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DISCUSSION PAPER FOR THE SCIENTIFIC COUNCIL ON DECISION 13.128 CLIMATE CHANGE AND MIGRATORY SPECIES

(Prepared by the COP-appointed Councillor for Climate Change)

Summary:

The aim of this document is to provide material for discussion by the Sessional Committee of Decision 13.128 which requests the Scientific Council to provide advice on interpretation of Paragraph 9 of Resolution 12.21 *Climate Change and Migratory Species*.

This document provides information about how species range may be altered as a result of climate change and includes a decision tree to aid Parties identify what action they might wish to undertake as a result. The document is provided for review by the Scientific Council.

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Background

1. Decision 13.128 states:

   The Scientific Council is requested, subject to the availability of resources, to provide advice on how the interpretation in paragraph 9 of Resolution 12.21 Climate Change and Migratory Species could be turned into pragmatic good practice. [1]

2. Resolution 12.21[2] Paragraph 9 states:

   Agrees that Article I (1) (c) (4) of the Convention, on the definition of "favourable conservation status" could be interpreted as follows in light of climate change, and invites the governing bodies of relevant CMS instruments to also approve this interpretation:

   According to Article I (1) (c) (4) of the Convention, one of the conditions to be met for the conservation status of a species to be taken as "favourable" is that: "the distribution and abundance of the migratory species approach historic coverage and levels to the extent that potentially suitable ecosystems exist and to the extent consistent with wise wildlife management". Whereas there is a continued need to undertake conservation action within the historic range of migratory species, such action will increasingly also need to be taken beyond the historic range of species in order to ensure a favourable conservation status, particularly with a view to climate-induced range shifts. Such action beyond the historic range of species is compatible with, and may be required in order to meet the objectives and the obligations of Parties under the Convention;

Interpreting Resolution 12.21 Paragraph 9

3. Over a sufficiently long timescale, no migratory route is fixed. Instead animals change where and when they migrate in response to environmental drivers, including changes in climate. Contemporary climate change, as a result of greenhouse gas emissions, poses a particularly severe threat to many migratory species. Firstly, the pace of change exceeds that observed in the geological record, making it harder for species and ecosystems to adapt. Secondly, the capacity of migratory species to shift their ranges is already limited by a range of other pressures resulting from human activity.

4. The Annex to this document, drafted by a Natural Environment Research Council Policy Intern working with the UK Joint Nature Conservation Committee, reviews evidence of the ways in which climate change may affect migratory species in terrestrial, freshwater and marine habitats.

5. Terrestrial and freshwater species face a wide variety of pressures linked to a changing climate. The three case studies examined – desertification, arctic vegetation shifts and sea level rise – are chosen to illustrate the diversity of threats posed to ecosystems and to the migratory species which rely on them. IPCC Special Reports are quoted in order to summarise current scientific understanding and to convey the degree of confidence associated with various ongoing and projected impacts of climate change. Three further case studies are examined with regards to marine species: ocean warming, arctic sea ice loss and ocean acidification. As for terrestrial and freshwater habitats, these examples are not intended to be exhaustive but are nonetheless highly useful in exploring the range of conservation scenarios and the framework for action which follows.

[1] https://www.cms.int/en/page/decisions-13126-13128-climate-change-and-migratory-species

[2] https://www.cms.int/sites/default/files/document/cms_cop12_res.12.21_climate-change_e.pdf

Discussion and analysis

6. The Annex is based upon a literature review and interviews with a range of scientists and organisations working on the impact of climate change on a range of species issues, and with expertise in the working with the Convention. Following the case studies noted above, the Annex considers scenarios and potential actions that Parties could undertake – supported by a Decision Tree which provides a framework for action.

7. Four scenarios are explored:
   i. Species not present throughout suitable range
   ii. Species range limited by natural barrier(s)
   iii. Species range limited by anthropogenic barrier(s)
   iv. Species range likely to be limited by anthropogenic barrier(s) in future

8. The decision framework is intended as a basis to guide the engagement between range states and for the prioritization of actions for migratory species at risk from climate change. By combining this framework with careful analysis of scientific evidence for each species, strategies can be focused on actions which make best use of resources to protect species and their migration routes. Four potential strategies are considered:
   i. Conservation
   ii. Restoration
   iii. Adaptation
   iv. Translocation

