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ECOLOGICAL CONNECTIVITY –TECHNICAL ASPECTS

(Prepared by the Secretariat)

Summary:

This document reports on progress on the implementation of relevant Resolutions' provisions and Decisions directed to the Scientific Council in the area of ecological connectivity namely Decision 13.114 *Improving Ways of Addressing Connectivity in the Conservation of Migratory Species* and Resolution 12.07 (Rev.COP13) *The Role of Ecological Networks in the Conservation of Migratory Species*.

The document also reports on the Scientific Council's work supporting the implementation of connectivity-related goals and targets of the Post-2020 Global Biodiversity Framework and the further development of its monitoring framework.

In addition, it presents preliminary work and proposals for next steps with regard to elements of Decision 13.114, as contained in Annexes 1-4.

This document needs to be read in conjunction with UNEP/CMS/ScC-SC6/Doc.12.2.1.1 *Ecological Connectivity – Policy Aspects* and its addendum.

The revision reflects amendments proposed by the Scientific Council Working Group on Ecological Connectivity at its first meeting held on 22 June 2023 and through further consultations.

ECOLOGICAL CONNECTIVITY – TECHNICAL ASPECTS

Background

1. The 13th Meeting of the Conference of the Parties to CMS (COP13, 2020) reaffirmed the importance of connectivity through the adoption of a number of Resolutions and Decisions, which are detailed in UNEP/CMS/ScC-SC6/Doc.12.2.1.2 *Ecological Connectivity - Policy Aspects*.
2. CMS Decision 13.114 *Improving Ways of Addressing Connectivity in the Conservation of Migratory Species* specifies mandates for the Scientific Council:

13.114 Directed to the Scientific Council

The Scientific Council is requested, subject to the availability of resources, to undertake the following tasks for enhancing the scientific understanding of connectivity issues in relation to migratory species:

- a) *review the scope for existing major databases to support relevant analyses and syntheses of information on connectivity, and identify options inter alia for ensuring sustainability and enhanced operability and coordination of such databases for this purpose;*
 - b) *investigate options for creating relevant data and knowledge holding capabilities and for enhancing analysis capabilities under the auspices of the CMS, in collaboration with suitably qualified institutions and processes;*
 - c) *investigate and report on the linkages between migratory species connectivity and ecosystem resilience;*
 - d) *having regard in particular to the Strategic Plan for Migratory Species, assess the needs and develop focused objectives for new research on key connectivity issues, including but not limited to climate change, which affect the conservation status of each of the major taxonomic groups of migratory wild animals covered by CMS in each of the world's major land and oceanic regions, and produce a report on the findings of this assessment prior to the 14th meeting of the Conference of Parties;*
 - e) *consider the need for additional guidance within the framework of the CMS on assessing threats to migratory species connectivity in particular priority situations identified by the work described in sub-paragraph (d) above; and*
 - f) *make recommendations as appropriate arising from the work described in this Decision.*
3. Decision 13.13 *Cooperation between the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and CMS* further specifies the Scientific Council's mandate with regard to engaging in relevant scoping processes and reviewing drafts of the IPBES thematic assessments to ensure that elements of connectivity are integrated.
 4. The 5th Meeting of the Sessional Committee of the Scientific Council (ScC-SC5), which was held online from 28 June to 9 July 2021, decided to establish a Working Group on Ecological Connectivity under the Scientific Council, with the aim of enhancing the scientific understanding of connectivity issues and providing advice on these in relation to migratory species. More specifically, it aims to help make progress based on the following key areas, as per its [Terms of Reference \(TOR\)](#) and workplan for the intersessional period COP13-COP14:
 - support the implementation of Decision 13.114 (a) – (e) as reproduced above;
 - support the implementation of elements relating to the Scientific Council in Resolution 12.07 (Rev.COP13) *The Role of Ecological Networks in the Conservation of Migratory Species*; and
 - support the implementation of the connectivity-related objectives of the Post-2020 Global Biodiversity Framework (GBF) (re-named the 'Kunming-Montreal Global Biodiversity Framework' after its adoption) and the further development of its monitoring framework.

5. The Working Group met on 22 June 2023 to review preliminary work on these mandates which was undertaken by the Secretariat in cooperation with the Chair of the Working Group, and is presented in the next sections and the annexes to this document. Inputs generated by the Working Group during the meeting and through further consultations are reflected in the revision of this document and its annexes.

