on, which in turn may affect the whole food web including the abundance and distribution of potential predators and competitors. However the effects that climate change will have on food availability and the distribution of competitors and predators is unclear.</p>	
<p>Interactions with other processes</p>	<p>Increasing incidence of drought in the Sahelian zone has contributed to a loss of woody vegetation in the region, both directly and by increasing pressure from humans. The use of these ligneous species for charcoal and firewood purposes by humans has also contributed to the destruction of this foliage which in turn has caused the decline of these species. In addition, long drought spells have also contributed to the destruction of the local fauna and the dama gazelle population have been forced to migrate from arid lands of the Sahel to south Sahel where the</p>	<p>A very threatened existence of the dama gazelle mainly due to long spells of drought situations and anthropocentric influences has contributed to its declining numbers. Hunting for sports and for meat has</p>	<p>5</p>

	density of pastoralists and farmers has put them at a much higher risk of extinction (CMS, 2006). Traditional methods of hunting are yet another factor that contributed to the decline of the dama gazelles (IUCN, 2008). The use of firearms and vehicles for hunting as a sport has further aggravated this problem. Other threats include the problem of overgrazing by livestock populations which has created a scarcity of foraging ground for the dama gazelles(CMS, 2006). Increase in the number of wells and the invasion of available habitats by various anthropocentric activities has also contributed to the threatened existence of the dama gazelles (CMS, 2006).	further added to its population decline. Overgrazing by livestock, destruction of local foliage for charcoal and fuel wood consumption by humans have forced the dama gazelle to migrate for better pastures, often migrating towards human settlements and making its existence further precarious in the process.	
			HIGH VULNERABILITY

Climate Change Vulnerability of Migratory Species							
Species Assessment					  		
Humpback Whale, <i>Megaptera novaeangliae</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Humpback Whales have a global range, from the ice fronts in polar areas, to tropical waters. Mating and calving occurs in tropical waters, whilst the majority of feeding occurs in the productive polar waters. The whales therefore migrate between the two, rearing their young in warmer waters, whilst feeding predominantly on krill in Polar Regions. This means that the effects of climate change which impact upon any areas in the global oceans, affect the habitats of Humpback Whales (Reilly et al, 2008). These impacts relate to changes to sea ice coverage, warming of the oceans, alterations to the currents as well as variations in salinity and PH.</p> <p>Warming in the Arctic and Antarctic is likely to greatly reduce the thickness and extent of sea ice and ice shelves. In fact by 2100, some models predict that Arctic sea ice will be seasonal (Meehl et al, 2007). Reduced sea ice cover will affect many mechanisms in polar oceans, such as the spatial distribution of food abundances (Tynan and DeMaster, 1997).</p>					<p>The main effects of climate change on Humpback whales habitats are likely to be related to changes in abundance and spatial distribution of prey. This is most likely to be caused by changes in sea-ice coverage, changes in ocean circulation and ocean acidification. However as Humpback Whales have such a large range, they should be buffered from some of the more severe effects.</p>	3

	<p>From 1961 to 2003, global 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. 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 Humpback Whales.</p> <p>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 Humpback Whales' habitat.</p> <p>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 Humpback Whales, for example by altering the species composition of oceanic environments, particularly plankton abundance (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: <i>M. novaeangliae</i> is a wide ranging species found in all major ocean basins (Reilly et al., 2008). They feed at high latitudes during the summer and migrate to the tropics to breed over winter, often in specific near shore breeding areas (Reilly et al., 2008). The exact timing of these migrations can vary depending on a variety of factors such as water temperature, sea ice, predation risk and prey availability (Department of the Environment, Water, Heritage and the Arts, 2009). Migration routes are learned by calves as they migrate with their mothers resulting in strong matrilineal site fidelity by many whales (Clapham, 2000).</p> <p>Birthing often occurs close to atolls and islands, but the importance of this is not understood (Clapham, 2000). In Antarctic feeding grounds humpbacks are widely distributed south of 55° latitude. This distribution relates to prey density rather than topographic features (Department of the Environment, Water, Heritage and the Arts 2009). It is not currently known what habitats are critical for the survival of the humpback, and the flexibility and adaptability of the species is not well understood (Department of the Environment, Water, Heritage and the Arts, 2009).</p> <p>The diet of the humpback varies dependent on location. In the Southern</p>	<p>Humpback whales are a widely distributed species found in all major ocean basins. They feed predominantly on krill at high latitudes during the productive summer months, but have been known to take a variety of other prey such as small schooling fishes. A high degree of site fidelity is exhibited by many individuals, though habitat utilisation is not fully understood.</p> <p>Sexual maturity is reached at around 5 years, but subsequent reproduction is slow with a single calf born</p>	<p>2</p>

	<p>hemisphere the diet consists almost entirely of Antarctic krill which congregates around the productive ice-edge zone (Department of the Environment, Water, Heritage and the Arts, 2009). Data is limited for other areas, but feeding on schools of fishes such as herring is known in the northern hemisphere (Reilly et al., 2008). Humpbacks are known to use a variety of feeding techniques (Department of the Environment, Water, Heritage and the Arts 2009). Nearly all feeding occurs during the summer months when individuals must eat enough to see them through their winter migrations supplemented only by occasional opportunistic feeding at lower latitudes (Department of the Environment, Water, Heritage and the Arts, 2009).</p> <p>Evidence of adaptation in the past: No information available</p> <p>Reproduction: Humpback whales reach sexual maturity at an average age of 5 years (Clapham 1992), though some populations take longer (NatureServe 2009). Gestation takes approximately 12 months (Alaska Dept of Fish and Game), and the single calf is weaned after a year (MarineBio, 2009). Females give birth every 2-3 years, although intervals of 1-4 years are known (NatureServe, 2009). This slow rate of reproduction makes them vulnerable (Department of the Environment, Water, Heritage and the Arts, 2009).</p> <p>Dispersal: Humpbacks regularly migrate huge distances between feeding and breeding sites. For example, populations in Alaska travel to Hawaii during the winter, a round trip of nearly 10000km (MarineBio, 2009).</p>	<p>every 2-3 years.</p>	
<p>Changing dynamics of species interactions</p>	<p>In the southern hemisphere the humpbacks diet consists almost exclusively of krill, but they will also feed upon schooling fishes during migration (Reilly et al., 2009). Krill feed on microalgae that proliferate on the bottom of sea ice during winter; however sustained warming is causing a reduction in the extent of sea ice, resulting in a significant decrease in krill numbers. This would have a significant impact on humpback whales, which depend on krill for their main source of food (UNEP-GRID, accessed 2009).</p> <p>(In a recent study the complex relationship between krill and salpa (a pelagic tunicate) have been documented (UNEP-GRID, accessed 2009).)</p> <p>Another factor affecting krill is salinity. Shifts in the community structure of phytoplankton, from diatoms to cryophytes, have been linked to glacial melt-water runoff and reduced surface water salinities, in the Antarctic Peninsula (Robinson et al., 2005). As Atlantic krill do not graze efficiently on cryophytes due to their small size, the spatial and temporal distribution and abundance of krill will change, which</p>	<p>If the spatial and temporal distribution and abundance of krill continues to change, this will have a significant impact on the whale's diet. Although humpback whales are also known to feed upon schooling fishes during migrations, a rise in sea temperature may also affect those species that make up the remainder of their diet.</p>	<p>3</p>

	<p>will again have a significant impact in on the humpback's (Robinson et al., 2005).</p> <p>A rise in sea 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).</p> <p>The humpback whales are mainly predated upon by Killer whale's (Orcinus orca), which usually focus their attempts on young adults (Reilly et al., 2009).</p>		
<p>Interactions with other processes</p>	<p>The humpback whale mostly inhabits in shallow seawaters. Hence, they are subjected to anthropogenic exploitation. Construction work, drilling of oil, mining and the disposal of waste into the sea all affect the humpback whale's habitat. As an apex predator, concerns have been raised about the level of toxicity and pollution in marine waters which could potentially affect humpback whales. Commercial fishing practice has also affected the humpback whale as they often get entangled in fishing nets particularly on the east coast of Canada (Johnson and Wolman, 1984). Shallow water habitats often subjects them to exploitation by the whaling industry and it is estimated that about 90 percent of the population were killed (ACS, 2004) due to petroleum exploration, mining, ocean dumping, tourism and by cruise ships and boat traffic (Johnson and Wolman, 1984). Accidental deaths from being hit by cruise ships is another factor responsible for the decline of the humpback whale. However, this does not pose as an imminent cause of threat as much as deaths from being caught in fishing and gill nets.</p>	<p>The main threat to the humpback whale through the fishing industry. Humpback whales often get entangled in commercial fishing gill nets frequently around the east coast of Canada and US. There are numerous other threats that the species faces, however the magnitude of these threats is generally low.</p>	<p>2</p>
		<p>MEDIUM VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Marine Otter, *Lontra felina*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	Lontra felina is exclusively found in marine habitats along coastlines extending up to 30m inland and 150m offshore. (Alvarez & Medina-Vogel 2008). Changes in the Humboldt Current could impact upon this species indirectly, but it survives in a wide range of habitats and therefore the habitat is unlikely to be significantly degraded by climatic changes					Broad niche along a range of latitudes which are not projected to alter outside of the Marine Otters environmental needs	1
Ecological flexibility	Lontra felina inhabits areas with strong winds, heavy seas, and a high diversity of rock fishes, molluscs, and crustaceans (Lariviere 1998). This species does not display specialised behaviour - it can thrive at a range of different latitudes and eats an omnivorous diet which includes fish, crustaceans and even berries. Lontra felina is a monogamous species which has between 2-4 young (with an average of 2) annually, The marine otter lives in a range of different latitudes which infers that it is unlikely that the fecundity of the population will be effected by rising temperatures or other climatic changes.					This species does not display specialised behaviour as it has a omnivorous diet and can thrive at a wide latitudinal range. There is no evidence to suggest that fecundity will be effected by the projected changes in the climatic system	1
Changing dynamics of species interactions	Diverse prey and few natural predators. The main predator of the marine otter is the orca, while sharks also take their toll. From IUCN OSG: The main food of the Marine otter is Crustaceans, Molluscs and Fish, though the proportion varies with location. They prefer omnivorous or carnivorous prey from the inter/sub tidal zone - for example, they rarely take echinoderms despite their abundance. The usual main component of the diet is crabs, such as the Chilean King Crab or la Centolla (Lithodes Antarctica). They also have a taste for freshwater prawns (Criphiops caementarius), and will follow freshwater streams high above sea level to find them. They have been seen attacking sea birds. At certain times of year, they seek out and eat fruit from coastal shrubs.					Broad diet, few predators and not exposed to phenological shifts as not truly migratory	1
Interactions with other processes	Based on current rates of decline and trends, these threats are estimated to result in future population reductions of at least 50% over the next 3 generations (30 years) unless conservation measures are strengthened (IUCN, 2009). Accelerating habitat destruction and degradation, reduction of prey biomass due to competition with man, direct persecution by aquaculturalists, poaching, killing by dogs and entrapment in fishing gear mean it is likely that this species will continue to decline by around 50% over the next ten years (IUCN OSG 2006). Increased					Habitat destruction and reduction of prey biomass by increasing fishing pressures pose a significant threat to this species	4

	fishing pressures, a problem which could be exacerbated by increased frequency and severity of El Nino events. Increased human coastal settlement also problematic. Whilst this species tends to favour harsh and exposed environments which are unlikely to be utilised for human settlements, increase coastal populations could prove to be obstacles to dispersal		
		LOW VULNERABILITY	

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Mexican free-tailed bat, <i>Tadarida brasiliensis</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	Most Mexican free-tailed bats reside within Mexico and the southern United States. They roost in caves and artificial structures, however less than 12 caves are important for rearing young (Hutson et al, 2001). They are found in a wide range of arid and semi arid habitats, from desert to various types of woodland and at altitudes of up to 3000m (Tuttle, 1994). In the southern USA and Mexico warming is expected to be in the magnitude of 2-3°C by 2100 with the most pronounced warming occurring in central regions in the summer. There is also likely to be a reduction in the amount of precipitation, probably in the magnitude of around 20% (Christensen et al, 2007). An increase of temperature and aridity is likely to expand the range of deserts and shrub land, at the expense of woodland and grassland (Grover and Musick, 1990; Hanson and Weltzin, 2000; Geist and Lambin, 2004) Caves generally reflect the annual averaged temperature of the region in which they are located. Therefore within the caves which the bats inhabit there is likely to be an increase in temperature of 2-3 degrees (Lowe and Walker, 1997).					The Habitat of the Mexican free-tailed bat is likely to become more arid which will affect land cover. The temperature within roosts is also likely to increase by around 2-3°C. However the Mexican free-tailed bat can alter its range in altitude, and withstand arid environments.	2
Ecological flexibility	Specialisation: Mexican Free-tailed bats use a wide variety of habitats (Barquez 2008) from deserts, to piñon-juniper woodland and pine-oak forests (Tuttle. 1994). They occur from the southern parts of the USA south to Chile and Argentina (Hutson et al 2001). Unlike most bat species, T. brasiliensis does not hibernate but spends the winter months at lower latitudes such as Mexico (Davis & Schmidly 1994). Most females are highly migratory, travelling in groups (Davis & Schmidly. 1994) to the, southwest United States to form huge maternity colonies from April					The Mexican free-tailed bat is a fairly generalist species which utilises a wide variety of habitats and has a broad, insectivorous diet. The majority of the species exhibits a specialised breeding strategy,	3



	<p>to September (McCracken, 1986). Migrations are thought to be triggered by climate, and departure dates from the USA can vary depending on the passage of strong cold currents from the north (Tuttle, 1994).</p> <p>This species primarily roosts in caves (in colonies of 10s of millions of individuals) but will also use abandoned mines, tunnels, bridges, rock shelters and hollow trees (Tuttle 1994). There are also found in urban areas nesting in buildings (Davis & Schmidly, 1994) showing recent adaptation to the changing environment. The largest populations nest in a very limited number of caves, mainly in Texas, and have been using the same sites for at least the last 100 years. Although Mexican free-tails typically return to their home areas (Tuttle, 1994), it has been shown that individuals are not compelled to return to the cave of their birth and range over large distances to find nest sites (Davis & Schmidly, 1994).</p> <p>Mexican free-tailed bats have a very diverse diet (López-Damián, 2007). They are insectivorous, taking prey items on the wing (Tuttle, 1994). Major prey items include moths, beetles, flying ants and true bugs (Davis & Schmidly, 1994). They often feed at high altitudes (Bat Conservation International), notably on swarms of corn earworm moths, major agricultural pests that migrate in huge numbers from Mexico following emergence in early summer (McCracken, 1996).</p> <p>Evidence of adaptation in the past: Other migratory bats species such as the Nathusius' pipistrelle (<i>Pipistrellus nathusii</i>) and eastern red bat (<i>Lasiurus borealis</i>) have shown changes in range in recent years (Mistry & Moreno-Valdez, 2008).</p> <p>Reproduction: <i>T. brasiliensis</i> females migrate north to give birth in enormous maternity colonies in caves in the southern United States (Bat Conservation International). From just 1 year old, the vast majority of females reproduce every year (Davis & Schmidly, 1994). Nearly all pups are born within a 2 week period in mid June following a 90 day gestation period (Davis & Schmidly, 1994), although this can vary slightly with weather conditions (Tuttle 1994). A single pup is born and nursed on rich milk from its mother (Tuttle, 1994). Mothers require a large amount of food to meet these energy requirements and may consume their body weight in insects nightly (Tuttle 1994). Young grow quickly in this warm environment and are able to forage on the wing after a month or so (Davis & Schmidly, 1994). Mortality of pre-fledglings and adults is probably low (Davis & Schmidly, 1994), however many fledglings die within the first year (Tuttle, 1994). Females are thought to live for around 12 years (McCracken, 1986).</p>	<p>migrating long distances to form enormous maternity colonies of millions of individuals in a few key caves in south west USA. However, a number of populations have alternative strategies and roosting sites indicating some degree of flexibility. <i>T. brasiliensis</i> females mature at a young age but only produce a single pup each year, requiring a plentiful food supply to provide enough energy rich milk to rear them successfully.</p>	
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	<p>Dispersal: This species has been known to travel up to 1800km, and they are morphologically adapted for travelling great distances at high speeds (Hutson et al., 2001). They are thought to forage up to 50km from the roost each night (Hutson et al., 2001).</p> <p>Climate related changes to fecundity: Non reported</p>		
<p>Changing dynamics of species interactions</p>	<p>The bats require a vast number of insects as prey, particularly at the higher latitude ends of their range, where they form very large maternity colonies (Robinson et al., 2005). Although they are considered to be highly adaptable foragers, who are able to cover large areas of terrain at night, a large number of insects are still required in order to sustain the larger populations (Robinson et al., 2005). Where the increased intensity of storms and desertification has been predicted in Mexico, as a result of climate change, it is thought that this may have an effect on prey availability during the winter months (Robinson et al., 2005).</p> <p>Many of the bats rely on a huge influx of the corn earworm moth that migrates up from Mexico as they form their maternity colonies (McCracken, 1996). The moths are a vital source of protein which is required to produce rich milk for rearing young (McCracken, 1996). However, the corn earworm moths are the number-one agricultural pest in America (McCracken 1996) and although there is no evidence to suggest that they may be affected by climate change, numbers may be reduced through new agricultural practices.</p> <p>The bats are predated upon by a number of species of snakes, birds, and mammals (Davis, 1994). However, given that the total loss of bats is small in proportion to the overall population, predators have very little impact on bat numbers (Davis, 1994).</p> <p>In terms of competition with other species, if temperatures were to increase as a result of climate change, then the bat may extend their range into higher latitudes, where they may create competition with species already inhabiting certain sites (Robinson et al., 2005).</p> <p>Any changes in prey availability and habitat changes will have little affect on the bats during migrations (Robinson et al., 2005). It seems that they will be able to track the availability of food and other environmental conditions as they only migrate in short hops (Robinson et al., 2005) However, it should be noted that the synchrony of births and the availability of suitable prey during the parturition and lactation period for the adults, and the post weaning period particularly for the</p>	<p>Any changes in prey availability and habitat changes are likely to have very little impact on the bats. They are highly adapted foragers and are able to extend their range, with rising temperatures, with relatively little impact on their migrations. However, if they were to extend their range into higher altitudes they may create competition with other species. Their natural predators also have very little impact on reducing bat numbers.</p>	<p>2</p>

	young or crucial (Robinson et al., 2005).		
Interactions with other processes	<p>An important reason for the decline in the number of bat population is the loss of habitat due to human interference and destruction of roosting sites. Studies have shown that the destruction of one large colony has a huge impact on the entire bat population (McCracken, 1986). This is mainly due to the slow recovery period of bats because of their slow reproductive process. For instance, an average female survives about 12 years producing one offspring per year (McCracken, 1986). Roosting habits of the Mexican free tailed bat has also made them susceptible to epidemics. However, disease outbreak has not been ascertained as the main reason for fluctuation in population size and is unlikely to lead to species-wide decline (McCracken, 1986). Decline in the population of the Mexican bat is indicative of the operation of other factors.</p> <p>Consumption of large number of insects as part of their diet has led them to consume a large amount of pesticides such as organo-chlorines, DDT and dieldrin (McCracken, 1986). Another important reason is the loss of food sources by converting lands and wild agave harvesting for the production of liquor in Mexico.</p>	<p>The Mexican free-tailed bat is declining mainly because of habitat destruction leading to the loss of roosting sites and foraging areas. Loss of habitat generating from conversion of lands into farming and agricultural areas has also led to the decline in the number of bat population. Given the fact that bat population takes a long time to recover due to their slow reproductive process, such interference can affect the total bat population. Another important reason for their decline is the consumption of large amount of pesticides whilst predated on insects.</p>	3
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Narwhal, *Monodon Monoceros*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Narwhals live in marine Arctic environments Making them 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.</p> <p>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 (Meehl et al, 2007).</p> <p>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.</p> <p>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.</p> <p>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</p>					<p>Climate change is likely to severely degrade most of the Narwhals habitats through reduced sea ice cover and ocean acidification.</p>	5

	<p>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.</p> <p>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.</p> <p>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).</p>		
<p>Ecological flexibility</p>	<p>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 and 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 were 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</p>	<p>The Narwhal is specialised. It eats a range of species but primarily hunts the Greenland Halibut. It can adapt to some change but cannot change it's habitat type - requiring sea ice, whilst it has a relatively low reproduction rate.</p>	<p>4</p>

	habitats.		
Changing dynamics of species interactions	<p>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).</p> <p>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).</p>	Climate change through changes to ocean circulation, acidification and reduced sea ice is likely to lead to less available species. Meanwhile reduced sea ice cover is likely to make Narwhals more vulnerable to predation	4
Interactions with other processes	Hunting and interference from industrial acuties 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 is underlines by the use of the North East Passage for commercial shipping for the first time (Halpin, 2009).	Climate change may increase hunting however the magnitude of this is unlikely to greatly affect the Narwhal population. However climate change is likely to increase the amount of disturbance by development and industry within the Arctic.	4
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

North Atlantic Right Whale, *Eubalaena glacialis*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Whilst the major decline in the population of the North Atlantic Right Whale occurred over three generations ago, the population is listed as endangered due to a very low population recovery. Very little is known about their ecology. Generally they inhabit coastal waters, however they have been sighted in the Azores. There are two population centres, one the Western Atlantic and one in the Eastern Atlantic, however there are very few individuals in the Eastern Atlantic. They range seasonally from subtropical waters where they calve, to polar waters where they feed on abundances of copepods (Reilly et al., 2008).</p> <p>Polar temperatures are predicted to rise by between 5 and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average (Christensen et al, 2007). This will have large effects on high latitude waters and sea-ice. This magnitude of warming is likely to greatly reduce the thickness and extent of sea ice. In fact by 2100, some models predict that Arctic sea ice will be seasonal (Meehl et al, 2007). Reduced sea ice cover will affect many mechanisms in the high latitude Atlantic and further south (Tynan and DeMaster, 1997). This may alter the distances North Atlantic Right Whales need to migrate to reach food abundances in high latitudes (Robinson et al, 2005).</p> <p>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 North Atlantic Right Whales.</p> <p>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</p>					<p>Climate change is likely to change the spatial distributions and abundances of prey species, this is the most important climate change impact on the habitat of the North Atlantic Right Whale. This will occur through changes to temperature, sea ice, ocean circulation, salinity and ocean acidification, therefore there is a substantial risk that the habitat of this species will be seriously degraded by climate change.</p>	4

	<p>circulation of the oceans. It will also affect processes such as species abundance and chemical processes, which will change the North Atlantic Right Whales' habitat.</p> <p>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 North Atlantic Right Whale, for example by altering the species composition of oceanic arctic environments, particularly plankton abundance (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: Prior to their exploitation, the North Atlantic right whale was found throughout temperate, subarctic, coastal and continental shelf waters throughout the North Atlantic Ocean , generally between 20° and 60°N (NOAA, 2006). There is no direct data available about thermal tolerance in this species, but they can be found occupying waters with sea surface temperatures between 0°C and 21.8°C (Kenney, 2007). They are also able to dive from water surface waters to forage at near bottom depths indicating they can cope with changing ambient temperatures (Kenney, 2007). However, <i>E. glacialis</i> tends to occupy waters below 20°C within given areas indicating they may have an upper limit to their thermal tolerance. This may mean they cannot cope with increased sea surface temperatures in their calving grounds, at the southern limit of their range (Kenney, 2007).</p> <p>Right whales are baleen whales, filtering the water for tiny zooplankton with their enormous baleen plates. These specialised feeding structures are only efficient while swimming at slow speeds and for specific size classes of prey. Subsequently North Atlantic right whales specialise on a few large species of slow moving zooplankton (Baumgartner et al., 2007), primarily copepods (NOAA, 2006). They must consume tons of zooplankton in a day to maintain their huge body weight. They are capable of skim feeding at the surface and subsurface feeding but require high prey concentrations to make feeding profitable (NOAA, 2006). <i>E. glacialis</i> is high mobile and very efficient at locating areas of high zooplankton density. It is thought to use a variety of methods including learning and memory, chemical and physical cues and possibly communication (Baumgartner et al., 2007). However, it relies on the environment to organise it's zooplankton prey into areas of sufficiently high concentration meaning it's survival is dependent on large scale oceanographic processes (Baumgartner et al., 2007).</p> <p>Evidence of adaptation in the past: No information available</p> <p>Reproduction: North Atlantic right whales have been documented to give birth to</p>	<p>The North Atlantic right whale has an extensive historic distribution throughout the subarctic and temperate waters of the North Atlantic and is though to be capable of tolerating temperatures of 0-20°C. It feeds on zooplankton and is well adapted to feed on aggregations of large, slow moving prey. Due to its specialised feeding apparatus it is inflexible in its diet and relies on oceanographic processes to concentrate high enough densities of zooplankton for feeding. It takes nearly 10 years to reach sexual maturity and calving usually occurs every 3-4 years. However, this appears to be strongly linked to environmental conditions and its reproductive rate has been seen to decrease in recent decades.</p>	<p>4</p>

	<p>their first calf at a variety of ages. Records of females as young as 5 years indicate a relatively early sexual maturation, however this depends on the health of the individual and first calving has been known to occur at over 20 years of age (Kraus et al., 2007). The average age at sexual maturity is thought to be 9 years – comparable to that of Southern right whales (Kraus et al., 2007). A single calf is born during the winter months after a gestation period of 12-13 months, and lactation can last over a year (NOAA, 2006). The calving interval also varies depending on environmental conditions, with averages of 3-4 years observed to increase to over 5 years between 1889 and 2003 (Kraus et al., 2007). The reasons for this are not known. Some females are known to have been reproductively active for over 30 years, but there are other known cases where sexually mature females fail to produce any offspring at all (Kraus et al., 2007).</p> <p>Dispersal: <i>E. glacialis</i> undertakes long distance seasonal migrations between subarctic feeding areas and lower latitude calving grounds. In the Western Atlantic they migrate thousands of kilometres from Nova Scotia to Florida during the winter months (Reilly et al., 2008).</p> <p>Climate related changes to fecundity: No information available</p>		
<p>Changing dynamics of species interactions</p>	<p>Right whales require dense patches of prey, such as copepods and krill when feeding (Greene et al., 2003). Therefore the distribution, abundance and migration of these whales reflect that of their prey (Greene et al., 2003). These dense prey patches have been linked to oceanographic features including fronts, eddies and primary productivity and can be affected by several factors, including temperature (Greene et al., 2003). Recent shifts in all copepod assemblages in the North Atlantic Ocean have resulted in a northward extension of more than 10° in latitude of warm-water species associated with a decrease in the number of colder-water species and are thought to reflect regional increases in SST (Greene et al., 2003).</p> <p>The North Atlantic Right Whales key prey species is the copepod <i>Calanus finmarchicus</i> (Reilly et al., 2009) and the connection between climate change and the abundance of this species in the North Sea have already been well established (Greene and Pershing, 2000; Greene et al., 2003). Researchers have suggested that that shifts in zooplankton populations could affect current North Atlantic Right Whale ranges, and in the absence of dense patches of this particular zooplankton, females will not be able to bulk up to prepare for calving, carry a pregnancy to term or produce enough milk (NEAQ, 2009).</p> <p>Copepod abundance in the North Sea has also been linked to the position of the</p>	<p>Shifts in zooplankton species could affect current North Atlantic right whales ranges and the absence of dense prey patches could also potentially affect the female's ability to feed their young. The predicted weakening of the Gulf Stream may also affect prey abundance. If prey were to become less abundant then the North Atlantic right whale may find itself in competition with Sei whales and planktivorous fish for food. It is unlikely that the impact their predators currently have on numbers will increase.</p>	<p>4</p>

	<p>Gulf Stream, where results suggest that the timing of the spring phytoplankton bloom on the European shelf and the start of seasonal stratification are related to the latitude of the Gulf Stream off the US coast (Robinson et al., 2005). The predicted weakening of the Gulf Stream due to climate change could therefore potentially affect plankton abundance, in turn affecting the right whales which rely on them (Robinson et al., 2005).</p> <p>It is thought that interspecific competition with either sei whales (<i>Balaenoptera borealis</i>) or planktivorous fish may limit northern right whale prey consumption (NOAA, 2006). In the North Atlantic in particular, sei whales are sympatric with right whales and because they both feed on small zooplankton species, they may compete (NOAA, 2006). Competition with other species of fish in the Gulf of Maine, including sand lance (<i>Ammodytes</i> spp.), herring (<i>Clupea</i> spp.), Atlantic mackerel (<i>Scomber scombrus</i>), river herrings (shad, blueback; <i>Alosa</i> spp.), menhaden (<i>Brevoortia tyrannus</i>), and basking sharks (<i>Cetorhinus maximus</i>) has also been speculated (NOAA, 2006).</p> <p>The whale's main predators are orcas and large sharks, which mainly predate on calves. It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution as well (Hearn et al., 2009).</p>		
<p>Interactions with other processes</p>	<p>The population of the north atlantic right whale is very low due to historic intensive whale harvesting activity. More recently however, anthropogenic activities have been assigned as the main cause of death of the north atlantic whales. Studies have shown that 20 percent of the deaths have been caused by shipping collision, 12% by entanglement in fishing gear, 57% of all clearly-photographed living individuals bore evidence of entanglement interactions and 7% bore scars from ship collisions (Knowlton and Kraus, 2001). Other studies showed that of the 50 reported dead right whales, 19 were killed by vessel collisions and at least six by fishing gear entanglements (Kraus et al., 2005).</p>	<p>The main cause of declining number of the north atlantic whale is death from shipping collisions and accidental deaths from entanglements in fishing nets especially along the east coast of North America.</p>	<p>4</p>
		<p>HIGH VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

North Pacific Right Whale, *Eubalaena japonica*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>There are two populations of North Pacific Right Whale. Both populations spend the summer in the Bearing Sea; however they over winter, either along the American West coast or along the Asian coast, sometimes straying as far afield as Hawaii. Very little is known about the whale's ecology, but it feeds on abundances of copepods, migrates seasonally, and is endangered due to whaling (Reilly et al., 2009).</p> <p>Arctic temperatures are predicted to rise by between 5 and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average (Christensen et al, 2007). This will have large effects on high latitude waters and sea-ice. This magnitude of warming is likely to greatly reduce the thickness and extent of sea ice. In fact by 2100, some models predict that Arctic sea ice will be seasonal (Meehl et al, 2007). Reduced sea ice cover will affect many mechanisms in the high latitude pacific, such as food abundance (Tynan and DeMaster, 1997). This may alter the distances North Pacific Right Whales need to migrate to reach food abundances in high latitudes (Robinson et al, 2005).</p> <p>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 North Pacific Right Whales.</p> <p>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 habitat of the North Pacific Right</p>					<p>Climate change is likely to change the spatial distributions and abundances of prey species; this is the most important climate change impact on the habitat of the North Pacific Right Whale. This will occur through changes to temperature, sea ice, ocean circulation, salinity and ocean acidification.</p>	4

	<p>Whale .</p> <p>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 North Pacific Right Whale, for example by altering the species composition of oceanic arctic environments, particularly plankton abundance (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: Little is known about habitat use by North Pacific right whales (Reilly et al 2008). They were formally abundant throughout the entire North Pacific north of latitude 30°N (NOAA 2006) and frequented the open ocean, the eastern and northern Gulf of Alaska shelf, the Bering sea and the inland seas of the western specific (Gregr & Coyle, 2009). There are few records of <i>E. japonica</i> sightings in winter suggesting they do not form inshore breeding concentrations like Southern right whales (Reilly et al 2008).</p> <p>Right whales are baleen whales, filtering the water for tiny zooplankton with their enormous baleen plates. These specialised feeding structures are only efficient while swimming at slow speeds and for specific size classes of prey. The prey base of <i>E. Japonica</i> is potentially much broader than that of <i>E. glacialis</i> because the earlier developmental stages of the local calanoids are large enough to make them suitable prey (Gregr & Coyle, 2009). They feed on copepods, mainly <i>Neocalanus</i> and <i>Calanus</i> species near the surface (Gregr & Coyle, 2009). They must consume tons of zooplankton in a day to maintain their huge body weight. They are capable of skim feeding at the surface and subsurface feeding but require high prey concentrations to make feeding profitable (NOAA 2006). <i>E. japonica</i> is highly mobile and very efficient at locating areas of high zooplankton density. It is thought to use a variety of methods including learning and memory, chemical and physical cues and possibly communication (Baumgartner et al 2007). However, it relies on the environment to organise its zooplankton prey into areas of sufficiently high concentration meaning its survival is dependent on large scale oceanographic processes (Baumgartner et al 2007).</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction: Little is currently known about the rate of reproduction for North Pacific right whales (NOAA, 2006). North Atlantic right whales have been documented to give birth to their first calf at a variety of ages. Records of females as young as 5 years indicate a relatively early sexual maturation, however this depends on the health of the individual and first calving has been known to occur</p>	<p>The North Pacific right whale has an extensive historic distribution throughout the entire North Pacific north of latitude 30°N (NOAA 2006). It feeds on zooplankton and is well adapted to feed on aggregations of large, slow moving prey. Due to its specialised feeding apparatus it is inflexible in its diet and relies on oceanographic processes to concentrate high enough densities of zooplankton for feeding. It takes nearly 10 years to reach sexual maturity and calving usually occurs every 3-4 years. However, this appears to be strongly linked to environmental conditions and its reproductive rate has been seen to decrease in recent decades.</p>	<p>4</p>

	<p>at over 20 years of age (Kraus et al 2007). The average age at sexual maturity is thought to be 9 years – comparable to that of Southern right whales (Kraus et al 2007). A single calf is born during the winter months after a gestation period of 12-13 months, and lactation can last over a year (NOAA 2006). The calving interval also varies depending on environmental conditions, with averages of 3-4 years observed to increase to over 5 years between 1889 and 2003 (Kraus et al 2007). The reasons for this are not known. Some females are known to have been reproductively active for over 30 years, but there are other known cases where sexually mature females fail to produce any offspring at all (Kraus et al 2007).</p> <p>Dispersal: Little is known about the migratory behaviour of this species (NOAA 2006). However, it is thought that it makes seasonal movement between high latitude summer feeding grounds and lower latitude calving grounds (Reilly et al 2008). It is likely that like other closely related species it is capable of moving extensive distances through coastal and oceanic waters.</p> <p>Climate related changes to fecundity: Insufficient data.</p>		
<p>Changing dynamics of species interactions</p>	<p>Right whales require dense patches of prey, such as copepods and krill when feeding (Greene et al., 2003). Therefore the distribution, abundance and migration of these whales reflect that of their prey (Greene et al., 2003). These dense prey patches have been linked to oceanographic features including fronts, eddies and primary productivity and can be affected by several factors, including temperature (Greene et al., 2003).</p> <p>In the North Pacific they feed mainly on Neocalanus and Calanus species near the surface (Gregn & Coyle, 2009). In the surface waters of the subarctic Pacific, the copepod Neocalanus plumchrus, which dominates the mesozooplankton biomass, has a seasonal timing of abundance that is tightly coupled with sea surface temperature (Hays et al., 2005). As climate change continues to cause an increase in sea temperature this may have a significant impact on copepod abundance, and in turn the species that rely on them as their main food source.</p> <p>Krill feed on microalgae that proliferate on the bottom of sea ice during winter; however sustained warming is causing a reduction in the extent of sea ice, resulting in a significant decrease in krill numbers. This may have a significant impact on the right whale, which depends on krill as a main component of their diet (UNEP-GRID, accessed 2009).</p>	<p>Both krill and copepod abundance and distribution are found to be linked to several factors, including sea temperature, which is significantly affected by climate change. Shifts in zooplankton species could affect Pacific right whales ranges, such as been predicated for Atlantic right whales. The absence of dense prey patches could also potentially affect the female's ability to feed their young, again as predicted for the Atlantic species.</p> <p>It is unlikely that the impact their predators currently have on numbers will increase.</p>	<p>4</p>

	<p>The whale's main predators are orcas and large sharks, which mainly predate on calves. It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution as well (Hearn et al., 2009).</p> <p>There is very little information about possible competition between North Pacific right whales and sympatric species (NOAA, 2006). As Bowhead whales (<i>B. mysticetus</i>) are similar in anatomy it is thought that they could conceivably be competitors (NOAA, 2006).</p>	<p>Interspecific competition may occur with Bowhead whale's s if prey abundance was to decrease.</p>	
Interactions with other processes	<p>Hunting has been the major cause of decline among the North Pacific Right Whales in the 1930s and in the 1960s. Some of the current threats include inbreeding depression and low population density effects (CITES, 2001). Deaths have been known to occur from ship strikes and entanglement in fishing gear, whilst degradation of water quality and the abundance of prey items in the feeding grounds of this species can also threaten their well-being. Interference in the form of ship and underwater noise is also know to be a problem for this species (Alaska University Report on Mammals, 2008). Due to its small population size and low fecundity rate (CITES, 2001), the north pacific right whale has a very slow recovery process from exploitation and it is mainly this that has led to their endangered status.</p>	<p>A small population number of the north Pacific Right Whale has been from several factors such as hunting and low fecundity rate. Even though hunting does not pose as a serious threat currently, yet inbreeding depression and low population density have been factors responsible for the declining number of the north Pacific right whale. Other factors include deaths from ship strikes, entanglements in fishing gear, habitat disturbance due to climate change leading to changes in prey availability.</p>	4
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Sei Whale, *Balaenoptera borealis*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Sei Whales have a global, largely offshore distribution, inhabiting all the worlds' oceans other than the North Indian Ocean and the North Arctic Ocean. They migrate seasonally from tropical and sub-tropical wintering grounds, to temperate and sub-polar summer areas, generally staying within the temperature range of 8-18°C (Reilly et al., 2009).</p> <p>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 Sei Whales. Furthermore, as climate change shifts the bands of tropical and temperate waters. This will alter the distribution of winter and summer areas and potentially the distance of the seasonal migration (Robinson et al., 2005).</p> <p>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 Sei Whales' habitat.</p> <p>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 Sei Whales, for example by altering the species composition of oceanic environments, particularly plankton abundance (Meehl et al., 2007).</p>					<p>The fact that Sei Whales have a global distribution and don't rely on particular prey abundances means that they are relatively well place to deal with changes to their habitat. However climate change is likely to lead to significant changes to the global oceans and therefore the habitats of the Sei Whale.</p>	2
Ecological	<p>Degree of Specialisation: The Sei whale is a cosmopolitan species, with a mainly offshore distribution, occurring in the North Atlantic, North Pacific and Southern</p>					<p>The Sei whale is a cosmopolitan species, which</p>	3