9. The Annex makes six recommendations to serve as a basis for discussion at Scientific Council, and thereafter to improve the resilience of CMS listed species, in particular, to the challenges posed by climate change.
   i. Testing by Parties or other stakeholders of the framework suggested in this paper – to deliver case studies that may help Parties to implement the framework in real-world scenarios.
   ii. Develop adaptation plans for CMS-listed species based on the framework outlined above, recognizing that different conservation actions may be needed in different parts of a species' life-cycle, in marine, freshwater and terrestrial environments, and that the appropriate actions may change as climate change progresses.
   iii. Identify species which might have a high probability to change their migration routes and promote knowledge exchange between relevant authorities to understand the changes in range state status that may occur.
   iv. Work towards a widely accepted definition for the term "barrier", so that there is consistency in the obligation to remove barriers to migratory species.
   v. Place increased emphasis on the need for international co-operation and concerted action to maintain and improve the connectivity of migration routes.
   vi. Promote greater understanding of the provision of ecosystem services which may result from preserving buffer zones for migratory species range changes.

Recommended actions

10. The Sessional Committee is recommended to:

   a) Review the document contained in the Annex of this document and consider the recommendations made;

   b) Consider convening an intersessional working group to further develop a document to be considered at the 6th meeting of the Sessional Committee, and by COP14

ANNEX

CLIMATE CHANGE AND MIGRATORY SPECIES

Contents

1. Introduction

The threat to migratory species posed by climate change has been formally recognised by the Convention on Migratory Species (CMS) since Recommendation 5.5 on Climate Change and its Implications for the Bonn Convention was introduced at the 1997 Conference of the Parties (COP5)[3]. Subsequent resolutions considered and addressed these implications, culminating at COP12 with a consolidation of previous resolutions through Resolution 12.21 on Climate Change and Migratory Species. Within the resolution, paragraph 9 recognises that conservation measures:

> *will increasingly also need to be taken beyond the historic range of species in order to ensure a favourable conservation status, particularly with a view to climate induced range shifts.*[4]

[3] https://www.cms.int/sites/default/files/document/cms_ccwg2017_inf-5_rec-5-5.pdf
[4] https://www.cms.int/en/document/climate-change-and-migratory-species-3

This led to the adoption at CMS COP13 of Decision 13.128 under which:

> *The Scientific Council is requested, subject to the availability of resources, to provide advice on how the interpretation in paragraph 9 of Resolution 12.21 Climate Change and Migratory Species could be turned into pragmatic good practice.* [5]

These statements recognise that over a sufficiently long timescale, no migratory route is fixed. Instead animals change where and when they migrate in response to environmental drivers, including changes in climate. In some cases, a species may undergo a continuous expansion, contraction, or translation in its range; in other cases, a species may make a discrete transition, such as between two flyways or between two ocean basins. Any species which is unable to either adapt its range or to evolve in response to climate change is more likely to go extinct.

Contemporary climate change, as a result of greenhouse gas emissions, poses a particularly severe threat to many migratory species. Firstly, the pace of change exceeds that observed in the geological record, making it harder for species and ecosystems to adapt. Secondly, the capacity of migratory species to shift their ranges is already limited by a range of other pressures resulting from human activity. Whilst international agreements on climate change seek to slow the pace of global change, conservation agreements such as CMS must seek to mitigate against those other pressures which prevent species from adapting to a changing climate.

Other multilateral environment agreements (MEAs) are also increasingly concerned with climate impacts. For example, the Ramsar Convention on Wetlands has adopted a resolution on climate change[6], and the United Nations Convention to Combat Desertification (UNCCD) was a co-author on the recent Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land (SRCCL)[7], addressing issues such as land degradation and desertification which impact on wildlife as well as on humans. The UNCCD is also concerned with protected areas for wildlife, and in its 2017 Global Land Outlook Paper on Protected Areas noted the dangers of losing habitat connectivity:

> *Although the protected area estate is growing, individual protected areas are increasingly becoming isolated habitats. Hard boundaries increase the risk of species loss, habitat degradation, human-wildlife conflicts and crop damage*[8]

Similarly, the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)[9] addressed issues such as coastal wetland loss, sea level rise and sea ice retreat, all of which may imperil migratory routes and populations. The necessity for adaptable conservation networks to ensure ecological connectivity was encapsulated in CMS Resolution 12.07[10], whilst the SROCC Summary for Policymakers warned that:

> *Geographic barriers, ecosystem degradation, habitat fragmentation and barriers to regional cooperation limit the potential for such networks to support future species range shifts in marine, high mountain and polar land regions (high confidence)*[11]

[5] https://www.cms.int/en/page/decisions-13126-13128-climate-change-and-migratory-species

[6] Resolution X.24 adopted at Ramsar COP10 in 2008: https://www.ramsar.org/document/resolution-x24-climate-change-and-wetlands