Activities to implement Decision 13.114 (a) – (e) *Improving Ways of Addressing Connectivity in the Conservation of Migratory Species*

Data needs and information sources - Decision 13.114 (a)

6. In implementing Decision 13.114 (a), it was considered appropriate not to take too narrow an approach to the interpretation of the term ‘database’, since a variety of data-gathering tools, data-sharing platforms and other relevant information management systems may all help to answer the question at hand.
7. While a preliminary list of relevant databases is contained in Annex 1, together with some observations on the sustainability, operability and coordination of such databases, it was deemed desirable to undertake a survey of relevant institutions, initiatives and Parties to establish what currently exists in order to review the potential role of relevant databases and options for enhancement. This should also inform the element of Decision 13.114 (a) that involves defining the types of relevant analyses and syntheses of information on connectivity that would be of most value for CMS purposes.
8. This exercise entailed first defining the key connectivity-related conservation and research *objectives* that would serve CMS purposes. Doing so, indicates the *knowledge and understanding needed* to achieve each objective, and this, in turn, helps to define the types of *data and information needed* in each case to generate the required knowledge.
9. A survey format along these lines has been developed, and is reproduced in Annex 2 of this document. It summarizes the formal CMS mandates (in the Convention text and in COP Resolutions) that provide the basis for the enquiry, and then provides a template for responses divided into taxonomic categories and structured according to data and information about (a) the animal movements that constitute migration systems, (b) the networks of areas on which these movements depend, and (c) the obstacles and pressures that restrict and threaten connectivity.
10. The element of Decision 13.114 (a) that relates to options for ensuring sustainability, enhanced operability and coordination of identified databases, will be limited to databases held or managed under the auspices of CMS itself (see Decision 13.114 (b) below). It will be most sensibly addressed after the work described below under Decision 13.114 (b) has advanced, and should include consideration of ways to optimize accessibility to the data for potential users.

Proposal for next steps:

11. Following the completion and approval of the survey by the Sessional Committee of the Scientific Council at its sixth meeting, based on the suggestions already provided by the Working Group on Ecological Connectivity, the Secretariat will prepare a distribution list for the survey, establish a timeline for its launch, return and analysis of results, and distribute it accordingly in mid-2023.

Data/knowledge-holding and analysis “under CMS auspices” - Decision 13.114 (b)

12. For the most part, this task – which requires investigating options for creating relevant data- and knowledge-holding capabilities and for enhancing analysis capabilities – is to be addressed through the work described above in response to Decision 13.114 (a). The

additional implication of 13.114 (b) is, principally, to consider which future capabilities should rest specifically within the auspices of CMS, as opposed to being taken forward within some other context or entity, and on what basis this question might be decided.

13. It could be worth establishing some clarity about what 'holding' is understood to mean in this context. It may cover acquiring data and knowledge for the purposes of conducting specific analyses, but it could also involve operating a repository or platform that will be accessible on an ongoing basis to users in the CMS Family, and perhaps beyond (thus implying arrangements for access and maintenance).
14. A particular instance of the considerations raised by this request relates to the proposed Global Atlas of Animal Migration. The Scientific Council has taken initial steps towards the development of a concept for the Atlas. This requires further work, but if developed, in due course it might function as a coordinated repository and access platform for a variety of data sets relating to animal migration.
15. CMS has led some initiatives that may be regarded as examples of the kind of data or knowledge products that would be relevant to the scope of this question. These include the Central Asian Mammals Migration and Linear Infrastructure Atlas, the Global Initiative on Ungulate Migration, a strategic review of ecological networks (UNEP/CMS/COP11/Doc.23.4.1.2), a compilation of case studies of ecological networks (UNEP/CMS/COP11/Inf.22), and a compilation of articles on connectivity and migratory species (CMS/COP12/Inf.Doc.20).
16. CMS Family instruments also have resources such as the AEWA Critical Site Network Tool, tracking data on albatrosses and petrels held by ACAP and on bats compiled by Eurobats, a site network for marine turtles created by IOSEA, and others that are being identified in consultation with each instrument. The same would apply to other CMS initiatives such as the Energy Task Force. The CMS Secretariat has documented data sets held by CMS Family instruments, together with metadata on the data sources and the hosting and access arrangements.
17. National Reports to COPs should be considered for the contribution they may make to ecological connectivity. The current format, for example, allows Parties to indicate whether barriers to migration are a significant threat to migratory species in their country. There are also other response fields that may produce information on ecological networks, as well as the general 'key messages' section where Parties can provide narrative comment on connectivity-related issues.
18. Consideration of the kinds of knowledge-holding and analysis capabilities that CMS should develop or enhance in the future might generate suggestions for additional questions in the National Report format that could address specific connectivity issues. Options for these could draw on the concepts put forward by CMS for some of the indicators in the Kunming-Montreal Global Biodiversity Framework for monitoring trends in adoption of legislative, policy, cross-border cooperation, and restoration initiatives that specifically aim to improve ecological connectivity. (For details, see the section later in this document on "*Supporting implementation of connectivity-related aspects of the Global Biodiversity Framework*").