<p>flexibility</p>	<p>Hemisphere, and is an occasional visitor to the Mediterranean (Reilly et al., 2009). Compared to other balaenopterids, Sei whales appear to be restricted to more temperate waters, between 8-18°C, and consequently are found within a smaller range of latitudes (NOAA 2006, Reilly et al., 2009). They are found in deeper waters associated with the continental shelf edge (NOAA, 2006).</p> <p>Sei whales feed on copepods when available, and in their absence, they feed on krill (NOAA, 2006). In some parts of the Northern hemisphere they are also known to feed extensively on small schooling fishes, such as anchovies (<i>Engraulis mordax</i>), sauries (<i>Cololabis saira</i>) and jack mackerel (<i>Trachurus symmetricus</i>) (NOAA, 2006). In the autumn they migrate several thousand miles toward equatorial waters and during the winter they eat very little or fast for several months, living off their fat reserves (NOAA, 2006). Sei whales are noted for their erratic appearance in specific feeding grounds, where they may be plentiful in some years and absent, sometimes for decades, in others (Reilly et al., 2009).</p> <p>Sei whales have the greatest flexibility relative to other balaenopterids in their feeding strategies, using both engulfing and skimming to capture prey (NOAA, 2006).</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction rate: Sei whales become sexually mature between 6-12 years of age (Reilly et al., 2009). The main breeding season lasts around 5 months during the winter in lower latitudes, with a gestation period of 11-13 months (Reilly et al., 2009). Females give birth to a single calf and weaning takes place after 6-9 months in preferred summer feeding grounds (Reilly et al., 2009). Females bear a calf every 2-3 years (Reilly et al., 2009). There is evidence of differential migration by reproductive class, with pregnant females reaching and leaving feeding grounds before males (NOAA, 2006). They have an estimate life span of 50-70 years (Reilly et al., 2009).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: Sei whales do not have a well defined school or social structure and are generally found in small groups of 2-5 or as solitary individuals, but can occasionally be found in larger loose aggregations of up to 30-50 (NOAA, 2006; Reilly et al., 2009). They migrate long distances from high-latitude summer feeding areas to relatively low-latitude winter breeding areas (NOAA, 2006). Although their summer feeding areas are fairly well documented, the location of wintering areas remains largely unknown (NOAA, 2006).</p>	<p>feeds mainly on copepods and krill and is well adapted to feed on aggregations of large, slow moving prey. Due to its specialised feeding apparatus it is inflexible in its diet and relies on oceanographic processes to concentrate high enough densities of zooplankton for feeding. It takes between 6-10 years to reach sexual maturity and calving usually occurs every 3-4 years. They are known for their erratic appearance in specific feeding grounds and little information is known about their wintering areas.</p>	
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<p>Changing dynamics of species interactions</p>	<p>Sei whales feed on copepods when available, and in their absence, they feed on krill (NOAA, 2006). In some parts of the Northern hemisphere they are also known to feed extensively on small schooling fishes (NOAA, 2006).</p> <p>Krill feed on microalgae that proliferate on the bottom of sea ice during winter; however sustained warming is causing a reduction in the extent of sea ice, resulting in a significant decrease in krill numbers. This may impact the Sei whale, however their diet is more varied than other baleen whales and they may be better equipped to cope with a change in diet (UNEP-GRID, accessed 2009).</p> <p>Another factor affecting krill is salinity. Shifts in the community structure of phytoplankton, from diatoms to cryophytes, have been linked to glacial melt-water runoff and reduced surface water salinities, in the Antarctic Peninsula (Robinson et al., 2005). As Atlantic krill do not graze efficiently on cryophytes due to their small size, the spatial and temporal distribution and abundance of krill will change, which may again have an impact of the sei whale (Robinson et al., 2005).</p> <p>A rise in sea temperature can 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).</p> <p>Sei whale predation by killer whales has not been reported, however it is likely given observations of killer whale attacks on other species of whale that attacks do occur and result in mortality or serious injury to young or weakened individuals (NOAA, 2006).</p> <p>In the Southern Hemisphere there evidence to suggest that Sei whales minimize direct interspecific competition with other species, such as the blue, fin and minke whales by foraging in warmer waters , consuming a relatively wider variety of prey and by arriving at feeding grounds later than other baleen whales (NOAA, 2006). As a proportion of their diet, krill make up a much smaller component than other baleen whales and this also suggests that the existence of copepods and amphipods in their diet is a means of avoiding interspecific competition with other whales (Department of the Environment, Water, Heritage and the Arts, 2009).</p>	<p>Both krill and copepod abundance and distribution are found to be linked to several factors, including sea temperature, which is significantly affected by climate change. However, the sei whales diet is much more varied than other baleen whales and they may be better equipped to cope with a change in diet. Predation by killer whales and sharks, although unreported, may go unnoticed by humans and may have very little impact on sei whale numbers. Interspecific competition with other baleen whales is thought to be avoided by sei whales through their late arrival at feeding grounds and more varied diet. However as climate change may cause a gradual break down in the food web, we may see an increase in interspecific competition as prey abundance decreases.</p>	<p>3</p>
<p>Interactions with other processes</p>	<p>Very little is known about the habitat conditions of the Sei whale to assess the vulnerable condition of its habitat. However, there is a potential of Sei whales suffering due to habitat degradation caused by anthropogenic activities. Activities such as acoustic pollution, entanglement, physical injury and death from boat</p>	<p>The main threat to Sei whale is commercial whaling activity. Other causes of their declining number are anthropogenic</p>	<p>3</p>

	<p>strikes, built structures and construction work that impact upon habitat vulnerability and use, changing water quality and pollution, changes to water flow regimes causing sedimentation or erosion in near shore habitats (Department of the Environment, Water, Heritage and the Arts, 2009). Habitat degradation from such activities has the potential of changing migration patterns, reproductive cycles, and mortality rates. Another cause of increasing vulnerability of the sei whale is commercial whaling and hunting activity. Even though such activities have been banned in certain countries yet countries like Japan and Iceland continue scientific whaling activity for research purpose after obtaining special whaling permits (Department of the Environment, Water, Heritage and the Arts, 2009). Other factors affecting the sei whale is climatic and oceanographic changes which could affect both prey and habitat availability. Studies have shown that there is a possibility that whale migration, breeding, calving site selection all may be affected by these changes (Department of the Environment, Water, Heritage and the Arts, 2009). For instance, whales predominantly predate on krill, their main source of food. Overfishing can lead to the decline in the number of krill population thus negatively affecting the krill population.</p>	<p>activities such as construction work in sites where the sei whale populate causing them disturbance in breeding or calving.</p>	
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Short-beaked Common dolphin, <i>Delphinus delphis</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
Vulnerability of habitat/s	1	2	3	4	5	<p>The fact that the Short Beaked Common Dolphin has a large range and population in addition to varied food requirements, makes it is well buffered against climate induced changes to it's habitat, which are likely to relate to prey distribution and</p>	2
	<p>The Short Beaked Common Dolphin has an almost global range, inhabiting both oceanic and coastal waters, throughout temperate and tropical regions, from oceans to seas. Therefore the affects of climate change on these areas will affect the habitats of Short-beaked Common Dolphin (Hammond et al, 2008). These changes can be grouped into changes in ocean temperature, sea level change, alterations to the currents as well as variations in salinity and pH.</p> <p>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).</p>						

	<p>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 Short Beaked Common Dolphins.</p> <p>Sea level change has the potential to change the nature of coastal areas. 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 sort of change will certainly affect coastal habitats through inundation. It also has the potential to change reef habitats. For example, coral may not be able to grow fast enough to keep up with the change. This will affect reef ecosystems and potentially Short Beaked Common Dolphins (Buddemeier and Smith, 1988).</p> <p>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 upwelling as well as 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 chemical processes, which will change the Short Beaked Common Dolphins' habitat.</p> <p>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 Beaked Common Dolphins, for example by altering the species composition of oceanic and coastal environments, particularly plankton and coral abundance (Meehl et al, 2007).</p>	<p>abundance. This means that the likely impacts of changes to temperature, sea level, circulation and acidity of the oceans, will affect the Short Beaked Common Dolphin, and particularly its prey but not to a dangerous degree.</p>	
<p>Ecological flexibility</p>	<p>Degree of specialisation: The short-beaked common dolphin is widely distributed, inhabiting all temperate, subtropical and tropical seas. They are usually found where surface water temperature is between 10-20°C and water depth is greater than 180m. However, they may follow warm currents beyond their normal range (Culik, 2004). They appear to have a preference for up-welling modified waters, areas with steep floor relief, and extensive shelf areas (Hammond et al., 2009).</p> <p>The dolphins feed mainly on small pelagic shoaling fish and some cephalopods. They appear to feed opportunistically, with their diet reflecting local prey</p>	<p>The short-beaked common dolphin is widely distributed, inhabiting all temperate, subtropical and tropical seas. The dolphins feed mainly on small pelagic shoaling fish and some cephalopods. They appear to feed opportunistically, with their</p>	<p>2</p>

	<p>abundance and availability (Young & Crockford, 1994).</p> <p>Evidence of adaptation in the past: Insufficient data</p> <p>Reproduction rate: Females become sexually mature between 2-7 years and the males between 3-12 years. Females have an estimated calving interval of 1-3 years and give birth, following a 10-11 month gestation period, to a single calf. Breeding usually takes place between the months of June and September. They have an estimated life span of up to 35 years (NOAA website).</p> <p>Climate related changes to fecundity: Insufficient data</p> <p>Dispersal: Migrations are not well known and common dolphins are present year round in some parts of their range. However, some studies have observed seasonal shifts in distribution in response to changes in water temperature and prey availability (Culik, 2004).</p>	<p>diet reflecting local prey abundance and availability (Young & Crockford, 1994).</p> <p>Females become sexually mature between 2-7 years and the males between 3-12 years. Females have an estimated calving interval of 1-3 years and give birth, following a 10-11 month gestation period, to a single calf (NOAA).</p>	
<p>Changing dynamics of species interactions</p>	<p>The common dolphin feeds mainly on small pelagic shoaling fish and some cephalopods. They appear to feed opportunistically, with their diet reflecting local prey abundance and availability (Young & Crockford, 1994). Many of the dolphins prey species, such as fish and cephalopods, require a particular set of environmental conditions in which to survive (Robinson et al., 2005). Cephalopods are particularly vulnerable 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).</p> <p>Associations with other marine mammals are common and mixed- species groups of common, striped (<i>Stenella coeruleoalba</i>) and Risso's dolphins (<i>Grampus griseus</i>) have been observed (Bearzi et al. 2003, Hammond et al., 2009). However, recent studies have suggested that competition with the striped dolphin (<i>Stenella coeruleoalba</i>) could be among the possible causes of the common dolphin's decline in the Mediterranean (Bearzi et al., 2003). However, although the two species share a common habitat, there is no evidence to suggest that striped dolphins are competing with common dolphins for food (Bearzi et al., 2003). Their decline can not be successfully attributed to competition either, as studies carried out in the Adriatic sea, where the common dolphins have disappeared, have shown that the area is rarely occupied by the striped dolphin (Bearzi et al., 2003).</p>	<p>Many of the dolphins prey species, such as fish and cephalopods, require a particular set of environmental conditions in which to survive (Robinson et al., 2005). A change in prey availability will ultimately affect the dolphin's distribution and migration and could have serious consequences for reproduction and survival (Robinson et al., 2005). They may also encounter competitive exclusion with other populations or species (Robinson et al., 2005).</p>	<p>3</p>

	<p>A study by McLeod et al. (2005) reported a decline in the relative frequencies of strandings and sightings of white-beaked dolphins (<i>agenorhynchus albirostris</i>) a colder-water species, and a relative increase in the strandings and sightings of the short-beaked common dolphin, which is a warmer water species off the coast of North West Scotland. These results suggest a possible range expansion of common dolphins and a decrease in range of white-beaked dolphins, which may also be attributed to the direct effects of changes in sea temperature or indirect effects, such as competitive exclusion (Macleod et al., 2005).</p> <p>It should be stressed that although in some areas the distribution of dolphins may be attributed to shifting environmental conditions, such as sea temperature, that these kinds of ‘fluctuations’ affect dolphin distribution and abundance primarily by influencing food web-dynamics and the availability and abundance of their prey (Bearzi et al. 2003) . Therefore it is difficult to differentiate between the effects of environmental shifts, whether natural or as a result of climate and other factors affecting the availability of dolphin prey, such as overfishing and habitat degradation (Bearzi et al., 2003), which is thought to be the key factor causing rapid declines in the number of common dolphins in certain areas .</p> <p>Predation by sharks is a significant cause of mortality in dolphins (Bearzi et al., 2008). It is likely that many shark species will be influenced by rising sea temperatures, leading to a change in their distribution as well (Hearn et al., 2009).</p>		
<p>Interactions with other processes</p>	<p>A number of factors are responsible for the decline of the common bottlenose dolphin. Environmental degradation resulting from climate change and natural fluctuations along with human interference have all contributed to the declining numbers of the bottlenose dolphin. Exploitation from overfishing has been a major factor apart from pollution, water quality degradation and other anthropogenic factors (Bearzi et al., 2003). Deaths from fishery bycatch in and around the Mediterranean have threatened the common dolphins to a large extent. Prey depletion has also played a role along with accidental deaths caused by being caught in fishing trawls and also from direct catch. Dolphins are often caught and hunted for their meat and oil. Another important factor responsible is the occurrence of xenobiotic contamination. This has caused malfunctioning of their reproductive system along with immuno-suppression (Bearzi et al., 2003) disorders. Studies have also showed that the numbers of the common dolphin in the Mediterranean went down because of the invasion of the striped dolphin species from the Atlantic Ocean.</p>	<p>The short-beaked common dolphin is currently threatened due to a number of factors. The primary factors for their decline are exploitation from overfishing, accidental deaths by being caught in fishing trawls around the Mediterranean and also deaths from direct catch. An important factor is death from xenobiotic contamination due to the presence of increased amount of toxic substance in the Mediterranean waters. This has caused malfunctioning of</p>	<p>4</p>

		the immunity system of the common dolphin along with reproductive disorders.	
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species						  		
Species Assessment								
Snow leopard, <i>Panthera uncia</i>								
Impacting factor	Severity of impacting factor					Conclusion	Overall Score	
	1	2	3	4	5			
Vulnerability of habitat/s	<p>The snow leopard inhabits the high alpine tundra and subalpine ecological zones. They generally occur at elevations above the treeline preferring rocky and rugged terrain with scrub (McCarthy&Chapron, 2003). They build their dens under rocky overhangs or in rock crevices (snowleopardnetwork09). Climate change may increase temperatures in these zones melting any snow and potentially extended the treeline and shrub layer to higher elevations (Fischilin A. et al., 2007). There is little known evidence that this may have any impact on snow leopard populations but is more likely to affect their prey which they rely on. Some researchers believe that snow cover depth and low temperatures is of high importance as it is a limiting factor to snow leopard distribution (Poyarkov et al. 2002) so there may be a potential for the leopards range to extend to higher altitudes and latitudes. For every degree celsius increase in temperature, the snow line will on average rise by about 150 m and a 4 degree temperature rise can potentially melt all glaciers, snow cover and permafrost (Fischlin A. et al., 2007).</p>					<p>Climate change will have minimal direct impact on the habitat for a snow leopard but with warming temperatures and melting snow their ranges could be extended to higher elevations and latitudes.</p>		2
Ecological flexibility	<p>Degree of specialisation: Snow leopards inhabit the alpine and sub-alpine ecological zones (Jackson et al. 2009). They prefer steep terrain broken by cliffs, ridges, gullies and rocky outcrops (Jackson et al. 2009, CMS Report 2002). However, in Mongolia and Tibet they also occupy relatively flat or rolling terrain, providing there is sufficient hiding cover and in the Sayan Mountains of Russia and parts of the Tien Shan range of China, they are also found in open coniferous forest (Jackson et al. 2009).</p> <p>Snow leopards are opportunistic predators, which are capable of killing prey up to three times their own weight (McCarthy & Chapron, 2003). They mainly prey on</p>					<p>Snow leopards inhabit the alpine and sub-alpine ecological zones (Jackson et al. 2009). They are opportunistic predators, however, they habitat one of the least productive rangeland systems in terms of graminoid biomass, meaning prey populations occur at relatively low densities</p>		3

	<p>blue sheep (<i>Pseudois nayaur</i>) and ibex (<i>Capra sibirica</i>), but may also prey on marmot (<i>Marmota spp</i>), pika (<i>Ochotona spp.</i>), hares (<i>Lepus spp.</i>), small rodents, and game birds (Jackson et al. 2009). There have also been reports of predation on livestock (Jackson et al. 2009).</p> <p>Due to low temperatures and high aridity, the snow leopards habitat is among the least productive rangeland systems in terms of graminoid biomass, meaning prey populations occur at relatively low densities (Jackson et al. 2009).</p> <p>Reproduction rate: Mating usually occurs between late January and mid –March and after a gestation period of approx. 93-110 days, one to five cubs are born (McCarthy & Chapron, 2003). Sexual maturity is reached between 2-3 years old (Chapron & Legendre, 2005).</p> <p>Dispersal: They are generally solitary animals; however groups of up to six have been reported (McCarthy & Chapron, 2003).). They occur at elevations of 3,000-4,500m, excluding their northern range limit where they are found at only 900-2,500m (Jackson et al. 2009). They are subject to seasonal movements in response to snowfall and prey availability, spending summers in high alpine pastures, moving to lower altitudes in the winter (CMS Report 2002).</p> <p>The young disperse around 18-22 months and siblings may remain together briefly upon independence (Chapron & Legendre, 2005) Evidence of adaptation in the past: Insufficient data. Climate related changes to fecundity: Insufficient data.</p>	<p>(Jackson et al. 2009).</p> <p>Mating usually occurs between late January and mid –March, with one to five cubs being born (McCarthy & Chapron, 2003). They are subject to seasonal movements in response to snowfall and prey availability, spending summers in high alpine pastures, moving to lower altitudes in the winter (CMS Report 2002).</p>	
<p>Changing dynamics of species interactions</p>	<p>Due to low temperatures and high aridity, the snow leopards habitat is among the least productive rangeland systems in terms of graminoid biomass, meaning prey populations occur at relatively low densities (Jackson et al. 2009). Their principal natural prey species are bharal (<i>Pseudois nayaur</i>) and ibex (<i>Capra sibirica</i>) whose distribution coincides closely with the snow leopard range (Jackson et al. 2009). Bharal are very tolerant of environmental extremes and are able to occupy a wide range of habitats, maintaining locally high densities in areas which are otherwise inhospitable to other species (Jackson et al. 2009). They feed mainly on grasses; however are highly adapted to changing food sources, due to the nature of their habitat, feeding also on supplemental shrubs, forbs and twigs (Animal Diversity Web, 2008).</p> <p>Ibex feed mainly on green grasses (<i>Reogneria</i>), especially during the summer months and are known to consume more than 140 plant species (Animal Diversity</p>	<p>The snow leopards principal natural prey species are tolerant of environmental extremes, are able to occupy a wide range of habitats and are highly adapted to cope with changing food sources. However, it is not yet understood what, if any, impacts climate change will have on the diversity of plant life in particular and how that would affect the snow leopards prey, in terms of their</p>	<p>2</p>

	<p>Web, 2008). They inhabit a wide range of mountain habitats, with elevations ranging from 500m to 6,700m (Jackson et al. 2009). Both species are listed as ‘Least Concern’ by the IUCN Red List. They will also prey on marmot (<i>Marmota</i> spp.), pika (<i>Ochotona</i> spp.), hares (<i>Lepus</i> spp.), small rodents and game birds (Jackson et al. 2009). There have also been a considerable number of reports of predation on livestock (Jackson et al. 2009).</p> <p>The snow leopards habitat may go through substantial changes brought about by the effects of climate change (McCarthy & Chapron, 2003). The geographically isolated environments in which they inhabit favour the natural selection of new species adapted to these conditions (Ourplanet). The diversity of flora and fauna found within these environments will be particularly susceptible to any changes brought about by climate change (Ourplanet). However, it is not yet known what impacts, if any, climate change will have on snow leopard populations and their prey.</p>	<p>dietary requirements.</p>	
<p>Interactions with other processes</p>	<p>Snow Leopard inhabits in the high alpine tundra which is a fragile ecosystem facing a number of threats. Overgrazing by domestic livestock on grassland areas can lead to loss of wild ungulates. Reduction in wild ungulate populations means that there are less prey available for the snow leopard. This could lead to increased preying on livestock leading to retribution killing by herders. A few other threats causing habitat fragmentation and habitat alteration is agro-pastoral activity both within and on the buffer zones of the protected areas. In addition, resource extraction, road building and urbanisation taking place within the fragile habitat range of the snow leopard further endangers the species. Another cause of threat to the snow leopard is poaching activity for pelts and hides which can fetch quite a large amount of money. Snow leopards are also subjected to accidental poisoning and hunting whilst hunting for other predators. Country boundaries included in snow leopard range, e.g. Soviet Block States, have been extensively fenced for national security reasons. These fences create barriers to the movements and migrations of leopards and ungulates and these physical barriers disrupt dispersal and breeding aggregations of these wild populations. This has an even more significant negative impact in areas with declining populations which are physically cut off from potential source populations of immigration therefore having an effect on metapopulation dynamics over a large range. Trans-boundary cooperation and management of protected areas is crucial for conservation of the snow leopard (McCarthy & Chapron 2003).</p> <p>There are nature reserves within the snow leopard’s range however these are partially unprotected due to lack of finance and resources and increasing</p>	<p>The snow leopards habitat is subjected to a number of threats resulting from habitat fragmentation, loss of prey species leading to killing of livestock of local herders. Loss of prey species is mainly due to overgrazing activities of livestock both within and outside protected areas. Preying on livestock therefore subjects the snow leopards to rampant retribution killing by the local herdsman leading to declining number of the snow leopards.</p>	<p>4</p>

	exploitation. Many snow leopards range exists outside the reserve systems and have no protection.		
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species Species Assessment Southern Right Whale, <i>Eubalaena australis</i>					  				
Impacting factor	Severity of impacting factor					Conclusion	Overall Score		
	1	2	3	4	5				
Vulnerability of habitat/s	<p>Southern Right Whales have become endangered from whaling. As their name suggests they are the southerly located species of Right Whales. They range from sub-tropical bays to polar oceans, throughout the southern hemisphere. Generally they migrate seasonally from sub-tropical waters where they calve, to polar waters where they feed on abundances of copepods (Reilly et al., 2008).</p> <p>Antarctic temperatures are predicted to rise by around 2.6°C by 2100 with a range of 1.4 to 5°C, this is significantly less than the predictions for the Arctic (Christensen et al, 2007). This warming is likely to reduce the thickness and extent of sea ice. However this is difficult to model, particularly as in the Antarctic, ice sheet dynamics are uncertain (Meehl et al, 2007). Reduced sea ice cover will affect many mechanisms in the high latitude Southern Ocean and further North (Tynan and DeMaster, 1997). This may alter the distances Southern Right Whales need to migrate to reach food abundances in high latitudes (Robinson et al., 2005).</p> <p>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, as the top-most layer of the ocean has absorbed a large proportion of the heat from the atmosphere, in the future the ocean temperatures are likely to rise 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 Southern Right Whales. El Niño has been shown to directly impact upon the breeding success of the whales, most likely through altering prey abundances (Leaper et al., 2006). However the future magnitude of</p>					<p>The main threat to the habitat of Southern Right Whales', comes from changes in the ocean affecting prey abundance. These can come from changes to, sea Ice, ocean temperature, ocean circulation, salinity, pH and El Nino. The majority of these changes are relatively uncertain, however the size of Southern Right Whales' range should buffer some of the negative effects.</p>			3

	<p>El Niño events is highly uncertain, therefore the impact of this phenomenon on the Whales' habitat is uncertain (Christensen et al., 2007).</p> <p>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 Southern Right Whales' habitat.</p> <p>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 Southern Right Whale, for example by altering the species composition of oceanic Antarctic environments, particularly plankton abundance (Meehl et al, 2007).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: The southern right whale has a circumpolar distribution from 20° – 60°S (NOAA, 2007). In the winter months populations are concentrated near coastlines in lower latitudes, migrating to productive high latitude waters to feed during the summer (Reilly et al., 2008). Calving areas tend to be very close to the shore (Department of Environment and Heritage, 2005), but breeding areas are not known for any population (NOAA, 2007). Females in particular are known to show strong signs of site fidelity in separate years (NOAA, 2007), but habitat utilisation is generally not well understood (Department of Environment and Heritage, 2005).</p> <p>Southern right whales feed almost entirely on Antarctic krill when south of 50°S, gradually shifting to a diet of copepods north of 40°S (Tormosov et al 1998). However, the details of this diet are not well described (Department of Environment and Heritage, 2005). This species favours summer feeding habitats where oceanographic features such as steep bottom topography, relatively cool water temperature, water column stratification, and ocean currents concentrate zooplankton (NOAA, 2007).</p> <p>Evidence of adaptation in the past: No available information</p> <p>Reproduction: Females reach sexual maturity at around 9 years of age and give birth to a single calf every 3-4 years (Cooke & Rowntree, 2003). Gestation lasts 12-13 months (Best, 1994), and lactation up to a year (NOAA, 2007). The interbirth</p>	<p>The Southern right whale is widely distributed throughout the colder waters of the southern hemisphere. Individuals migrate great distances seasonally between low latitude calving grounds in the winter and more productive high latitude waters in the summer. The details of habitat utilisation are poorly understood making it difficult to assess the ecological flexibility. This species feeds on krill and copepod prey depending on availability.</p> <p>Females take 9 years to reach sexual maturity, and calving intervals are generally at least 3 years.</p>	<p>3*</p>

	<p>interval can be longer if conditions are poor (Leaper et al., 2006). Longevity is not known for this species but is thought to be at least 50 years, possibly much longer (NOAA, 2007).</p> <p>Dispersal: Like other baleen whales, seasonal migrations of the southern right whale cover 1000s km demonstrating strong dispersal capabilities (NOAA 2007).</p>		
<p>Changing dynamics of species interactions</p>	<p>Right whales require dense patches of prey, such as copepods and krill when feeding (Greene et al., 2003). Therefore the distribution, abundance and migration of these whales reflect that of their prey (Greene et al., 2003). These dense prey patches have been linked to oceanographic features including fronts, eddies and primary productivity and can be affected by several factors, including temperature (Greene et al., 2003).</p> <p>South of 50°S the Southern rights whales' diet consists mainly of krill (Reilly et al., 2009). Krill feed on microalgae that proliferate on the bottom of sea ice during winter; however sustained warming is causing a reduction in the extent of sea ice, resulting in a significant decrease in krill numbers. This would have a significant impact on southern right whales, which depend on krill for their main source of food (UNEP-GRID, accessed 2009).</p> <p>(In a recent study the complex relationship between krill and salpa (a pelagic tunicate) have been documented (UNEP-GRID, accessed 2009).)</p> <p>Another factor affecting krill is salinity. Shifts in the community structure of phytoplankton, from diatoms to cryophytes, have been linked to glacial melt-water runoff and reduced surface water salinities, in the Antarctic Peninsula (Robinson et al., 2005). As Atlantic krill do not graze efficiently on cryophytes due to their small size, the spatial and temporal distribution and abundance of krill will change, which will again have a significant impact on the right whales (Robinson et al., 2005).</p> <p>North of 40°S their diet consists mainly of copepods, in particular Calanoid sp. (Reilly et al., 2009; NOAA, 2007). Large-scale changes in the biogeography of calanoid copepod's have been detected in the North Atlantic (Robinson et al., 2005). Recent shifts in all copepod assemblages in the North Atlantic Ocean have resulted in a northward extension of more than 10° in latitude of warm-water species associated with a decrease in the number of colder-water species and are thought to reflect regional increases in SST (Greene et al., 2003).</p> <p>As a correlation between the breeding success of the North Atlantic right whale</p>	<p>The Southern right whales require dense patches of prey, mainly krill or copepods depending on their location. Both krill and copepod abundance and distribution are found to be linked to several factors, such as sea temperature, which are highly affected by climatic changes. This may result in moderate-high changes to the food web and the Southern right whale's may change their current range to match that of their prey.</p>	<p>4</p>

	<p>and prey abundance has been demonstrated (Greene et al., 2003), these affects could all damage recruitment of the southern right whale.</p> <p>The whale's main predators are orcas and large sharks, which mainly predate on calves. 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 at present this is poorly understood.</p>		
<p>Interactions with other processes</p>	<p>The main threat to southern right whale is hunting for commercial whaling purposes. An additional area of concern is commercial whaling under the guise of scientific whaling. Other threats include anthropogenic activities, which has led to the degradation of habitats. Some of the activities include construction, entanglement in fishing nets, physical injury and ship strike, water pollution from development work around the coastal waters leading to obstacles for the southern right whale (Department of Environment, Water, Heritage and the Arts, 2009). This is mainly because they use shallow coastal waters for calving and some of these areas coincide with densely human populated areas. Another potential source of crisis for the southern right whale is the loss of prey species such as krill due to overfishing. Krill is one of the major source of food for the southern right whale and is consumed in large quantities to accumulate energy essential for migration and breeding (Department of Environment, Water, Heritage and the Arts, 2009).</p>	<p>Main cause of concern for the southern right whale are anthropogenic activities which has caused habitat degradation. These activities are: construction work, entanglement in fishing nets, physical injury and boat strike creating threats for the southern right whale. Killing of whales for commercial or scientific whaling purposes are also another important cause of threat for the southern right whale. Even though commercial whaling has been banned yet there is a lot of commercial whaling undergoing under the guise of scientific whaling.</p>	<p>4</p>
		<p>HIGH VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Sperm Whale, *Physeter macrocephalus*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Sperm Whales have a global range, covering the vast majority of the oceans, from the Polar Regions to the tropics (Taylor et al., 2008). This global ocean habitat is likely to be affected by; changes in sea level, warming of the oceans, changes to the extent of sea ice, alterations to the currents as well as differences in salinity and pH (Bindoff et al., 2007). Sea level rise over short timescales is unlikely to have a significant impact on Sperm Whales. From 1961 to 2003, global ocean temperature has risen by 0.1°C, from 0 to 700m in depth. It is probable that there has been less warming at depth, although this inference is based on limited evidence (Bindoff et al., 2007). Warming affects the range of males, as the sea ice breaks up earlier and nearer the poles. This may also affect prey abundance (Bluhm and Grandinger, 2008). Warming also affects the females' and juveniles' range as the 15°C thermal boundary moves towards the poles, thereby affecting social interactions within the population (Robinson et al., 2005). Changes in ocean currents due to changes in weather patterns, water temperature and salinity may also affect Sperm Whales. They use currents to migrate and currents also cause nutrient upwelling, providing prey (Bindoff et al., 2007). Ocean acidification is likely to affect sperm whales through prey abundance, as cephalopod species are particularly vulnerable (Simmonds and Isaac, 2007).</p>					<p>As Sperm Whales' range is so large, many of the negative impacts from climate change will be mitigated, whilst their range is likely to increase in size. However changes in temperature and ocean circulation could affect social structures negatively, however this is highly uncertain. In addition if severe, ocean acidification could significantly undermine Sperm Whales' food web.</p>	2
Ecological flexibility	<p>Specialisation: The Sperm Whale is a widely distributed species, present in nearly all deep water marine areas not covered by pack ice (Taylor et al., 2008). Females and young males are limited to warmer tropical or subtropical waters at latitudes lower than 40°-50°, corresponding to sea surface temperatures of 15°C or higher (Department of the Environment, Water, Heritage and the Arts, 2009). Males begin to slowly migrate towards the poles between the ages of 4 and 21 years (NOAA, 2009). They remain at high latitudes, returning to breed seasonally in warmer waters (NOAA, 2009). Sperm whales tend to be found far offshore, in waters of 600m depth or more and are known to congregate in areas where the seabed rises steeply from great depth, probably associated with increase food availability in areas of upwelling (Department of the Environment, Water, Heritage and the Arts, 2009). This broad ranged habitat use indicates a fairly generalist species.</p>					<p>The sperm whale has a huge global distribution and is primarily a pelagic species, capable of travelling extensive distances through the ocean basins. They tend to congregate around areas with high sea floor relief where upwelling results in higher prey densities. They are generalist feeders, with large cephalopods making up the core of their diet. Females</p>	3

	<p>P. macrocephalus primarily feeds on medium and large sized squids, but it has been documented to feed on a wide variety of other prey including other cephalopods, and a range of medium and large demersal fishes (Department of the Environment, Water, Heritage and the Arts 2009). They are capable of diving very deep to forage, but it is not fully known how they locate their prey in the dark at these depths (Department of the Environment, Water, Heritage and the Arts 2009). This generalist diet, and the ability of this species to travel extensive distances and forage throughout the water column means it is likely to be able to cope with changes in the marine environment better than other species.</p> <p>Evidence of adaptation in the past:</p> <p>Reproduction: P. macrocephalus is a very large species, taking decades to reach physical maturity. Females reach sexual maturity at 7-13 years (8.3-9.2m), whereas males take 18-21 years (11.0-12.0m) (Bannister et al., 1996). Sperm whales can live up to 60 years (Department of the Environment, Water, Heritage and the Arts, 2009), although females over the age of 40 years rarely become pregnant (NOAA 2009). A single calf is born after a gestation period of well over a year, and mothers lactate for 2 years (NOAA, 2009). Consequently the interbirth interval is 4-6 years even for prime aged females (Bannister et al., 1996), meaning reproductive capacity is low (Department of the Environment, Water, Heritage and the Arts, 2009). Generation length is estimated to be around 27 years (Taylor et al., 2008). Calving occurs in temperate and tropical waters, but no specific localities (Bannister et al., 1996) or specific reproductive behaviours that may make this species very vulnerable are known (Department of the Environment, Water, Heritage and the Arts, 2009).</p> <p>Dispersal: Sperm whales are capable of travelling great distances, illustrated by the males breeding migrations that can extend from the edge of the sea ice into the tropics (Department of the Environment, Water, Heritage and the Arts 2009).</p> <p>Climate related changes to fecundity: No information available</p>	<p>reach sexual maturity at around 10 years of age, and are thought to be reproductively active until they are around 40. However, even females in their prime are only likely to calve every 4-6 years.</p>	
<p>Changing dynamics of species interactions</p>	<p>Although the effects of climate and oceanographic change on sperm whales remain uncertain at this point, there has been some evidence to suggest that habitat and food availability may be affected (NOAA, 2009).</p> <p>Sperm whales feed primarily on large and medium sized squids, but will also feed</p>	<p>Although the effects of climate and oceanographic change on sperm whales remain uncertain at this point, there has been some evidence to suggest that</p>	<p>2</p>

	<p>on a wide range of other prey, such as octopuses and medium and large-seized demersal fishes, including rays and sharks (Department of the Environment, Water, Heritage and the Arts, 2009). Many fish and cephalopods, require a particular set of environmental conditions in which to survive (Robinson et al., 2005). Cephalopods are particularly vulnerable 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). Sharks however flourished during the warmer climates of the Mesozoic and survived the recent periodic ice ages, therefore it seems likely, depending on the magnitude, patterns and speed of climate change, that most chondrichthyan species will survive the effects of climate change (Fowler et al., 2009). Although it is likely that their level of abundance, and patterns of distribution will change (Fowler et al., 2009). It is also worth noting that the feeding range of sperm whales is likely the greatest of any species on earth and it is likely that they will be more resilient to climate change than species with narrow habitat requirements (NOAA, 2009).</p> <p>The sperm whales greatest natural predator is the killer whale (<i>Orcinus orca</i>), however most attacks are thought to be unsuccessful (NOAA, 2009). Large sharks also pose a threat, especially to young sperm whales (NOAA, 2009). As previously mentioned, climate change is unlikely to have any major impact on most shark species.</p> <p>Site selection for migration, feeding and breeding in sperm whales may be influenced by factors such as ocean currents and water temperature (NOAA, 2009). There has been some evidence to suggest that the whales feeding success and calf production rates are negatively affected by an increase in sea surface temperature, especially during El Nino years (NOAA, 2009).</p>	<p>habitat and food availability may be affected (NOAA, 2009). Site selection for migration, feeding and breeding in sperm whales may be influenced by factors such as ocean currents and water temperature (NOAA, 2009). However from the evidence available, it appears unlikely that there will be a major disturbance of their broad food-web.</p>	
<p>Interactions with other processes</p>	<p>Habitat disturbance is mostly caused by climatic factors which culminates in rising sea temperatures which in turn affects the distribution of prey species for the predator species. However, anthropogenic influence is causing the decline of the sperm whale population (DEWHA, 2009). Sperm whales are intensely affected by shipping and fishing operations (DEWHA, 2009). Deaths from ship strikes, accidental bycatch, oil spills as well as accumulation of toxic chemicals on the body of the whale had resulted in the increasing number of deaths in the population of the whale (Perry et al., 1999). Pollution from increasing amount of toxic drainage</p>	<p>Sperm whale population have been most affected by human activities such as shipping and fishing operations. Other forms of threat include loss of prey species due overharvesting of fish, release of industrial and toxic waste into the sea</p>	<p>3</p>

	into the sea such as plastic debris and bio-chemical waste has also been a factor in the decline of the sperm whale population.	leading to the accumulation of toxic substances in the body of the whale. On the balance of evidence, the threat posed by anthropogenic activities (excluding climatic change) is moderate.	
			MEDIUM VULNERABILITY

Climate Change Vulnerability of Migratory Species							
Species Assessment					  		
West African Manatee, <i>Trichechus senegalensis</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>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, along the coast from Mauritania in the north, to Namibia in the south, and far into the wetlands of the interior (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, server weather, sedimentation rates, sea level as well as ocean circulation, salinity and pH.</p> <p>West Africa is predicted to warm by around 3.3°C by 2100 (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 much lesser extent. This increase in temperature has the potential to impact upon the manatees in many ways from individuals over heating, 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 has the potential to reduce water availability in the Manatees habitats.</p>					<p>Increased rainfall variability is likely to increase the variability of water levels in the freshwater areas of their habitats. As Manatees suffer from both high levels and low levels, this is likely to be a detrimental change to the inland habitats. Sea level change is likely to significantly degrade their coastal habitats. Other climate change processes will also degrade both habitats but to a much lesser extent. This means that climate change is predicted to highly degrade the main types of West African Manatee habitat.</p>	4

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. 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).

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).

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., N.D.). 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).