[7] IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

[8] UNCCD Global Land Outlook Working Paper on Protected Areas [Dudley, N; Mackinnon, K]. September 2017 https://knowledge.unccd.int/publication/protected-areas

[9] IPCC, 2019: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

[10] https://www.cms.int/en/document/role-ecological-networks-conservation-migratory-species-1

[11] SROCC Summary for Policymakers; Paragraph C2.1

This document addresses CMS Decision 13.128. Sections 2 and 3 review the status of terrestrial and marine habitats respectively. In each case three key pressures arising from climate change are described, as are the potential impacts on range shifts for migratory species vulnerable to these pressures. In Section 4 a set of scenarios and actions is presented, along with a framework for decision making. Section 5 suggests synergies between CMS and other MEA's. Finally, Section 6 proposes six recommendations for consideration by the Scientific Council.

2. Terrestrial and Freshwater Habitats

Terrestrial and freshwater species face a wide variety of pressures linked to a changing climate. The three case studies examined here – desertification, arctic vegetation shifts and sea level rise – are chosen to illustrate the diversity of threats both to ecosystems and to the migratory species which rely on them. IPCC Special Reports are quoted in order to summarise current scientific understanding and to convey the degree of confidence associated with various ongoing and projected impacts of climate change.

a. Pressures and Vulnerabilities

i. Desertification

A clear manifestation of desertification is in the widening of the Sahara desert, which affects both the long distance migrations of birds and the survival of the endemic antelope and gazelle species that make up a key component of Sahelo-Saharan biodiversity. Seven of these desert ungulate species are listed by CMS on Appendix I and as subjects of the Concerted Action for Sahelo-Saharan Megafauna[12]. Many of them are prey for apex predators such as cheetah (*Acinonyx jubatus*) (Trouwborst & Blackmore, 2020) and provide ecosystem services such as assisting plant germination and dispersal (Newby, *et al*., 2016).

Since the 19th century mechanized hunting has severely depleted species such as the dorcas gazelle (*Gazella dorcas*) and addax (*Addax nasomaculatus*), whilst the scimitar-horned oryx (*Oryx dammah*) has now been hunted to extinction in the wild. At the same time, droughts, overgrazing and desertification have degraded habitats for those remnant populations of antelope and gazelle which remain.

The SRCCL defines desertification as:

> *Land-degradation in arid, semi-arid and dry sub-humid areas resulting from many factors, including climate variation and human activity*[13]

and warns that:

> *climate change and desertification are projected to cause reductions in crop and livestock productivity (high confidence), modify the plant species mix and reduce biodiversity (medium confidence).*[14]

As noted in the 2007 CITES Proposal for Inclusion on Appendix I[15], dorcas gazelle (*Gazella dorcas*) were once present over much of northern Africa, but are now restricted to a smaller section of the Sahel. Meanwhile addax (*Addax nasomaculatus*) are now split between two isolated populations, in Niger and in Chad. In the dry season both species tend to shelter in more vegetated areas and near riverbanks, so these habitats are of particular concern if they undergo desertification (Newby, *et al*., 2016).

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[12] https://www.cms.int/en/document/concerted-action-sahelo-saharan-megafauna

[13] SRCCL Chapter 6: Executive Summary

[14] SRCCL Summary for Policymakers; Paragraph A5.5

[15] https://cites.org/eng/cop/14/prop/index.php

Sahelo-Saharan antelope and gazelle are relatively tolerant of harsh conditions, and are highly mobile, so might be expected to show good resilience to climate change. However their capacity to adapt is hindered by their low numbers and the fragmented nature of their populations.

ii. Arctic vegetation shifts

The land masses around the Arctic are important breeding habitats for many species of migratory bird, acting as the source of many of the global flyways. Some waterbirds, such as spoon-billed sandpiper (*Calidris pygmaea*) breed in Siberia and then follow the East Asian-Australasian flyway south (Bamford, *et al*., 2008). The Siberian crane (*Leucogeranus leucogeranus),* which was the subject of the first CMS Memorandum of Understanding[16] in 1999, is split between two breeding populations migrating south along different routes, with a third population already extinct.

This role of the Arctic across different flyways is recognised in the Arctic Migratory Bird Initiative (AMBI)[17], initiated by Arctic Council through its working group on Conservation of Arctic Flora and Fauna (CAFF). Arctic breeding grounds are under increasing pressure for development, such as for hydro-electric power, whilst also being impacted by shifting of the boundaries between tundra, shrubland and boreal forest habitats.

iii. Rising sea levels

Intertidal zones serve as stopover sites for many of the wetland birds mentioned above, particularly on the East Asian-Australasian Flyway. These coastal wetlands are highly sensitive to human activity:

> *Nearly 50% of coastal wetlands have been lost over the last 100 years, as a result of the combined effects of localised human pressures, sea level rise, warming and extreme climate events (high confidence).*[18]

The need for connectivity along waterbird flyways means that each lost wetland is a threat to migratory species unless it can be replaced at another suitable location along the flyway.