Proposal for next steps

19. Following analysis of results of the survey proposed in connection with Decision 13.114 (a), as described above, recommendations should be developed for the specific types of data-holding, analysis and data set management that are most appropriate for the work undertaken under the auspices of CMS.

Linkages between migratory species connectivity and ecosystem resilience - Decision 13.114 (c)

20. Components of the linkages between migratory species connectivity and ecosystem resilience are explored in Annex 3. Resilience can be a property of ecosystems but, in this context, it is relevant to consider it also as a property of populations of migratory species. Migration itself is an adaptive strategy that enhances the ability of species to be resilient to change, and its functioning depends directly on connectivity. Connectivity also supports the spreading of risk, and enhances the migratory options that animals may have in response to threats and opportunities. Annex 3 offers some initial specifics that address this in relation to the particular example of climate change.

Proposal for next steps

21. The Scientific Council will seek to coordinate further with the UK-led project on migratory species and climate change described in Annex 3, with a view to potential joint publication of the findings that relate specifically to connectivity. Other dimensions of the relationship between ecological connectivity and resilience (as it affects migratory species) beyond climate change could be explored further. Additional consideration of links between connectivity and resilience should feature, where relevant, in future research that addresses the priorities identified in response to Decision 13.114 (d) (see below).

Priorities for future research on connectivity - Decision 13.114 (d)

22. Information collated through the work undertaken in response to Decision 13.114 (a) (see earlier section above) will provide a good indication of data availability and the type of research needed in relation to (i) migration pathways, (ii) critical sites and (iii) threats to connectivity, thus responding to relevant elements of the Strategic Plan for Migratory Species 2015-2023 (Resolution 11.2 (Rev.COP12)) – namely, Target 7 on multiple anthropogenic pressures, Target 10 on critical habitats and sites and area-based conservation measures, and Target 15 on knowledge and technologies. The information will be organized according to “each of the major taxonomic groups of migratory wild animals covered by CMS”; but this taxonomic disaggregation of research issues, and the further disaggregation by regions that is also mentioned in Decision 13.114 (d), will, in most cases, require the development of a further phase of work.
23. In addition, a preliminary list of key areas for research has been compiled from existing Resolutions and is contained in Annex 4.

Proposal for next steps

24. Results of the survey under Decision 13.114 (a) will complement the list in Annex 4. The new Strategic Plan for Migratory Species (UNEP/CMS/COP14/Doc. 14.1) will provide further context for the setting of priorities.

Additional guidance on assessing threats to migratory species connectivity - Decision 13.114 (e)

25. Decision 13.114 (e) makes specific reference to “assessing threats to migratory species connectivity in particular priority situations identified by the work described in sub-paragraph (d)” (sub-paragraph (d) relates to the priorities for research on key connectivity issues affecting the conservation status of migratory wild animals).
26. The content and direction of this work will therefore be dependent on the ‘priority situations’ that the work under 13.114 (d) identifies, once that work has been undertaken. The scope would therefore most sensibly be elaborated at a later stage.

27. It could also be useful to take into account the link with the provisions of Decisions 13.131-133, which requested the Scientific Council to establish a working group on linear infrastructure, to consider standards, best practices, guidelines and advice on addressing the impacts of linear infrastructure on migratory species. The Secretariat compiled existing guidance, which is available in UNEP/CMS/COP14/Doc. 28.3.1.
28. Resolution 12.26 (Rev.COP13) also identified a number of categories of threats to connectivity that may be relevant to consider, including barriers to migration, anthropogenic additional mortality, fragmented resources and disrupted processes, genetic isolation, population non-viability, altered behaviour patterns, shifts in range caused by climate change or depletion of food or water resources, and inconsistencies in management across and beyond national jurisdictions. Increasing urbanisation in general has also been highlighted by the CMS Scientific Council Working Group on Ecological Connectivity.
29. Care may be needed in developing ideas for any new guidance to ensure that it is targeted meaningfully to the needs of Parties and others who are expected to use it. Some advance canvassing of end-user perspectives on this might form a useful part of this task.