	<p>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). 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 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 has the potential to inundate large areas of the coast, particularly the shallow areas the manatees frequent, significantly degrading the manatee's coastal habitats.</p> <p>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 coastal 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).</p>		
<p>Ecological flexibility</p>	<p>Specialisation: The West African manatee is restricted to the coastal waters and adjacent rivers and lakes of West Africa from southern Mauritania to Angola and east to Mali, Niger and Chad (Marshall et al., 2003). They are found in a variety of habitats including large and small rivers, coastal estuaries, freshwater and saltwater lagoons, coastal bays, lakes and reservoirs (Powell & Kouadio, 2008). Their main habitat requirements include sheltered water, with access to food and freshwater (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</p>	<p>The West African manatee is found in a large array of habitats and can travel freely from salt to freshwater (although they are thought to prefer estuarine habitats). They feed primarily on vegetation, particularly overhanging vegetation rather than submerged, and have also been observed feeding on small fish. Their habitat requirements are not as specific, in contrast to river</p>	<p>4</p>

	<p>disturbance and waters are shallow and calm (Powell & Kouadio, 2008).</p> <p>They feed primarily on vegetation including hippo grasses (<i>Vossia</i> sp.), water hyacinth (<i>Eichornia crassipes</i>), rigid hornwort (<i>Ceratophyllum demersum</i>), red mangrove (<i>Rhizophora racemosa</i>), water cabbage (<i>Pistia stratiotes</i>), several species of sea grass (<i>Cymodocea nodosa</i>, <i>Halodule</i> sp.) and many more (Powell & Kouadio, 2008). They have also been documented feeding on small fish and shell remains of molluscs 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).</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction rate: 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).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: 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).</p>	<p>dolphins for example, however they are still fairly restricted in their current range.</p> <p>They have low reproductive rates and have a fairly long calving interval. Little is known about their reproductive rates.</p> <p>Although some populations are isolated, many undertake significant seasonal migrations, which are important as they are in response to food availability.</p>	
<p>Changing dynamics of species interactions</p>	<p>Manatees are almost exclusively herbivores, with the West African Manatee feeding on plant species such as <i>Vossia</i> sp., <i>Eichornia crassipes</i>, <i>Polygonum</i> sp., <i>Cymodocea nodosa</i>, <i>Ceratophyllum demersum</i>, <i>Azolla</i> sp., <i>Echinochloa</i> sp., <i>Lemna</i> sp., <i>Myriophyllum</i> sp., <i>Pistia stratiotes</i>, <i>Rhizophora racemosa</i>, and <i>Halodule</i> sp. (IUCN Red List). However, it is suggested that occasionally West African Manatees may eat small fish from fisherman's nets, and that the remains of molluscs have been found inside stomachs (IUCN Red List).</p> <p>Manatees need an abundance of plant life to survive. Raised temperatures may</p>	<p>West African Manatees feed mainly on aquatic and semi-aquatic vegetation, and these plants may be affected by climate change, for example as a result of changes in salinity, increases in the concentration of dissolved inorganic carbon (leading to increased algal</p>	<p>3</p>

	<p>effect vegetation growth, preventing many of the plant species from growing as they normally would (Manatee-world).</p> <p>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).</p> <p>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).</p> <p>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.</p>	<p>growth) and an increase in storm disturbance and associated overwash. West African Manatees may be predated by crocodiles and sharks, and climate change may have an impact on these species. Shark distribution is likely to change, and there may be negative impacts on crocodilians. However, the main sources of prey for these predators may become scarcer, which could lead to an increase in predation on the defenceless manatee.</p>	
<p>Interactions with other processes</p>	<p>Changes to its habitat, including mangrove destruction (for rice farming, wood, fish smoking, salt extraction and other needs), as well as development projects such as dams (Sirenian.Org, 2009). 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. They are sometimes killed in turbines or control gates of dams. The decline of the manatee is partly due to their coastal wetland habitat being heavily degraded and threatened. However,</p>		<p>4</p>

	<p>fishing practices are in conflict with the manatees feeding and travel behaviour and have impacts on the manatees long term survival by the removal of floating vegetation thereby altering the aquatic habitat. And also by competition for aquatic vegetation from fishermen using live vegetation as habitat for certain fish harvesting methods resulting in reduced access to feeding resources (Sirenian.Org, 2007). Woodcutting is resulting in the clearance of mangrove swamps as well as erosion due to forest clearance upstream which increase sedimentation that silts up lagoons and estuaries (Animalinfo.Org 2009). Mangroves have thick corses and interconnected roots and are essential for purifying sea water, regulating the tides, balancing underwater ecosystems, and mitigating the effects of floodwater damage (African Conservation.Org, 2007).The construction of sea wall defences along coastal habitats against sea level rise could possibly interfere with migration routes or 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 3 generation period due to habitat loss by mangrove harvesting, siltation, dams. This % can increase when combined with the effects of climate change described above. Many small dams have been on tributaries of the Senegal river for irrigation and agriculture. Manatees often become trapped behind dams which block access to the main Senegal River. Due to the remoteness of the river, the muddy water quality and its seasonal fluctuations manatees are susceptible to becoming stranded when water levels fall during the dry season, which were once high enough for the manatees to swim in during the rainy season. As the number of dams constructed increases so do the number of places the manatees can become trapped. In some cases the water completely dries up before the next rainy season, so manatees left there would eventually die, while in other cases enough water remains but there are no plants for them to eat as water levels fall (Sirenian.Org, 2009).</p>		
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Basking Shark, *Cetorhinus maximus*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>According to coupled climate models the thermohaline circulation (THC) of the Atlantic Ocean will be affected by the addition of freshwater from melting ice will lead to the cooling of surface climates. Global warming can effect the THC in two ways: surface warming and surface freshening, both reducing the density of high-latitude surface waters and thus inhibiting deep water formation. This could lead to disruption or even breakdown of the THC and to abrupt climate change, but only for a quadruple CO₂ emissions scenario. Many coupled climate models state the probability of the THC collapsing is low but more likely is the weakening of the THC by 20-50% (Rahmstorf, 1999).</p> <p>The IPCC anticipates that if anthropogenic CO₂ emissions continue to accelerate at its current pace, that pH will fall an additional 0.3 to 0.4 by the end of this century causing ocean acidification. The IPCC AR4 reports observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000m and that the ocean has been taking up over 80% of the heat being added to the climate system. Furthermore DEFRA report on UK Climate Projections predicts a high probability that annual sea level pressure will change up to 2 hPa under high and low emissions scenario (UKCP, 2009). AR4 models also predict that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down by 25% by 2100 (Solomon et al., IPCC 2007).</p> <p>Basking sharks migrate up the Atlantic and Irish Sea during summer months and follow the coastline. Coasts are highly vulnerable to extreme weather events, such as storms. Calm coastal sea conditions are correlated with copepod blooms in surface waters however, storms lead to considerable mixing of surface and upper water layers disrupting copepod bloom densities. Most models predict an increase in occurrence of cyclones and increase storm intensity and winds in the North Atlantic, dependent on sea temperature changes (Christensen et al., 2007).</p>					<p>Changes in sea temperatures, pH and THC are likely to alter the physio-chemical factors in the North Atlantic which may have a negative impact on the biology of basking sharks. Increases in extreme weather events around coastlines will certainly impact the feeding behaviour and migratory patterns of these sharks.</p>	3

<p>Ecological flexibility</p>	<p>Specialisation: The basking shark has a circumglobal distribution and is known to be present in boreal to warm-temperate latitudes of the Atlantic and Pacific Oceans. They inhabit both coastal and pelagic waters. They can be seen feeding on their small zooplankton prey just below the surface, and recently have also been recorded to dive to depths of over 1000m for extended periods (Skomal et al., 2009). This indicates a broad thermal tolerance for the species. The basking shark's diet consists of a range of zooplankton (primarily copepods). They are highly selective, and choose profitable plankton patches above a threshold plankton density to feed on (Sims and Quayle, 1998). They forage in shallow water along thermal fronts and are able to follow shifting patterns of secondary production (Sims and Quayle, 1998). This implies they have the potential to cope with changes to foraging behaviour that may be brought about by climate change.</p> <p>For many years it was believed that basking sharks spent the winter months hibernating in the deep ocean, at the bottom of continental shelves (Parker and Boeseman 1954). It is now known that this is not the case. Some individuals migrate along the coastal shelf, but others undertake extensive migrations covering 1000s of kilometres (Gore et al., 2008, Skomal et al., 2009). During these migrations basking sharks frequently dive to mesopelagic depths up to 1000m for extended periods. It is not yet known if they feed there, but if that proved to be the case it would suggest a greater degree of flexibility.</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproductive rate: The reproductive biology of the Basking shark is not fully understood. Pregnant females are almost entirely unknown, but examination of non-pregnant females revealed large numbers of small eggs within the ovaries. This suggests uterine cannibalism, where the embryos feed on the eggs (Campagno, 2001). Females are viviparous and it is thought they give birth to 5-6 pups after a gestation period of 1-3 years (The Wildlife Trust, 2008). A birth size of 1.5-1.7m is unconfirmed. Basking sharks are slow growing and mature late (males 12-16 years, females up to 20 years based on von Bertalanffy growth models) (Campagno 2001). There is a probably cycle of 2-3 years between litters. This species, like other large sharks, thus has a very low reproductive rate making it vulnerable to threats.</p> <p>Dispersal: Recent developments in technology have allowed the tracking of a number of basking sharks. These have demonstrated extensive migrations, with individuals travelling 1000s of kilometres (Skomal 2009), even across the great</p>	<p>The Basking shark is present in both the Pacific and Atlantic oceans at boreal to warm-temperate latitudes. It is able to dive to great depths indicating a broad thermal tolerance. It's ability to forage for it's zooplankton prey along shifting thermal fronts would be beneficial in a changing environment. It undertakes extensive migration, and ventures into the deep ocean. It is not yet known if it feeds at depth.</p> <p>Further work is needed to help us understand the reproductive biology of the Basking Shark. It is currently thought that females take up to 20 years to reach sexual maturity and give birth every 2-3 years. Gestation for 5-6 pups could be up to 3 years.</p>	<p style="text-align: center;">3</p>
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	oceanic basins (Gore 2008).		
	Climate related changes to fecundity: Insufficient data.		
Changing dynamics of species interactions	<p>Basking sharks are selective filter-feeders that choose the richest, most profitable plankton patches. They forage along thermal fronts and actively select areas that contain high densities of large zooplankton above a threshold density. They remain for up to 27 hours in rich patches that are transported by tidal currents and move between patches over periods of 1–2 days. Foraging behaviour of basking sharks therefore indicates the distribution, density and characteristics of zooplankton directly. This makes these sharks unique biological ‘plankton recorders’, with potential use as detectors of trends in abundance of zooplankton species that are influenced by climatic fluctuations of the North Atlantic Oscillation (Sims & Quayle, 1998).</p> <p>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, but only very weakly to zooplankton density. This suggests that the changes in number of basking sharks recorded over large spatio-temporal scales are more closely related to the availability of climate-driven thermal resources than prey availability, whereas the converse is supported by previous studies at local scales. Taken together, these results imply scale-dependent behavioural responses in basking sharks, with small-scale foraging movements linked by broad scale responses to temperature variation (Cotton et al., 2005)</p> <p>Basking sharks have few if any predators, however, white sharks have been reported to scavenge on the remains of basking sharks. Parasites or commensals such as remoras and especially sea lampreys (<i>Petramyzon marinus</i>), are often seen attached to the skin of the basking shark. The lamprey cannot cut through the denticle-armed skin, but they may be enough of an irritant to cause a reaction like jumping or rubbing against an object or the bottom to dislodge them. The cookiecutter shark (<i>Isistius brasiliensis</i>), has also been known to attack basking sharks by using its suction cup-like lips and muscular pharynx to bore out plugs of flesh on the outside of the shark (FLMNH 2009).</p>	Rising sea temperatures caused by climate change are likely to disrupt the timing and distribution of plankton blooms upon which the basking shark relies.	3
Interactions with other processes	The Basking Shark is very slow to mature, long-lived, and has very few young due to its long gestation period. These aspects make Basking Sharks extremely vulnerable to outside impacts, such as disturbance and harassment from boats or jet skis. A major concern is overfishing as a large number have been	Exploitation of this long-lived species which is slow to reach maturity puts the population under pressure. If fishing	3

	<p>caught for their liver oil, meat, fins and cartilage, especially for the Asian market. The liver is very large (up to a third of its body weight) and yields 60-75% oil. This is a rich source of squalene (a low-density hydrocarbon) and vitamin A, and is used in manufacturing processes, to tan leather, as lamp oil and for lubricating machinery (Shark Trust, 2007). The meat is used for food or animal feed, and the cartilage processed into health food pills (FLMNH, 2009). The fins are the most valuable commodity and single large fins may be worth over US\$ 10,000 in East Asia, as a soup ingredient (Shark Trust, 2007). Fisheries for basking sharks have existed all around the world, including Scotland, Ireland, Norway, Iceland, California, China, Peru and Ecuador. These have all shown similar trends of high initial catches followed by a depletion of stock and long term closure of the fishery (Shark Trust, 2007).</p>	<p>pressures cannot be kept to a minimum the population will be ill-equipped to cope with the challenges posed by climate change</p>	
	MEDIUM VULNERABILITY		

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Common Sturgeon, <i>Acipenser sturio</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>For the Common Sturgeon, the biggest impact climate change is likely to be the loss of breeding habitats. Sturgeons breed in the lower basins of major rivers, in deep pits of a few metres, made of shingles and gravel subject to strong currents. When born, these fish stay around the spawning bed area for approximately 6 months then swim towards the estuary where they progressively get used to more saline waters where water levels are about 5 m deep and temperatures remain constant around 20 degrees (UNEP-WCMC 2009). Therefore as climate change will lead to higher temperatures this will increase evaporation rates of shallow breeding pools. This would have a serious negative impact on the fish as they need enough water to travel to their spawning areas by reducing the amount of water flow through their migration. However, increasing sea levels will counteract this but with rising sea levels will increase salinity of estuarine waters which the young fish may need to become used to earlier in their life cycle. Increased temperatures in spawning pools, streams and rivers, the biological oxygen demand will increase and the temperature may also affect hatching or development of eggs (Climate</p>					<p>Threats to breeding habitats by climate change and serious barriers to migration coupled with changes in physio-chemical properties of estuaries are likely to negatively impact upon the Common Sturgeon. Changes in seasonal temperature cues may affect migration patterns and timing, and increased salinity of rivers may pose a threat to juveniles. However, some reports suggest that this species is unlikely to be</p>	2

	<p>Change North, 2009). Increased melting of glaciers and permafrost may cause more landslides and erosion along river banks causing more dirt and gravel to build up and potentially cover up the shallow spawning areas of the sturgeon. Increases amounts of sediments in rivers could also make it harder for fish to breathe and find food as they require soft sandy or muddy substrates to find food (UNEP-WCMC 2009). Higher temperatures and reduced rainfall or periods of droughts may cause shallow parts of rivers to dry up blocking migration routes. Around the UK coast, predictions based on medium emission scenarios show mean temperatures for Southern North Sea will vary from 1.2°C - 3.3°C and precipitation will vary from -32% to +21%. In the Eastern English Channel under the same scenario, 1.2°C - 3.4°C degrees temperature change is expected and a -49% - +31% change in precipitation (DEFRA, 2009). As seasonal movements of sturgeon seem to be motivated by warmer temperatures rather than salinity especially during winter (Rochard et al., 2001), these projected temperature changes could alter migration habits considerably. Previous studies in Georgia have shown that <i>A. Sturio</i> is not sensitive to climate change (Berry, 2008). However, projected sea level rise and increase storm surges will impact upon coastlines and alter the biochemical properties of the water (Paskoff, 2004). This may increase the salinity of upstream rivers which could be important for recruitment of the population - first year juveniles can only tolerate low salinity levels, up to 5‰ brackish waters (Rochard et al., 2001).</p>	<p>affected by climate change.</p>	
<p>Ecological flexibility</p>	<p>Specialisation: The Common Sturgeon is an anadromous species which spends the majority of its adult life in the sea but migrates into freshwater to spawn (Fishbase). Previously widespread in the northeast Atlantic, the species is now limited to only two naturally spawning populations. The Atlantic population migrates up the Gironde in France (Williot et al 1997), and a population in the Black Sea spawns in the Rioni River basin in Georgia (Kolman and Zarkua 2002). During it's time at sea the species has a relatively wide range and is found from the Bay of Biscay to the Bristol Channel and the North Sea (Lepage and Rochard 1995). The Common Sturgeon inhabits shallow littoral areas, usually between 10 and 70m (Williot 1997). They feed on a variety of benthic invertebrates, the adults at sea mainly worms, crustaceans and molluscs, and the juveniles on insects and larvae on the river bed (UNEP-WCMC). The extensive historical range and broad diet may suggest a low degree of specialisation in this species. However, they require a variety of specialised habitats throughout their lifecycle (International Action Plan 2005, Lepage and Rochard 1995) and mature adults usually return to their natal river to spawn (UNEP-WCMC) meaning their adaptability may be low.</p> <p>Evidence of adaptation in the past: Insufficient data although this species is</p>	<p><i>Acipenser sturio</i> has a large historical range and widely distributed marine phase. Combined with a broad diet of benthic invertebrates, this could indicate a fairly generalist species. However, the sturgeon requires a variety of specialised habitats throughout its lifecycle. In addition, its specialised breeding biology, high age at sexual maturity and low survival rate reduce this species resilience.</p>	<p>3</p>

	<p>reported to be a “living fossil” (Gardiner, 1984) with early remains of this species being found dating back to 26 million years (Kirchhofer & Hefti, 1996). This suggests that the species main limiting factor is anthropogenic impacts rather than an ability to adapt to changing environmental conditions.</p> <p>Reproductive rate: The Common Sturgeon has a very low reproductive rate. They migrate and spawn seasonally, with a peak in late spring. Mature adults do not feed while they are migrating upstream and are often in very poor condition when they return to the sea – many die on the way (UNEP-WCMC). Females lay huge numbers of eggs – numbering hundred of thousands to millions (Lepage and Rochard 1995) – but the survival rate is low. The species takes a very long time to reach sexual maturity (males 12-14 years, females 16-18 years) (International action plan 2005). The older the female the more eggs she is able to produce (Fishbase). The species has very low resilience, and population doubling time is thought to be more than 14 years (Fishbase).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: The species is known to spawn in very limited locations, and yet their distribution while at sea is quite wide. Many individuals are known to stay in coastal waters near to estuaries, but others have been caught many hundreds of kilometres away (UNEP-WCMC). This indicates the potential for Common Sturgeons to colonise new rivers in the region if suitable habitat is available.</p>		
<p>Changing dynamics of species interactions</p>	<p>A. sturio do not appear to be dependent on any one prey species, they feed opportunistically on bottom dwelling creatures. Young sturgeon feed on benthic invertebrates in rivers especially midge larvae and other insects, worms crustaceans and molluscs. At sea they feed on the larger worms, crustaceans and molluscs, but they also take some fish notably sand-eels and gobies (UNEP-WCMC, 2009).</p> <p>There do not appear to be any significant competitors or predators that threaten A. sturio, and there is no evidence of important symbiosis.</p>	<p>A. sturio do not appear to be dependent on any one prey species, they feed opportunistically on bottom dwelling creatures. There do not appear to be any significant competitors or predators that threaten A. sturio, and there is no evidence of important symbiosis.</p>	<p>1</p>
<p>Interactions with other processes</p>	<p>The major threat to common sturgeon is fishing for their roe. On the European continent the flesh of the sturgeon is highly valued and especially more because of the roe which is processed to make caviar. With the rapid decline in numbers, the previously prominent commercial fisheries have also closed down as the stock numbers declined.</p> <p>Most of the wild stocks caught in the North Sea are destroyed through bycatch. An important cause of their decline is the pollution of its freshwater breeding grounds. Habitat destruction also occurs through infrastructural developments</p>	<p>Major threats include poaching for roe. Other threats include habitat fragmentation due to major water management and irrigation projects destroying valuable spawning ground for the common sturgeon</p>	<p>5</p>

	<p>such as construction of water management and irrigation projects, hydro-technical installations on the major rivers which are most frequented by the common sturgeons. This has restricted their mobility (Peterson et al, 2003). Construction of dams has also been responsible for destruction of its habitat especially their spawning grounds. Further threats arise because of its slow growth making it vulnerable to exploitation (Lepage and Rochard, 1995).</p> <p>The other important factor is poaching. Despite legal measures and actions of the so-called ecological police, poaching goes on particularly intensively during the sturgeon spawning migrations. It seems that the active protection of the Black Sea population of the common sturgeon involving artificial spawning of the fish captured in the Rioni, egg incubation, and rearing of the hatch and larvae under controlled conditions are some of the ways in which they could be regenerated. A small fraction of the juvenile fish could also be used to build up a broodstock.</p>		
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species Species Assessment Mekong Giant Catfish, <i>Pangasianodon gigas</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Studies on the giant catfish show that their habitat preference is for deep water of up to 15 metres rather than shallow inlets. The average temperature range in these waters is 20°C - 30°C and the amount of dissolved oxygen decreases with depth and rising temperatures. The fish have been found to be tolerant to hypoxic waters and their movements are not limited to temperature (Mitamura et al., 2009). Any rapid changes in environmental conditions across the 6 countries through which they migrate may have potential impacts, especially at spawning sites. The future loss of the catfish may have an impact on intricate ecosystems in the Mekong River Basin (IUCN, 2005). In the future catfish may be further endangered by droughts and a reduced water level of the river. However, the IPCC states that as sea levels will rise by 1m, 15 - 20 thousand km² of the Mekong basin is projected to be flooded before increased run off from melting glaciers is taken into account (Eastham et al., 2008).</p>					<p>The impact of climate change on the catfish is likely to be low. The largest impact is likely to come from Increased flooding due to rising sea levels changing the physio-chemical properties of the river basin. Periods of drought may cause parts of the basin with reduced flow to dry up creating barriers to migration. Spawning areas need most protection from drying out as they are critical</p>	2

<p>Ecological flexibility</p>	<p>The Giant catfish is endemic to the Mekong River Basin where it inhabits medium to large freshwater rivers and lakes (Hogan 2003). One of the largest freshwater fish in the world, it has been reported to reach lengths of 3m with a mass of 300kg (WWF fact sheet). Relatively little is known about the ecology of this species (Lopez 2006). They are found in the Tonle Sap Lake of north west Cambodia and are known to undertake seasonal migrations, moving into the mainstream of the Mekong River from October to December. It is thought that they travel hundreds of miles upstream towards spawning sites in north eastern Cambodia, Laos and Thailand, but only one location has been confirmed near Chiang Khong in Thailand. The details and cues for migration are unknown, and thus it is difficult to assess their vulnerability to climate change. However, the extensive tracts of river they require for their seasonal journeys are likely to be threatened in a changing climate.</p> <p>Adult <i>P. gigas</i> consume detritus and algae found on the river floor (Fishbase). Juveniles can be cannibalistic but feed mainly on tiny animal plankton (WWF). Although the degree of specialisation is unconfirmed their sensitivity to water quality and temperature (Hogan 2004) suggests they would be unable to tolerate an altered environment.</p> <p>The reproductive ecology of the Giant Catfish in the wild is not well understood, but individuals have been breed in captivity and released into the wild. Few of these reintroductions have been successful (WWF fact sheet). The species has a notably high growth rate - growing to 150-200kg in 6 years (Rainboth 1996). However, it is likely they do not reach sexual maturity for a number of years and generation times are thought to be in the region of 10-15 years (Hogan 2003). This makes the population of low resilience and vulnerable to threats from climate change.</p>	<p>for future breeding success.</p> <p>Little is known about the ecology of this species. A large freshwater fish species, it is thought that the giant catfish undertakes extensive migrations to specialised breeding sites. Although its diet is fairly broad, it is thought to be sensitive to water quality and temperature. There is very little information available on the reproductive biology of this species, but its generation times are thought to be 10-15 years.</p>	<p>3</p>
<p>Changing dynamics of species interactions</p>	<p>The giant catfish feeds on vegetation growing on the river bed, therefore food availability for this species is limited by the range size and quality of habitat. This species has no known competitors or predators.</p> <p>Genetic introgression with cultured stocks is considered to be a threat to this species survival (Hogan, 2003).</p>	<p>The giant catfish feeds on vegetation growing on the river bed, therefore food availability for this species is limited by the range size and quality of habitat. This species has no known competitors or predators.</p> <p>Genetic introgression with</p>	<p>2</p>

		cultured stocks is considered to be a threat to this species survival (Hogan, 2003)	
Interactions with other processes	<p>Fishing is the most important threat to <i>P. gigas</i>. The construction of dams, navigation projects and destruction of habitats has critically endangered this species. For instance, the controversial Mekong Navigation and Channel Improvement Project have managed to destroy miles of spawning ground for the giant catfish and other fish species (Hogan, 2004). In the Mun river the construction of a dam has blocked the habitual migration of the giant catfish leading to similar destruction of breeding grounds (Hogan, 2004). On a generic level, it is assumed that large species, which breed comparatively late in life, are more susceptible to fishing and environmental changes, especially in the context of habitat fragmentation often caused by water-related development projects, such as dams (Mattson et al, 2002).</p> <p>According to a WWF report, it is a popular food fish in and around the Mekong basin. They were usually caught in large numbers using seines, gillnets and stationary bagnets in Thailand particularly at Chiang Kong mostly around the spawning grounds. With the rise of infrastructural developments there has been a restriction on the movement of these giant cats up and down the river. Restricted mobility gave them less opportunity to breed and interact with other individuals which leads to low numbers and overall genetic diversity (WWF report). Hence, most of the existing species of giant catfish are being raised in captivity in order to prevent them from getting extinct.</p>	Giant catfish are most threatened by fishing. Habitat destruction through the construction of dams and other infrastructural development activities through the waterways has further damaged the breeding ground of this catfish by restricting their migration and mobility	5
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Great White Shark, *Carcharodon carcharias*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Sea-level is estimated to rise due to thermal warming and melting glaciers and ice sheets by an additional +0.18 to 0.59 m (+0.6 to 1.9 feet) by 2100. Numerical model climate projections for this century show global mean surface temperature increasing, with a range of +1.1 to 6.4°C (+2.0 to 11.5°F) above late 20th century levels. Negative impacts arise both directly, via effects of elevated temperature and lower pH on individual organisms, and indirectly via changes to the ecosystems on which they depend for food and habitat. Sharks have been around for millions of years and survived large climate and acidification variations in the past, but the projected rates of climate change and ocean acidification over the next century are much faster than experienced by the planet in the past except for rare, catastrophic events in the geological record. As ocean temperatures rise sharks ranges may shift towards the poles as they prefer cold water where nutrient upwelling's occur. Sharks could invade Antarctic waters within the next 10 to 15 years which may have a consequence on fragile communities which already exist there, mostly by predation. Sharks have a chemical called triethylamine oxide (TMAO), which is needed to counterbalance the build up of urea generated by their continuous movement. But TMAO is needed in greater doses at lower temperatures and so there appears to be a thermal cut off point of how much they produce (Heffernan O. 2008). The Antarctic has previously marked that cut off point, but the researchers highlighted that this is one of the fastest warming regions of the planet. It's currently warming at a rate of approximately 1 degree Celsius each 25 years. The Memorandum of Understanding on the Convention of Migratory Sharks (2008) states that their conservation status is favourable as there is, and will be in the foreseeable future, sufficient habitat to maintain the population of migratory sharks on a long term basis. White sharks being endothermic fish and are able to migrate long distances using their own metabolic heat from their large muscles. They will therefore be able to tolerate larger temperature variations and have a wider ecological niche.</p>					<p>Changes brought about by climate change are unlikely to have a direct impact on the shark's biology however there may be range shifts notable later on this century. Great Whites have large ranges and are adaptable to a broad range of temperatures giving them a broad niche tolerant of temperatures ranging 4 - 26 degrees. They are mostly pelagic and spend 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.</p>	1
Ecological flexibility	<p>The Great White Shark is an apex predator, positioned at the top of a complex marine food web. Its large size, extremely powerful jaws and teeth and efficient locomotion make it a well adapted and very versatile predator (IUCN 2009). The</p>					<p>The great white shark has one of the widest habitat and geographic ranges of any fish-</p>	2

	<p>most important prey items for Great Whites are marine mammals (including seals, sea lions, dolphins and porpoises) and fish (including other Chondrichthyans and a wide range of bony fish) (Compagno 2001). They are also known to prey on invertebrates and seabirds, and scavenge on secondary kills of fish caught on lines and carrion of large Cetaceans (Compagno 2001). A degree of habituation to human-provided food sources has been observed in some areas, such as feeding stations and fishing boats used in the ecotourism industry (IUCN 2009). This broad diet suggests a low degree of specialisation, and consequently the potential to adapt more readily than other species to a changing environment.</p> <p>Great Whites are primarily epipelagic (living in the upper part of the water column), found in neritic (near shore) waters. They are present from the surface down to the bottom in epicontinental areas (Compagno 2001), but regularly penetrate the epipelagic zone. Long term movement patterns of white sharks is still relatively unknown, but tagging and acoustic monitoring studies have shown white sharks to have a relatively large home range encompassing several island groups that they use for feeding (Bruce et al 2005), to which they apparently show seasonal fidelity (Commonwealth of Australia 2002). They are capable of extensive movements, on local, regional and intercontinental scales. Larger individuals are known to undertake long journeys across great ocean basins (Boustany 2002). The ability to swim long distances for extensive periods may enable Great Whites to keep up with a changing environment and colonise newly favourable habitats.</p> <p>The Great White has one of the widest habitat and geographic ranges of any fish-like vertebrate (Compagno 2001). Larger individuals are most common in cold and warm temperate waters, but records suggest they have a wide temperature range and regularly penetrate the tropics (Boustany 2002). Smaller individuals are mostly restricted to temperate continental areas, and results indicate nursery grounds are in similar areas (Compagno 2001). Patterns in movement and abundance within some areas appear to be linked with seasonal variations in surface temperatures, but it is still unknown how much this influences the overall distribution of the species (Martins & Knickle).</p> <p>Great Whites have very low intrinsic rate of population increase (Wildlife Conservation Society 2004). Adult males are thought to mature around 3.8m (Pratt 1996), and most females at 4.5-5.0m. Based on the growth curve for the species, these figures correspond to ages of 8-9 years and 12-15 years respectively (Francis). White sharks are viviparous, with females giving birth to live young after an extensive gestation period. Based on estimates of related species it is probable the</p>	<p>like vertebrate, and a wide thermal tolerance. It also has a very broad diet, suggesting a low degree of specialisation. Long term movement patterns of white sharks not well known, but they appear to have a relatively large home range to which they show seasonal fidelity. They are capable of moving extensive distances across oceanic basins.</p> <p>Like all sharks, the great white has a very low intrinsic rate of population increase. Reproductive biology is not well known, but it is thought females do not reach sexual maturity until 12-15 years of age. Gestation is likely to exceed a year, and breeding probably only occurs every 2-3 years. On average on 5-10 offspring are born.</p>	
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	<p>gestation period exceeds 12 months, with females breeding only every 2-3 years (Wildlife Conservation Society 2004). Young are 120-150cm at birth and litter sizes are small; 5-10 on average (Francis). Their large size at birth and status as a top predator results in a probable low rate of natural mortality, and thus a low reproductive rate has been adequate to maintain shark populations for millions of years. However, the low reproductive potential and long generation time in this species is likely to mean very low resilience and limited potential for rapid adaptation.</p>		
<p>Changing dynamics of species interactions</p>	<p>The great white shark is regarded as an apex predator with an important role in maintaining the health of ecosystems. They have virtually no natural predators, however, infrequent reports do exist of predation of white sharks by killer whales (<i>Orcinus orca</i>). Reduced sightings of white sharks in the location of an attack has led to speculation of competitive displacement and predator avoidance (MMS, 1999). Due to the rarity of such reports, human activities are the only significant threat to the survival of white sharks.</p> <p>White sharks appear to exhibit an age/size preference for certain foods (Bruce et al. 2001). They begin life by feeding on fish, rays, and other sharks, and as they grow their diet expands to include marine mammals and they will also scavenge on large animal carcasses such as whales.</p> <p>Where habitat is suitable for large populations of seals and sea lions to exist, they are the preferred prey for adult white sharks. “There are very few regions of the world that support white shark populations without a corresponding pinniped population” (Ellis & McCosker, 1991). Pinniped colonies are most likely critical habitat areas for white sharks and it is in these areas where they are most vulnerable to impacts from fishing operations (Bruce et al. 2005)</p> <p>Studies of white sharks sighted at pinniped colonies suggest that the sharks are mainly transient, with a few longer term residents (Klimley & Anderson, 1996). White sharks are thought to return to feeding grounds annually on a seasonal basis to take full advantage of the reproductive cycle of pinnipeds. Tagged individual have been re-sighted at particular locations all over the world (Bruce, 1995)</p> <p>A prey species of white sharks - the Australian sea-lion (<i>Neophoca cinerea</i>), has an IUCN Red List classification of Endangered. Populations of Australian sea-lions are significantly reduced in size from historical levels and are still in decline (Goldsworthy & Gales, 2008). Reduced prey availability could affect some populations of white shark, however as an opportunistic predator, they are not</p>	<p>The great white shark has no specific dependencies upon which it relies for food. But numerous pinniped colonies provide rich breeding grounds for the sharks. Climate change is expected to affect some pinniped species through ecosystem impacts relating to plankton production, however the direct impact that this will have on the Great White Shark's prey cannot be quantified.</p>	<p>2</p>

	dependent on this species.		
Interactions with other processes	<p>The Memorandum of Understanding on the Convention of Migratory Species recognises the critical role migratory sharks play in marine ecosystems, and concerned about the significant and continuing mortality of sharks listed on Appendix I and II through a range of impacts and threats including targeted (directed) fisheries, fisheries by-catch, illegal, unreported and unregulated (IUU) fishing, trophy hunting, marine debris, habitat destruction – including prey depletion, boat strikes and disturbances, and increasing pressures on the marine environment due to climate change</p> <p>There has been an extensive exploitation of the great white shark for their fins (Chapman et al, 2003; Mahmood et al, 2005). Hunting for shark fins has severely affected maintenance of sustainable population number. The loss of the apex predator has negative ramifications on the marine ecosystems of the world. In addition to the hunting for their fins, their jaws and teeth are invaluable trophies for the curio market (Mahmood et al, 2005). Another cause of threat is tourism (Commonwealth of Australia, 2002). Although, tourism does not play a direct role, yet the indirect effects are quite damaging. For instance, shark cage diving and shark tours require attracting sharks to an area by berleying. Berleying involves releasing a mixture of fish oil and animal products into the water at regular time intervals to develop a slick to attract sharks in the vicinity (Commonwealth of Australia, 2002). This has the potential danger of encouraging sharks to stay in close proximity to humans and boats with food. Another negative aspect of tourism activity is that it encourages sharks preying on sea lions and seals alongside causing disturbance to the white sharks and their prey (Commonwealth of Australia, 2002). Recent reports have also pointed that the sale of shark jaw has risen in the market at the rate of \$50 000 for jaws (from South Africa) and \$600 for individual teeth (Commonwealth of Australia, 2002).</p>	<p>The major threat to white shark is from hunting for trophies, fins, jaws and teeth which are priceless in the market and accidental catching. Another cause of threat is from tourism which plays an indirect role in causing disturbances and boat strikes. Habitat destruction is also a factor leading to prey depletion and increasing the pressure on marine life due to changing climatic conditions.</p>	3
		MEDIUM VULNERABILITY	

7.3.4. BIRDS

Climate Change Vulnerability of Migratory Species						ZSL LIVING CONSERVATION	UNEP	CMS
Species Assessment								
Andean Flamingo, <i>Phoenicoparrus andinus</i>								
Impacting factor	Severity of impacting factor					Conclusion	Overall Score	
	1	2	3	4	5			
Vulnerability of habitat/s	On the altiplano, there is likely to be an increase between 2.5 and 3.3 degrees by 2100, variability between seasons is likely to increase and there is a chance of reduced rainfall (Christensen et al, 2007). This could reduce the available wetlands, and alter the timings of Andean Flamingo migration. However it is likely that habitat will keep pace with the eco-zone shift.					The habitat of the Andean Flamingo is likely to be effected, but it is likely that the habitat will endure these changes.	2	
Ecological flexibility	Andean Flamingos are a specialised species, they require a certain type of wetland to fulfil their dietary requirements (Hurlber and Chang, 1983). Their range contains many such environments which have existed through previous different climatic conditions (Baker et al, 2001a). Seasonal migration in flamingos is driven by climate, and therefore it is likely that the species can adapt to future changes in climate by changing migration patterns. However there is no information on past Andean Flamingo adaptation. Reproduction rates are low, therefore the species is vulnerable and does not respond quickly to improving conditions (Valqui et al, 2000).					Andean Flamingos rely on specific food stuffs, and they have low reproduction rates. However it is likely that they can adapt their migrations to changes in climate.	4	
Changing dynamics of species interactions	Andean Flamingos are rarely predated on, and they prey upon microorganisms that live in saline environments. Changes in evaporation and precipitation can effect the salinity of these environments, which in turn, can affect the species composition of microorganisms in these wetlands (Baker et al, 2001b; Hurlber and Chang, 1983). potentially effecting the feeding of the Andean Flamingo. However, precipitation is likely to reduce, therefore most wetlands are likely to remain saline.					It is unlikely that climate change will make Andean Flamingos more vulnerable to predators. However some of their prey may become more scarce because of changes to salinity, yet this is unlikely to be widespread.	2	

Interactions with other processes	The main reasons for the vulnerability of flamingos are not directly related to climate change. Andean Flamingos have undergone negative anthropogenic effects. A warming climate could make this more likely with increased human incursion; However the Andean Flamingos' range is mainly within a number of national parks (BirdLife International 2008). Warming could potentially lead to an invasion of species and pathogens. However, salinity should limit the effects of invasive species, whilst little is known about the effects of climate change on disease.	Much of the Andean Flamingo's current range is protected by national park. It is also unlikely that they will have significant problems with disease or invasive species.	2
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species Species Assessment Aquatic Warbler, <i>Acrocephalus paludicola</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>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: Hungary, 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). 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 (Christensen et al., 2007). 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.</p> <p>In west Africa, 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</p>					<p>The precipitation response to climate change is likely to be very important to the survival of this species. There is high uncertainty whether the amount of rainfall will increase or decrease in the areas that it frequents by the end of the century. However, it requires such a specific habitat that it is likely that one or more of the habitats upon which it relies (breeding, wintering or migration stopover) will be adversely affected by too much or too little precipitation.</p> <p>*more information needed before this section can be</p>	3*

	<p>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.</p> <p>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.</p> <p>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.</p>	scored with confidence*	
Ecological flexibility	<p>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).</p> <p>Whilst the dietary niche of 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 nesting 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.</p> <p>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</p>	The dietary niche of this species appears to be broad as the insect intake upon which this species relies can be altered depending on which species are available at the time. However the presence of shallow water appears is a prerequisite for a habitat for this bird. The reproductive rate of this species is high, as is the fledging success. There is a suggestion that sexual determination of the brood is linked to temperatures, however this is as yet unproven. Dispersal appears to be poor. On the balance of evidence collected, this species appears to have moderate ecological flexibility.	3

	<p>low nest predation-rate, and a 50% rate of second broods some years ensures a high reproductive output (Schulze-Hagen et al., 2004).</p> <p>Climate related changes in fecundity: There have been suggestions that warmer temperatures can alter the sex-ratio of aquatic warbler broods. In 2004, Dyrzcz 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 (Dyrzcz et al., 2004).</p> <p>Dispersal: 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. This suggests dispersal to other suitable habitats would be possible but is unlikely to happen.</p>		
<p>Changing dynamics of species interactions</p>	<p>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.</p> <p>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 vison), 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.</p> <p>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.</p>	<p>The various prey species of the aquatic warbler are likely to be available, albeit possibly in different relative abundances. However, the affect that climate change is likely to have upon the nesting success of the aquatic warbler is unclear. There is no suggestion that the small mammals that predate upon eggs and hatchlings are expected to significantly change in abundance due to climate change, however it remains a possibility.</p>	<p>2</p>
<p>Interactions with other processes</p>	<p>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</p>	<p>BirdLife International (2009) regards the three major threat facing Acrocephalus paludicola</p>	<p>4</p>

	<p>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.</p> <p>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.</p> <p>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).</p> <p>Another less severe threat stems from the eutrophication of the wetlands in both the wintering and breeding habitats (BirdLife International, 2008).</p> <p>Little is known about the quality of the migrational stop-over sites that are utilised outside of western-Europe (AWCT, 2009).</p>	<p>as threats which have rapid severity, but medium impacts in scope. These threats are:</p> <p>Agriculture: the intensification and expansion of agricultural land</p> <p>Biological resource use – gathering terrestrial plants and the unintentional side effects/direct effects of hunting</p> <p>Natural system modification: water management, use and the creation of large dams.</p> <p>The combined impact of these threats is very high</p>	
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Balearic Shearwater, *Puffinus mauretanicus*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Balearic Shearwater habitat includes marine coastal, marine neritic and marine oceanic environments. Whilst breeding, it relies of sea-cliffs and rocky offshore 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).</p> <p>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 reports of this species since the mid-1990s have shown a substantial and sustained increase in the number of Balearic shearwaters in UK waters (see Figure 1, background document). This is a trend that has also been witnessed across other northwest European waters (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. 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 (Wynne et al. 2007). 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). 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.</p>					<p>There is no firm evidence to suggest that the threats posed to the breeding habitat of this species by climate change will have a significant impact on its survival. However, the northward shift of its non-breeding food source is significantly increasing the distance between the two habitats that this bird occupies, a process which is increasing the pressure on this species as it is having to travel further to forage for food. A 10° northward shift in latitude of prey species since the mid-1980s has greatly increase the migration-distance of this bird. 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 Shearwaters.</p>	4

	<p>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, A.J and Schoeman, D.S, 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.</p> <p>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). The 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 effects.</p> <p>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).</p>		
<p>Ecological flexibility</p>	<p>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 (<i>Sardina pilchardus</i>) and anchovy (<i>Engraulis encrasicolus</i>). 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).</p> <p>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-</p>	<p>This species has a very low reproductive rate and a higher mortality than other members of the Procellariiformes family. There is recent evidence to show that it is capable of altering its migration, however as it appears to be anchored to its breeding habitat in the Balearic Islands, it may not be flexible enough to alter its migration to the extent</p>	<p>4</p>