Rising sea levels are also of concern for marine turtle nesting sites. Species such as loggerhead turtle (*Caretta caretta*) rely on a small number of beaches as nesting sites, habitats which again may be squeezed by a combination of local pressures and climate change (Witt, *et al*., 2010). Meanwhile seabird populations such as the black-footed albatross (*Phoebastria nigripes*) in the central Pacific nest at or close to the water line, putting them at risk as sea levels rise (Reynolds, *et al*., 2015).

b. Forecasting Range Shifts

i. Desertification

Future rainfall patterns over arid regions such as the Sahara are difficult for climate models to predict, but some studies suggest a decrease in precipitation in the Sahara, accompanied by increasing rainfall in the Sahel (Freemantle, *et al.*, 2013). This could cause difficulty for desert ungulates, which would then be forced further south in the dry season, into lands increasingly in demand for agriculture. This could lead to increased human-wildlife conflicts, including with large carnivores such as cheetah (*Acinonyx jubatus*) which feed on antelope and gazelle (Trouwborst & Blackmore, 2020).

[16] https://www.cms.int/siberian-crane/en

[17] https://www.caff.is/assessments/576-caff-webb/caff-is/strategies/arctic-migratory-birds-initiative-ambi

[18] SROCC Summary for Policymakers; Paragraph A6.1

ii. Arctic vegetation shifts

The Arctic is expected to undergo pronounced vegetation shifts as climate change progresses:

> *Woody shrubs and trees are projected to expand to cover 24–52% of Arctic tundra by 2050 (medium confidence). The boreal forest is projected to expand at its northern edge, while diminishing at its southern edge where it is replaced by lower biomass woodland/shrublands (medium confidence).*[19]

The loss of tundra habitat would threaten many migratory bird breeding grounds, particularly in western Alaska and eastern Russia. This may in turn cause birds such as spoon-billed sandpiper (*Calidris pygmaea*) to shift from the East Asian-Australasian Flyway to other flyways (Wauchope, *et al*., 2017). Similar shifts are observed from genomic records of peregrine falcons (*Falco peregrinus*) (Gu, *et al.*, 2021) and from recent observations of ruff (*Philomachus pugnax*) migration (Rakhimberdiev, *et al.*, 2011). However such shifts rely on the continued existence of high-latitude refugia in the Eurasian and Canadian Arctic islands, with many of these potential refugia not currently protected.

iii. Rising sea level

Significant uncertainties remain on both the global average sea level rise and how this sea level rise will be distributed. Nonetheless, a recent study of the Mai Po Ramsar site suggests that whilst current wetlands may be submerged, habitats further inland could remain suitable, provided this territory is not subject to development (Wikramanayake, *et al*., 2020). The loss of habitats which serve as stopover sites for migrating waterbirds is an example of coastal squeeze, whereby the impacts of sea level rise:

> *are exacerbated by direct human disturbances, and where anthropogenic barriers prevent landward shifts of marshes and mangroves (termed coastal squeeze) (high confidence"*[20]

It has also been projected that some Pacific Islands could become ecological traps for seabirds such as the black-footed albatross (*Phoebastria nigripes*), as sea level rise pushes nesting areas into higher altitude habitats which have already been degraded or which have been invaded by mammalian predators (Reynolds, *et al*., 2015).

3. Marine Habitats

Three further case studies are examined with regards to marine species: ocean warming, arctic sea ice loss and ocean acidification. As for terrestrial and freshwater habitats, these examples are not intended to be exhaustive but are nonetheless highly useful in exploring the conservation scenarios and framework for action which follow.

a. Pressures and Vulnerabilities

i. Ocean warming

Many marine CMS-listed species are threatened by ocean warming, either directly through their narrow range of temperature tolerance or indirectly via changes in quantity and location of prey. In addition to the overall warming trend, increasingly frequent marine heatwaves will pose a threat to migratory species, such as by forcing non-food ingestion in starving seabirds (Roman, *et al*., 2021)

Most sharks are entirely ectothermic, making them very sensitive to increases in ocean temperature. Many species have also been targets for intensive fishing, which has depleted numbers significantly.

[19] SROCC Summary for Policymakers; Paragraph B4.2

[20] SROCC Summary for Policymakers; Paragraph A6.3

As apex predators, they are vital for ecosystem functioning, as has been recognised in recent CMS Resolutions[21] and in the creation of large protected areas such as the Palau National Marine Reserve[22].