Proposals for next steps

30. Suggestions for any 'priority situations' for which new guidance might be needed should be developed in light of the results of the work undertaken in response to Decisions 13.114 (a) and 13.1124 (d), once that work is completed. A synthesis of findings from national reports to COP14 may also shed light on any particular needs in this respect that have been expressed by Parties, and some follow-up on Party perspectives on this may be useful. Careful consideration should be given to the resourcing and capacity implications of any eventual commitment to generate new guidance products.

Activities to implement Resolution 12.07 (Rev.COP13) *The Role of Ecological Networks in the Conservation of Migratory Species*

31. The TOR for the Scientific Council Working Group on Ecological Connectivity include supporting the implementation of elements relating to the Council in Resolution 12.07 (Rev.COP13). They cite the following in particular:
 - supporting the development of further site networks within the CMS Family or other forums and processes that identify important sites for migratory species and promoting their internationally coordinated conservation and management (*paragraph 13*);
 - working with Parties and international and regional organizations in organizing regional and sub-regional workshops to promote the conservation and management of critical sites and ecological networks among Parties (*paragraph 24*); and
 - working closely with relevant organizations such as the European Space Agency and its Focal Points to support new technology developments, such as the ICARUS experiment, to track the movement and fate of migratory animals globally (*paragraph 31*).
32. Available capacity has not allowed significant progress to date within the Council on these items, but the intention behind these is reaffirmed for the forthcoming triennium.

Activities to implement connectivity-related aspects of the Global Biodiversity Framework

33. The TOR for the Scientific Council Working Group on Ecological Connectivity include supporting the implementation of the connectivity-related objectives of the GBF and the further development of its monitoring framework, through:
 - helping to develop or promote meaningful indicators on ecological connectivity in line with the processes agreed by COP15 of the Convention on Biological Diversity; and

- providing guidance to adequately reflect and implement the connectivity-related objectives of the GBF in CMS workstreams.

Guidance on GBF implementation

34. When the Working Group TOR were drawn up, the adoption of the Global Biodiversity Framework (GBF) was expected to occur earlier than in fact proved to be the case; it was not formally agreed until December 2022. While the 'implementation' period has been short, much progress has been made by the Secretariat – and is reported in UNEP/CMS/ScC-SC6/Doc.12.2.1.1 *Ecological Connectivity – Policy Aspects*.

GBF indicators

35. In parallel with the development of the GBF itself, there were processes contributing to the development of the accompanying Monitoring Framework. CMS made various submissions and attended technical meetings on proposed indicators for this Framework. This included specific proposals from CMS for indicators on connectivity, developed initially at a special workshop convened by CMS in Bonn in March 2021. These proposals were presented to the 5th Meeting of the Sessional Committee of the CMS Scientific Council (28 June – 9 July 2021, online) in Document UNEP/CMS/ScC-SC5/Doc.4.2 and were submitted to the Convention on Biological Diversity (CBD) on various occasions. CMS continued working with other collaborating organizations, notably the Center for Large Landscape Conservation and the United Nations Environment Programme World Conservation Monitoring Programme (UNEP-WCMC), on the development of connectivity indicators. This included the development and submission of a [report](#) on "Ecological Connectivity Indicators for measuring progress towards the post-2022 Global Diversity Framework" and the organization of a webinar, which was held on 31 October 2022.
36. Two of the CMS-proposed indicators are now included as proposed 'complementary indicators' in the adopted Monitoring Framework. The 'CMS connectivity indicator' is listed under GBF Goal A, and relates to the "Conservation status of terrestrial and aquatic migratory species, as a proxy indicator of connectivity"; while the "extent to which protected areas and other effective area-based conservation measures" (OECMs) cover Key Biodiversity Areas (KBAs) that are important for migratory species" is listed under GBF Target 3.
37. 'Complementary indicators' are optional indicators for thematic or in-depth analysis of individual goals and targets. There is therefore not the same level of expectation regarding universal national reporting on them as there is for those that are categorized as 'headline indicators'. All the listed indicators are described in the Framework as "proposed", since, although the Monitoring Framework was adopted at the same time as the GBF in December 2022, further work is needed to make many of the indicators operational, and the Monitoring Framework, as a whole, is subject to a process of review before it is finalized in time for the 16th meeting of the CBD Conference of Parties in 2024.
38. Parties to the CBD, at its COP15, decided to establish an Ad Hoc Technical Expert Group (AHTEG), with a time-bound mandate until the 16th meeting of the COP, to advise on the further operationalization of the GBF Monitoring Framework. CMS is not directly represented, as such, in the list of selected experts of the AHTEG, but the list includes individuals who have close working relationships with the Convention, including the Scientific Council, and there will be opportunities for collaborative input on aspects of the work as it develops. The CBD Secretariat has also created an online discussion forum on issues related to the Monitoring Framework, offering another avenue for input.