	<p>shift in prey species is likely to be detrimental to the population waters (Wynn et al. 2007).</p> <p>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).</p> <p>There are no reported direct climate-related changes in the fecundity</p>	needed.	
<p>Changing dynamics of species interactions</p>	<p>Balearic Shearwaters rely on small pelagic fish, especially pilchard (<i>Sardina pilchardus</i>) and anchovy (<i>Engraulis encrasicolus</i>). 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.</p> <p>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).</p>	<p>There is a an observed decline in species abundance in the traditional Balearic Shearwater habitats, a situation which is forecast to get worse as sea surface temperatures increase. The breeding success of this bird has been linked to the discards of unwanted fish from trawlers, a situation that suggests the available prey-base may already be insufficient should bycatch discards be halted</p>	4
<p>Interactions with other processes</p>	<p>As the Balearic Shearwater is a long-lived, slow-breeding species with a low population, any impact that threatens adult or chick survival can have a serious effect on the integrity of the population (Louzao et al. 2006). The threats that this species faces come from three main sources; the fishing industry, invasive species and marine pollution (BirdLife International, 2009). These threats are all assessed to pose a “moderate” risk to the remaining Balearic Shearwater.</p> <p>Domestic cats (<i>Felis catus</i>), the common genet (<i>Genetta genetta</i>) and the black</p>	<p>Individually, all non-climatic threats faced by this species were listed as moderate, however the population level is perilous and the current rate of decline suggests that the species will be extinct in around 40 years time. One change in fisheries policy could</p>	5

	<p>and brown rats (<i>Rattus rattus</i> and <i>Rattus norvegicus</i>) 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 (Iguar et al., 2007).</p> <p><i>Puffinus mauretanicus</i> 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 (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). Feeding on bycatch may also encourage decoupling of the Balearic Shearwaters range to the range of their prey species as this shifts further north. This would leave the Balearic Shearwater dependent on bycatch and limit their natural adaptation to climate change which would leave them vulnerable if fishing stopped.</p>	<p>push this species to the brink of extinction</p>	
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Basra reed warbler, *Acrocephalus griseldis*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>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). Following the diversion of large amounts 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 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 (see background document) shows that precipitation to the south-west of Asia is expected to drop substantially over the course of this century, however the resolution of the GCMs utilised for the IPCC Fourth Assessment Report is poor.</p> <p>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 reproduces 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 2081-2099) and a high warming scenario (4.8° C rise in average annual temperatures by temperatures by the period 2081-2099). Figure 2 (see background document) 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.</p> <p>The New Scientist (2009) report that the ‘Fertile Crescent’ is already experiencing</p>					<p>The wetlands in Mesopotamia are under serious threat from climate change. Even without any direct anthropogenic interference the discharge of the rivers feeding the wetlands will drop significantly (29-73%) over the course of this century due to climate change. It appears that restoration plans for the wetlands are already being abandoned due to drought, which does not bode well for the future when precipitation is projected to drop even further. 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. No deleterious effects from climate change were detected for this species' wintering grounds, however there is uncertainty over the location of the stop-over sites utilised. If these are Sahelian sites, they may also be subjected to considerable drying.</p>	4

	<p>serious drought and that the re-flooding of the wetlands is being abandoned.</p> <p>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.</p> <p>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 (background document) 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. This could lead to enhanced habitats for this species.</p>		
Ecological flexibility	<p>The Basra Reed Warbler is capable of nesting in a variety of wet environments, however there also 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).</p> <p>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 *More information is needed to assess the reproductive potential of this species*</p>	<p>Generally this species is reliant upon water in south-eastern Iran, however there are reports of it utilising both different locations to breed, and breeding away from water. It also has a broad diet. Therefore this assessment finds the species to have a low-moderate degree of specialisation.</p>	2*
Changing dynamics of species interactions	<p>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.</p> <p>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</p>	<p>There is currently little evidence suggesting that important phenological relationships might break-down due to climate change, or that the food sources of this species will decline. However a reduction in precipitation over the breeding area of this species could reduce the</p>	2

	species is broad, so there is a good chance that if some insect species populations decreased, there would still be sufficient alternatives.	quantity of food available.	
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 programs 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).	Increasing pressure on water resources is likely to act synergistically with climate change to deplete the Mesopotamian wetlands further. As rainfall decreases, more water will be diverted from the Tigris and Euphrates rivers and the wetlands will suffer as a result. In recent decades, wars and political instability have also degraded the breeding habitat of this species.	4
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species					  		
Species Assessment							
Bermuda Petrel, <i>Pterodroma cahow</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>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).</p> <p>The breeding habitat of this species appears to be at risk from climate change</p>					<p>There appears to be a serious threat to the Bermuda petrel's habitat from sea level rise inundating nests with water during high seas. This problem has been occurring at a higher frequency in the last 20 years than at any point since the</p>	3

	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>Changes in pH from CO₂ dissolved in the oceans are likely to have a large effect on</p>	<p>rediscovery of the birds. Coupled with this threat is the risk of increased storminess due to rising SSTs, however there is more work needed before the general behaviour of future cyclones in the area can be projected with confidence. However, these impacts have been mitigated by the creation of artificial nests. Changes in SST, pH and ocean circulation are also expected to affect the foraging habitat of this species, however resulting impacts of this are as yet unknown.</p>	
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	<p>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).</p>		
Ecological flexibility	<p>Degree of Specialisation: This species formerly nested in burrows which are excavated in 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.</p> <p>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.</p> <p>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).</p> <p>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.</p> <p>There is no evidence of climate change-related changes in fecundity in this species, nor is there evidence of adaptation in the past.</p>	<p>There is a moderate degree of specialisation in this species, although it had a rare and specific breeding habitat, it has taken to artificial burrows and different burrows due to the unavailability of its preferred habitat. Its diet appears to be relatively broad, taking in fish, shrimp and squid food items. The dispersal potential of this species is good, however due to the high fidelity which they show to their breeding sites, realisation of this potential may be unlikely. The reproductive rate of this species is very low. Only one chick is reared per year, and rearing success is just 25%.</p>	4
Changing	Cahows, predominately predate upon squid, but also take small fish and shrimps	There is a moderate degree of	2*

<p>dynamics of species interactions</p>	<p>(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, 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).</p> <p>Cahows do not face any predatory threats, however they do face competition for the available nesting habitats from the White-Tailed Tropicbird, <i>Phaethon lepturus</i>. 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.</p>	<p>specialisation in this species, although it had a rare and specific breeding habitat, it has taken to artificial burrows and different burrows due to the unavailability of its preferred habitat. Its diet appears to be relatively broad, taking in fish, shrimp and squid food items. The dispersal potential of this species is good, however due to the high fidelity which they show to their breeding sites, realisation of this potential may be unlikely. The reproductive rate of this species is very low. Only one chick is reared per year, and rearing success is just 25%.</p>	
<p>Interactions with other processes</p>	<p>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.</p>	<p>There is a low availability of suitable nesting habitat for this species, but extensive effort has been made to provide suitable alternative nesting sites. Light pollution has been cited as disrupting the nocturnal mating of this species, however other threats are well managed by a conservation programme.</p>	<p>2</p>
		<p>MEDIUM VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Humboldt Penguin, *Spheniscus humboldti*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Humboldt Penguin can be found across a vast latitudinal range, from 5°S – 42°S (Williams, 1995). This species nests in guano along rocky coastlines. 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).</p> <p>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.</p>					<p>The habitat of this species is likely to be resilient to climate change over the next century, however periodic or more frequent ENSO events will have a deleterious effect on the breeding habitat</p>	2
Ecological flexibility	<p>This species mainly feeds in near-shore waters, predated on pelagic school fish and squid (Martinez, 1992), especially anchovy (<i>Engraulis ringens</i>) (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.</p> <p>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</p>					<p>This species relies heavily on the vast productivity of the Humboldt Current. In the absence of this productive current; during ENSO conditions, population trends appear to be unsustainable. However, population recovery from such events is good. If necessary, this species can migrate along a long stretch of coastline to find more favourable conditions - the range of this species spans 5°S – 42°S (Williams, 1995).</p>	3

	<p>from years of low breeding success is good (Paredes et al., 2003).</p> <p>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.</p>		
Changing dynamics of species interactions	<p>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. 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).</p>	<p>ENSO cycles have a large impact upon the prey species of the penguin, and also upon the penguin population's breeding success. However, the relative effect of ENSO on nesting through flooding and on food supplies are uncertain. Apart from ENSO years, the vulnerability through climate change and altering species interactions should be small.</p>	2
Interactions with other processes	<p>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.</p> <p>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).</p> <p>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,</p>	<p>There are numerous anthropogenic threats to the Humboldt Penguin population, however these are now limited as a number of breeding areas are now protected. The main threat to this species is through fishing mortality, but areas where gillnets are causing serious problems are now limited to northern Peru. Overfishing is a major concern. 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</p>	3

	<p>an annual average of 120 adult penguins were reported to have become entangled in fishing gear.</p> <p>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).</p>	<p>quotas have now been implemented in Peru, overfishing is likely to slow any penguin population recovery.</p>	
			MEDIUM VULNERABILITY

Climate Change Vulnerability of Migratory Species						  	
Species Assessment							
Pallas Fish-Eagle, <i>Haliaeetus leucoryphus</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>This species utilises wetland habitats, generally large lakes and rivers at a range of altitudes from lowlands up to 5000m in Central Asia. It nests is known to nest close to water either in trees or on cliffs (Birdlife International, 2009).</p> <p>The vast majority of the breeding range of the species traverses two land regions depicted in the IPCC FAR – central Asia and the Tibetan Plateau.</p> <p>The large altitudinal range of this species suggests that temperature variations in the order of a few degrees will not adversely affect this bird. However, temperatures in the Pallas fish eagles’ range are predicted to increase by much more than the global mean under the A1B scenario: 3.7°C in central Asia and 3.8°C in the Tibetan Plateau (Christensen, 2007).</p> <p>Whilst this increase in temperature may not directly affect this bird, the increased evaporation rates which are associated with warmer weather are likely to have the significant consequences on the amount of wetland habitat available. Coupled with this, the large variations in the precipitation regime over much of the range of this species are expected by the end of this century, as figure 2 shows.</p> <p>A1B models show precipitation over the central Asia and Tibetan Plateau region to</p>					<p>The increased temperatures and the decreased summer rainfall by the end of the century have the potential to decrease wetland habitats seasonally, which could affect the prey that reside within them.</p>	3

	increase over the winter months (by 4% and 19% respectively), but there is expected to be a significant decrease in precipitation during the summer months – 13% over the region as a whole (Christensen, 2007).		
Ecological flexibility	<p>This species lives at a diverse range of altitudes and across a vast range. The only requirement necessary for this species appears to be access to freshwater wetlands, lakes or rivers (BirdLife International 2009). It has a broad carnivorous diet, consuming a wide variety of live or dead prey. Fish of various sizes appear to be the principal source of food in most regions (BirdLife International, 2009). However, accounts of this species consuming almost the broadest spectrum of species have been given, including frogs (especially large bull-frogs), turtles and other reptiles. The snakes <i>Xenochropis piscator</i> and <i>X. cerasogaster</i> were part of the diet in Bangladesh. Geese, waterfowl, the Painted Stork <i>Mycteria leucocephala</i> have also been a source of food for some individuals. In addition, a pair on the Yamuna river apparently “ravished countless clutches” of tern, skimmer and plover eggs on a sandbar (BirdLife International, 2001).</p> <p>The female lays 1-3 eggs, however generally the youngest sibling will die (BirdLife International, 2001). There are no specific data available on the longevity of this species however, we can assume from its mode of life and physical attributes that it is long lived with a low natural mortality rate; comparable to other species to which it is related.</p>	<p>Although predominantly associated with wetland environments, the niche of this species appears to be broad as it can catch a wide broad range of prey across many different habitat types. The reproductive rate of this species is assumed to be comparable to other species in its genus. Considering these factors, it has a good degree of ecological flexibility.</p>	2
Changing dynamics of species interactions	<p>The Pallas fish eagle is carnivorous, consuming a wide variety of live or dead prey. Fish of various sizes appear to be the principal source of food in most regions feeding on floating fish carcasses and pirated food from piscivorous birds such as cormorants and terns (BirdLife International, 2001).</p> <p>There is a risk that the predominant food source of this species suffers as summers become increasingly hot and dry, however it appears to have the capacity to alter its diet and take whatever food items are available. Also, in the short term it appears that this drying of pools may benefit the eagle as they have been reported a preference for fish stranded in the shallows (Symthies, 1986).</p> <p>The invasive species water hyacinth <i>Eichhornia crassipes</i> is a major threat in parts of Indian subcontinent as the growth of this plant can lead to reduced feeding potential (BirdLife International, 2009). Warmer winters will increase winter survival of this plant and extend the breeding season (US EPA, 2008). However the extent to which this will threaten the Pallas fish eagle across its range is low as this only appears to currently be a problem in India and Bangladesh.</p>	<p>Although increased annual variability in rainfall is likely to negatively affect the prey of this species, it is probable that in the short-term this could actually increase the birds' feeding opportunities as it is primarily an opportunist. Invasive plant species could prove to be very detrimental in some areas.</p>	2
Interactions with	The main threats to this species are habitat loss, degradation and disturbance	This species sparsely covers a	3

other processes	<p>(BirdLife International, 2009). The draining of wetlands for agriculture has produced a direct reduction of the habitat for this species whilst the increasing agricultural pressures have led to a prevalence of chemicals across much of the range of this eagle. Anthropogenic overexploitation of prey species and persecution are also problems which have contributed to the decline in this species.</p> <p>In the future, it is likely that these threats will remain, and in some areas they are highly likely to be exacerbated by increasing human interference as populations grow and adapt to climatic change. For example, in Bangladesh large amounts of fertile agricultural land is being lost and degraded as sea levels rise. This has the potential to impact directly upon the Pallas fish eagle, but also indirectly as people move further inland and utilise hitherto wild areas to grow food.</p> <p>Water shortages amongst the human population are also likely to impact upon this species – higher summer temperatures and decreased summer rainfall will lead increased extraction of water from wetland areas which would have negative consequences for the prey species of this bird.</p>	<p>broad range and therefore the threats that it faces are diverse. Climate change and population rise are likely to increase threats from agriculture and human encroachment into natural areas as wetlands are drained to grow food. Rising sea levels are likely to exacerbate this situation in areas close to the coastal zone, especially in Bangladesh.</p>	
		MEDIUM VULNERABILITY	

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Puna Flamingo, <i>Phoenicoparrus jamesi</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>On the altiplano, there is likely to be an increase between 2.5 and 3.3 degrees by 2100, variability between seasons is likely to increase and there is a chance of reduced rainfall (Christensen et al, 2007). This could reduce the available wetlands, and alter the timings of Puna Flamingo migration. However it is likely that habitat will keep pace with the eco-zone shift.</p>					<p>The habitat of the Puna Flamingo is likely to be effected, but it is likely that the habitat will endure these changes.</p>	2
Ecological flexibility	<p>Puna flamingos feed upon predominantly upon diatoms found within high salinity environments. Their prey can be found only in a certain type of wetland environment and therefore they are a specialised species. The range of the Puna flamingo contains environments which have existed through previous different</p>					<p>Puna Flamingos rely on specific food stuffs, and they have low reproduction rates. However it is likely that they can adapt</p>	3

	<p>climatic conditions (Baker et al, 2001) which would suggest they have a reasonable degree of flexibility to climate change. However, flamingos are specialised and the likely effects of climate change on their habitats are unknown.</p> <p>Seasonal migration in flamingos is driven by climate, and therefore it is likely that the species can adapt to future changes in climate by changing migration patters. However there is no information on past Puna flamingo adaptation. Birth rates of the Puna flamingo are low; the female lays only a single egg upon a truncated cone of mud each year (Sargatal et al 1992).</p> <p>However, flamingo species enjoy significant longevity, and natural death rates are low (Valqui et al, 2000). Yet, as reproduction rates are low the species is vulnerable and can not respond quickly to improving conditions after a population crash.</p>	<p>their migrations to changes in climate.</p>	
Changing dynamics of species interactions	<p>Puna flamingos are rarely predated on, and due to the remoteness of the habitat in which they reside, this is unlikely to change. They prey upon microorganisms that live in saline environments. Changes in evaporation and precipitation can affect the salinity of these environments, which in turn, can affect the species composition of microorganisms within in these wetlands (Baker et al, 2001b; Hurlber and Chang, 1983). This has the potential to affect the feeding of the Puna flamingo, however precipitation is likely to reduce, and therefore most wetlands are likely to remain saline.</p>	<p>It is unlikely that climate change will make Puna Flamingos more vulnerable to predators. However some of their prey may become more scarce because of changes to salinity, yet this is unlikely to be widespread.</p>	2
Interactions with other processes	<p>The main reasons for the vulnerability of flamingos are not directly related to climate change. Puna Flamingos have undergone negative anthropogenic effects. A warming climate could make this more likely with increased human incursion; However the Puna Flamingos' range is mainly within a number of national parks (BirdLife International 2008). Warming could potentially lead to an invasion of species and pathogens. However, salinity should limit the effects of invasive species, whilst little is known about the effects of climate change on disease.</p>	<p>Much of the Puna Flamingo's current range is protected by national park. It is also unlikely that they will have significant problems with disease or invasive species.</p>	2
			MEDIUM VULNERABILITY

Climate Change Vulnerability of Migratory Species

Species Assessment

Red-breasted Goose, *Branta ruficollis*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The red-breasted goose breeds in tundra habitats. The moderate HadCM2Gsa1 model predicts a 67% decline this breeding range alterations by 2070-2099 as tundra environments give way to forests. The change in habitat projected by the more extreme UKMO model shows a loss of 87% of breeding range (Zöckler & Lysenko 2000).</p> <p>In addition to these changes, their traditional wintering and staging wetland sites have been modified or destroyed (Madsen et al., 1999).</p> <p>The over-wintering habitat of this bird is also likely to be effected by climate change. An increase in the variability in of precipitation is projected in the Danube River Basin (WWF 2008). As 80-90% of the global population roost on this site and 4 others in the vicinity, increased likelihood of flooding and droughts will put further pressure on this species. Unlike most European bird species, which are expected to have better winter-survival rates due to milder temperatures, sporadic winter droughts in the south-eastern Black Sea region could destroy wetland habitats (WWF 2008).</p>					<p>The breeding habitat is likely to be severely depleted by climate change and there is some evidence suggesting wintering habitats are likely to suffer.</p>	4
Ecological flexibility	<p>The diet of this species takes in grasses in the Siberian breeding habitat and cereals, grasses and herbs through the winter (Kear, 2005). However, the breeding habitat itself is more specialised. This goose requires tundra with thin vegetation; often dwarf birch <i>Betula</i>, willow <i>salix</i>, and dead grass. It has a preference for high and dry areas on steep river banks and precipices, low hills, rock outcrops and rocky islands (BirdLife International, 2009). Breeding success of the red-breasted goose is correlates with the presence of birds of prey, often the peregrine falcon. This nesting association is a tactic that is believed to be useful in protecting the nest against predation from species such as arctic foxes (Quinn et al., 2002).</p> <p>The wintering range of the Red-breasted goose varied significantly during the 20th Century, with a westward shift of around 1,800km. Until the 1960s the whole population wintered on the south-west cost of the Caspian Sea. Within a decade, the entire population moved its wintering site to the Black Sea; by the late 1960s</p>					<p>This species has shown ecological flexibility by altering its wintering habitat very rapidly in the absence of suitable habitat around the Caspian Sea. This highlights that the species' migration is culturally driven rather than wholly genetically driven. However, loss of tundra habitat with sparse vegetation cover would seriously affect this species. Whilst these geese are likely to have the ability to</p>	3

	<p>large around 25,000 birds) were recorded in Romania and by the late 1970s, large flocks were also recorded in Bulgaria (Dereliew, 2006).</p> <p>The reason for this westward wintering range was attributed to habitat changes along the coast of the Caspian Sea, large hunting pressures and in addition to other factors (Isakov 1979; Sutherland and Crockford, 1993).</p>	alter their breeding location, as tundra habitats shrink competition for the remaining or newly forming habitat could be intense.	
Changing dynamics of species interactions	<p>The red-breasted goose has a nesting association with the peregrine falcon, a tactic that is believed to be useful in protecting the nest against predation from foxes (Quinn et al., 2002). Therefore, although the peregrine is known itself to predate upon the goose, the goose breeding success is aided by the persistence of the falcons.</p> <p>This goose forms part of a complex arctic predator-prey cycle, which involves migratory geese, waders and lemmings, as well as numerous predators. Until 1994, peaks in the lemming population (<i>Lemmus</i> spp. and <i>Dicrostonyx</i> spp.) occurred on a three-year cycle on the Taimyr Peninsula in northern central Siberia but recently the cycle appears to have broken down. The lemming populations peaked in 1994, 1996 and 1999; however there was no peak in 2002 (Ebbinge B., 2009). In years when lemming populations are low, the nests of migratory geese are more likely to become the target of mammalian and avian predators. Climate change has been suggested as a possible reason for the reduced availability of lemming prey (Soloviev & Tomkovich 2003). Reduced snow-cover in Arctic regions may expose wintering lemmings to predators before they have the chance to build up to peak population levels.</p>	<p>The lemming population appears to be relatively important for the breeding success of migrating geese, and this relationship appears to be under threat from climatic changes. However, quantification of the effect that projected climatic changes are likely to have on lemming populations and the effects that this will have on breeding red-breasted goose populations is unknown.</p> <p>*Score is tentative pending further information*</p>	2*
Interactions with other processes	<p>The main threat that the red-breasted goose faces is in their wintering grounds, the Black Sea coast of NE Bulgaria in particular. They are hunted prior to their spring migration back to the Siberian Arctic, during a crucial period in their annual cycle. This hunting prevents them from settling and building up sufficient strength for their migration back to Siberia (Dereliew, 2006). It is not necessarily the hunting of the Red-breasted goose itself which poses the problems to this species. The more numerous Greater White-fronted Goose is the preferred target for hunters, however the disturbance that the shooting causes can be substantial (Sutherland and Crockford, 1993).</p> <p>In addition to the threats that this species faces through hunting; modification and destruction of their wintering and wetland habitats also pose a substantial threat (Madsen et al., 1999), as does oil exploitation in their breeding habitat (WWT, 2009).</p>	Habitat loss and hunting have had a serious impact upon this species, contributing largely to the relocation of its wintering habitat. Any major disturbance to the current wintering habitat could prove disastrous for the remaining population. In addition to this, agricultural shifts from winter cereal crops to winter vegetables remain a threat to this depleted population	4

	Agricultural changes in their wintering areas have seen winter wheat replaced by vegetable crops and vineyards which limits the quantity of food available to these geese (Dereliew, 2006).		
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species					  			
Species Assessment								
Relict Gull, <i>Larus relictus</i>								
Impacting factor	Severity of impacting factor					Conclusion	Overall Score	
	1	2	3	4	5			
Vulnerability of habitat/s	<p>The Relict Gull lives in Central and Eastern Asia. There are two breeding sites in eastern Kazakhstan, one in Russia as well as several in Mongolia and China. Little is known about the wintering grounds, however some overwinter in South Korea, some on the east coast of China, whilst there is also evidence of individuals wintering on the flank of the Tibetan plateau. Within these areas semi-arid wetlands and estuaries are important.</p> <p>Temperatures in East Asia are predicted to rise by 3.3°C by 2100, whilst temperatures in Central Asia are predicted to rise by 3.7°C by 2100, meanwhile Tibet is expected to warm by 3.8°C by 2100. Therefore, depending on where in the range the Gulls are, the temperature increases they are likely to experience will vary, however the increases are likely to be within the range of 3.3 to 3.8°C (Christensen et al., 2007).</p> <p>Precipitation is likely to increase by 9% by 2100 in East Asia, whilst it is predicted to decrease by 3% by 2100 in Central Asia. There is also a possibility that precipitation may become more variable with fewer heavier rainfall events. This means that the gulls are likely to experience both increased and decreased rainfall (Christensen et al., 2007).</p> <p>Estuarine habitats are likely to be affected by sea level rise as this could inundate and degrade coastlines. 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</p>					<p>The breeding areas of the Relict Gull are very sensitive to climate change. Therefore it is likely that these areas will be severely degraded by climate change mainly through changes in precipitation. Furthermore, other areas such as estuarine environments are likely to be moderately degraded.</p>		5

	<p>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 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 has the potential to greatly reduce the number of coastal habitats available to Relict Gulls. However, Precipitation regimes, because of their increased strength, are predicted to increase sediment flux into coastal flats, thus enhancing them (Walling and Fang, 2003). This may somewhat balance out the loss of estuarine environments.</p> <p>The effects of sea level rise and increased sediment flux will change the coastal habitats of the Relict Gull. However the effects of changes in temperature and precipitation will have much larger effects. Relict Gulls only breed on islands in saline and slightly saline lakes in arid and semi-arid areas, which have variable water levels. The Gulls will not breed if the islands become connected to the shore through low water levels. They also cannot breed if the islands are flooded (Birdlife International, 2008). This means that, increased evaporation because of higher temperatures and increased or decreased rainfall, which the gulls are likely to experience within their range all has the potential to inhibit breeding, particularly the chance of low water levels which seem likely to occur in Central Asian arid environments where the breeding areas are located.</p>		
<p>Ecological flexibility</p>	<p>Degree of Specialisation & Dispersal: The Relict Gull breeds very locally on steppe lakes in Mongolia and adjacent parts of Kazakhstan, Russia and China (Birdlife International, accessed 2009). They are gregarious birds, gathering in flocks when feeding, roosting and nesting (Birdlife International, accessed 2009). Breeding colonies are found below 1,500m, in the arid-steppe zone on saline and slightly saline lakes with highly fluctuating water levels, nesting usually on small islands in large lakes (Birdlife International, accessed 2009). In Russia, the gulls have extremely strict ecological requirements and to successfully breed they require wet and warm weather conditions and the presence of large areas suitable for forming colonies. The gulls will not nest if lakes dry up completely, if the islands become joined to the shore or if the water-level is too high and the islands become too small or overgrown with vegetation (Birdlife International, accessed 2009). In China, on the Ordos plateau they nest on lakes in deserts and semi-desert grasslands (Birdlife International accessed 2009).</p> <p>The gulls are also thought to have strict ecological requirements outside their breeding season, showing a strong preference for extensive largely sandy areas, with river channels with gently shelving banks and drier areas a considerable</p>	<p>The Relict Gull is a highly specialised species requiring strict ecological requirements both in and outside of their breeding season. The 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. Their diet is slightly more specialised than other gulls, with 90% of their diet consisting of midge larvae during the breeding season.</p>	<p>4</p>

	<p>distance from both the river and the tide line (Birdlife International, accessed 2009). The gulls were rarely observed on muddier areas and on the tide line, which is the habitat preference for most other gulls species found in the area (Birdlife International, accessed 2009). Although the gulls non-breeding range is poorly understood, there have been records in northern and eastern China, South Korea, Japan and Vietnam, and also unconfirmed reports from Bulgaria and Turkey suggesting the birds may winter in the Black and Mediterranean Sea areas (Birdlife International, accessed 2009).</p> <p>During the breeding season in China the gulls feed mainly on invertebrates (of which more than 90% are midge larvae), small fish and some plants, including the leaves of grasses and sedges (Birdlife International, accessed 2009). In Mongolia the birds have been recorded feeding on Brandt's voles <i>Microtus brandti</i> (Birdlife International, accessed 2009). The Relic Gull, unlike most other gulls shows very little tendency to scavenge around human establishments (Birdlife International, accessed 2009). Occasionally they have been observed feeding in estuarine channels, foraging on sand flats for small crabs (Birdlife International, accessed 2009).</p> <p>Evidence of past adaptation: Insufficient data.</p> <p>Reproduction rate: The Relict Gull nests in colonies, usually on small islands in large lakes (Birdlife International, accessed 2009). In China the breeding season lasts from early May to early July and clutch sizes are between 1-4 (Birdlife International, accessed 2009). In Kazakhstan and Russia the average clutch size is also between 1 and 4 (Birdlife International, accessed 2009). The gulls reach sexual maturity at 3 years old (Birdlife International, accessed 2009). The death rate of young birds is relatively high, owing to injury, cold and starvation (Birdlife International, accessed 2009).</p> <p>Climate related change to fecundity: Insufficient data.</p>		
<p>Changing dynamics of species interactions</p>	<p>Relict gulls are often documented feeding on small crustaceans, shellfish, small fish, midge larvae and other tidal flat animals. They have also been documented to consume some plant matter, including leaves of sedges and grasses. In one area of Mongolia, Relict Gulls have even been documented feeding on Brandt's voles <i>Microtus brandti</i> (Birdlife International). However, unlike many other gulls, they do not often scavenge around human settlements (Birdlife International)..</p> <p>Animals that are fairly opportunistic with a wide dietary range could have greater adaptive ability than that of species with narrower dietary ranges. These species are probably less likely to suffer prey shortage than species with specific diets</p>	<p>Relict gulls are often found feeding on mudflats, and mainly consume a variety of aquatic or semi aquatic organisms such as small crustaceans, shellfish and small fish. As this species feeds on a variety of food items, it may be less likely to suffer food shortages than some more</p>	<p>3</p>

	<p>(Hawkes, Broderlick, Godfrey, Godley, 2009).</p> <p>However, despite the fact that Relict gulls may feed on a range of aquatic or semi aquatic species, many of these food items such as crustaceans and fish are likely to be affected by climate change. Fish physiology can be intricately linked to temperature, and fish are adapted to cope with specific habitat niches and hydrologic regimes. Therefore, their physiology and life histories will be affected by any changes caused by climate change (Ficke, Myrick & Hansen (2007)). Also many fish feed on small organisms such as plankton, and abundance, distribution and seasonal timing of availability of this food source is likely to be affected by changes to the climate (Hays, Richardson and Robinsons; 2005), which may have far reaching affects on the food web. Crustaceans are likely to be affected by changing water temperatures and ocean acidification, undergoing shifts in range and changes in abundance. A decrease in ocean pH will have negative consequences for oceanic calcifying organisms, such as crustaceans, as they are dependent on the availability of calcium and bicarbonate ions for the mineralization of their exoskeletons (The Royal Society). This would lead to a decrease in populations. However, there has also been findings that some crustaceans such as crab species are increasing in abundance as a result of climate change. For example, certain species of crab in the north sea are undergoing a population increase, as Cod (<i>Gadus sp.</i>) which feed on the crabs are declining as a result of decreasing food availability for cod larvae caused by climate change (Kirby, Beaugrand and Lindley; 2009). Also, Blue Crabs (<i>Callinectes sapidus</i>) south of Chesapeake Bay are expected to experience a population increase, as warmer temperatures means that winter hibernation will be unnecessary, therefore crabs can complete their lifecycle within just one year, instead of having to wait until the following year (Goldman, 2006).</p> <p>Climate change will have wide ranging effects on aquatic ecosystems by affecting water levels, salinity, surface temperature etc, and this is also likely to affect the aquatic organisms that this species feeds on, resulting in disrupted food webs.</p> <p>The relict gull competes with other gull species for food and nesting sites and these other species of gulls can also act as predators of Relict Gulls and may take eggs. However, climate change is likely to impact these gull competitors/ predators in similar ways as for relict gulls, for example by degrading suitable breeding habitat and affecting aquatic prey species.</p>	<p>specialised species. However, the majority of food items are aquatic organisms, and it is likely that the food webs of aquatic communities will be affected by climate change, so many prey species may change in abundance and distribution. Other species of gull act as both predators and competitors. These bird species may be affected by climate change in similar ways as for the relict gull, for example a decline in suitable nesting areas and changes in aquatic food availability.</p>	
Interactions with other processes	There are two main threats to Relict Gull populations which are not related to climate change; disturbance at the breeding sites and developments on important	There is likely to be a high level of habitat loss from coastal	4

	<p>coastal habitats. Disturbance of nesting sites in Russia and China has increased the mortality rate of eggs and chicks. This threat is generally indirect, increasing the risks posed by adverse weather and predation (Birdlife International, 2008). Furthermore, tourism at the main breeding site in China has further increased this vulnerability (Zhang et al, 2009). There is also a significant threat from development of the coastal habitats which the gulls rely on during winter (Liu et al, 2006). In fact there are plans to develop 43% of the remaining habitat, clearly significantly threatening the Relict Gull (Birdlife International, 2009).</p>	<p>developments. There is also some exploitation from tourism. However the other main threats are related to disturbance of the breeding sites, which reduce breeding success thus degrading the habitat.</p>	
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Short-tailed Albatross, <i>Phoebastria albatross</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Short-tailed Albatross is vulnerable because it was thought to be extinct between 1949 and 1951, whilst the recovery of the species has led to only two breeding colonies, of which the larger is situated on an active volcano. The species ranges throughout the North Pacific, from the Bering Sea to the tropics and from China to the United States. However, its main breeding grounds are Torishima and Minami-kojima, two small islands south of Japan, which the birds migrate to and from seasonally. Short-tailed Albatrosses inhabit oceanic and coastal environments, from the open ocean to sea cliffs.</p> <p>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 Short-tailed Albatross.</p> <p>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</p>					<p>Processes occurring in the ocean are likely to fragment the spatial distribution of prey because of climate change. Whilst coastal habitats, particularly nesting sites are likely to be moderately degraded, mainly through increased precipitation.</p>	3

	<p>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.</p> <p>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).</p> <p>Coastal habitats are likely to be affected by sea level rise as this could inundate and degrade coastlines. 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 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 has the potential to greatly reduce the number of coastal habitats available to Short-tailed Albatrosses.</p> <p>In East Asia, temperatures are predicted to rise by 3.3°C, and precipitation is likely to increase by 9%, by 2100 (Christensen et al., 2007). This could have significant detrimental impacts on Short-tailed Albatrosses nesting sites (Birdlife International, 2008). It has been shown that breeding success is closely linked to slope stability of the nesting grounds. Changes in temperature could alter the species composition of the vegetation on the slope possibly destabilising them. Meanwhile increased precipitation is likely to reduce stability (Trauth et al., 2000). Furthermore, increased sea surface temperatures could lead to, higher frequency, higher intensity typhoons (Learmonth et al, 2006), which could be detrimental to the Birds. Therefore climate change could lead to increased levels of mass movement, thus reduced breeding success.</p>		
Ecological flexibility	<p>Degree of Specialisation & Evidence of past adaptation: Short-tailed albatrosses formerly ranged widely across the Pacific, breeding in huge numbers on at least 11 islands in the Izu-Bonin island chains, on cliffs in the Senkaku islands, the Ryuku islands of Japan, in Taiwan and more than likely on several islands off China (UNEP-WCMC, accessed 2009). Now the species is mainly found in the region of Japan, and important breeding grounds include the volcanic slopes of Torishima, on cliffs in the Senkaku islands, Japan and on Midway Atoll (Northwestern Hawaiian</p>	<p>Short-tailed albatrosses formerly ranged widely across the Pacific breeding in huge numbers on at least 11 islands. Now they mainly occur only in Japan, on the volcanic slopes of Tori-shima, their main</p>	4

	<p>Islands) (UNEP-WCMC, accessed 2009). Short-tailed albatrosses are pelagic for much of the year, however they do return to colonies on small offshore islands, where as in the past they seemed to prefer level, open areas adjacent to tall clumps of the grass (<i>Miscanthus sinensis</i>) for nesting (Birdlife International, accessed 2009). The main nesting colony is currently based on Tori-shima, where the nesting ground is mainly bare or sparsely vegetated, where it now appears to require bare ground surrounded by cliffs at its nesting grounds, with runways to allow it to take off (Birdlife International, accessed 2009).</p> <p>The short-tailed albatross is a surface feeder and is thought to feed mainly at night due to its fondness for squid (Birdlife International, accessed 2009). Their diet also consists of a variety of fish and crustaceans and they have been frequently observed following ships, to feed on galley scraps (Birdlife International, accessed 2009).</p> <p>Reproduction rate: Like many seabirds, short-tailed albatrosses are slow to reproduce and are long lived. They are sexually mature at four years old, however they do not start to nest until around their sixth year (Birdlife International, accessed 2009). Before they start to breed the birds will return to the colony for several years to gain experience in breeding activities and to establish a pair-bond, which will often last for life (Birdlife International, accessed 2009). The birds are a colonial nesting species, arriving at breeding grounds in mid – October (Birdlife International, accessed 2009). Only one egg is laid per nest (incubated by both sexes) and the chicks hatch between early January and February, eventually fledging between April and June (Birdlife International, accessed 2009).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: Seasonal movements of the birds are not well known (Birdlife International, accessed 2009). They begin to arrive at Tori-shima in early October and increase in numbers until breeding begins towards the end of the month. Those birds that have failed to breed or are non-breeders leave the island in winter and spring, where successful breeders and fledglings depart from late May to June (Birdlife International, accessed 2009). After leaving Tori-shima the birds move northwards along the Japanese coast to summer in the Bering Sea, then moving down the west coast of North America (from the Gulf of Alaska as far south as Baja California) before returning to Tori-shima in late Autumn (Birdlife International, accessed 2009). It is thought that outside the breeding season they</p>	<p>breeding ground. The albatrosses are pelagic for much of the year, however they do return to colonies on small offshore islands, where as in the past they seemed to prefer level, open areas adjacent to tall clumps of the grass (<i>Miscanthus sinensis</i>) for nesting (Birdlife International, accessed 2009). This shows that the birds have adapted in the past to changing environments and exhibit a certain degree of flexibility in their habitat requirements. Like many seabirds, short-tailed albatrosses are slow to reproduce and are long lived, feeding on a wide variety of fish and crustaceans, although they are particularly fond of squid.</p>	
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	<p>scatter widely in the north Pacific but they concentrate in nutrient-rich waters (Birdlife International, accessed 2009).</p>		
<p>Changing dynamics of species interactions</p>	<p>Short-tailed Albatross feed on the ocean surface, preying mainly on squid, fish and shrimp. This species is also documented to scavenge discarded bycatch and offal from fish trawlers. Short-tailed Albatross chicks are fed on regurgitated food from its parents.</p> <p>It has been documented that in the Bering Sea, Short-tailed Albatross are attracted to the continental shelf edge, where upwelling of cold water brings nutrients to the euphotic zone, supporting high levels of primary production. This in turn supports high densities of zooplankton and other sea life such as fish and cephalopods, providing food for the albatrosses (Piatt et al., 2006). It is likely that climate change will affect such ocean upwelling's, which in turn will influence productivity and have knock on effects through the food chain. For example, during El Niño events off of the Peruvian coast, rising sea surface temperatures contribute to the cessation of upwellings. During this period, nutrient rich cold water can not reach the euphotic zone, resulting in a dramatic decrease in biodiversity.</p> <p>Climate change will have wide ranging effects on aquatic ecosystems by affecting water levels, salinity, surface temperature etc, and this is also likely to affect the marine animals that this species feeds on, resulting in disrupted food webs. The Short-tailed Albatross feeds on the surface of the water, and as this layer is likely to undergo the greatest change in temperature, which will almost certainly affect the species that the albatross usually feeds on here.</p> <p>Many cephalopods (e.g. squid), require a particular set of environmental conditions in which to survive (Robinson et al., 2005). Cephalopods are particularly vulnerable as their embryonic development and hatching, growth, migration patterns and range are all influenced by temperature (Robinson et al., 2005). It is thought that the Humboldt Squid (<i>Dosidicus gigas</i>) is very vulnerable to climate change due to a combination of sea temperature rise, ocean acidification and the existing lack of oxygen in the deep sea (Rosa and Seibel, 2007). It was found that ocean acidification and the associated reduction in oxygen availability decreases the Humboldt Squids metabolism, which prevents it from feeding efficiently at the surface. This is particularly pronounced at higher temperatures (Rosa and Seibel, 2007). This may also be the case for other species of squid, and could lead to changes in their abundance and distribution, which would have wider ramifications throughout the food chain.</p>	<p>Short-tailed Albatross feed on the ocean surface, preying mainly on squid, fish and shrimp, all of which are likely to be affected by climate change. Climate change will have wide ranging effects on aquatic ecosystems by affecting water levels, salinity, surface temperature, pH etc, and this is also likely to affect the marine animals that this species feeds on, resulting in disrupted food webs. The Short-tailed Albatross feeds on the surface of the water, and as this layer is likely to undergo the greatest change in temperature, which will almost certainly affect the species that the albatross usually feeds on here. The main predators of the Short-tailed Albatross are invasive rats and cats, which are unlikely to be affected by climate change. The Short-tailed Albatross competes with other seabirds, particularly with Black-footed Albatross. It is likely however that climate change will have similar effects on these competitors.</p>	<p>4</p>

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). Fish physiology can be intricately linked to temperature, and fish are adapted to cope with specific habitat niches and hydrologic regimes. Therefore, their physiology and life histories will be affected by any changes caused by climate change. (Ficke, Myrick & Hansen, 2007). Also many fish feed on small organisms such as plankton, and abundance, distribution and seasonal timing of availability of this food source is likely to be affected by changes to the climate (Hays, Richardson and Robinsons; 2005), which may have far reaching affects on the food web.