Fisheries also impact migratory species via bycatch, particularly that of marine turtles and seabirds. In 1999 the Food and Agriculture Organization of the United Nations (FAO) presented proposals[23] for mitigating against bycatch of seabirds, but there remain discrepancies between countries and between Regional Fisheries Management Organizations (RFMOs). In the Southern Ocean the major bycatch is of albatrosses and petrels, which led to the negotiation of the Agreement on Conservation of Albatrosses and Petrels (ACAP). Many of the species under ACAP cross boundaries of important fisheries such as albacore tuna (*Thunnus alalunga*).

ii. Arctic sea ice retreat

> *In polar regions, ice associated marine mammals and seabirds have experienced habitat contraction linked to sea ice changes (high confidence) and impacts on foraging success due to climate impacts on prey distributions* (*medium confidence*).[24]

Some CMS-listed species are particularly vulnerable to loss of sea ice *(McNamara, et al.*, 2010). Bowhead whales (*Balaena mysticetus*) feed on the krill associated with seasonal blooms of algae at the edge of pack sea ice. As the ice thins, retreats and shifts, bowhead whales may find their ecological niche severely degraded. Narwhal (*Monodon monoceros*) are similarly vulnerable, given that they feed primarily on fish living underneath sea ice. Both these species have in the past been severely depleted by over-hunting – although unlike the megafauna of the Sahel they have since undergone significant recoveries.

In addition to direct loss of habitat, sea ice loss may also impact migratory species by opening up new areas of previously inaccessible open water. This creates new opportunities both for human navigation and for some migratory species to cross between ocean basins (Alter, *et al*., 2015). Industrial activity is already increasing in the Arctic, subject to the exclusion zones managed by the Arctic Council's Protection of the Arctic Marine Environment (PAME) working group.

iii. Ocean acidification

Hawksbill turtles (*Eretmochelys imbricata*) are a particularly threatened species (McNamara, *et al*., 2010), depleted by deliberate take and by bycatch, squeezed in their nesting sites and, in the pelagic drifting stage of their life cycle, vulnerable to changes in ocean currents. Their most critical sensitivity is to the loss of coral reef systems due to ocean acidification, since they rely on these reefs at multiple stages in their life cycle.

b. Forecasting Range Shifts

i. Ocean warming

Modelling studies of CMS-listed shark species predict shifts in the Pacific (Hazen, *et al*., 2013) and on the Australian continental shelf (Birkmanis, *et al*., 2020). In particular, species such as longfin mako (*Isurus paucus*) are predicted to move polewards, although sharks may also be able to avoid horizontal range shifts by residing for longer times in cooler waters at depth.

[21] https://www.cms.int/en/document/chondrichthyan-species-sharks-rays-skates-and-chimaeras-2

[22] https://www.cms.int/sharks/en/publication/palau-national-marine-reserve-shark-conservation

[23] International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries. Rome: FAO, 1999

[24] SROCC Summary for Policymakers; Paragraph A5.2

The IPCC has concluded that:

> *Rates of poleward shifts in distributions across different marine species since the 1950s are 52 ± 33 km per decade and 29 ± 16 km per decade (very likely ranges) for organisms in the epipelagic (upper 200 m from sea surface) and seafloor ecosystems, respectively.*[25]

In the Southern Ocean it is predicted that foraging grounds will continue to move polewards and thus further away from the small number of sub-Antarctic islands which are breeding grounds for albatrosses and petrels. For species such as grey-headed albatross (*Thalassarche chrysostoma*), this separation between life-cycle stages may have a severe impact on survival chances (Krüger, *et al.*, 2018). At the same time, fisheries are likely to shift, and there may be an increase in overlap between albatross and petrel foraging grounds and high-bycatch fisheries.

Conversely, the strengthening and polewards shifting of westerly winds in the Southern Ocean has been shown to improve chances of survival for very large gliders such as wandering albatross (*Diomedea exulans*) (Weimerskirch, *et al.*, 2012). Thus modelling which incorporates changes to wind patterns can give different forecasts for albatross and petrel range shifts (Somveille, *et al.*, 2020) compared to modelling which only considers scalar variables such as temperature and chlorophyll concentration as inputs.