Activities to implement Decision 13.13 *Cooperation between the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and CMS*

39. The Scientific Council Working Group on Ecological Connectivity participated in the review of the draft initial scoping report for a methodological assessment of integrated biodiversity-inclusive spatial planning and ecological connectivity for consideration by IPBES-10. Further details are contained in UNEP/CMS/COP14/Doc.18.2 *Cooperation with the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)*.

Discussion and analysis

40. The revision of this document and its annexes reflects amendments proposed by the Scientific Council Working Group on Ecological Connectivity at its first meeting held on 22 June 2023 and through further consultations.

Recommended actions

41. The Scientific Council is recommended to review the reports in Annexes 1 – 4 and provide guidance to the Scientific Council and Secretariat as regards further work on these topics.

ANNEX 1

DATABASES TO SUPPORT RELEVANT ANALYSES AND SYNTHESSES OF INFORMATION ON CONNECTIVITY – DECISION 13.114 (A)

1. One of the key data sets of relevance is the ***Eurasian-African Bird Migration Atlas***. This Atlas was formally launched in May 2022 as an online repository (<https://migrationatlas.org/>) of data on ringing recoveries collated through the EURING Databank hosted by the British Trust for Ornithology and Movebank hosted by the Max Planck Institute.
2. Of the 300 species included in the Atlas (with data in some cases going back over 100 years), some 140 species are covered by an online mapping tool that overlays movement patterns identified through bird ringing with tracks obtained through satellite transmitters, GPS-GSM tags or geo-locators. Linked to this are four research modules that provide analyses addressing different aspects of bird migration. One of these modules, led by Roberto Ambrosini of the University of Milan, specifically addresses connectivity; but two others may also be relevant – the module that looks at long-term changes in migration patterns caused, inter alia, by climate change, and the one that looks at the distribution of ‘hotspots’ of intentional bird killing (which may act as barriers to connectivity).
3. There should be scope for the Scientific Council to elaborate thinking and advice on the further development and use of these modules, and the data in general, to support connectivity-related objectives. Resolution 12.26 (Rev.COP13) (paras 6-7) has invited Parties, other States and relevant organizations to provide support for doing so.
4. One potential line of investigation might be to explore the scope for linking information in systems such as the Eurasian-African Bird Migration Atlas with selected base maps and geographic issue data layers available from Esri’s ArcGIS ‘*Living Atlas of the World*’ (<https://livingatlas.arcgis.com/en/home/>), to overlay, for example, with infrastructure, hydroperiods, or other factors linked to connectivity. Another example of analysis possibilities is described in a recent paper by Fattorini et al. (2023) on “Eco-evolutionary drivers of avian migratory connectivity”.
5. Beyond the Atlas, there may be additional ways of applying data directly from the Movebank database in its own right for particular purposes, and this could be explored.
6. One of the projects feeding tracking data to Movebank is the Max Planck Institute’s ***ICARUS*** (International Cooperation for Animal Research Using Space) project. Since March 2022, however, the cooperation with Russia that enabled the role of the International Space Station in this has been suspended. In the meantime a new initiative, ***MoveApps*** (https://www.icarus.mpg.de/115463/news_publication_18956292_transferred?c=2482) has provided enhanced accessibility to analytical tools, and could usefully be examined for potential connectivity-related applications.
7. Other avian atlas or related dataset examples created in the Americas include the Smithsonian Migratory Bird Center and US Geological Survey’s ***Migratory Connectivity Project*** <http://migratoryconnectivityproject.org/>, the Smithsonian Migratory Bird Center’s ***Shorebird Science and Conservation Collective*** <https://nationalzoo.si.edu/migratory-birds/shorebird-science-and-conservation-collective>, the National Audubon Society’s ***Migratory Bird Initiative*** <https://www.audubon.org/conservation/migratory-bird-initiative>, and Birds Canada’s ***Motus Wildlife Tracking System*** <https://motus.org/>.
8. Another key tool and data resource, developed through CMS itself, is the ***Central Asian Mammals Migration and Linear Infrastructure Atlas*** (CMS Technical Series No. 41), launched in 2019. For Asiatic Cheetah, Snow Leopard, antelopes, deer, gazelles, wild horses