Crustaceans (such as shrimp) are likely to be affected by changing water temperatures and ocean acidification, undergoing shifts in range and changes in abundance. A decrease in ocean pH will have negative consequences for oceanic calcifying organisms, such as crustaceans, as they are dependent on the availability of calcium and bicarbonate ions for the mineralization of their exoskeletons (The Royal Society). This would lead to a decrease in populations.

Koeller et al. (2009) found that eggs of the Northern Shrimp (*Pandalus borealis*) hatch in time with spring phytoplankton bloom, when food is most abundant for the larvae. The shrimp are adapted to local temperature, which determines the development time for the eggs. To get the timing right, the Northern Shrimp has to mate the previous year at exactly the right time, which is determined by the local temperature that the shrimp is adapted to. Koeller et al. (2009) suggest that it would be impossible for the species to adapt to rapid temperature changes at the seafloor, and if the water increased in temperature the eggs would develop too quickly and hatch before food became abundant, leading to low survival rates (Koeller et al., 2009). Other shrimp species are likely to be affected in similar ways.

Currently, the main predators of the Short-tailed Albatross are introduced rats and cats, and as these invasive species easily adapt to different environments, it is unlikely that climate change will affect these.

Short-tailed Albatross have an overlapping range with Black-footed and Laysan Albatross, and compete for resources with these species, as well as with other seabird species. Competition with black-footed albatrosses for nesting habitat is thought to be one of the natural threats to short-tailed albatrosses today (U.S. Fish

	and Wildlife Service). However, it is likely that climate change will affect these competitors in similar ways.		
Interactions with other processes	<p>There are a number of processes, other than climate change, which make the Short-tailed Albatross vulnerable. These include exploitation for feathers, entanglement in fishing gear, contact with marine pollutants, the introduction of non-native species, volcanic eruption, slope instability and typhoons. Clearly some of these threats are related to climate change; however they are processes in their own right (Birdlife International, 2008).</p> <p>Historically, the small population size has been caused by exploitation. Around the turn of the 19th century 5 million Short-tailed Albatrosses were killed for their feathers. This has led to a significant population decline, which has subsequently left the Albatross vulnerable to other processes, such as volcanic activity (U.S. Fish & Wildlife Service, 2001).</p> <p>Entanglement in fishing gear has also led to significant Albatross mortality. However mitigation policies are in place to limit this impact, which has alleviated some of the problems. Marine pollutants can also cause Albatross mortality. Plastics and oil are the most common dangerous pollutants, and are particularly dangerous if ingested (Birdlife International, 2008).</p> <p>Small mammals such as rats have been accidentally introduced onto important breeding islands. These animals eat the eggs and therefore reduce breeding success. The most important remaining breeding site is also vulnerable to volcanic activity. This was particularly detrimental in the 1950 when an eruption killed many birds which were already vulnerable from hunting (U.S. Fish & Wildlife Service, 2001).</p> <p>These islands also suffer from slope instability due to their volcanic soil, this can affect the Albatrosses as mass movement can destroy nests. This can also be compounded by extreme weather events such as typhoons, which in themselves can also be detrimental to the birds and their breeding success (Birdlife International, 2008).</p>	<p>The Short-tailed Albatross has experienced unsustainable levels of exploitation. However, due to conservation policies, this is no longer a significant problem. Nevertheless other processes such as pollution and fishing increase the vulnerability of the species. There are also concerns about invasive species preying on Albatross nests. Furthermore there are three natural hazards which reduce the size of the habitats, and more directly cause mortality, these are volcanic activity, typhoons and mass movement.</p>	4
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

Siberian Crane, *Grus leucogeranus*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Siberian Crane breeds in open tundra/taiga wetlands. Good visibility in this habitat owing to the lack of trees is important factor in the Cranes breeding success (Archibald & Meine 1996). However, tundra and taiga habitat are likely to be amongst the most vulnerable to the impacts of climate change (Piersma & Lindström 2004) due to the fact that very sparse tree cover in tundra and taiga habitats is largely due to the presence of permafrost (Harding et al. 2002).</p> <p>Global warming is projected to be amplified in polar regions and Northern wetlands (areas with a latitude >60°N) in comparison to the rest of the planet (Christensen et al., 2007). Indeed, amplification has already been observed in these regions (Chapin et al., 2005). In addition to this, according to Flannigan et al. (2000), intensified fire regimes are likely to impact boreal forests at least as much as climate change itself. This is likely to accelerate transitions and allow pioneer shrub and tree species into the tundra, greatly assisting the conversion of tundra into more afforested areas (Johnstone and Chapin, 2006).</p> <p>Under both A2 and B1 emissions scenarios, significant encroachment of forest cover and woodland towards tundra and taiga habitats is expected. However the A2 model shows the encroachment to be much more extensive, almost ubiquitous across the breeding areas.</p> <p>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.</p> <p>Climatic changes are already impacting upon Siberian Arctic habitats utilised by the cranes. 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). The population breeds across an extensive area, some 26,000 sq. km. Analysis of aerial surveys and satellite images spanning the period from 1954 to 2004 and covering 47 lakes. Only three of these</p>					<p>More than one of this species' habitats will be affected by climate change. The chance of tundra ecosystem which is used as a breeding habitat shifting to new area in pace with the rate of ecosystem is very small and this coupled with hydrological changes in the wintering habitat will put pressure on this population. This habitat is unique and is likely to lose a large proportion of its area. The loss of this amount of habitat coupled with the very low breeding density of the species is likely to seriously effect the remaining population in the future.</p>	5

	<p>lakes had increase 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).</p> <p>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 a loss of breeding areas.</p> <p>In addition to the threats that climatic changes pose to the breeding areas of this species, drought and reductions in precipitation are also effecting the wintering and staging areas utilised by this species. Poyang Lake reduced considerably in size in the 2003-2004 winter. The increased occurrence of such drought conditions will pose a considerable threat to the population in the future (BirdLife International, 2008).</p> <p>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. The East Asia region is expected to see a 3.0°C rise in the summer and 3.6°C rise in the winter (Christensen et al., 2007).</p> <p>Along with the projected increase in temperature, evapo-transpiration rates will rise. Whilst the changes in precipitation rates across the East Asia region are projected to vary significantly, the areas utilised by the Siberian Cranes are projected to see increased annual precipitation rates, especially during the winter months in which the cranes would be present (Christensen et al., 2007).</p> <p>Research conducted by Zhai et al. (2005) showed that the intensity of rainfall events in these regions is likely to increase substantially. The precipitation for this region is likely to become more variable with increased droughts and floods, both of which are likely to have deleterious effects for the aquatic plants on which the cranes feed (DEFRA, 2005).</p>		
<p>Ecological flexibility</p>	<p>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 feed upon the tubers of the submerged aquatic macrophyte <i>Vallisneria spiralis</i> (Li et al., 2005). Outside their breeding season they are predominately vegetarian.</p>	<p>On it's breeding habitat, the Siberian Crane has a relatively broad diet but its nesting habitat is very specific. Over winter, this species predominately feeds upon just one food item. However, there</p>	<p>3</p>

	<p>Whilst the diet of this species is relatively broad, they are tied to they have narrow specification for their breeding habitat. The Siberian Crane breeds in open tundra/taiga wetlands. Good visibility in this habitat owing to the lack of trees is important for the Cranes breeding success (Archibald & Meine 1996). Although this species has the ability to change its migration habitats and it breeds across an extensive area, they require a breeding habitat which is declining in its</p> <p>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.</p>	<p>is some evidence that the birds have only located to their present wintering grounds in the recent past, and at one time they were also to be found in a variety of different areas across the north of Eurasia. Evidence showing that some individuals mix or have mixed from the central and western flyways also suggests some degree of ecological flexibility</p>	
<p>Changing dynamics of species interactions</p>	<p>In the breeding season this species is omnivorous; taking in a wide range of food items (Meine et al., 1996) of which non 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 <i>Vallisneria spiralis</i>. A report from DEFRA (2005) suggests that the abundance of this plant may drop significantly due to increased intensity of flooding and drought events.</p> <p>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.</p>	<p>There are no predator/prey cycles to be considered and phenological shifts do not seem to be important. However, some doubt over the future of the main winter foodstuff due to more extreme weather events is a concern</p>	<p>2</p>
<p>Interactions with other processes</p>	<p>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 are cited as the primary factors leading to the population's demise (SCWP, 2009a). The western population of Siberian crane 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 species faces are generally low, consisting of hunting, fishing and forestry operations. Oil and gas exploration however is a growing threat in the Uvat area, and oil pollution in the River Ob is a significant problem (CMS, 2001).</p> <p>The key threat for this species is wetland loss and degradation of the wintering habitats, critical staging areas and migration stopover grounds. The main driver of</p>	<p>The loss of wintering and staging habitats is the major threat to this species. Anthropogenic water resource issues in China are likely to impact upon wetlands. In addition to this, large-scale hydro-electric programs threaten to affect the hydrological regime migration stop-over sites and the Poyang Lake basin.</p>	<p>3</p>

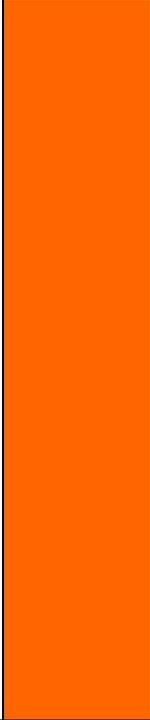
	<p>this habitat loss is agricultural development and fossil-fuel extraction (BirdLife International, 2008). In addition to these factors, water diversion for human use from rivers which supply key wetlands within protected areas is a concern for wetlands in the semi-arid climate of north-eastern China as traditional water sources become increasingly scarce (SCFC, 2004).</p> <p>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 which could alter the hydrological regime (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) a 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 <i>Vallisneria spiralis</i>, the Siberian Crane’s main food source in this area.</p>		
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species							
Species Assessment							
Sociable Plover, <i>Vanellus gregarius</i>							
Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Sociable Plover is critically endangered having suffered substantial population decline. It migrates between wintering areas in North East Africa and North West India, through stopover sites in the Middle East, to summers breeding sites in Northern Kazakhstan. The wintering grounds are often semi-arid, and are characterised by sandy areas, short grass and dry plains, often in close proximity to water. The breeding areas are predominantly steppe grassland, with breeding taking place on saline areas next to water. The most important areas occur around <i>Stipa</i> and <i>Artemisia</i> grasslands. <i>Artemisia</i> grasses are the preferred habitat due to increased abundances of dung and shorter vegetation. Fire is also important as it has been proposed that fire increases the viability of the habitat (Birdlife International, 2008).</p>					<p>Throughout the habitat of the Sociable Plover there is likely to be less rainfall and higher temperatures from climate change. This is likely to lead to less grassland and wetland habitats, with more desert habitats. Plovers can live in deserts but grasslands and wetlands are also important. This means that there is likely to be some moderate habitat</p>	3

	<p>In North East Africa the temperature is predicted to rise by between 2.2 and 4.5°C by 2100. This is in line with the predicted warming for all of Africa, which is placed at between 3 and 4.5°C, this is 1.5 times the global mean. Precipitation is likely to vary seasonally. During the winter when the birds are present, there is likely to be reduced rainfall, by around 20-25% by 2100. There is likely to be increased rainfall, by between 5-20% by 2100. These changes will be driven by changes to the extent of seasonal rainfall. The annual picture shows relatively stable rainfall with increases or decreases of less than 5% over their African range (Christensen et al, 2007).</p> <p>These changes are likely to lead to both increased desertification and increased forest and shrubland gain within the Sociable Plover's winter range. This is most likely going to be at the expense of grassland areas (Fischlin et al., 2007). These changes will greatly affect this section of the Sociable Plover's winter range. More shrubland and forest will reduce the amount of available habitat. The increase in desert size will also partially reduce the available habitat as the plovers prefer to reside on grasslands; however they also can live in more arid areas.</p> <p>In North West India the temperature is predicted to increase by about 3.3 °c by 2100. This increase is also thought to be most pronounced during the winter when the birds are present. Precipitation is likely to become more seasonal with winter receiving 5% less rainfall and summer receiving 11% more in 2100 (Christensen et al., 2007). These changes are likely to cause increased desertification. As discussed previously this is most likely to negatively affect Sociable Plovers, however they can survive in semi-arid and sandy environments.</p> <p>In the Middle East 3.5-4.5 °c of warming is expected by the end of the century, with up to 3.7°C expected further east. The whole region is expected to become drier with at least 3% less precipitation by 2100 (Christensen et al., 2007). This is unlikely to significantly change the land cover type, as throughout the area grassland and desert are both predicted to increase, thus not fundamentally changing the habitat.</p> <p>In Central Northern Asia the temperature is likely to increase significantly somewhere in the range of 3.7 to 4.3 °c. Precipitation is likely to be relatively stable in northern Kazakhstan as rainfall in Central Asia is predicted to decrease by 5% whilst it is predicted to increase in North Asia (Christensen et al., 2007). There is also likely to be some limited desertification in the Plover's northern range (Fischlin et al., 2007). This could negatively affect some areas of habitat if grassland</p>	<p>fragmentation and degradation.</p>	
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	<p>becomes desert particularly as certain grassland is important for the plovers nesting. However this effect may be limited by the ability of Plovers to live in arid areas. The reduced rainfall and increased temperatures may produce more fire; this may in fact benefit the Sociable Plover. However Sociable Plovers like to be near water, within their arid and grassland habitats, therefore reduced rainfall and increased temperatures may reduce suitable habitat as wetland areas dry up.</p>		
<p>Ecological flexibility</p>	<p>Degree of specialisation: Sociable plovers have a sporadic pattern of semi-colonial breeding, mainly in the transition zones between Stipa and Artemisa grassland steppes where bare saline areas occur near water bodies (Birdlife International, accessed 2009). Their wintering grounds are dry plains, sandy wastes and short-grass areas, often adjacent to water (Birdlife International, accessed 2009). Nesting birds in Kazakhstan appear to favour grazed land and in wintering grounds in SE Asia the birds are thought to prefer cultivated or semi-cultivated tracts rather than stony or sandy wastes and deserts (Birdlife International, accessed 2009). Like other plovers the birds feed by walking slowly and picking up visible items from the ground, probing between clods and around the base of small plants (Birdlife International, accessed 2009). On breeding grounds their diet consists almost entirely of insects, particularly beetles and their larvae, grasshoppers (Orthoptera) and moth larvae (Lepidoptera) (Birdlife International, accessed 2009).</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction Rate: Their breeding season falls between the end of March and early July, with most eggs being laid between mid-April and mid-June (Birdlife International, accessed 2009). The sociable plover is a semi-colonial breeding species, nesting in open country (Birdlife International, accessed 2009). Their nest usually consists of a simple unlined scrape in the earth, apart from a small amount of leaves, grass, moss etc. (Birdlife International, accessed 2009) However, when the substrate is damp or boggy, such as the shores of lakes and rivers, the birds may construct a nest using grass and weeds (Birdlife International, accessed 2009). As with other plover species the sociable plovers clutch size usually contains four eggs, with incubation lasting 25 days and the young fledging the nest 35-40 days later (Birdlife International, accessed 2009). Pairs may lay late or second clutches up until late July (Birdlife International, accessed 2009).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: Early records indicate that the species migrated in very large flocks, however this is no longer the case (Birdlife International, accessed 2009). The</p>	<p>The Sociable plover's diet is broad, consisting almost entirely of insects, with a preference for beetles and their larvae, grasshoppers (Orthoptera) and moth larvae (Lepidoptera). Although their breeding habitats are more complex in comparison to their wintering grounds, the birds appear to show a certain degree of flexibility, supported by their mixing with other waders. Early records show that the birds used to form larger colonies and detail past migratory routes, enabling us to see how they have adapted to change in the past.</p>	<p>3</p>

	<p>precise migratory routes taken by the birds appear to vary considerably from year to year (Birdlife International, accessed 2009). (Birdlife international details past migratory routes – may be relevant).</p> <p>In India the birds are generally found in singles, pairs or small parties, and have been recorded mixing with other waders, such as coursers Cursorius in Gujarat (Birdlife International, accessed 2009). Post- breeding flocks formerly consisted of sometimes several hundred or up to a thousand birds and in recent years in Kazakhstan, flocks of 70-180 birds have been recorded (Birdlife International, accessed 2009). However, birds on spring migration in south-eastern Kazakhstan have been recorded mostly alone or in very small flocks (Birdlife International, accessed 2009).</p>		
<p>Changing dynamics of species interactions</p>	<p>Sociable Plover are largely insectivorous, consuming grasshoppers, beetles and their larvae, moth larvae and arachnids. These birds are also thought to consume molluscs and plant matter including leaves, grains and flowers (BirdLife International, 2009). Although Sociable Lapwings do seem to prefer insects, they appear to be fairly generalistic, consuming a range of arthropod species, as well as eating some non-insect food. It is uncertain how climate change will affect insect availability and abundance within the Sociable Plovers range, but generalist species are likely to have a greater adaptive ability and are probably less likely to suffer shortages of food, compared to species with a specialist diet.</p> <p>The main nest predators include Foxes (<i>Vulpes vulpes</i>), Rooks (<i>Corvus frugilegus</i>), polecats, long-eared hedgehogs and souslik (ground squirrel) species (Birdlife International, 2009). Climate change effects on these predators are unknown, however due to species range shifts as a response to climate change, it is possible that the distribution of these predators may change, and novel predator species may also appear.</p> <p>It is thought that Sociable Plovers may depend on Saiga antelope (<i>Saiga tatarica</i>) to provide ideal nesting habitat, created by the periodic grazing of these ungulates which keeps the grass short (Watson et al., 2006). The nomadic nature of Saiga means that they keep the vegetation short, but have a limited presence in an area which limits the probability of nests being trampled. It is likely that climate change will affect Saiga antelope, altering their migratory behaviour, increasing the incidence of mass mortality and contributing to low reproductive success during extreme climatic events (Robinson et al., 2005). This is likely to have detrimental effects on Lapwing numbers.</p>	<p>Plovers have numerous predators (e.g. foxes and Rooks), but the climate change effects on such predators are unknown. It is possible that the ranges of such predators may shift, changing their distribution. It is thought that the Sociable Plover relies on Saiga antelope to create ideal breeding habitat through grazing and trampling of grassland. However, climate change could potentially negatively effect Saiga, which would be detrimental to Sociable Plover.</p>	<p>4</p>
<p>Interactions with</p>	<p>There are a number of threats, other than climate change, which are likely to affect</p>	<p>Breeding habitats have been</p>	<p>4</p>

<p>other processes</p>	<p>the population of the Sociable Plover. These include changes to agricultural practices, human disturbance of nest sites, hunting and pollution. These processes are generally situated at the breeding grounds. However some interference, particularly hunting, takes place on the migration routes and wintering grounds (Birdlife International, 2008).</p> <p>Historically, the conversion of large parts of the steppe to arable land, has probably contributed to the species' decline. As the loss of the steppe habitat, represents the loss of important breeding grounds. However with the collapse of the Soviet Union, much of the arable land has reverted to steppe, nevertheless this has not lead to a population increase. These changes in agricultural practices have also altered where the Plovers like to breed. As collectives have been disbanded, the heavily grazed areas the Plovers favour for breeding have become closer to villages. This has lead to increased disturbance of nesting sites, and trampling of nests by domesticated animals, which may have lead to population decline (Birdlife International, 2008).</p> <p>Hunting is probably the largest threat to Sociable Plovers. As Sociable Plovers are critically endangered and heavily protected this hunting is illegal, and therefore represents difficulties in policy enforcement. This means it is likely that the Plovers are being targeted throughout much of their range. However this is a difficulty which can be resolved (Birdlife International, 2008).</p>	<p>significantly degraded through changes in agricultural practices. Meanwhile, hunting in the wintering grounds and on the migration route, is thought to have significantly effected the population, perhaps even pushing it to extinction, however this is uncertain.</p>	
		<p>HIGH VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Steller's Eider, *Polysticta stelleri*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>Steller's Eider is a small marine duck, generally found in high latitude areas. They commonly over-winter in southern Alaska, Northern Japan and the Baltic. They then migrate to their summer breeding grounds which are located on the Alaskan planes and in North Eastern Russia. Summer breeding sights are generally fresh water ecosystems such as arctic pools, small lakes, rivers and tundra bogs. Conversely, in the winter Steller's Eiders generally inhabit coastal habitats including low-lying rocky coasts, bays and river mouths (Birdlife International, 2008).</p> <p>The Arctic is predicted to warm by between 5 and 7°C by 2100, higher by a magnitude of 2 when compared to the predicted global average. However, this is seasonal with greatest warming occurring in the winter, the birds are further south. (Christensen et al., 2007). Yet, this is likely to change processes within the habitat and change the composition of species. Warming of this magnitude is also likely to shift the biomes north. This has the potential to reduce suitable habitat as certain other land cover types take over from the Steller's Eider's preferred habitat, for example through forest cover gain, which could potentially alter the hydrology (Fischlin et al., 2007). This is compounded by the fact that the bird's summer range borders on the most northerly continental margins, therefore there is limited opportunity to shift the summer range northwards. Furthermore, if their range was to move northwards, the length of the migration may increase, whilst the route may also be negatively affected, for instance by the necessity to fly over the Arctic Sea to Arctic islands. Increased temperatures will also cause higher rates of evaporation. This may limit the supply of freshwater to wetland habits, reducing the number of suitable locations for the ducks (Arnell, 1999). Conversely, precipitation in the Arctic is likely to increase by between 10% and 28% by 2100 (Christensen et al., 2007). This is likely to mean that wetland habitats will not be water stressed by climate change and could potentially be more numerous. This could however change the nature of wetland habitats through flooding, potentially changing the structure and species composition of arctic wetlands.</p>					<p>Steller's Eider's summer grounds are likely to be affected by land cover change particularly the encroachment of trees. This is then combined with the geographical constraint of the arctic sea, leading to limited possibilities for northward range expansion. The wintering grounds will also be affected by significant warming, however land cover change will be less of a problem for coastal regions. However, sea level rise is likely to significantly affect important parts of the coastal habitats.</p>	4

	<p>Estuaries are used by the Steller's Eider. Precipitation regimes, because of their increased strength, are predicted to increase sediment flux into estuaries, thus enhancing them (Walling and Fang., 2003). However, 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 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 has the potential to greatly reduce the extent of estuarine and coastal environments which the ducks can use.</p>		
<p>Ecological flexibility</p>	<p>Degree of specialisation: The birds breeding habitat is usually several kilometers inland, where they inhabit pools of various shapes and sizes, in areas that characterize flat coastal belt within open tundra (Birdlife International, accessed 2009). In certain areas, for example, the Lena Delta and Barrow, the birds favour moss-lichen tundra (Birdlife International, 2009). They forage in areas of fresh, saline or brackish water and tidal flats (Birdlife International, 2009). They build their nests on small hummocks or in depressions between hummocks that are usually well concealed by grass and are within a few metres of a tundra pond (Birdlife International, 2009). The nests are deep and are lined with lichens, grass and down (Birdlife International, 2009).</p> <p>Following hatching the birds move to their non-breeding coastal habitats (Birdlife International, accessed 2009). They winter mostly at sea, along low-lying rocky coasts, frequenting bays and river mouths (Birdlife International, accessed 2009). In their non-breeding grounds the birds forage in water less than 10m deep, favouring areas where freshwater streams enter the sea (Birdlife International, accessed 2009). The birds feed mainly on mollusks, crustaceans and other marine invertebrates (Birdlife International, 2009). During the breeding season they may also feed on freshwater prey, including chironomid and caddisfly larvae and during moult, bivalve molluscs are their main food source (Birdlife International, 2009).</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction Rate & Dispersal: The birds begin to breed in June, sometimes nesting in single pairs at a very low density or in small colonies of up to 60 + nests (Birdlife International, accessed 2009). At the time of hatching the males congregate in large flocks off the coast near the breeding ground (Birdlife International, accessed 2009). The females, shortly after hatching, then move their</p>	<p>The birds have a broad diet feeding on both marine and freshwater prey, foraging in areas of fresh, saline or brackish water and tidal flats. However, in their non-breeding grounds the birds require water less than 10m deep in order to feed.</p> <p>Although their breeding ground requirements are fairly specific, their habitat requirements are not as narrow as many other species.</p> <p>The timing of their moult migration is highly variable, suggesting that they may be able to adapt to changes in the climate with more ease than other species.</p>	<p>3</p>

	<p>broods to the coast as well (Birdlife International, 2009).</p> <p>The birds can migrate up to 3000km to their moulting sites, where they become flightless for a short period, before continuing to their wintering sites (Birdlife International, accessed 2009). The timing of their moult migration is highly variable and can occur as early as August or as late as November, in which case the moult occurs prior to arrival (Birdlife International, accessed 2009). On their moulting grounds they form flocks sometimes exceeding 50,000 birds, this also occurs in the spring when the birds pair up and depart for their breeding grounds (Birdlife International, 2009).</p> <p>Climate related changes to fecundity: Insufficient data.</p>		
<p>Changing dynamics of species interactions</p>	<p>Steller's eider feeds on molluscs (including mussels and clams), crustaceans and other aquatic invertebrates such as marine worms, insects and larvae (BirdLife International, 2009).</p> <p>Crustaceans and molluscs are likely to be affected by changing water temperatures and ocean acidification, undergoing shifts in range and changes in abundance. A decrease in ocean pH will have negative consequences for oceanic calcifying organisms (such as crabs and bivalve molluscs) as they are dependent on the availability of calcium and bicarbonate ions for the mineralization of their exoskeletons (The Royal Society, 2005). This would lead to a decrease in populations. However, there has also been findings that some crab species are increasing in abundance as a result of climate change. For example, certain species of crab in the north sea are undergoing a population increase, as Cod (<i>Gadus</i> sp.) which feed on the crabs are declining as a result of decreasing food availability for cod larvae caused by climate change (Kirby, Beaugrand and Lindley, 2009). Also, Blue Crabs (<i>Callinectes sapidus</i>) south of Chesapeake Bay are expected to experience a population increase, as warmer temperatures means that winter hibernation will be unnecessary, therefore crabs can complete their lifecycle within just one year, instead of having to wait until the following year (Goldman, 2006). Nest predators include both mammalian and avian species such as arctic foxes (<i>Alopex lagopus</i>), short-tailed weasels (<i>Mustela erminea</i>), common ravens (<i>Corvus corax</i>), jaegers (<i>Stercorarius</i> spp.), and glaucous gulls (<i>Larus hyperboreus</i>) (Alaska SeaLife Centre, 2010). It is not fully known how climate change will affect every individual predator species. However, it has been documented that due to climate change there has been a Northward expansion of the range of red foxes (<i>Vulpes vulpes</i>) and a simultaneous retreat of Arctic fox (<i>Alopex lagopus</i>) range, due to interspecific competition with the advancing red foxes (Hersteinsson and MacDonald, 1992; Tannerfeldt et al., 2002). Climate change could potentially cause</p>	<p>Steller's Eider feeds on aquatic prey, mainly crustaceans, molluscs and some other invertebrates such as aquatic insects and larvae. Organisms such as these are likely to be affected by climate change, especially calcifying organisms such as crustaceans and molluscs as ocean acidification will leave them less able to mineralise their exoskeletons. However, some crustacean species are increasing in abundance due to climate change, Steller's Eider has several mammalian and avian predators. It is not certain how each of these predator species will be affected by climate change. However it is known that Lemmings (a main source of prey for predators of Steller's Eider) are negatively affected by the rising temperatures, which potentially causes increased</p>	<p>3</p>

	<p>other range shifts, changing the abundance and distribution of current and novel predators. Many predators of Steller's eider rely on lemmings as a food source. However, late arrival of autumn snow, and earlier spring melt is a threat to lemming populations (Kausrud et al., 2008), and a decrease in Lemmings may have negative impacts on some predators. However, when lemming prey is less available, predation on species such as Steller's eider increases. This may be an indirect effect of climate change, as it may decrease lemming numbers and consequently increase eider predation.</p> <p>Finally, Steller's Eider tend to nest when there is an abundance of nesting pomarine jaegers (<i>Stercorarius pomarinus</i>), snowy owls (<i>Bubo scandiacus</i>) and lemmings. This is because jaegers and owls may unintentionally provide protection to nearby eider nests, and lemmings provide an alternative prey source for predators of Steller's eider (Quakenbush et al, 2004).</p>	<p>predation on the Eiders. Climate change may affect the range and distribution of current and potentially novel predators, and this has been demonstrated with the changing range of the Red Fox and the Arctic Fox.</p>	
<p>Interactions with other processes</p>	<p>There are a number of threats, other than climate change, which are likely to affect the population of the Steller's Eider. These threats are hunting, Pollution, natural resource prospecting, and an increase in the number of predators because of increased human habitation (Birdlife International, 2008). These problems are mainly occurring in the northern parts of their range where climate change impacts will be most pronounced (Christensen et al, 2007).</p> <p>Most populations of Steller's Eiders have undergone subsistence hunting, which may have reduced their numbers. Associated with this is the use of lead shot, which is now illegal, although still practiced, in Alaska. This has lead to individuals receiving lead poisoning, which has reduced their numbers still further. Other types of pollution have also been important (Birdlife International, 2008). As Steller's Eiders inhabit wetlands, they are particularly vulnerable to water pollution which is an increasing problem in the Arctic (Allen-Gil et al, 2002). Other forms of pollution are related to oil and gas prospecting, these include oil spills, as well as industrial pollutants associated with heavy machinery and industrial processes. They also represent a threat due to the increased possibility of disturbance that comes with increased human activity. These increases in human populations are associated with increases in predators such as Ravens and large Gulls. This clearly negatively effects the Steller's Eider population (Birdlife International, 2008).</p>	<p>A combination of low level hunting, some invasive species and significant habitat loss from pollution and other human activities, means that Steller's Eiders will be more vulnerable to climate change.</p>	<p>3</p>
		<p>HIGH VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

Swan Goose, *Anser cygnoides*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The Swan Goose migrates between summer breeding zones in North-east Asia to wintering areas further south. Within these areas the Swan Goose populate wetlands. In the summer they inhabit; steppe and forest-steppe zones, including river deltas, river valleys with meadows, the margins of brackish and freshwater lakes, and in mountainous areas along narrow, fast-flowing rivers. Whilst in winter they reside in lowland lakeside marshes, rice-fields, estuaries and tidal flats. (Birdlife International, 2008).</p> <p>East Asia is predicted to warm by 3.3°C by 2100, with seasonal variation causing summer temperatures to be 3.6°C higher, whilst winter temperatures are likely to be 3 °C warmer than today, which is slightly more than the global average (Christensen et al., 2007). This is likely to change processes within the habitat and change the composition of species. Warming of this magnitude is also likely to shift the biomes north. This has the potential to reduce suitable habitat as certain other land cover types take over from the goose’s preferred habitat, for example through forest cover gain, which could potentially alter the hydrology (Fischlin et al., 2007). Furthermore, with suitable habitat moving northward, the length of the migration may increase, whilst the route may also be negatively affected.</p> <p>Increased temperatures will also cause higher rates of evaporation. This may limit the supply of freshwater to wetland habits, reducing the number of suitable locations for the geese (Arnell, 1999). Conversely, precipitation in East Asia is likely to increase 9% by 2100 (Christensen et al, 2007). This is likely to mean that wetland habitats will not be water stressed by climate change and could potentially be more numerous. However there is some evidence that rainfall could become more variable, with heavier rainfall occurring less often (Christensen et al, 2007). This could change the nature of wetland habitats through flooding, and potentially reduce their numbers through terrestrialisation, however this seems unlikely.</p> <p>Estuaries and tidal flats are sometimes used by the Swan Goose. Precipitation regimes, because of their increased strength, are predicted to increase sediment flux into coastal flats, thus enhancing them (Walling and Fang, 2003). However,</p>					<p>Climate change will certainly affect both the wintering and summering grounds of the Swan Goose. However in most cases climate change is unlikely to completely degrade them. Increased temperatures may shift the migration further north changing the route, perhaps pressurising the species.</p>	3

	<p>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 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 has the potential to greatly reduce the extent of coastal environments which the geese use.</p>		
<p>Ecological flexibility</p>	<p>Degree of specialisation: Swan geese breed in marshes and near rivers and lakes in the steppe and forest-steppe zones (Birdlife International, accessed 2009). In eastern Russia it breeds in both upland and lowland landscapes, in the mountains, inhabiting lakes and tall grass along rivers (Birdlife International accessed 2009). On Sakhalin the geese nest on dry ridges with bushes of shrub pine, alder, dwarf birch, heath and labrador tea, with sparse larches and a carpet of lichen-crowberry (Birdlife International, accessed 2009). Moulting flocks have been found in larch swamps and on tidal flats (Birdlife International, accessed 2009). In Mongolia the birds nest in areas with dense grass and bushes, often along remote rivers with reeds or poplars or on islands in salt-freshwater lakes (Birdlife International accessed 2009). In north-east China the birds have been recorded in marshes and by lakes, and on occasion in grasslands near saline lakes (Birdlife International, accessed 2009). In Ningxia the birds usually occur in the plains near rivers, lakes and marshes, particularly in areas with dense water plants (Birdlife International accessed 2009). It's habitats in Japan include freshwater lakes and marshes, tidal flats and harvested paddies and in South Korea the birds have also been recorded in rivers, estuaries, lakes, reservoirs, canals, small ponds and on marshes with cattail and reed beds (Birdlife International, accessed 2009).</p> <p>The birds diet changes with the seasons and location of populations, on their breeding grounds they feed on sedges, whereas in autumn their diet includes a variety of berries (Birdlife International, accessed 2009). They usually feed at night on plants, algae and some molluscs (Birdlife International, accessed 2009). Studies have revealed that in the birds main wintering areas along the eastern Chinese coast and in the Yangtze basin, a high proportion of its diet consists of the roots of the water plant <i>Vallisneria asiatica</i>, and the seeds of a halophyte <i>Suaeda salsa</i> (Birdlife International, accessed 2009).</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction rate: The birds nests are sited on islands in rivers, in thick grasses and reeds in marshland, in remoter, drier parts of reed beds, on grassy hills and on</p>	<p>Swan geese inhabit a wide variety of habitats, including those used as breeding grounds in the steppe and forest-steppe zones, indicating a large degree of flexibility in habitat requirements. The birds diet is varied, changing with the seasons, however studies have revealed a dependency on certain species of plant in their main wintering grounds along the eastern Chinese coast and in the Yangtze basin.</p> <p>Clutch size is quite large, ranging between 3-9, suggesting a slightly higher reproduction rate than some of the other birds on the list.</p>	<p>3</p>

	<p>islands in reservoirs (Birdlife International, accessed 2009) . They start nesting in early to mid-May on the lower Amur and in early May on Sakhalin but from mid-April in Heilongjiang in China (Birdlife International, accessed 2009). Swan geese in Mongolia nest in colonies (Birdlife International, accessed 2009).Clutch sizes vary between breeding grounds but usually average around 5 per nest. Although it has been recorded that two or three females may sometimes lay eggs in the same nest, accounting for some of the larger clutches that have been recorded (Birdlife International, accessed 2009). The eggs hatch by mid-June in the lower Amur and on Sakhalin, whereas in Heilongjiang the goslings have already reached adult size by mid-June (Birdlife International, accessed 2009). The broods then tend to aggregate into flocks and float downstream to broader valleys or larger lakes in Amur or to the coastal plains on Sakhalin, where the juvenile birds start to fly in early September (Birdlife International, accessed 2009). Non-breeding birds form separate flocks and remain in close proximity to shallow lakes in the coastal lowlands (Birdlife International, accessed 2009).</p> <p>Climate related changes to fecundity: Insufficient data.</p> <p>Dispersal: Swan geese arrive in the lower Amur area by early April, considerably earlier than other goose species, and spring migration on Sakhalin occurs in the last 10 days of April through to early May and in autumn it occurs between September and October (Birdlife International, accessed 2009). In Mongolia the birds arrive from the middle to the end of April and starts to nest in May, moulting in August and departs around the beginning of September (Birdlife International, accessed 2009). In China they arrive on breeding grounds in mid-to late March and depart in mid-October (Birdlife International, accessed 2009).</p>		
<p>Changing dynamics of species interactions</p>	<p>Depending on the location and time of year, Swan Geese may feed on Sedges (Carex sp.), a variety of berries (such as blueberry Vaccinium uliginosum and crowberry Empetrum), algae, some molluscs, roots of the water plant Vallisneria asiatica, as well as the seeds of a halophyte, Suaeda salsa (Birdlife International, accessed 2009). This species is also known to feed in rice paddies and grasslands at night (Birdlife International, accessed 2009). The Swan Goose is omnivorous and has a fairly broad diet. This omnivorous species is likely to consume a wide variety of food items and may be fairly opportunistic with a wider dietary range compared to many other bird species. The Swan Goose is more likely to have greater adaptive ability and is probably less likely to suffer shortages of prey, compared to species with a specialist diet. However, climate change is likely to have some affect on some of its food sources, such as predicted changes in aquatic plant abundance</p>	<p>The main food items of this species include plants such as sedges (Carex sp.), the halophyte Saeda salsa, and the water plant Vallisneria asiatica, as well as a variety of berries. Other food items include some molluscs, and food sourced from grasslands and rice paddies. This omnivorous species is likely to consume a wide variety of food items and is probably less likely to suffer</p>	<p>2*</p>

	<p>and distribution.</p> <p>There are no know records of predators of the Swan Goose, and this species may compete for resources with other water birds found within its range, for example the White-fronted Goose. However, due to climate change induced species range shifts, it is possible that new predators and competitors may move into the current range of the Swan Goose.</p>	<p>shortages of prey, compared to species with a specialist diet.</p> <p>There are no know records of predators of the Swan Goose, and this species may compete for resources with other water birds found within its range</p>	
<p>Interactions with other processes</p>	<p>There are a number of threats to the Swan Goose which are not related to climate change. The wintering grounds are affected by developments and pollution. Whist at the breeding grounds are threatened by habitat loss, disturbance and hunting. These processes have probably contributed to the majority of the population decrease experienced by the species (Birdlife International, 2008).</p> <p>Developments on wetlands in China have seriously affected the number of available wintering sites. There has been development on freshwater habitats, yet it is the large numbers of developments along china’s east coast which have probably had most impact (Démurger, 2001; Birdlife International, 2008). The development and increased human activity within China has also contributed to higher levels of pollution. As Swan Geese live in wetland habitats they are particularly vulnerable to pollution (Dudgeon et al, 2006; Birdlife International, 2008).</p> <p>The main mechanism that has caused the Swan Goose to loose parts of its summer habitat is agricultural development. Areas of wetlands have been drained and ploughed rendering these areas unsuitable. Meanwhile increased human activity has lead to disturbance of nesting sites and even trampling of nests reducing breeding success. Some disturbance is intentional; poaching is a large problem for the species and includes the harvesting of eggs and adult birds (Birdlife International, 2008). Hunting of waterfowl is common In China Mongolia and Russia, and has been detrimental to many populations of water birds including the Swan Goose (Hongyu, 1997).</p>	<p>The Swan Goose is exposed to significant, but not extreme, habitat loss and exploitation. There are also threats from pollution and nest disturbance which seem to be less significant. This means that there are substantial threats, other than climate change, to the population of Swan Geese.</p>	<p>3</p>
		<p>MEDIUM VULNERABILITY</p>	