The polewards shift in the Northwest Atlantic may have impacts on migratory timing for species such as fin whale (*Balaenoptera physalus*) (Jordaan, *et al.*, 2020). In the same region genomic evidence indicates that the migratory salmonid Arctic charr (*Salvelinus alpinus*), which forms an important fishery for indigenous communities, may be lost from large parts of its current range (Layton, *et al.*, 2021). The negative consequences of such polewards shifts are an example of the phenomenon noted by the IPCC, namely that:

> *Climate change impacts on marine ecosystems and their services put key cultural dimensions of lives and livelihoods at risk (medium confidence), including through shifts in the distribution or abundance of harvested species and diminished access to fishery or harvesting areas.*[26]

ii. Retreating sea ice in the Arctic

Mapping tools such as AquaMaps (Kaschner, *et al.*, 2019) can be used to visualise projected range shifts, as shown in Figure 1 for the northwards expansion of narwhal (*Monodon monoceros*) in the high Arctic. However large uncertainties remain as to how far sea-ice adapted species will be able to follow the retreating sea ice, especially as fishery and industrial activity expands northwards at the same time.

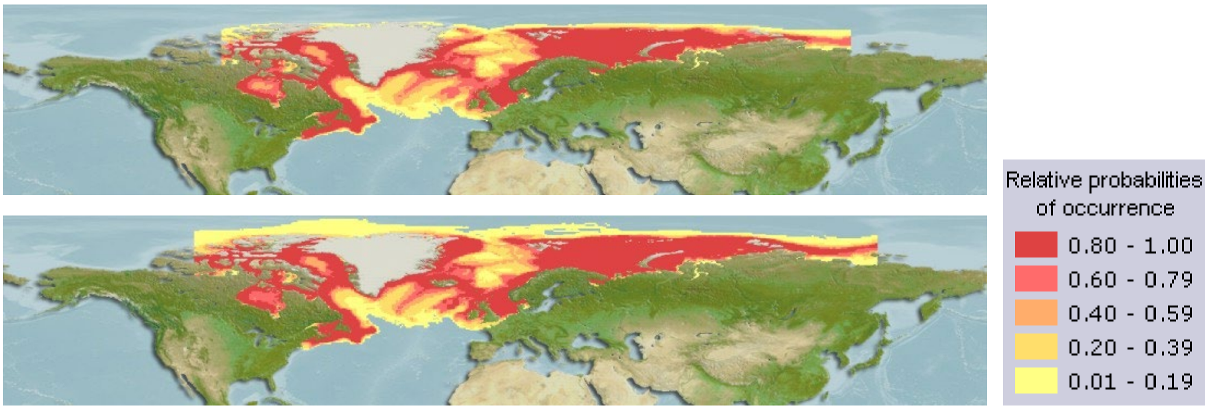

Figure 1: Current (top) and predicted 2050 (bottom) ranges for narwhal (Monodon Monoceros)[27].

[25] SROCC Summary for Policymakers; Paragraph A5.1

[26] SROCC Summary for Policymakers; Paragraph B8.4

[27] Computer Generated Map for narwhal (*Monodon monoceros*). www.aquamaps.org, version 10/2019 (accessed 16 Mar 2021)

The loss of sea ice will afford new opportunities for whales to cross between ocean basins. Genomic evidence indicates that gray whale (*Eschrichtius robustus*) populations have in the past repeatedly crossed through the Bering Straits when it was free of sea ice (Alter, *et al*., 2015). Again, however, these new sub-populations would likely move into areas of high human disturbance which could obstruct range shifts and expansions.

iii. Ocean acidification

Forecasts for the coral reef systems upon which hawksbill turtles (*Eretmochelys imbricata*) depend are stark:

> *Almost all warm-water coral reefs are projected to suffer significant losses of area and local extinctions, even if global warming is limited to 1.5ºC (high confidence). The species composition and diversity of remaining reef communities is projected to differ from present-day reefs (very high confidence).*[28]

Ocean acidification also effects deeper-lying cold water corals, as well as other calcifying organisms such as coccolithophores, which constitute a large portion of the ocean's microscopic phytoplankton (Krumhardt, *et al*., 2016). Shifts in coccolithophore distribution and abundance could have cascading effects due to their position at the base of marine ecosystems.