and yaks, maps of each species' distribution range are combined with maps of different types of linear infrastructure (including railways, fences and pipelines), highlighting where problems for connectivity may be expected. A number of specialized data sets were used to feed raw data into this. The Atlas is intended to help inform the planning and implementation of future wildlife-friendly infrastructure developments, and to support adaptation of existing ones to mitigate their barrier effects. Practical pathways for achieving these benefits could be further explored.

9. CMS and a consortium of 91 other partners have recently launched an *Ungulates Atlas* in the context of the **Global Initiative on Ungulate Migration (GIUM)**, to make freely available to policy and decision makers the best available science on mapped ungulate migrations around the world. This is a direct response to threats from habitat fragmentation, and it offers new opportunities for use in promoting connectivity for these species (for example, targeting fences that need to be modified or removed, positioning road-crossing structures, adjusting energy development footprints and conserving habitat on critical migration routes).
10. Resolution 12.26 (Rev.COP13) (paras 6-7) has also invited Parties, other States and relevant organizations to provide support for the **Migratory Connectivity in the Ocean (MiCO)** system (<https://mico.eco/>), launched as a prototype in 2019 by the Global Ocean Biodiversity Initiative (GOBI) and a MiCO Consortium of data repositories, national observing systems, taxa conservation groups, museums, NGOs, universities, individuals, intergovernmental organizations and UN bodies. The 4th meeting of the Scientific Council's Sessional Committee also recommended developing links with MiCO.
11. MiCO's focus is to deliver free and easily accessible (online open access), actionable geospatial knowledge of migratory marine animal movements (distribution and connectivity, using network models that describe how various parts of a species migratory cycle are connected). The system is notable for working with aggregated knowledge rather than just data, and although it relates specifically to the marine environment, there is interest in seeing how its general approach might be applied in the terrestrial context too.
12. COP13 has also drawn attention to the potential relevance of the **Ocean Biogeographic Information System (OBIS)** of UNESCO's Intergovernmental Oceanographic Commission, which integrates millions of marine species occurrence records from thousands of data sets to make them available as a single data set.
13. In Resolution 12.26 (Rev.COP13), CMS Parties acknowledged the relevance of **AEWA's Critical Site Network Tool (CSN)** as an open-access web portal "providing a strong basis for identifying ecological networks and emphasizing their connectivity aspects, while also providing insights into climate change vulnerability and informing conservation decision-making at site, national and international levels". COP Decision 13.113 invited Parties to support the further redevelopment and application of CSN as well as its development and application to cover other major flyways. Specific connectivity-related applications in this context could usefully be fleshed out in detail as part of the Scientific Council's work.
14. Also in relation to waterbirds, further relevant uses of data from the **International Waterbird Census** (IWC, coordinated by Wetlands International - <https://www.wetlands.org/knowledge-base/international-waterbird-census/>) could also be explored. BirdLife International's **Seabird Tracking Database** (<http://www.seabirdtracking.org/>) could be examined in the same way, together with data sets held by ACAP on albatrosses and petrels, Manomet's **International Shorebird Survey** (<https://www.manomet.org/project/international-shorebird-survey/>), WHSRN's **Important Shorebird Sites** (<https://whsrn.org/about-shorebirds/important-sites-map/>) and the **Migratory Shorebird Project** (<https://migratoryshorebirdproject.org/>).
15. The Marine Mammal Protected Areas Task Force has created a searchable **database of Important Marine Mammal Areas (IMMAs)**, which contains details of all such areas that have currently been identified - <https://www.marinemammalhabitat.org/imm/imm-searchable->