Climate Change Vulnerability of Migratory Species

Species Assessment

White-naped Crane, *Grus vipio*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The White-naped Crane migrates between summer breeding zones in North-east Asia near Mongolia, to wintering areas further south in China, Korea and Japan. In the summer they inhabit; steppe and forest steppe wetlands, grassy marshes, wet sedge-meadows, reed beds in broad river valleys, lake depressions and boggy uplands. Whilst in winter reside in; freshwater lakes, farmland and sometimes coastal flats (Birdlife International, 2008). Whilst migrating, the cranes also stop over at numerous other wetland sites between the main summer and winter locations (Harris et al, 2000).</p> <p>East Asia is predicted to warm by 3.3 degrees by 2100, with seasonal variation causing summer temperatures to be 3.6 degrees higher, whilst winter temperatures are likely to be 3 degrees warmer than today, which is slightly more than the global average. (Christensen et al, 2007). This is likely to change processes within the habitat and change the composition of species. Warming of this magnitude is also likely to shift the biomes north. This has the potential to reduce suitable habitat as certain other land cover types take over from the cranes preferred habitat, for example through forest cover gain, which could potentially alter the hydrology (Fischlin et al, 2007). Furthermore, with suitable habitat moving northward the length of the migration may increase whilst the route may also be negatively affected through limited stop over habitats (Fujita et al, 2004). Increased temperatures will also cause higher rates of evaporation. This may limit the supply of freshwater to wetland habits, reducing the number of suitable locations for the cranes (Arnell, 1999). Conversely, precipitation in East Asia is likely to increase by 9% by 2100 (Christensen et al, 2007). This is likely to mean that wetland habitats will not be water stressed by climate change and could potentially be more numerous. However there is some evidence that rainfall could become more variable, with heavier rainfall occurring less often (Christensen et al, 2007). This could change the nature of wetland habitats through flooding, and potentially reduce their numbers through terrestrialisation, however this seems unlikely.</p>					<p>Climate change will certainly affect both the wintering and summering grounds of the White-naped Crane. However in most cases climate change is unlikely to completely degrade them. Increased temperatures may shift the migration further north changing the route, perhaps pressurising the species.</p>	3

	<p>Coastal flats are sometimes used by White-naped Cranes. Precipitation regimes, because of their increased strength, are predicted to increase sediment flux into coastal flats, thus enhancing them (Walling and Fang, 2003). However, 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 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 has the potential to greatly reduce the extent of coastal flats which the cranes sometimes use.</p>		
<p>Ecological flexibility</p>	<p>Degree of Specialisation & Dispersal: Breeding habitats in Russia, Mongolia and China includes wetlands and wet meadows in broad river valleys, along lake edges, and in lowland steppes or mixed forest-steppe areas (Meine et al. 1996, International Crane Foundation accessed 2009). In their breeding habitats they nest and feed in shallower sedge-dominated wetlands and along wetland edges, foraging in adjacent grasslands or agricultural fields (Meine et al. 1996, International Crane Foundation accessed 2009). It appears that they require a combination of sedge swamps and meadows and/or farmlands, explaining their sporadic distribution throughout their breeding range (Birdlife International, accessed 2009). On arrival at the breeding grounds in China, they feed mainly on seeds, grass roots, wasted grain and dead fish (Birdlife International, accessed 2009). After May when it becomes warmer they feed mainly on fish, shrimps and shellfish, and some plant material such as maize, wheat, young roots, stems, leaves and buds (Birdlife International, accessed 2009). The stomach contents of a bird collected in Inner Mongolia revealed a diet of fish, tadpoles, grasshoppers, aquatic insects (Birdlife International, accessed 2009). On arrival at feeding grounds in Russia they feed in rice and cornfields in Primorye, and in corn, soya and wheat fields in Amur (Birdlife International, accessed 2009).</p> <p>During migration and on their wintering grounds the cranes are use both wetlands and agricultural fields, and feed on waste grains, seeds and tubers (Meine et al. 1996). At the artificial feeding stations in Japan they are provided with rice and other cereal grains (Meine et al. 1996, International Crane Foundation accessed 2009). On the Korean peninsula they also use rice paddies, fallow fields, the edges of reservoirs and mudflats (Meine et al. 1996). They are excellent diggers and can excavate the tubers of several species of sedges (Meine et al. 1996).</p> <p>The White-naped crane has been described as intermediate in its ecological niche, in that it is less aquatic than the Siberian Crane, and more aquatic than the Hooded</p>	<p>The White-naped crane has been described as intermediate in its ecological niche it appears that they require a combination of sedge swamps and meadows and/or farmlands, explaining their sporadic distribution throughout their breeding range (Birdlife International, accessed 2009). They feed on a variety of seeds, grass roots, maize, wheat, stems, leaves, buds and also fish, shrimps and shellfish in their breeding and wintering grounds. White-naped cranes are often found in the company of other cranes that also occur within their range, including the Red-crowned, Hooded, Demoiselle, and Eurasian Cranes (Birdlife International, accessed 2009), which may suggest a degree of flexibility in their habitat requirements. Although most pairs will only lay two eggs, they will lay again if the first batch is lost (Birdlife</p>	<p>4</p>

	<p>and Eurasian Cranes (Meine et al. 1996, Birdlife International, accessed 2009). In the breeding habitats in Mongolia and Russia that are shared with Demoiselle Cranes, the White – naped cranes prefer areas such as the shores of shallow lakes (Meine et al. 1996).</p> <p>White-naped cranes are often found in the company of other cranes that also occur within their range, including the Red-crowned, Hooded, Demoiselle, and Eurasian Cranes (Birdlife International, accessed 2009), which may suggest a degree of flexibility in their habitat requirements.</p> <p>Evidence of adaptation in the past: Insufficient data.</p> <p>Reproduction rate: In the breeding habitats of Russia, Mongolia and China the White-naped Crane nests consist of mounds of dried sedges and grasses in open wetlands (Meine et al. 1996). Eggs are laid from April to late- May, usually two per clutch, with incubation (by both sexes) lasting 28-32 days and chicks fledging the nest at 70-75 days old (Meine et al. 1996, International Crane Foundation accessed 2009). Although most pairs will only lay two eggs, they will lay again if the first batch is lost (Birdlife International, accessed 2009). White-naped cranes reach sexual maturity when they are 3-4 years old and are monogamous with lasting pair bonds (Birdlife International, accessed 2009).</p> <p>Climate related changes to Fecundity: Insufficient data.</p>	International, accessed 2009).	
<p>Changing dynamics of species interactions</p>	<p>The diet of the White-naped Crane consists mainly of insects (e.g. grasshoppers and aquatic insects), small vertebrates (such as frogs and toads), roots, seeds, fruits, tubers (particularly from sedges), plant material (such as sedges, grass roots, maize and wheat), cereal grains, fish, shrimp and shellfish (International Crane Foundation, 2009; Birdlife International, accessed 2009). The White-naped Crane is omnivorous and has a broad diet. This omnivorous species is likely to consume a wide variety of food items and may be fairly opportunistic with a wider dietary range compared to many other bird species. The White-naped Crane is more likely to have greater adaptive ability and is probably less likely to suffer shortages of prey, compared to species with a specialist diet. However, climate change is likely to have some affect on some of its food sources, such as negative affects predicted for fish and other aquatic organisms.</p> <p>Predators of the White-naped Crane include both avian and mammalian predators. Gombobaatar (2002) found that in Mongolia, predators of White-naped Crane</p>	<p>This omnivorous species is likely to consume a wide variety of food items and is probably less likely to suffer shortages of prey, compared to species with a specialist diet. Food items include insects, small vertebrates, plant material, cereal grains, roots, fruits, seeds, tubers, fish, shrimp and shellfish. White-naped cranes have both avian and mammalian predators, and climate change may affect the abundance and distribution of</p>	<p>2*</p>

	<p>nests included the Steppe Eagle <i>Aquila nipalensis</i>, the Eurasian Badger <i>Meles meles</i> and the Grey Wolf <i>Canis lupus</i>. Foxes and wildcats are also thought to predate this species (Detroit Zoological Society). Climate change may affect the distribution and ranges of these predators, and may bring more predators into contact with this crane species, which could in turn affect White-naped Crane numbers.</p> <p>The White-naped Crane shares its range with several other species of crane, including Red-crowned, Hooded, Demoiselle, and Eurasian Cranes (International Crane Foundation, 2009), and may compete for resources with these species. However, it is likely that climate change will have similar effects on these other species of crane.</p>	<p>these predators and may cause novel predators to move into their range. Climate change may affect the White-naped cranes competitors in a similar way to the White-naped Crane, especially if their ecology and habitat are very similar.</p>	
Interactions with other processes	<p>The white-naped crane has been subjected to a number of threats mainly due to the loss of habitat. Extension of farmlands and conversion of wetland areas into agricultural lands has led to the loss of breeding grounds for the white-naped crane (Curt and Archibald, 1996). Other anthropogenic factors include direct exploitation and poisoning. Climatic conditions have also played a role in loss of habitat for the white-naped crane. For instance, drought conditions between 2000 and 2007 has also caused a loss of wetland areas (IUCN Red List, 2008). Even though drought conditions are a part of the climatic cycle yet it has managed to affect breeding and migratory patterns of the white-naped crane. Studies have also shown that breeding birds have been affected by steppe fires along with overgrazing activity of livestock which has consequently caused disturbance and subsequent loss of breeding habitat of the white-naped crane (IUCN Red List, 2008). Development and construction of the Three Gorges Dam along the Yangtze basin has also caused considerable disturbance to the wetland areas along the basin area. Dam construction has affected the migratory pattern of fish and other aquatic life along with a change in the flow of water in the Yangtze river basin.</p>	<p>A considerable amount of anthropogenic factors have been responsible for the declining numbers of the white-naped crane. Conversion of wetland areas into extensive agricultural lands around the Yangtze river basin has resulted in the loss of breeding grounds and migratory pattern of the white-naped crane. Drought conditions along with construction of dams along the river basin has further exacerbated the problem increasing the vulnerability of the white-naped crane.</p>	4
		HIGH VULNERABILITY	

Climate Change Vulnerability of Migratory Species

Species Assessment

White-tailed Eagle, *Haliaeetus albicilla*



Impacting factor	Severity of impacting factor					Conclusion	Overall Score
	1	2	3	4	5		
Vulnerability of habitat/s	<p>The white tailed-eagle ranges over extensive areas of lake, coast or river valley, within the boreal, temperate and tundra zones, nearby to undisturbed cliffs or open stands of large, old-growth trees for nesting (Birdlife International 2009). This species has a wide range of habitats but productive, shallow waters and low levels of human disturbance appear to be vital. If residing in a forested area, mature foliage is necessary. (Helander and Stjernberg et al. 2002).</p> <p>This species is very faithful to its breeding sites; sites are often occupied by generation after generation of pairs. As the population increased in the final part of the 20th Century, territories rendered vacant by the population declines earlier in the Century were the first to be reoccupied (Stjernberg and Koivusaari, 1995). This strong preference generational continuity in breeding areas and territorial ranges should raise special concern for the conservation of habitats in which this species currently resides.</p> <p>In Greenland a change to a climate with higher precipitation since the 1970s has been linked with the reduction of the productivity of the white-tailed eagle.</p> <p>When nesting in trees this big eagle builds huge nests which are added to year by year, and therefore needs strong nest-trees; such trees are usually much older than the rotation period in modern forestry.</p>					<p>Individual sites or populations (e.g. Greenland) may be under a heightened risk of deleterious effects from climatic changes, and other anthropogenic impacts. 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</p>	2
Ecological flexibility	<p>The White-tailed Eagle is compensating for a low annual offspring production by high adult survival. This strategy makes the species very sensitive to increased adult mortality. The mean clutch size is 2.1, with clutch sizes of 1-3 being normal. In more northern populations, the mean can be significantly lower, with populations in northern Sweden recording a mean clutch size of 1.6 eggs (Helander, 1985). Sexual maturity of this species occurs at around 5 years of age (Helander, 2003), and individuals breed until in excess of 30 years of age (Whitfield et al. 2009).</p> <p>White-tailed eagles are very faithful to their breeding sites; sites are often occupied by generation after generation of pairs. As the population of this species increased in the final part of the 20th Century, territories rendered vacant by the population</p>					<p>Evidence suggests that this eagle has a high preference for territories and breeding areas which have been utilised by other white-tailed eagles in the past. Although there is evidence that they prefer these areas, there is no evidence to suggest that they could not colonise new areas if sites that had been bred on before were</p>	2

	<p>declines earlier in the Century were the first to be reoccupied (Stjernberg and Koivusaari, 1995). This strong preference generational continuity in breeding areas and territorial ranges should raise special concern for the conservation of habitats in which this species currently resides.</p> <p>The time of egg-laying varies with latitude and climate, starting in January in the south of Europe through to early April in more northern continental areas. This suggests a good degree of ecological flexibility is present in this species (Helander and Stjernberg et al. 2002).</p> <p>Their diet is closely associated with the aquatic environment, with fish and water birds constituting the main part of their diet. Fish are generally taken from near the surface of shallow waters. In early summer their food source is predominately fish-based, whereas later in the breeding season birds are increasingly added to the diet. Birds are occasionally taken on the wing, however it is much more common for this prey to be taken on the ground or on the water.</p> <p>Although a generalist in most areas, a drop in overall productivity or prey availability in the freshwaters of some northern populations could prove to be catastrophic. In Greenland, over-exploitation of fish resources and the subsequent reduction of bird colony density have been cited as the main reason behind the drop in the population's productivity (Hansen, 2002).</p> <p>Productive waters are therefore very important to this species; however it is also known to feed on carrion and to scavenge from other birds, whilst in some habitats mammal prey is also readily utilised. (Helander and Stjernberg et al. 2002).</p>	<p>not available.</p> <p>This eagle is substantially less specialised than many other raptors. Its diet and ecological niche are wide. The reproduction rate is low (mean 2.1 eggs per clutch) but so is the adult mortality. This species already 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.</p>	
<p>Changing dynamics of species interactions</p>	<p>The diet of this eagle is broad and it is capable of catching a wide range of prey in the water, on the ground and also on the wing. In addition to this, this eagle is an opportunist; utilising carrion and also scavenging prey from other predators.</p> <p>The latitude and climate differentiated breeding periods along with the sedentary nature of most breeding pairs suggests that phenological discordance is unlikely across the majority of white-tailed eagles.</p>	<p>Research has unearthed no known links between climatic changes and major variations in species interactions relating to this species</p>	<p>1</p>
<p>Interactions with other processes</p>	<p>The population of this species dropped sharply in the 19th Century and the first half of the 20th Century, during which time the European range contracted substantially. Since the 1970s, this trend has reversed in the northwest of its range, but the population trend in the southeast of Europe is still downward. The main reason for the continued decline is due to the degradation of wetland habitats, increased anthropogenic disturbance, deforestation and accidental poisoning (BirdLife International 2009).</p>	<p>The main threats that this species faces are habitat disturbance through changes in water regimes, forestry operations and energy development. Pollution is also a significant risk to some populations although this risk</p>	<p>2</p>

	<p>The development of wind farms in European coastal areas is an area for concern. Disturbance caused during construction and maintenance and the threat of collision with the turbines is likely to effect the population of this long-lived species. The impact of new wind farm developments, especially of two large developments on the Smøla archipelago in Norway, where two wind farms have been sited in an area with an extraordinarily high density of <i>Haliaeetus albicilla</i> should be monitored (Greenwood, 2005). Pesticides and other contaminants are readily stored in the fatty tissues of aquatic organisms. A diet of fish and waterfowl has the potential to hamper breeding success should pesticides or other pollutants enter the watershed. (BirdLife International, 2009)</p> <p>Changes to the water regime in a catchment area are likely to have a negative impact upon the white tailed eagle. Drainage of wetlands, widening or deepening of rivers for navigational or flood relief purposes and hydroelectric projects all pose a threat to this species. Across eastern Europe there are many projects of this nature currently underway (Helander and Stjernberg et al. 2002).</p>	<p>appears to have peaked. Increased protection for the species and a curtailing of contaminants and pollutants in many areas have led to population increases across the majority of the bird's range. Disease and invasive species are not threats that are prominent in the literature</p>	
	LOW VULNERABILITY		

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

Distribution: Sahelo-Saharan Africa

Native: Chad, Mauritania, Niger

Regionally Extinct: Algeria, Egypt, Libyan Arab Jamahiriya, Sudan, Sahara

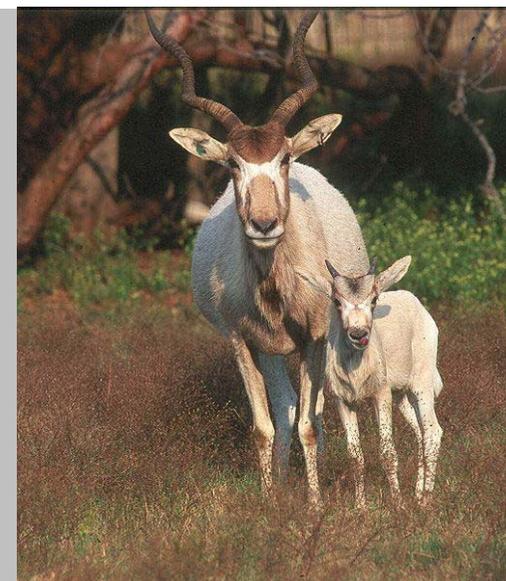
Reintroduced: Morocco, Tunisia

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).

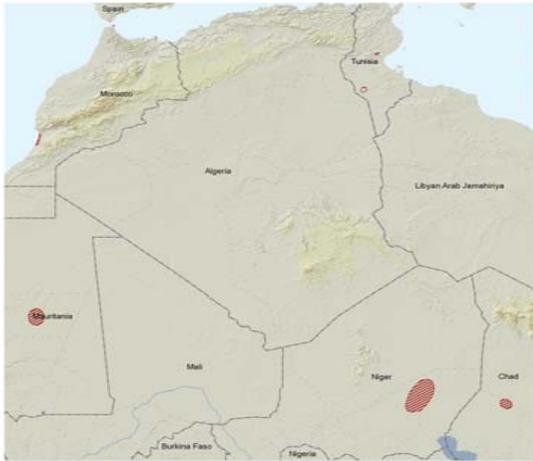


Figure 1: Species Range Map (left)

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 by at least 2°C with the 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' prediction is large (Christensen, 2007). Moderate precipitation

decline could prove to substantially increase the vulnerability of the habitat, as perennial grazing comes 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 Wachter, 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 Wachter 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 and 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*

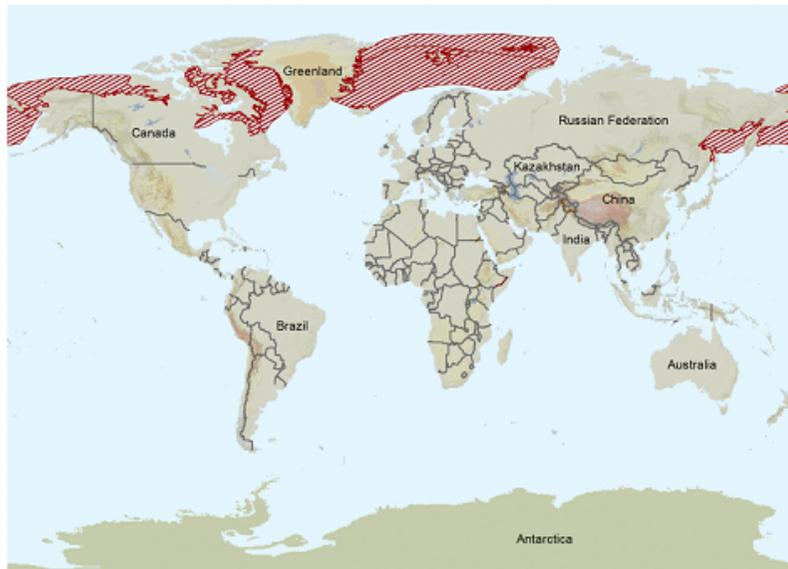
Distribution: Circum-polar

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 (5)

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

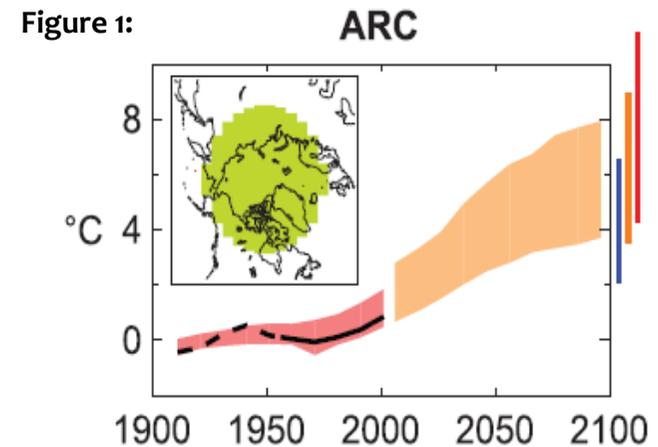


Figure 1: Shows temperature anomalies with respect to 1901 – 1950 for the whole of the Arctic for 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The 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:

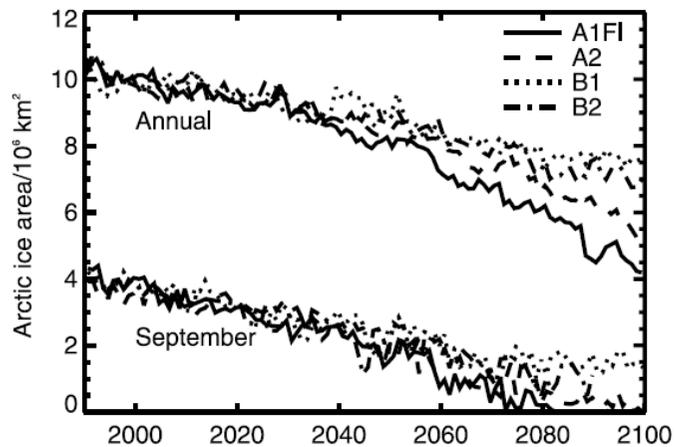


Figure 2: Shows 4 model predictions for the extent of Arctic sea ice. It is possible to see that by September 2100, the models show no sea ice or a very limited extent (Gregory *et al.*, 2002).

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 CO₂ 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 18th Century there has been a 30-35% decline in the shell weight of Antarctic foraminifera (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 effects on the vast majority of species is uncertain at present, 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.

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).

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



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

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 arising 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).

2.2. Species Interactions (4)

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).

1.1. Interactions with other Processes (3)

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 m a^{-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

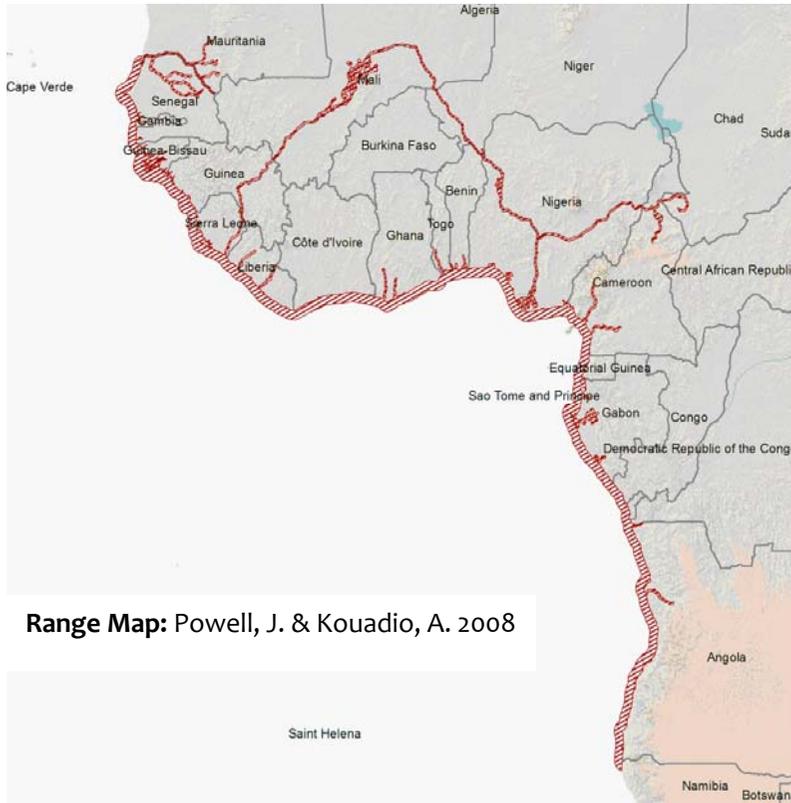
Population Estimate: No estimates available <10,000

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).



2. Species Vulnerability to Climate Change

2.1. Habitat Vulnerability (4)

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).

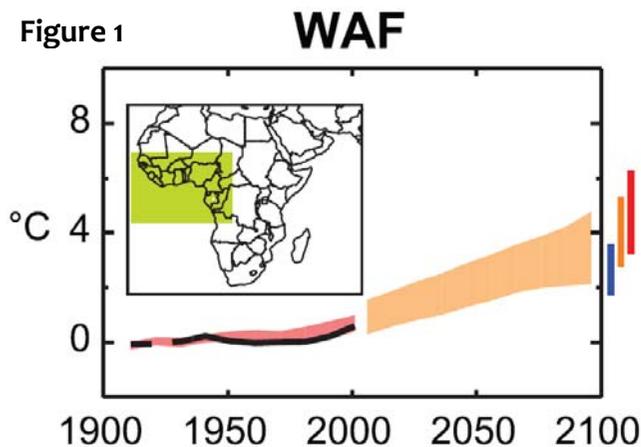


Figure 1: Shows temperature anomalies with respect to 1901 – 1950 for West Africa from 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The bars at the 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).

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

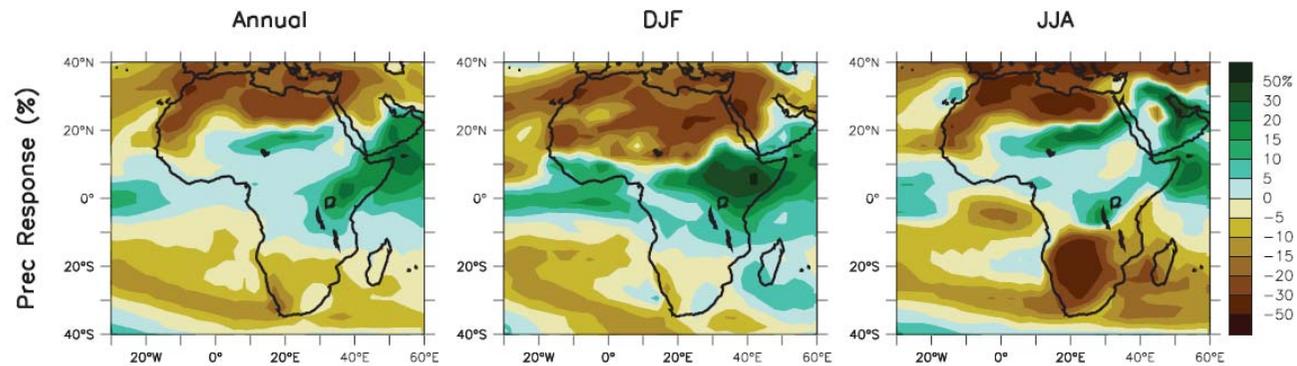


Figure 2: Projected precipitation variations for the 2080 – 2099 period compared with 1980 – 1999 conditions. Projections are averaged over the 21 models utilised in the IPCC AR4. Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).

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.

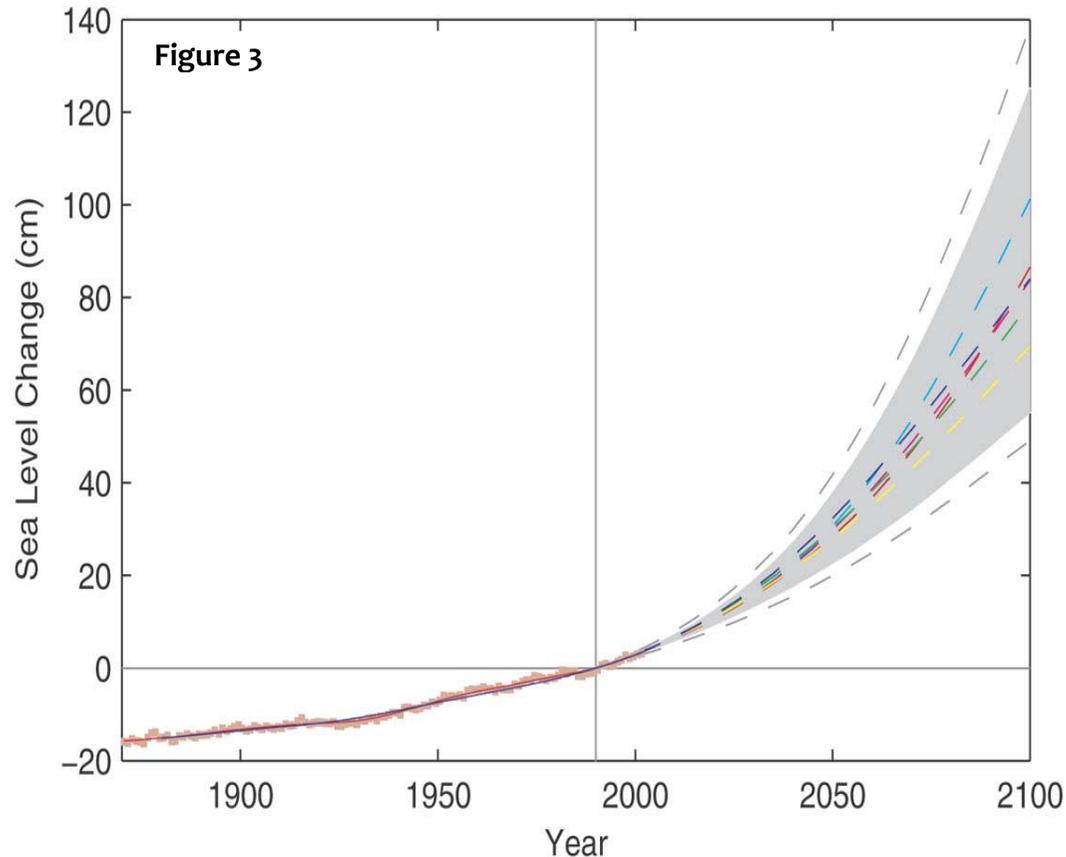


Figure 3: Past sea level and sea level predictions. The grey area represents uncertainty, whilst the coloured lines represent different emissions scenarios from light blue, the A1FI scenario, to yellow the B1 scenario (Rahmstorf, 2007).

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 racemosa*), water cabbage (*Pistia stratiotes*), 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

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 coastal 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).

1.2. Ecological Flexibility (4)

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

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).

1.3. Species Interactions (3)

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 Crocodylians, 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.

1.4. Interactions with other Processes (4)

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:

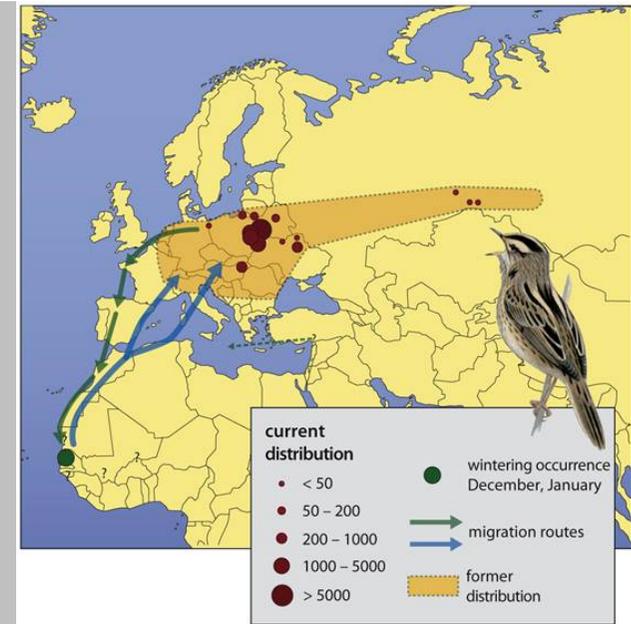
- Eastern-Europe (summer)
- Sahelian Belt of sub-Saharan Africa (winter)

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).

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

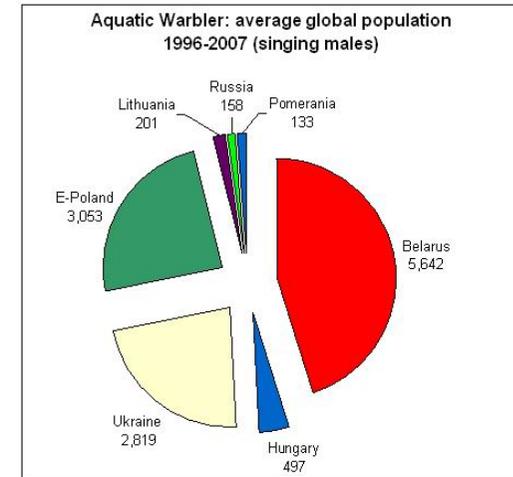


Figure 1. Average global population 1996-2005. (Singing males). Source: AWCT, 2009

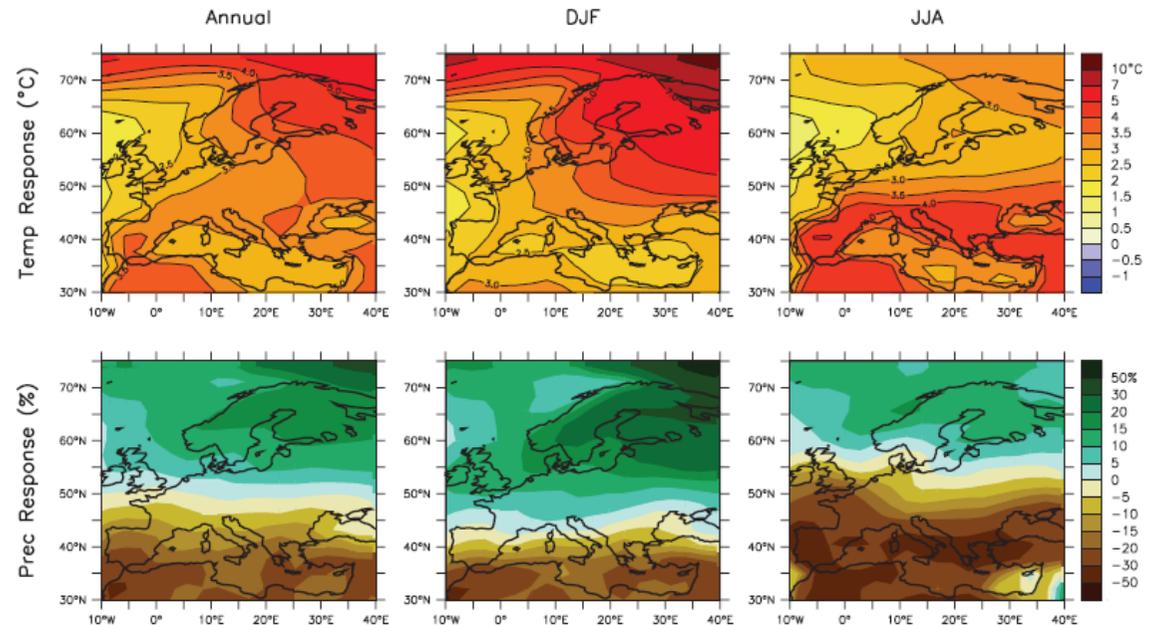


Figure 3 (right) shows the changes in conditions that the aquatic warbler can expect to encounter when it arrives in west Africa for the winter months. By 2100 under an A1B emissions scenario, the minimum temperature response in the winter months (December, January and February) due to anthropogenic 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.

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

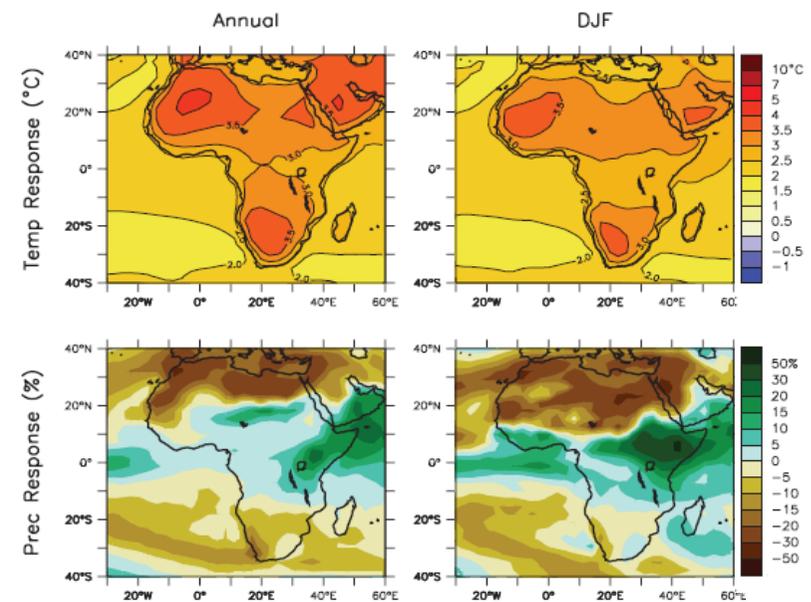


Figure 3. Temperature changes (top) and precipitation changes over Africa under A1B scenarios for 1980-1999 and 2080-2099 time period. DJF indicates winter variations whilst Annual indicates the annual mean. Source: Christensen et al., 2007

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, Dyrzcz 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 (Dyrzcz 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 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 vison*), 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.

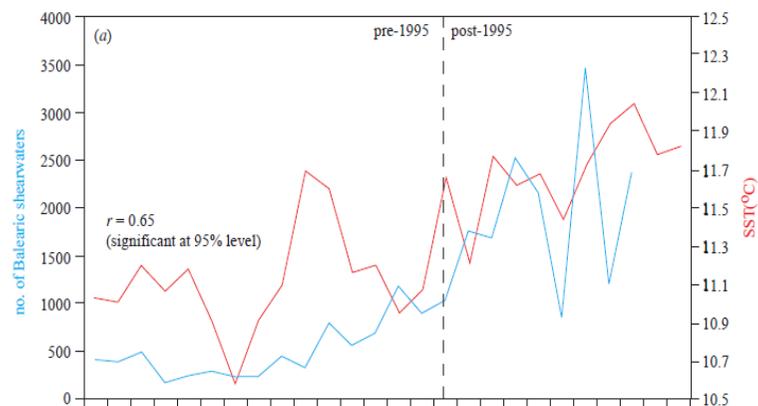
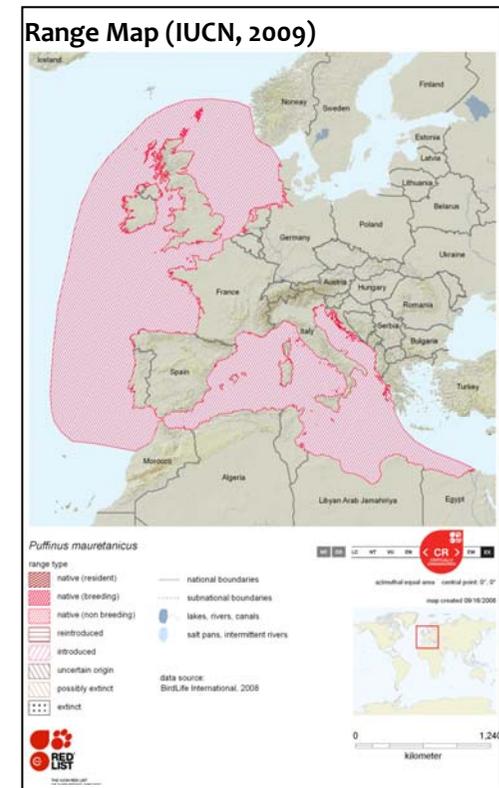


Figure 1. Red line - The average total of shearwaters in UK and Irish waters in the time period 1980-2003. Blue line - The average annual SST in the UK and Ireland region during the time period 1980-2003. (Source: Wynn *et al.* 2007)

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).