4. Scenarios and Actions

a. Categorizing scenarios

Based on the preceding literature review, four scenarios are considered which cover the different statuses of migratory species with respect to climate induced range shifts. In the following, the term "barrier" is used to refer to any factor which inhibits migratory species from expanding their range or acts as an impediment to connectivity of their migratory route.

i. Species not present throughout suitable range

Some CMS-listed species have been so severely depleted that they only occupy a small part of the range which is climatically suitable for them, such as addax (*Addax nasomaculatus*), or are extinct-in-the-wild, such as scimitar-horned oryx (*Oryx dammah*).

ii. Species range limited by natural barrier(s)

As climate change degrades habitat in one location, it may not be possible for that habitat to naturally recover in adjacent areas. Examples include the coral reef systems used by hawksbill turtles (*Eretmochelys imbricata*). A related issue is where breeding or nesting grounds are required to stay geographically fixed, whilst foraging grounds are pushed away by climatic change, as may be the case for loggerhead turtles (*Caretta caretta*) and grey-headed albatross (*Thalassarche chrysostoma*).

iii. Species range limited by anthropogenic barrier(s)

Where there is no natural barrier to range expansion, there may instead be a barrier resulting from human activity. This is the case at nesting sites for seabird species such as the black-footed albatross (*Phoebastria nigripes*), where sea level rise may push birds to nest at higher altitudes on islands which are unsuitable due to the presence of rats or other invasive predators. Anthropogenic barriers may also be present at boundaries between RFMOs where a range expansion may take species into seas with different bycatch mitigation standards.

[28] SROCC Summary for Policymakers; Paragraph B6.4

iv. Species range likely to be limited by anthropogenic barrier(s) in future

Even where there is currently capacity for species to adapt their movements in response to climate change, there may be a probability that these future habitats will undergo changes which will make them unsuitable. This is particularly an issue in the Arctic, where retreating sea ice is permitting greater navigation and therefore more industrial activity. Whilst much of the Arctic could currently accommodate polewards shifts of species such as bowhead whale (*Balaena mysticetus*), by the time these range shifts occur the Arctic marine environment may be further developed and thus less accommodating than it is today. Similarly, wetlands which are currently unused by waterbirds and under consideration for development may become more in demand as stopover sites due to sea level rise. Finally, the advance of aridification in the Sahara and changing rainfall in the Sahel could push wildlife such as Dorcas gazelle (*Gazella dorcas*) to compete for habitat with land increasingly needed for agriculture.

b. A framework for action

The following decision framework is influenced by approaches to ecosystem observation and management in fisheries (Link, *et al*., 2020); by decision science used to prioritize conservation (Xiao, *et al.*, 2021) and by ranking of research priorities (Rushing, *et al*., 2020) for migrating birds. It is intended as a basis for engagement between range states and for prioritization of actions for migratory species at risk from climate change. By combining this framework with careful analysis of scientific evidence for each species, strategies can be focused on actions which make best use of resources to protect species and their migration routes.

Four strategies are considered:

i. Conservation

Examples of conservation strategies include setting aside buffer zones inland from current coastal wetlands (Wikramanayake, *et al*., 2020), and limiting of industrial expansion into the Arctic, the latter perhaps utilizing tools such as the World Wildlife Fund (WWF) ArcNet[29].

ii. Restoration

Examples of restoration strategies include removal of invasive predators from potential seabird nesting sites (Reynolds, *et al*., 2015) and enhanced bycatch mitigation measures across fishery boundaries (Krüger, *et al*., 2018).

iii. Adaption

Examples of possible adaption strategies include rebuilding of coral reef systems (Rinkevich, 2014) and construction of artificial nesting sites for turtles.

iv. Translocation

Examples of translocation strategies include the reintroduction of captive addax (*Addax Nasomaculatus*) into protected areas of north Africa (Newby, *et al.*, 2016), and the use of light aircraft to guide Siberian crane (*Leucogeranus leucogeranus*) migration (the “Flight of Hope” project) in Russia.