- [database/](#). (IMMAs are defined as discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation). The **World Database of Key Biodiversity Areas** (<https://www.keybiodiversityareas.org/>) is also relevant here. WWF and partners also recently published a [map of blue corridors for whales](#), based on a compilation of satellite tagging data.
16. A similar concept to the IMMAs work has guided the identification of Important Shark and Ray Areas (ISRAs), defined as “discrete, three-dimensional portions of habitat, important for one or more shark species, that are delineated and have the potential to be managed for conservation”. An international team of scientists, conservationists and policymakers has created a **web-GIS ISRA Atlas**, with downloadable data layers - <https://sharkrayareas.org/e-atlas/>.
 17. A **Global Swimways** partnership project led by IUCN through the Cambridge Conservation Initiative from 2019-2021 identified potential swimways according to the presence of migratory freshwater fish and the migrations they undertake. The intention was to visualize these with an online interactive map explorer and a tool to highlight the presence of fish migration routes near existing or planned infrastructure, and then to develop a full-scale project to map all global swimways using a broader set of metrics and improved data. Outputs from this pilot include an online interactive map explorer (<http://www.explorer.globalswimways.org/>) and a manuscript proposing development of a Global Swimways program and next steps towards its development (<https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/fee.2550>). UNEP-WCMC, the World Fish Migration Foundation and WWF were partners in the project.
 18. In the meantime, Wetlands International Europe in 2022 launched a **Trans-European Swimways Network**, which aims to draw attention to the importance of habitat connectivity for the conservation of migratory freshwater fish. The Network will bring together stakeholders for transboundary information exchange and joint projects to improve available information - <https://europe.wetlands.org/news/wetlands-international-europe-launches-swimways-network-aimed-at-boosting-migratory-fish-conservation/>.
 19. Eurobats published a review of ringing data for 36 bat species in 2005 (<https://www.nhbs.com/bat-migrations-in-europe-book>). A data set of bat communities from the Atlantic forests of Brazil, Paraguay, Argentina and Uruguay was published for 98 species in 2017 (<https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecy.2007>). Further investigations could be desirable to discover other relevant sources covering bats.
 20. The Scientific Council in the past has considered the issue of **movement tracking data sets for marine turtles**. Seaturtle.org is one platform that has established a Satellite Tracking and Analysis Tool (STAT) and a ‘Maptool’; while CMS itself, in collaboration with the Department of Environment and Science in Queensland, Australia, has more recently launched **TurtleNet**, an interactive atlas that shows nesting, courtship, feeding and migration routes of marine turtles - <https://www.cms.int/en/news/launch-interactive-atlas-%E2%80%9Cturtlenet%E2%80%9D-milestone-marine-turtle-conservation>.
 21. In relation to impediments to connectivity, the **European Barrier Atlas** (<https://amber.international/european-barrier-atlas/>) is a pan-European atlas of in-stream river barriers, documenting 630,000 unique barrier records from existing data sets, and modelling a further 400,000+ additional barrier points. The project is accompanied by tools developed to help resource managers quantify stream fragmentation, assess barrier impacts and benefits, and make informed decisions on existing and future barriers (see <https://amber.international/wp-content/uploads/2020/11/AMBER-Policy-Brief-2.pdf>). This degree of detail may not be feasible in other regions, but its general approach could perhaps be replicable.
 22. In the context of light pollution as a potential impediment to connectivity, two particular sources may be worth investigating. These are a **world atlas of artificial night sky brightness**

(<https://www.science.org/doi/10.1126/sciadv.1600377>), and a **global atlas of artificial light at night under the sea** (<https://online.ucpress.edu/elementa/article/9/1/00049/119144/A-global-atlas-of-artificial-light-at-night-under>). There is also a more locally-based study focused on the northern Gulf of Aqaba in the Red Sea (<https://www.nature.com/articles/srep42329>).

23. Turning to data on positive connectivity measures, in 2016, UNEP-WCMC, working with IUCN and others, conducted an online survey to identify connectivity conservation initiatives to be compiled in a **Global Connectivity Conservation Database (GCCD)**. The survey was promoted to CMS Parties via CMS Notification 2016/006. No resulting database appears at this stage to be accessible, but this could usefully be followed up.
24. More recently, UNEP-WCMC, working with IUCN, the Center for Large Landscape Conservation and others has proposed the development of a **World Database on Ecological Corridors**, linked to 'Protected Planet' (<https://www.protectedplanet.net/en>). Protected Planet is the authoritative source of data on protected areas and other effective area-based conservation measures (OECMs). It draws on extensive efforts of governments and other stakeholders to map, monitor and report data on protected areas and OECMs. Through the Protected Planet website, users can explore the World Database on Protected Areas (WDPA), World Database on OECMs, Global Database on Protected Area Management Effectiveness (GD-PAME), and a wealth of associated information. For parts of the eastern US and Canada, GEO BON has built a dashboard for projects on ecological connectivity - <https://ecologicalconnectivity.com/explore>.
25. The resource, **Linkage Mapper**, is not a data set, but is relevant as an automated GIS toolbox designed to support regional wildlife habitat connectivity analyses. It consists of six tools that work with algorithms of GIS maps of 'core habitat areas' and the 'resistances' (energy cost and mortality risk) of moving between grid cells in the map. See <https://consbio.org/software/linkage-mapper/>.
26. Other platforms and facilities that may be worth investigating could include the Global Biodiversity Information Facility (GBIF), the Global Earth Observation System of Systems (GEOSS), the European Marine Observation and Data Network (EMODnet), the Ocean Tracking Network, the Animal Telemetry Network, the European Telemetry Network, the Arctic Animal Movement Archive and the European Commission's Digital Observatory for Protected Areas.