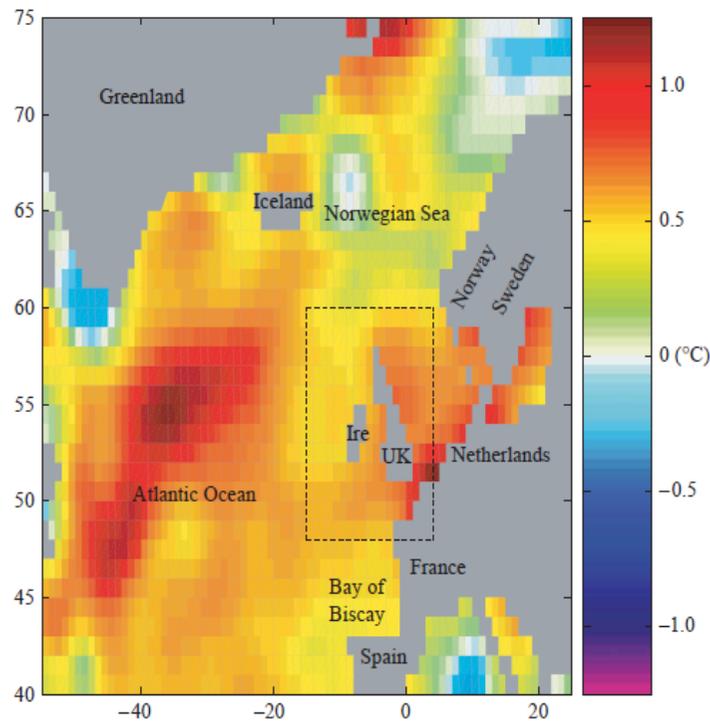


Figure 2. Change in annual mean sea surface temperatures between the two periods 1995–2005 and 1980–1994. Source: Wynn *et al.* (2007).

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 in 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 (Igal 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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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.

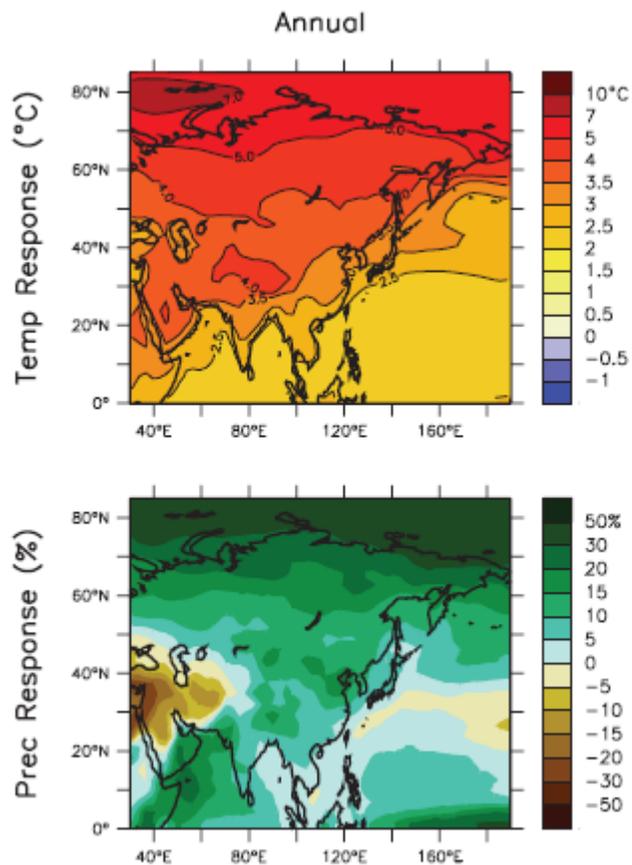
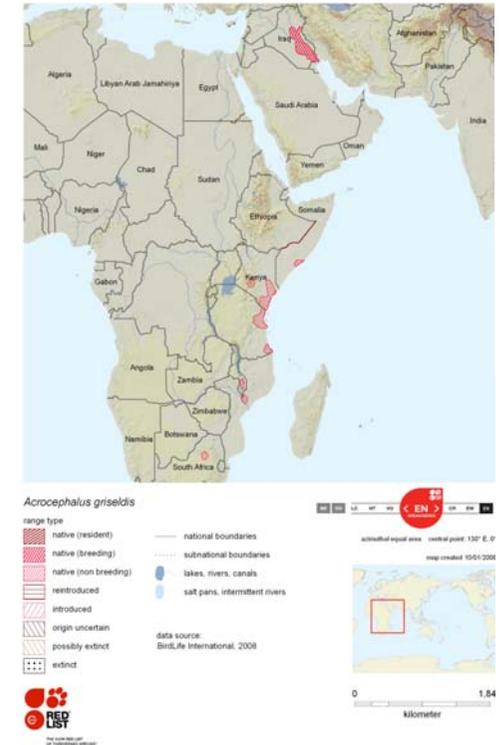


Figure 1. Temperature changes (top) and precipitation changes over Asia under A1B scenarios for 1980-1999 and 2080-2099 time period. Source: Christensen et al, 2007

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 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.



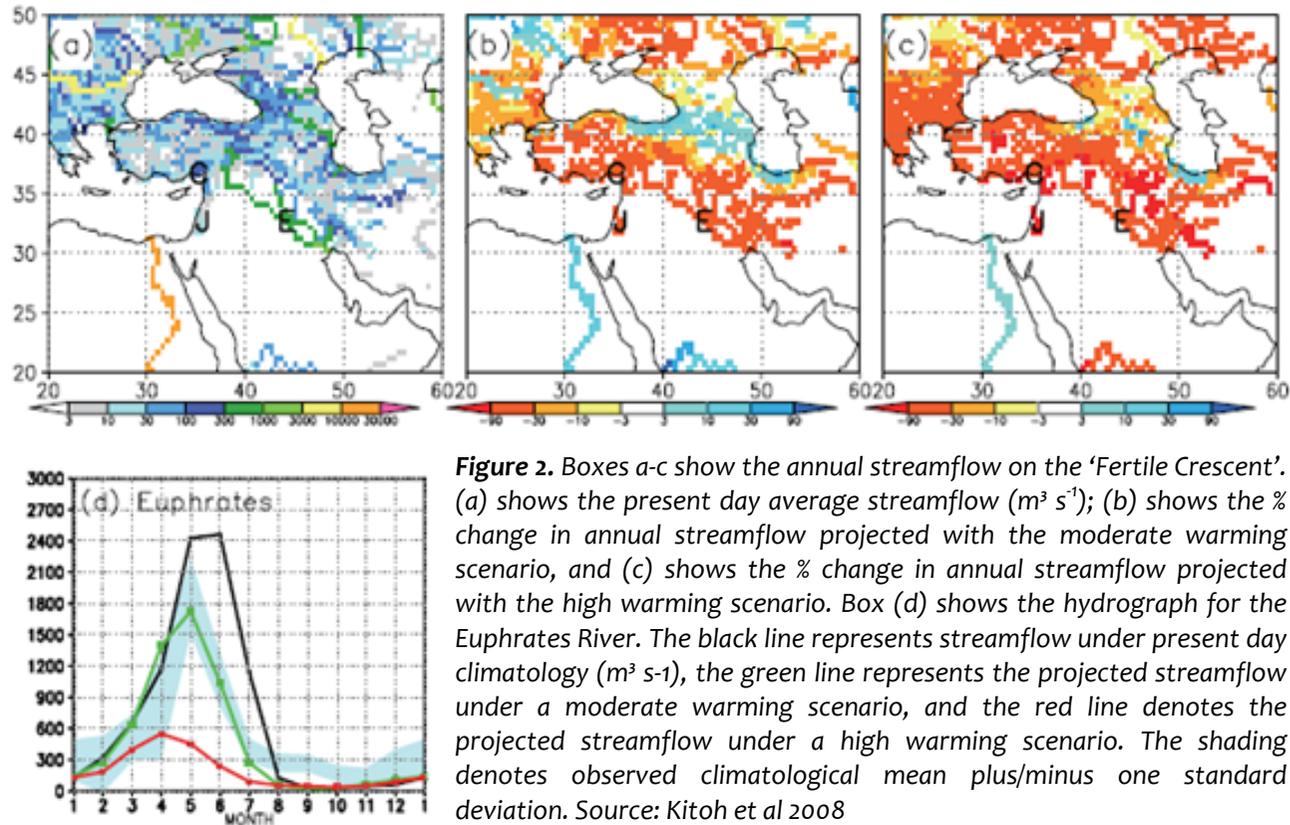


Figure 2. Boxes a-c show the annual streamflow on the ‘Fertile Crescent’. (a) shows the present day average streamflow ($m^3 s^{-1}$); (b) shows the % change in annual streamflow projected with the moderate warming scenario, and (c) shows the % change in annual streamflow projected with the high warming 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.

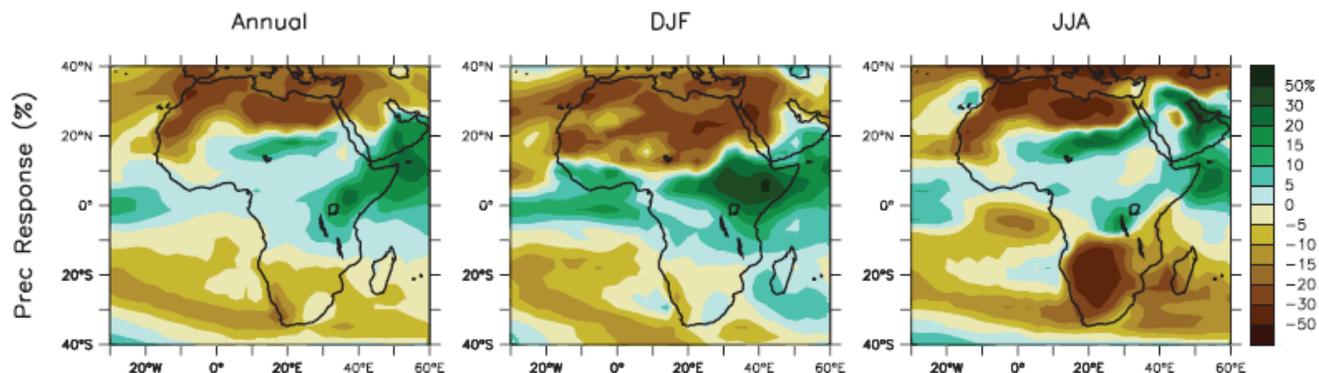


Figure 3. Projected average precipitation change in the period 2081-2100 compared to 1981-1999.
Source: Christensen et al. 2007

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)



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.

1. Species Vulnerability to Climate Change

1.1. 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).

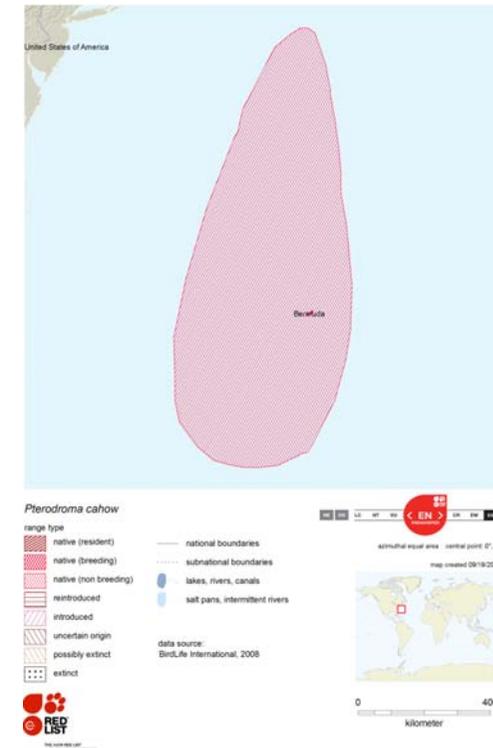
The breeding habitat of this species appears to be at risk from climate change through rising sea levels and increasing storminess. Sea level rise already appears to be having a negative affect on this species – in the 25 years prior to the 1990s there were no significant problems arising from flooding, however during the 1990s there were 5 separate events where 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 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 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.

Figure 1: Range Map (IUCN, 2009)



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).

1.2. 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.

1.3. 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 specialisation 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.

1.4. 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, *Spheniscus humboldti*

Distribution: Coastal Peru and Chile

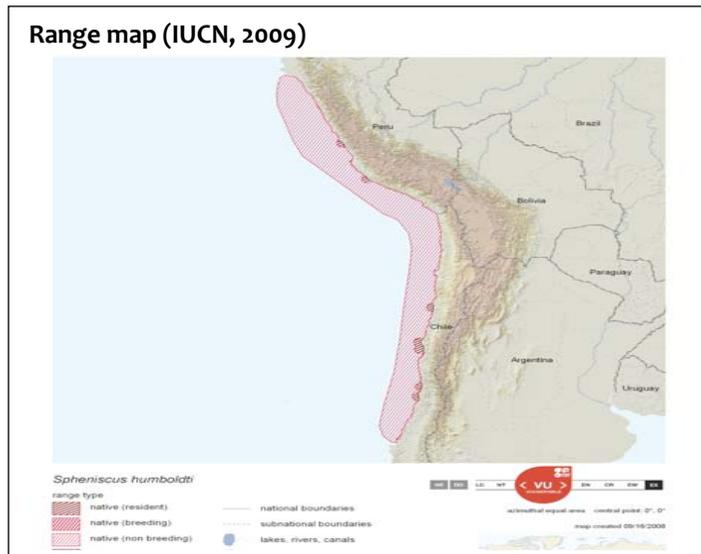
IUCN Classification: Vulnerable

Population estimate: 3,300-12,000

CMS Appendix: 1



Range map (IUCN, 2009)



1. Background information

The Humboldt Penguin (*Spheniscus 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).

Spheniscus 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 Niño 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 Niño 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, preying 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.

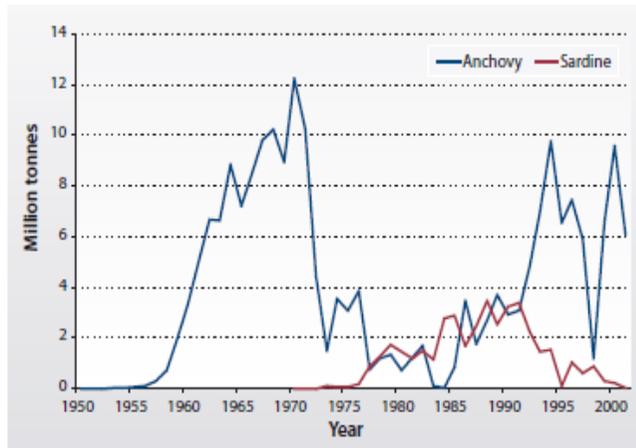
The Humboldt Penguin is capable of breeding year-round, and they are able to take advantage of favourable years by producing two successive broods in a single season (BirdLife International, 2009). According to the International Penguin Working Group, two eggs are laid in each clutch and the incubation 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.

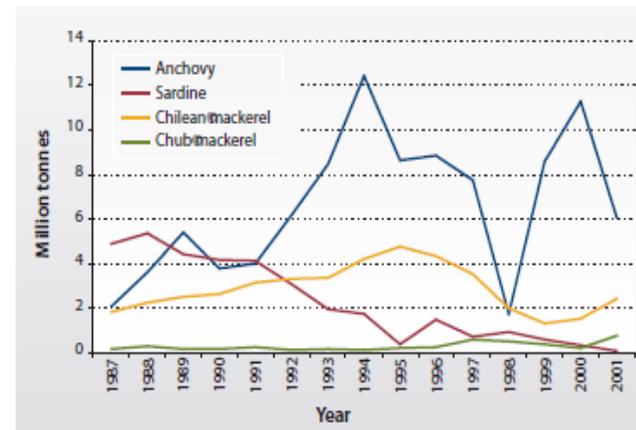
2.3. Species interactions

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

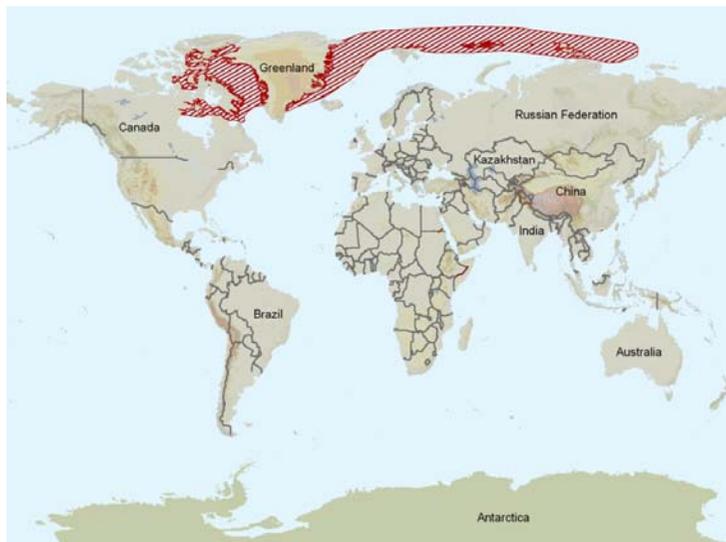
IUCN Classification: Near Threatened

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 activities 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 (5)

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.

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

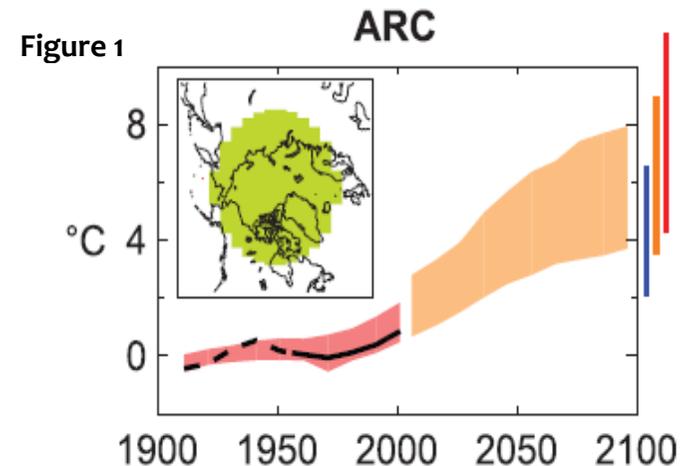


Figure 1: Shows temperature anomalies with respect to 1901 – 1950 for the whole of the Arctic for 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The 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).

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

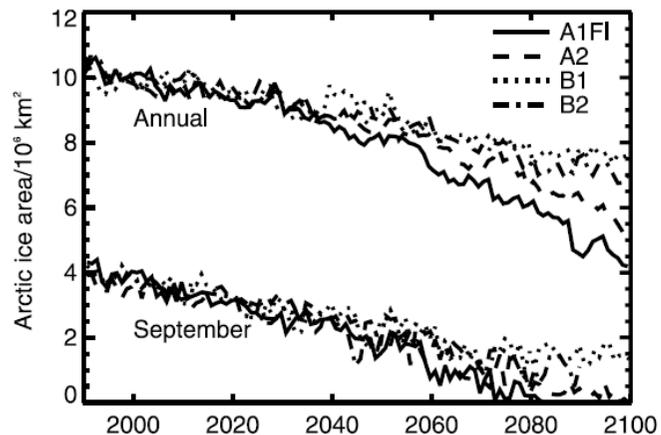


Figure 2: Shows 4 model predictions for the extent of Arctic sea ice. It is possible to see that by September 2100, the models show no sea ice or a very limited extent (Gregory et al, 2002).

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 (4)

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 were 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 (4)

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 below 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 (Learnmouth 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 (4)

Hunting and interference from industrial acuties 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 CITES 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



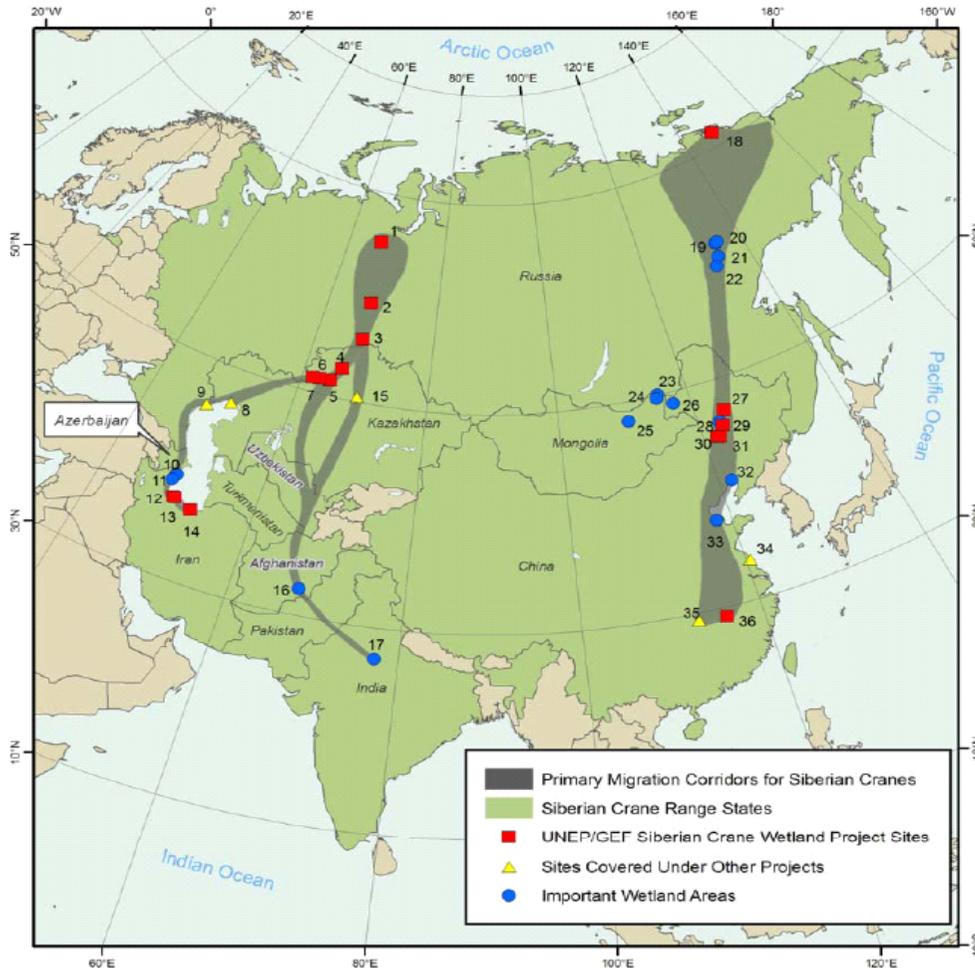
Picture: Birdlife International (2009)

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 overwintering, 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 (5)

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 $>60^{\circ}\text{N}$). 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).

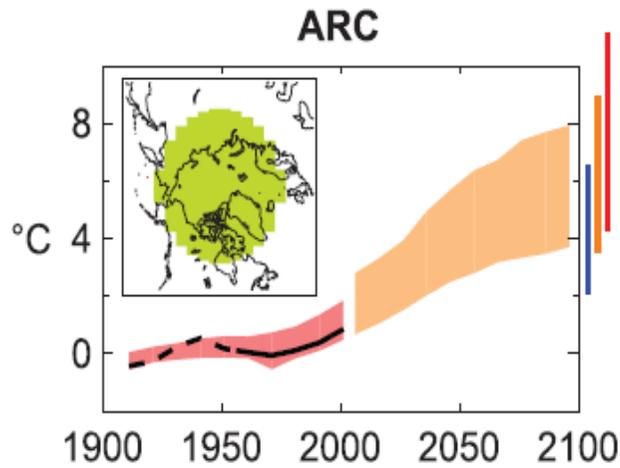


Figure 1: Shows temperature anomalies with respect to 1901 – 1950 for the whole of the Arctic for 1906 – 2005 (black line) as simulated (red envelope) by multi-model datasets (MMDs) incorporating known forcings and as projected for 2001 – 2100 by MMD models for the A1B scenario (orange envelope). The 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).

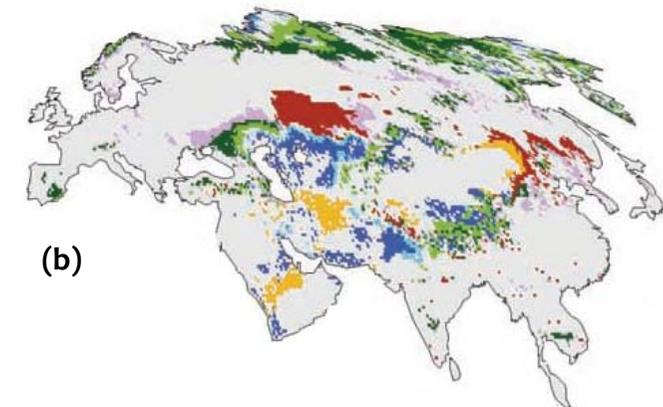
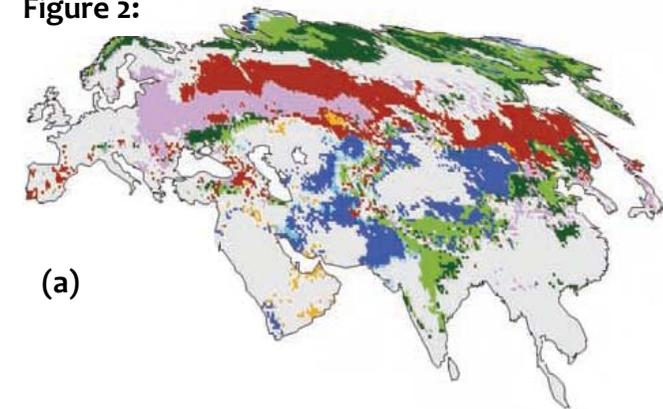
Figure 2 shows the projected appreciable changes in boreal ecosystems relative to 2000 under a) A2 and b) B1 scenarios. Both models show a significant encroachment of forest cover and woodland towards tundra and taiga habitats. However the A2 model shows the encroachment to be much more extensive, almost 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, IPCC AR4, Chapter 4

Figure 2:



- 1 – Forest cover gain
- 2 – Shrub/woodland cover gain
- 3 – Herbaceous cover gain
- 4 – Desert amelioration
- 5 – Grass/tree cover loss
- 6 – Forest/woodland decline
- 7 – Forest type change

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).

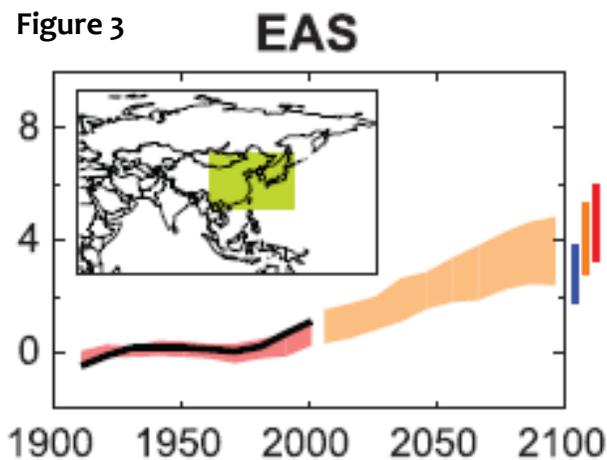


Figure 3 shows the future temperature predictions for the Eastern Asia region up to 2100. The multi-model data set for the A1B emissions scenario, shows a median warming of 3.3°C by the end of this century, with the majority of this warming occurring in the winter. Figure 4 shows the projected annual 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 change 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

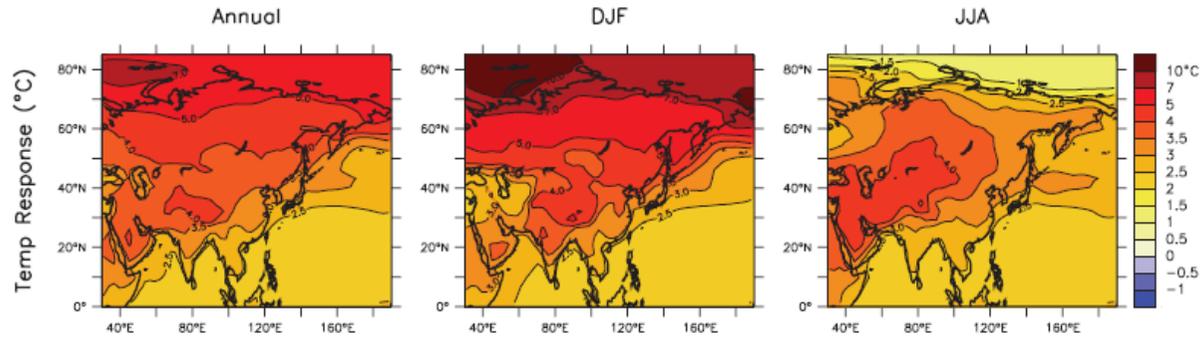


Figure 4: Projected temperature variations for the 2080 – 2099 period compared with 1980 – 1999 conditions. Projections are averaged over the 21 models utilised in the IPCC AR4. Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).

Figure 5

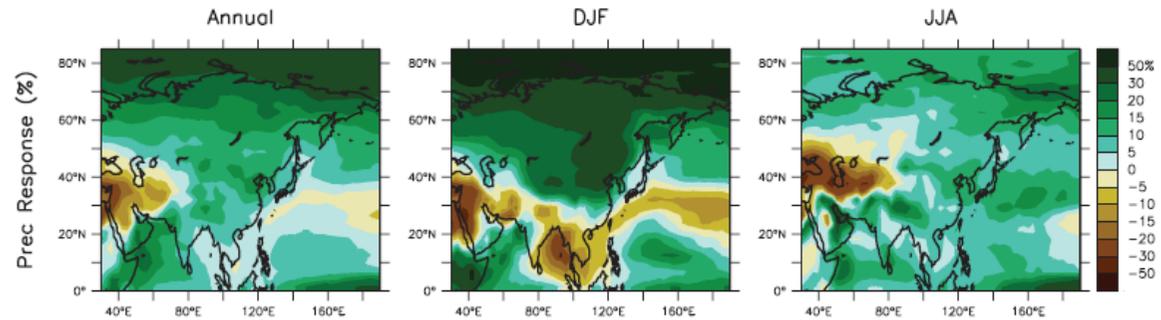


Figure 5: Projected precipitation variations for the 2080 – 2099 period compared with 1980 – 1999 conditions. Projections are averaged over the 21 models utilised in the IPCC AR4. Source – extracted from IPCC AR4 Chapter 11 (Christensen, 2007).

2.2. Ecological flexibility (3)

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 (2)

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 (3)

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 species 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 assess 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 rationale 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:

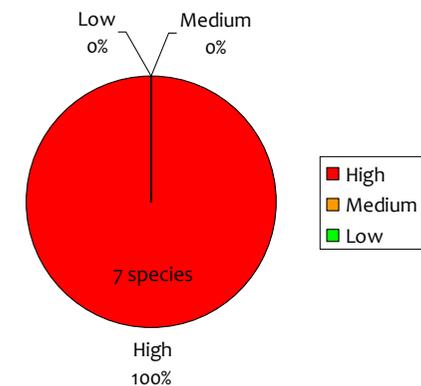
2	NARWHAL	High (17)
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9.2. CMS Appendix I Case Study Species Vulnerabilities to Climate Change reviewed by Taxonomic Group

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)

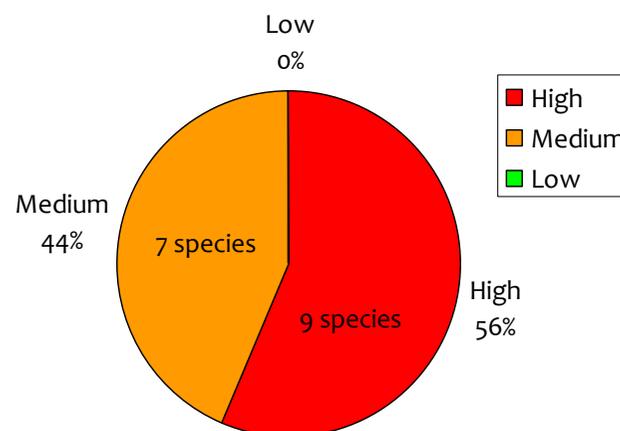
- The Olive Ridley and the Leatherback Turtle rank as the least vulnerable migratory reptile species to climate change out of those studied within CMS Appendix I. However these still have very high vulnerability compared to other species studied ranking 5th place in overall species vulnerability.

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.

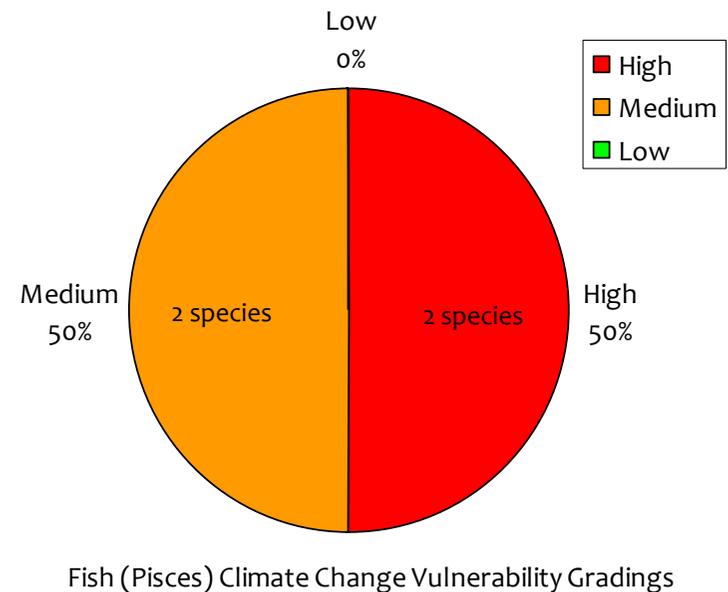


Mammals (Mammalia) Climate Change Vulnerability Gradings

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

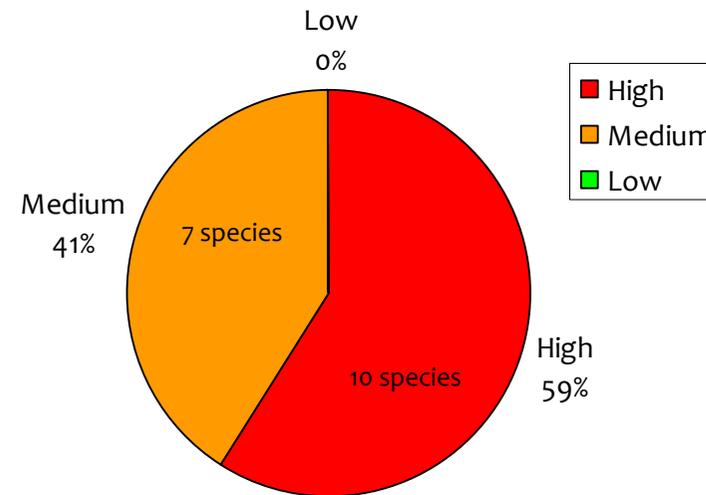
RANK	Mammals	Climate Change Vulnerability Gradings Identified for Species
1	Giant Catfish	High (12)
2	Common Sturgeon	High (11)
3	Basking Shark	Medium (12)
4	Great White Shark, White Shark	Medium (8)



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 increase 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 Gaviel	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 than 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)
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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 than 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 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 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)
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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 Narwhal, 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 than many other migratory species. Alongside these impacts from warming, ocean acidification will have major effects on the food chain of the Arctic and this will be seen much earlier within polar cold waters than 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 than 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 depends.

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)

Bird Species	Habitat Vulnerability	Ecological Flexibility	Species Interactions	Interactions with other processes	Total
Puna Flamingo	Low / Medium	Medium	Low / Medium	Low / Medium	Medium (9)
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 than 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 than 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 patterns 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:

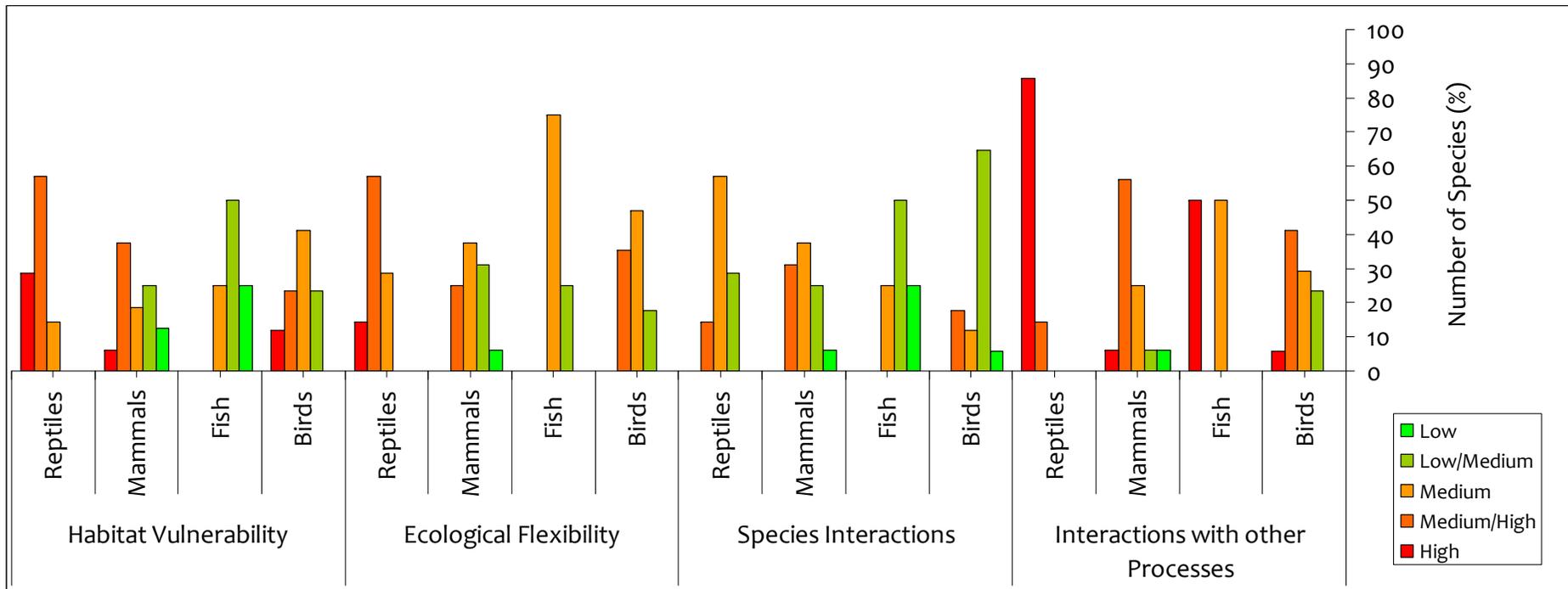
- The Balearic Shearwater, Short tailed Albatross and the Sociable Plover have been identified as having the highest vulnerability due to Species Interactions of all bird species studied.