[29] https://arcticwwf.org/work/ocean/arcnet/

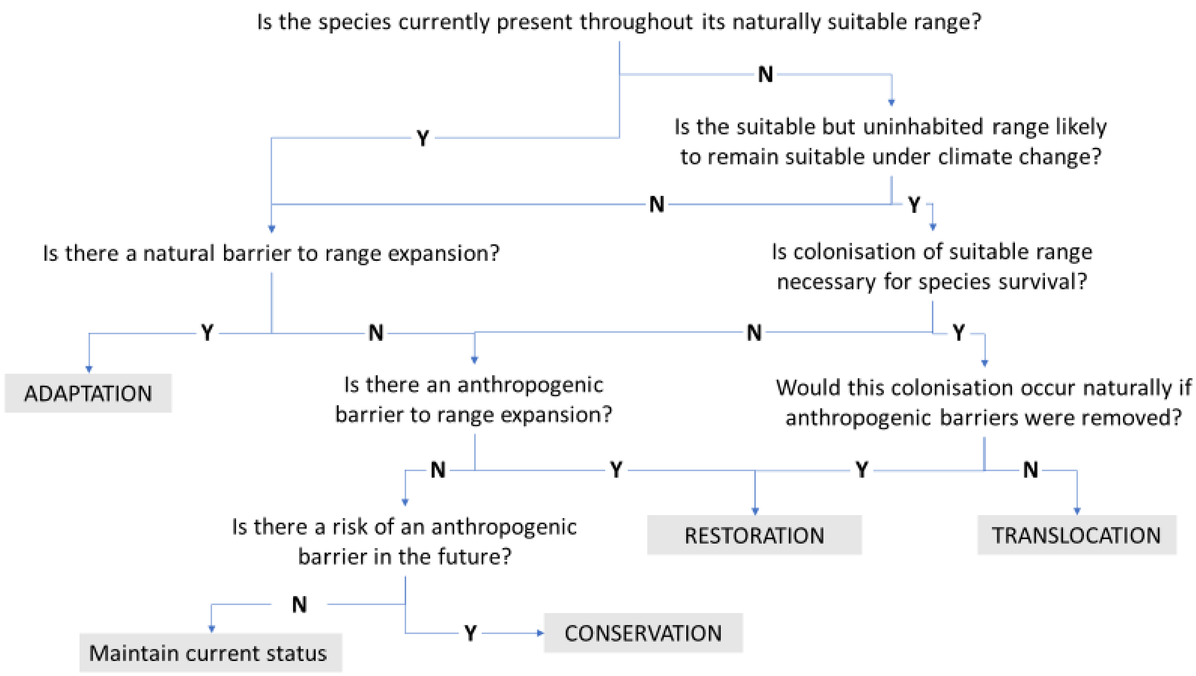

Figure 2. Decision tree using yes/no (Y/N) questions to link diagnosed scenarios to possible strategies for ensuring favourable conservation status of migratory species.

At each stage of the decision process, other factors will have to be taken into account, such as cost (Shoo, *et al*., 2013) and the potential risks and benefits incurred by other species which share the habitats in question. In particular, any attempt at translocation – either for assisted colonisation or recolonisation – should follow the International Union for Conservation of Nature (IUCN) Guidelines for Reintroduction and Other Conservation Translocations[30].

5. Synergies

CMS Resolution 11.10 from COP 13 calls for

> *enhanced cooperation with regard to work on cross-cutting issues, such as climate change*[31]

between MEAs including CMS. An example of an existing collaboration is the Joint CMS-CITES African Carnivores Initiative[32], an instrument which covers species such as cheetah (*Acinonyx jubatus*) and African wild dog (*Lycaon pictus*) that are expected to be affected by climate induced range shifts (Trouwborst & Blackmore, 2020). Opportunities for further collaboration with CITES may exist in relation to desert ungulates and marine turtles.

Cooperation between CMS and the Ramsar Convention is ongoing and has been formalised in recent agreements[33] but does not put a special emphasis on climate change. Regarding waterbird breeding grounds, cooperation with CAFF[34] through the Arctic Migratory Bird Initiative will remain important. Cooperation with CBD[35] will become increasingly important if large-scale reintroduction plans are introduced for threatened migratory species; also in relation to the ecosystem service benefits of preserving migratory routes.

[30] https://www.iucn.org/content/guidelines-reintroductions-and-other-conservation-translocations
[31] https://www.cms.int/en/document/synergies-and-partnerships-9
[32] https://www.cms.int/en/document/joint-cites-cms-african-carnivores-initiative-0
[33] https://www.cms.int/en/document/cooperation-between-cms-and-ramsar-2
[34] https://www.caff.is/administrative-series/297-resolution-of-cooperation-between-caff-and-the-convention-of-migratory-species
[35] https://www.cms.int/en/document/cooperation-between-cms-and-cbd-0

6. Recommendations

The following recommendations are intended to serve as a basis for discussion at Scientific Council, and thereafter to improve the resilience of CMS to the challenges posed by climate change.

i. Testing by Parties or other stakeholders of the framework suggested in this paper – to deliver case studies that may help Parties to implement the framework in real-world scenarios.

ii. Develop adaptation plans for CMS-listed species based on the framework outlined above, recognizing that different conservation actions may be needed in different parts of a species' life-cycle, in marine, freshwater and terrestrial environments, and that the appropriate actions may change as climate change progresses.

iii. Identify species which might have a high probability to change their migration routes and promote knowledge exchange between relevant authorities to understand the changes in range state status that may occur.

iv. Work towards a widely accepted definition for the term "barrier", so that there is consistency in the obligation to remove barriers to migratory species.

v. Place increased emphasis on the need for international co-operation and concerted action to maintain and improve the connectivity of migration routes.

vi. Promote greater understanding of the provision of ecosystem services which may result from preserving buffer zones for migratory species range changes.

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