- *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 led 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 than 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

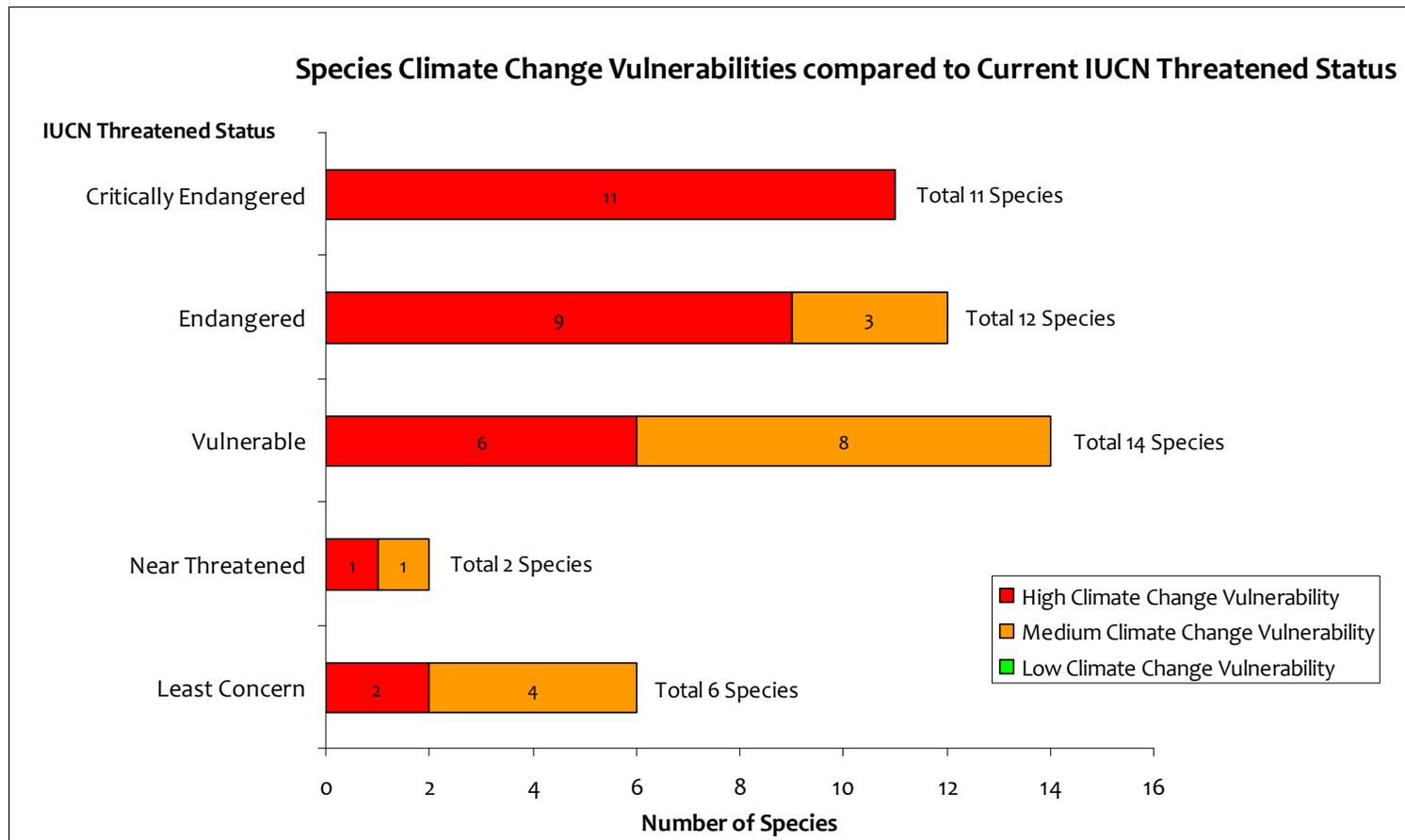
- A higher percentage of high vulnerabilities were recorded across all taxa for these species vulnerabilities to climate change Interactions with other Threat Processes.
- This indicates that a key measure for conservation will be to limit and reduce other threats, primarily anthropogenic driven, to 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 are 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 than their threatened status indicates as 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 than those currently given more severe 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 than 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	<i>Eretmochelys imbricata</i>	High (18)	1	1	CR	Decreasing
Aves	Balearic Shearwater	<i>Puffinus mauretanicus</i>	High (17)	2	1	CR	Decreasing
Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	<i>Lepidochelys kempii</i>	High (16)	3	2	CR	Not provided
Reptilia	Gharial, Indian Gaviel	<i>Gavialis gangeticus</i>	High (15)	4	3	CR	Decreasing
Aves	Sociable Plover, Sociable Lapwing	<i>Vanellus gregarius</i>	High (14)	5	4	CR	Decreasing
Mammalia	Dama Gazelle	<i>Gazella dama</i>	High (14)	5	3	CR	Decreasing
Reptilia	Leatherback Turtle,	<i>Dermodochelys coriacea</i>	High (14)	5	4	CR	Decreasing

Aves	Siberian Crane	<i>Grus leucogeranus</i>	High (13)	6	5	CR	Decreasing
Mammalia	Addax	<i>Addax nasomaculatus</i>	High (13)	6	4	CR	Decreasing
Pisces	Giant Catfish	<i>Pangasius gigas</i>	High (12)	7	1	CR	Decreasing
Pisces	Common Sturgeon	<i>Acipenser sturio</i>	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	<i>Chelonia mydas</i>	High (18)	1	1	EN	Decreasing
Mammalia	North Pacific Right Whale	<i>Eubalaena japonica</i>	High (16)	3	1	EN	Unknown
Mammalia	Northern Atlantic Right Whale	<i>Eubalaena glacialis</i>	High (16)	3	1	EN	Unknown
Reptilia	Loggerhead Turtle	<i>Caretta caretta</i>	High (15)	4	3	EN	Not provided
Aves	Red-breasted Goose	<i>Branta ruficollis</i>	High (13)	6	5	EN	Decreasing
Mammalia	Blue Whale	<i>Balaenoptera musculus</i>	High (13)	6	4	EN	Increasing
Aves	Basra Reed-warbler	<i>Acrocephalus griseldis</i>	High (12)	7	6	EN	Decreasing
Aves	Bermuda Petrel	<i>Pterodroma cahow</i>	High (11)	8	7	EN	Increasing
Mammalia	Snow Leopard	<i>Uncia uncia</i>	High (10)	9	5	EN	Decreasing
Mammalia	Cuvier's Gazelle	<i>Gazella cuvieri</i>	Medium (11)	11	6	EN	Unknown
Mammalia	Sei Whale Coalfish Whale	<i>Balaenoptera borealis</i>	Medium (11)	11	6	EN	Unknown
Mammalia	Marine Otter	<i>Lontra felina</i>	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	<i>Larus relictus</i>	High (16)	3	2	VU	Decreasing
Aves	Short-tailed Albatross	<i>Diomedea albatrus</i>	High (15)	4	3	VU	increasing
Mammalia	West African Manatee	<i>Trichechus senegalensis</i>	High (15)	4	2	VU	Unknown
Reptilia	Olive Ridley	<i>Lepidochelys olivacea</i>	High (14)	5	4	VU	Decreasing
Aves	White-naped Crane	<i>Grus vipio</i>	High (13)	6	5	VU	Decreasing
Aves	Steller's Eider	<i>Polysticta stelleri</i>	High (13)	6	5	VU	Decreasing
Aves	Aquatic Warbler	<i>Acrocephalus paludicola</i>	Medium (12)	10	8	VU	Decreasing
Pisces	Basking Shark	<i>Cetorhinus maximus</i>	Medium (12)	10	3	VU	Decreasing
Aves	Swan Goose	<i>Anser cygnoides</i>	Medium (11)	11	9	VU	Decreasing
Aves	Andean Flamingo	<i>Phoenicopterus andinus</i>	Medium (10)	12	10	VU	Decreasing
Aves	Humboldt Penguin	<i>Spheniscus humboldti</i>	Medium (10)	12	10	VU	Decreasing
Aves	Pallas Fish Eagle	<i>Haliaeetus leucoryphus</i>	Medium (10)	12	10	VU	Decreasing
Mammalia	Sperm Whale	<i>Physeter macrocephalus</i>	Medium (10)	12	7	VU	Unknown
Pisces	Great White Shark	<i>Carcharodon carcharias</i>	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	<i>Monodon monoceros</i>	High (16)	2	1	NT	Unknown
Aves	Puna Flamingo	<i>Phoenicopterus jamesi</i>	Medium (9)	13	11	NT	Decreasing

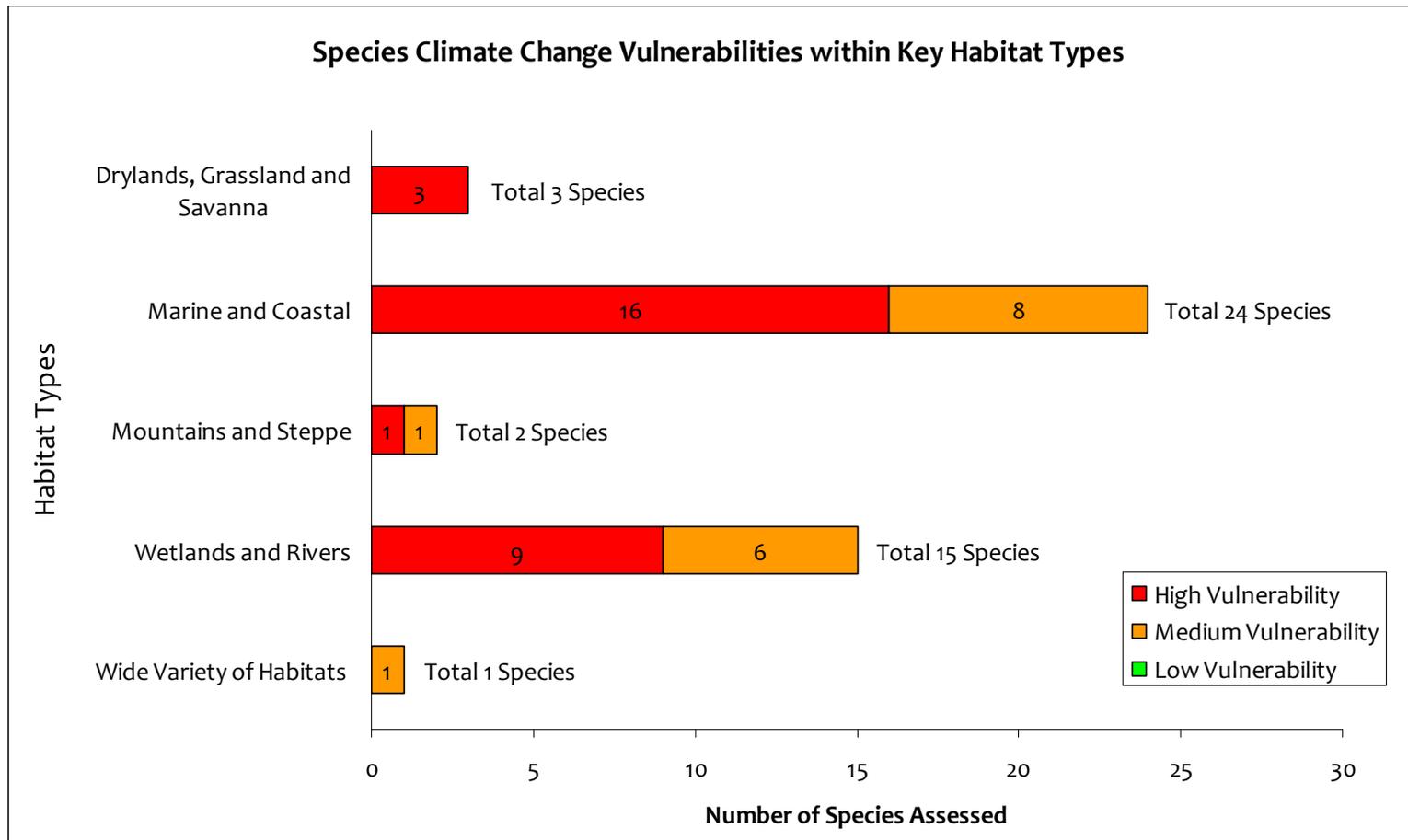
IUCN RED List LEAST CONCERN Species Vulnerability to Climate Change

- 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	<i>Balaena mysticetus</i>	High (15)	4	2	LC	Increasing
Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	High (14)	5	3	LC	Increasing
Mammalia	Short-beaked Common Dolphin	<i>Delphinus delphis</i>	Medium (11)	11	6	LC	Unknown
Mammalia	Mexican Free-tailed Bat	<i>Tadarida brasiliensis</i>	Medium (10)	12	7	LC	Stable
Mammalia	Humpback Whale	<i>Megaptera novaeangliae</i>	Medium (10)	12	7	LC	Increasing
Aves	White-tailed eagle	<i>Haliaeetus albicilla</i>	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	<i>Puffinus mauretanicus</i>	High (17)	2	1	Medium / High	Marine	Sea Cliffs and Rocky Offshore Islands, Coastal Freshwater Lakes
Reptilia	Kemp's Ridley Turtle, Atlantic Ridley Turtle	<i>Lepidochelys kempii</i>	High (16)	3	2	Medium / High	Marine	Marine, Sandy Beaches, Sea Grasses, Coastal Marshes including East & West Atlantic
Mammalia	Narwhal	<i>Monodon monoceros</i>	High (16)	3	1	High	Marine	Marine Arctic and areas including sea ice
Mammalia	North Pacific Right Whale	<i>Eubalaena japonica</i>	High (16)	3	1	Medium / High	Marine	Marine - Bering Sea to North Pacific
Mammalia	Northern Atlantic Right Whale, Biscayan Right Whale	<i>Eubalaena glacialis</i>	High (16)	3	1	Medium / High	Marine	Marine Coastal - North Atlantic feeding to subtropical shallow coastal waters for breeding
Mammalia	Bowhead Whale	<i>Balaena mysticetus</i>	High (15)	4	2	High	Marine	Marine migrating circumpolar from High Northern latitudes to Arctic
Reptilia	Loggerhead Turtle	<i>Caretta caretta</i>	High (15)	4	3	Medium / High	Marine	Marine, Sandy Beaches, Coral Reefs, Sea Grass, Mudflats
Aves	Short-tailed Albatross, Steller's Albatross	<i>Diomedea albatrus</i>	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,	<i>Dermochelys coriacea</i>	High (14)	5	4	Medium / High	Marine	Marine, Tropical Sandy Beaches
Reptilia	Olive Ridley	<i>Lepidochelys olivacea</i>	High (14)	5	4	Medium / High	Marine	Marine Semipelagic Coastal
Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	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	<i>Balaenoptera musculus</i>	High (13)	6	4	Medium / High	Marine	Marine Pelagic with global migration from cold to tropical waters
Aves	Bermuda Petrel	<i>Pterodroma cahow</i>	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	<i>Acipenser sturio</i>	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	<i>Cetorhinus maximus</i>	Medium (12)	10	3	Medium	Marine	Marine Pelagic and Coastal
Mammalia	Sei Whale, Coalfish whale, Pollack whale, Rudolph's Rorqual	<i>Balaenoptera borealis</i>	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	<i>Delphinus delphis</i>	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	<i>Spheniscus humboldti</i>	Medium (10)	12	10	Low / Medium	Marine / Terrestrial	Coastal and Rocky Islands range including Peru and Chile
Mammalia	Humpback Whale	<i>Megaptera novaeangliae</i>	Medium (10)	12	7	Medium	Marine	Marine Pelagic. Global range excluding Polar Regions
Mammalia	Sperm Whale	<i>Physeter macrocephalus</i>	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	<i>Carcharodon carcharias</i>	Medium (8)	14	4	Low	Marine	Marine coastal / neritic and epi-pelagic. Global range excluding Polar Regions
Mammalia	Marine Otter	<i>Lontra felina</i>	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	<i>Uncia uncia</i>	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	<i>Gazella cuvieri</i>	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	<i>Larus relictus</i>	High (16)	3	2	High	Terrestrial	Semi Arid Wetlands, Estuaries in Central & Eastern Asia, Sand Flats and Saline Lakes
Reptilia	Gharial, Indian Gaviol	<i>Gavialis gangeticus</i>	High (15)	4	3	Medium	Terrestrial / Freshwater	Rivers (slow moving and deep) & Sandbanks in India and Nepal

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	West African Manatee	<i>Trichechus senegalensis</i>	High (15)	4	2	Medium / High	Marine / Freshwater	West African Coastal & Inland Wetlands, Estuaries, Rivers, Lagoons, Coastal Flats & Mangrove Creeks
Aves	Red-breasted Goose	<i>Branta ruficollis</i>	High (13)	6	5	Medium / High	Terrestrial	Tundra Wetlands within Central & Western Europe, Siberia. Breeding sites in Caspian and Black sea
Aves	Siberian Crane	<i>Grus leucogeranus</i>	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	<i>Polysticta stelleri</i>	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	<i>Grus vipio</i>	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	<i>Acrocephalus griseldis</i>	High (12)	7	6	Medium / High	Freshwater	Brackish, Freshwater Reed Beds, Mangroves, Dense Vegetation Wetlands, Lakes, Marshes, Swamps
Pisces	Giant Catfish	<i>Pangasius gigas</i>	High (12)	7	1	Low / Medium	Freshwater	Freshwater Rivers in Mekong Basin (South East Asia)
Aves	Aquatic Warbler	<i>Acrocephalus paludicola</i>	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, Brazilian 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 than 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 Gaviel	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	<i>Eretmochelys imbricata</i>	2	Medium / High	High (18)	1
Aves	Balearic Shearwater	<i>Puffinus mauretanicus</i>	3	Medium / High	High (17)	2
Mammalia	Narwhal	<i>Monodon monoceros</i>	4	Medium / High	High (16)	3
Aves	Relict Gull	<i>Larus relictus</i>	4	Medium / High	High (16)	3
Reptilia	Kemp's Ridley Turtle	<i>Lepidochelys kempii</i>	4	Medium / High	High (16)	3
Mammalia	North Pacific Right Whale	<i>Eubalaena japonica</i>	4	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	<i>Eubalaena glacialis</i>	4	Medium / High	High (16)	3
Mammalia	West African Manatee	<i>Trichechus senegalensis</i>	5	Medium / High	High (15)	4
Reptilia	Gharial, Indian Gavial	<i>Gavialis gangeticus</i>	5	Medium / High	High (15)	4
Aves	Short-tailed Albatross	<i>Diomedea albatrus</i>	5	Medium / High	High (15)	4
Reptilia	Olive Ridley	<i>Lepidochelys olivacea</i>	6	Medium / High	High (14)	5
Mammalia	Blue Whale	<i>Balaenoptera musculus</i>	7	Medium/High	High (13)	6
Aves	White-naped Crane	<i>Grus vipio</i>	7	Medium / High	High (13)	6
Aves	Bermuda Petrel	<i>Pterodroma cahow</i>	8	Medium / High	High (11)	8
Pisces	Common Sturgeon	<i>Acipenser sturio</i>	8	Medium / High	High (11)	8
Aves	Andean Flamingo	<i>Phoenicopterus andinus</i>	9	Medium / High	Medium (10)	12
Mammalia	Bowhead Whale	<i>Balaena mysticetus</i>	10	Medium	High (15)	4
Reptilia	Loggerhead Turtle	<i>Caretta caretta</i>	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	<i>Dermochelys coriacea</i>	11	Medium	High (14)	5
Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	11	Medium	High (14)	5
Aves	Sociable Plover	<i>Vanellus gregarius</i>	11	Medium	High (14)	5
Aves	Siberian Crane	<i>Grus leucogeranus</i>	12	Medium	High (13)	6
Aves	Red-breasted Goose	<i>Branta ruficollis</i>	12	Medium	High (13)	6
Aves	Steller's Eider	<i>Polysticta stelleri</i>	12	Medium	High (13)	6
Pisces	Giant Catfish	<i>Pangasius gigas</i>	13	Medium	High (12)	7
Mammalia	Snow Leopard	<i>Uncia uncia</i>	14	Medium	High (10)	9
Pisces	Basking Shark	<i>Cetorhinus maximus</i>	15	Medium	Medium (12)	10
Aves	Aquatic Warbler	<i>Acrocephalus paludicola</i>	15	Medium	Medium (12)	10
Aves	Swan Goose	<i>Anser cygnoides</i>	16	Medium	Medium (11)	11
Mammalia	Sei Whale,	<i>Balaenoptera borealis</i>	16	Medium	Medium (11)	11
Mammalia	Mexican Free-tailed Bat	<i>Tadarida brasiliensis</i>	17	Medium	Medium (10)	12
Mammalia	Sperm Whale	<i>Physeter macrocephalus</i>	17	Medium	Medium (10)	12
Aves	Humboldt Penguin	<i>Spheniscus humboldti</i>	17	Medium	Medium (10)	12
Aves	Puna Flamingo	<i>Phoenicopterus jamesi</i>	18	Medium	Medium (9)	13
Mammalia	Dama Gazelle	<i>Gazella dama</i>	19	Low / Medium	High (14)	5
Mammalia	Addax	<i>Addax nasomaculatus</i>	20	Low / Medium	High (13)	6
Aves	Basra Reed-warbler	<i>Acrocephalus griseldis</i>	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	<i>Eubalaena japonica</i>	3	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	<i>Eubalaena glacialis</i>	3	Medium / High	High (16)	3
Mammalia	Bowhead Whale	<i>Balaena mysticetus</i>	4	Medium / High	High (15)	4
Aves	Short-tailed Albatross	<i>Diomedea albatrus</i>	4	Medium / High	High (15)	4
Aves	Sociable Plover	<i>Vanellus gregarius</i>	5	Medium / High	High (14)	5
Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	5	Medium / High	High (14)	5
Mammalia	Blue Whale	<i>Balaenoptera musculus</i>	6	Medium / High	High (13)	6
Reptilia	Green Turtle	<i>Chelonia mydas</i>	7	Medium	High (18)	1
Reptilia	Kemp's Ridley Turtle	<i>Lepidochelys kempii</i>	8	Medium	High (16)	3
Aves	Relict Gull	<i>Larus relictus</i>	8	Medium	High (16)	3
Reptilia	Gharial	<i>Gavialis gangeticus</i>	9	Medium	High (15)	4
Reptilia	Loggerhead Turtle	<i>Caretta caretta</i>	9	Medium	High (15)	4
Mammalia	West African Manatee	<i>Trichechus senegalensis</i>	9	Medium	High (15)	4
Mammalia	Dama Gazelle	<i>Gazella dama</i>	10	Medium	High (14)	5
Mammalia	Addax	<i>Addax nasomaculatus</i>	11	Medium	High (13)	6
Aves	Steller's Eider	<i>Polysticta stelleri</i>	11	Medium	High (13)	6
Pisces	Basking Shark	<i>Cetorhinus maximus</i>	12	Medium	Medium (12)	10
Mammalia	Sei Whale	<i>Balaenoptera borealis</i>	13	Medium	Medium (11)	11
Mammalia	Short-beaked Common Dolphin	<i>Delphinus delphis</i>	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 than 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	<i>Puffinus mauretanicus</i>	2	High	High (17)	2
Reptilia	Kemp's Ridley Turtle,	<i>Lepidochelys kempii</i>	3	High	High (16)	3
Reptilia	Gharial, Indian Gavial	<i>Gavialis gangeticus</i>	4	High	High (15)	4
Reptilia	Loggerhead Turtle	<i>Caretta caretta</i>	4	High	High (15)	4
Mammalia	Dama Gazelle	<i>Gazella dama</i>	5	High	High (14)	5
Reptilia	Leatherback Turtle	<i>Dermodochelys coriacea</i>	5	High	High (14)	5
Pisces	Giant Catfish	<i>Pangasius gigas</i>	6	High	High (12)	7
Mammalia	Narwhal	<i>Monodon monoceros</i>	7	Medium / High	High (16)	3
Mammalia	North Pacific Right Whale	<i>Eubalaena japonica</i>	7	Medium / High	High (16)	3
Mammalia	Northern Atlantic Right Whale	<i>Eubalaena glacialis</i>	7	Medium / High	High (16)	3
Aves	Relict Gull	<i>Larus relictus</i>	7	Medium / High	High (16)	3
Aves	Short-tailed Albatross, Steller's Albatross	<i>Diomedea albatrus</i>	8	Medium / High	High (15)	4
Mammalia	West African Manatee	<i>Trichechus senegalensis</i>	8	Medium / High	High (15)	4
Aves	Sociable Plover	<i>Vanellus gregarius</i>	9	Medium / High	High (14)	5
Mammalia	Southern Right Whale	<i>Eubalaena australis</i>	9	Medium / High	High (14)	5
Reptilia	Olive Ridley	<i>Lepidochelys olivacea</i>	9	Medium / High	High (14)	5
Mammalia	Addax	<i>Addax nasomaculatus</i>	10	Medium / High	High (13)	6
Aves	Red-breasted Goose	<i>Branta ruficollis</i>	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	<i>Grus vipio</i>	10	Medium / High	High (13)	6
Aves	Basra Reed-warbler	<i>Acrocephalus griseldis</i>	11	Medium / High	High (12)	7
Pisces	Common Sturgeon	<i>Acipenser sturio</i>	12	Medium / High	High (11)	8
Mammalia	Snow Leopard	<i>Uncia uncia</i>	13	Medium / High	High (10)	9
Aves	Aquatic Warbler	<i>Acrocephalus paludicola</i>	14	Medium / High	Medium (12)	10
Mammalia	Short-beaked Common Dolphin	<i>Delphinus delphis</i>	15	Medium / High	Medium (11)	11
Mammalia	Cuvier's Gazelle	<i>Gazella cuvieri</i>	15	Medium / High	Medium (11)	11
Mammalia	Marine Otter	<i>Lontra felina</i>	16	Medium / High	Medium (7)	16
Mammalia	Bowhead Whale	<i>Balaena mysticetus</i>	17	Medium	High (15)	4
Aves	Steller's Eider	<i>Polysticta stelleri</i>	18	Medium	High (13)	6
Aves	Siberian Crane	<i>Grus leucogeranus</i>	18	Medium	High (13)	6
Pisces	Basking Shark	<i>Cetorhinus maximus</i>	19	Medium	Medium (12)	10
Mammalia	Sei Whale	<i>Balaenoptera borealis</i>	20	Medium	Medium (11)	11
Aves	Swan Goose	<i>Anser cygnoides</i>	20	Medium	Medium (11)	11
Aves	Humboldt Penguin	<i>Spheniscus humboldti</i>	21	Medium	Medium (10)	12
Mammalia	Mexican Free-tailed Bat	<i>Tadarida brasiliensis</i>	21	Medium	Medium (10)	12
Aves	Pallas Fish Eagle	<i>Haliaeetus leucoryphus</i>	21	Medium	Medium (10)	12
Mammalia	Sperm Whale	<i>Physeter macrocephalus</i>	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 than 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 than 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 than 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 than 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 than 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 whilst 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 °C, with a best likely estimate of 2.8 °C. However the MET Office Hadley Centre has indicated that temperature are likely to increase by more than 5.5 °C 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 breeding 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 than 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 effects 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 than global average temperature rises
 - Ocean acidification will also affect colder waters in polar waters much earlier than 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 by at least 2°C with the 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, Scimitar 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 than 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 than 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 be 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.
- An 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 <i>Puffinus mauretanicus</i>	<ul style="list-style-type: none"> - 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 effective 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, <i>Lepidochelys kempii</i>	<ul style="list-style-type: none"> - 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 effective if breeding can not be sustained and adaptation facilitated by some mechanism. - Requires climate change mitigation otherwise species likely to go extinct.
Narwhal <i>Monodon monoceros</i>	<ul style="list-style-type: none"> - 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 <i>Eubalaena japonica</i>	<ul style="list-style-type: none"> - 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, <i>Eubalaena glacialis</i>	<ul style="list-style-type: none"> - 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 <i>Larus relictus</i>	<ul style="list-style-type: none"> - 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 Gaviel <i>Gavialis gangeticus</i>	<ul style="list-style-type: none"> - 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 <i>Caretta caretta</i>	<ul style="list-style-type: none"> - 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 effective 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, <i>Diomedea albatrus</i>	<ul style="list-style-type: none"> - 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 <i>Trichechus senegalensis</i>	<ul style="list-style-type: none"> - 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 <i>Balaena mysticetus</i>	<ul style="list-style-type: none"> - 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 <i>Gazella dama</i>	<ul style="list-style-type: none"> - 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, <i>Dermochelys coriacea</i>	<ul style="list-style-type: none"> - 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 <i>Vanellus gregarius</i>	<ul style="list-style-type: none"> - Reduction of anthropogenic threats would significantly increase resilience to climate change impacts.
Southern Right Whale <i>Eubalaena australis</i>	<ul style="list-style-type: none"> - 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 <i>Lepidochelys olivacea</i>	<ul style="list-style-type: none"> - 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 <i>Addax nasomaculatus</i>	<ul style="list-style-type: none"> - 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 <i>Branta ruficollis</i>	<ul style="list-style-type: none"> - Shows some degree of adaptability. Migration cultural rather than 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 <i>Grus vipio</i>	<ul style="list-style-type: none"> - 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 <i>Polysticta stelleri</i>	<ul style="list-style-type: none"> - Reduction other anthropogenic threats necessary to increase resilience.
Siberian Crane <i>Grus leucogeranus</i>	<ul style="list-style-type: none"> - 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 <i>Balaenoptera musculus</i>	<ul style="list-style-type: none"> - 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 <i>Pangasius gigas</i>	<ul style="list-style-type: none"> - Limit anthropogenic impacts, including dams.
Basra Reed-warbler <i>Acrocephalus griseldis</i>	<ul style="list-style-type: none"> - 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 <i>Acipenser sturio</i>	<ul style="list-style-type: none"> - Limit anthropogenic impacts, including dams.
Bermuda Petrel <i>Pterodroma cahow</i>	<ul style="list-style-type: none"> - 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 <i>Uncia uncia</i>	<ul style="list-style-type: none"> - 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 their 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.

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_o8_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 I 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	<p>Davis MB, Shaw RG (2001) Range shifts and adaptive responses to Quaternary climate change. <i>Science</i> 292: 673–679 [Link]</p> <p>McCarty J (2001) Ecological consequences of recent climate change. <i>Conserv Biol</i> 15:320–331 [Link]</p> <p>Robinson RA, Crick HQP, Learmonth JA, Maclean IMD and others (2009) Travelling through a warming world— climate change and migratory species. <i>Endang Species Res</i> 7:87–99 [Link]</p> <p>Root TL, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA (2003) Fingerprints of global warming on wild animals and plants. <i>Nature</i> 421:57–60 [Link]</p> <p>Sala OE, Chapin FS, Armesto JJ, Berlow E and others (2000) Global biodiversity scenarios for the year 2100. <i>Science</i> 287:1770 [Link]</p> <p>Visser ME, Both C (2005) Shifts in phenology due to global climate change: the need for a yardstick. <i>Proc R Soc Lond B Biol Sci</i> 272:2561–2569 [Link]</p> <p>Walther GR, Post E, Convey P, Menzel A and others (2002) Ecological responses to recent climate change. <i>Nature</i> 416:389–395 [Link]</p>
Reptiles	<p>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. <i>Conserv Biol</i> 19: 482–491 [Link]</p> <p>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. <i>Ocean Coast Manag</i> 51:330–341 [Link]</p> <p>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. <i>Endangered Species Research Journal</i>. [Link]</p> <p>Fuentes MMPB, Limpus CJ, Hamann M, and Dawson J (2009). Potential impacts of projected sea level rise to sea turtle rookeries. <i>Aquatic conservation: marine and freshwater ecosystems</i>.doi:10.1002/aqc.1088 [Link]</p> <p>Fuentes MMPB, Hamann M, and Lukoschek V (2009). Marine Reptiles and Climate Change. In <i>A Marine Climate Change Impacts and Adaptation Report Card for Australia 2009</i> (Eds. ES Poloczanska, AJ Hobday and AJ Richardson), NCCARF Publication 05/09, ISBN 978-1-921609 03-9. [Link]</p> <p>Fuentes MMPB, Hamann M and Limpus CJ (2010). Past, current and future thermal profiles for green turtle nesting grounds: implications from climate change. <i>Journal of Experimental Marine Biology and Ecology</i> 383, 56-64. [Link]</p> <p>Fuentes MMPB, Limpus CJ, and Hamann M (In Press). Vulnerability of sea turtle nesting grounds to climate change. <i>Global Change Biology</i>. doi : 10.1111/j.1365-2486.2010.02192.x [Link]</p> <p>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. <i>Journal of Marine and Freshwater Research</i>. [Link]</p> <p>Grifn, E., Frost E., White L., Allison D. (2007) Climate Change and Commercial Fishing: A One-two Punch for Sea Turtles. [Link]</p> <p>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) <i>Climate change and the Great Barrier Reef: a vulnerability assessment</i>, Great Barrier Reef Marine Park Authority and Australia Greenhouse Office, Hobart, p 465–496</p> <p>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. <i>Glob Change Biol</i> 9:642–646</p> <p>Hawkes L.A., Broderick A.C; Godley M.H, (2007) Investigating the potential impacts of climate change on a marine turtle population. <i>Global</i></p>

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

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	kazto@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 communities¹². 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.



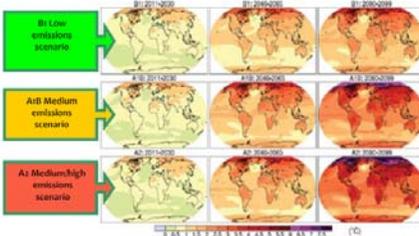
Mexican-free tailed bats

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 century¹. 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 period². 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 warm³.



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**⁴ and the **narwhal**⁵ (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 breed⁶. Intense warming is projected for the Arctic⁷, with ice free summers expected by 2025-2040^{8,9}.

Collapsing Food Webs Linked to Changes in Zooplankton Abundance: Baleen whales, a number of fish (e.g. **basking shark**)¹⁰ 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 decline¹¹. 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**⁴ and three **right whale** species will be affected as krill abundances decline.

Changing Sex Ratios: Many reptiles are reliant on temperature sex determination¹⁴, as are some birds¹⁵ and fish¹⁶. 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 populations¹⁷, 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 latitudes¹.

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 **whitetailed crane**¹⁸. To breed, the **Basra reed warbler** requires aquatic vegetation in or around shallow water, on marshlands and in river basins across Mesopotamia¹⁹. 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 scenarios¹⁰, 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 region²¹ 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 nesting²².

Precipitation across much of this breeding habitat is expected to increase in variability³, 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 hatchlings²³. 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 hatchlings²⁴. In 2008, early monsoon flooding destroyed all nests in Katerniaghath, 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 frequent²⁵. 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 heating²⁶. 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 turbulence²⁷ 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 cyclones²⁸, 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 nests²⁹. The **Mexican-free tailed bat** is also expected to suffer because the availability of its insect prey is reduced in poor weather³⁰.

Precipitation Extremes: The **West African manatee** is vulnerable to both high and low extremes in river flow³¹. Precipitation in West Africa is expected to become more extreme with more infrequent, heavy rainfall³. Optimum habitat for the manatee is deep, slow moving river waters³². 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 1980-1999³² levels. However, other models indicate a much greater magnitude of sea level rise by the end of the century³³, with some predicting it to be in the range of 0.5m - 1.4m³⁴. 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 migration³⁴.

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 grounds³⁵. 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

CO₂ is the primary molecule influencing the pH of oceans³⁶. Since the 1800's, oceans have absorbed 1/3 of anthropogenic CO₂ emissions³⁷ 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 units³⁸ by 2100. Increases in atmospheric CO₂ are currently more rapid than at any point in the last 650,000 years³⁹. 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 2016⁴⁰ and both calcite and aragonite concentrations expected to be insufficient for mineralisation in Arctic waters by 2060⁴¹. 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^{39,41,43,44}, species directly or indirectly dependent on these (e.g. whales, dolphins) are likely to suffer³⁹.



Coral reef ecosystem

Habitat Loss: **Hawksbill turtles** depend upon coral reef ecosystems at various stages of their life-cycle⁴⁵. The shelves and caves formed by coral reefs provide resting and sheltering areas for this species⁴⁶, whilst adult hawksbills feed almost exclusively upon reef fauna⁴⁶. By 2030-2050, reefs globally will be facing severe acidification stress⁴⁷. Coral reef formation depends upon aragonite, which has decreased considerably in tropical seawaters⁴⁷. When atmospheric CO₂ levels reach approximately 450ppm, the ability of coral reefs to withstand erosion and grow will be severely impeded⁴⁸. 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 ecosystems⁴⁹, 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 cycle⁵⁰. 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 system⁵¹. 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 impacts⁵².

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**⁵³, **basking shark**⁵⁴) are likely to be affected by changing ocean circulations as these will affect prey distribution. Migration routes will have to adapt⁵⁵ 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**⁵⁶ 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 basins⁵³. Changes in ocean circulation are likely to change the distributions and migration patterns of such species⁵⁴.

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 vulnerable⁵⁷. 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^{58,57,58,59}. 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 occurring⁶⁰ 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. Mismatching 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 species⁶⁶. 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.biodclimate.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 microflight 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 effects 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”



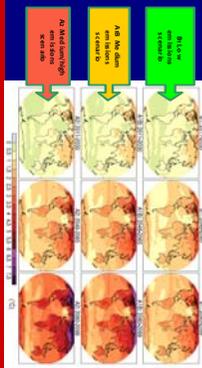
Climate Change Impacts on Migratory Species
Uncertain Destinations

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Migratory species provide some of the most impressive spectacles in the natural world. The migration pathways that they trace uniquely highlight the interconnectivity between greatly dispersed global ecosystems. Relying upon high-quality habitats at specific times of the year, migratory species are particularly vulnerable to climatic disturbances.

- A diverse range of climate change processes are already affecting migratory species
- Conservation methods need to evolve to ensure they are effective at mitigating these emerging threats
- For the long-term survival of these species, urgent action is required now to reduce greenhouse gas emissions



Humpback Whale: At the turn entrance of CO₂ emissions, by 2050, the number of humpback whales is predicted to decline by 50%. Many species from the ends of their calcium carbonate exoskeletons. This would profoundly affect zooplankton species, as using cascading effects through the food webs of the humpback whale.

Green Turtle: A 5m sea level rise is predicted to eliminate 32% of turtle nesting grounds. Sea levels are likely to rise 0.9m-1.4m by 2100.

Siberian Crane: Amplified warming around the Arctic Circle is causing forest to encroach tundra habitats. It is predicted that 70% of this habitat will be lost in 100-200 years. To breed, Siberian crane pairs require extensive areas of tundra.

Antelope: Although adapted to arid climates, more severe and prolonged periods of drought in north Africa are predicted. This will exacerbate pressure on wild and domestic ungulates as grazing habitats decline.

Monarch Butterfly



Migrating into the Future

Identifying Extinction Risk: There is a real need for climate change vulnerability assessments to be carried out on species listed within the CMS Appendices, as well as those not currently protected under the convention. These assessments and subsequent monitoring work are vital in order to identify key limiting factors, the 'weak links', upon which the survival of each species hinges. Re-basification of CMS priority species may be necessary.

Managing Changing Environments: The mobility of migratory species provides them with a potential to adapt to climate change, allowing them to track habitat shifts and find more suitable ranges. To facilitate this, it is vital that we improve and direct the connectivity of habitats essential for species survival, with species and habitat range shifts in mind. Critical site networks and tools are being developed under CMS, such as the Wings Over Wetlands Project (see [spoonerandking.org](#)). The resilience of some species to cope with climate change can be improved by maintaining viable habitats and reducing current threats; by focusing conservation efforts upon these actions, we can increase the adaptive potential of species.

Importance of Mitigation: Efforts to aid species adaptation are necessary. If species are to survive in the short term, however, these will require huge investments and their long-term success is completely dependent on the speed and degree to which climate change proceeds. It is therefore vital that a dual approach be taken where proactive adaptation measures are applied to species already threatened by the levels of climate change to which we are already committed, alongside rapid emissions reduction to limit further impacts. This is the only cost-effective and practical way to safeguard migratory species today and into the future.

It is clear that with the scale of the threats many migratory species are facing, traditional conservation measures alone will not prevent extinctions amongst CMS listed species, or the numerous economically important migratory species globally.

A reduction in greenhouse gases to safe levels is the only viable long-term solution.