ANNEX 2

CMS CONNECTIVITY DATA SOURCES SURVEY - DECISION 13.114 (D)

1. Introduction and purpose of this survey

The CMS Parties, in COP Decision 13.114 (2020), requested the Scientific Council, subject to the availability of resources, to undertake a number of tasks for enhancing the scientific understanding of connectivity issues in relation to migratory species. These tasks include investigating the potential contribution of relevant databases (Dec.13.114 a), reviewing options for enhancing data coordination (Dec.13.114 b) and analysis capabilities, and considering future research priorities (Dec.13.114 d).

To frame this work appropriately, there is a need at the outset to develop a clear description of the types of data and information that may be relevant to the purpose of these tasks, and to establish where sources of such data and information may exist. The scope of what is 'relevant' is defined in the first instance by specific mandates related to connectivity contained in the Convention text and in Resolutions of the COP, relating to (a) the animal movements that constitute migration systems, (b) the networks of areas on which these movements depend, and (c) the obstacles and pressures that restrict and threaten connectivity. (A summary of the individual mandates is given in section 3 at the end of this Annex).

The present survey aims to develop a full but targeted picture of what may be available as inputs to this work. This is a key opportunity, for all who have a stake in relevant research and information management, to demonstrate the utility of their work towards a rapidly escalating global agenda on connectivity conservation, including the political and funding impetus that will be driven now by the Kunming-Montreal Global Biodiversity Framework. It is also highly opportune to frame this in the context of new cost-efficient collaborations that could be enabled through CMS.

For each of the five main taxonomic groups of migratory animals, and for each of the three topics covered by CMS mandates mentioned above, tables in the survey template indicate key conservation and research objectives, the knowledge and understanding needed to achieve these objectives, and examples of the types of data and information needed in each case to generate the knowledge concerned.

2. How to complete the survey

For each section of the survey, where applicable, you are invited to provide details of existing data and information sources that match any of the specific needs defined. This should focus on any significant databases/data sets you hold, or data-gathering/data-sharing processes you operate, which can support analyses and syntheses of information on **connectivity** in any of the contexts listed in the tables. In each case, please enter your response in the section addressing the particular taxonomic group(s) concerned. For data sets or analyses that are not confined to any particular taxonomic group, you may describe these in a supplementary text.

Where the tables in the framework on the following pages refer to "types of data and information sources", this can refer to repositories of raw data; data that are aggregated or summarized (for example, totals, averages, proportions, expressions of trends, etc.); map and plot-based data, including overlays; imagery, both real and virtual (i.e., including model simulations); and text-based information (e.g., observation records, analysis reports). The intention is to take an inclusive approach.

Respondents answering on behalf of **CMS Contracting Parties** and/or their relevant implementing agencies are invited to specify the data and information sources **used** in this context, where such respondents may not necessarily be the data holders themselves.

➤ **For each data/information source you wish to identify, please answer the following questions, as far as you are able:**

1. What type(s) of data /information source do you hold? (See the examples in column C).
2. Which species does this relate to?
3. Have you done /do you do any analysis (including mapping, informing indicators etc) using these data with respect to the key knowledge and understanding needs identified in column B? Please indicate which of the needs are addressed by this.
4. Are the results directly applied in practice to the shaping or implementation of spatial planning or migratory species conservation policies in your country/area? If yes, please describe.
5. Are there types of analysis using the data you hold (other than those mentioned in response to question 3) that could support the objectives in Column A? If yes, please describe.
6. Where/by whom is the data/information held?
7. How/by whom can the data/information be accessed?
8. Are there opportunities for enhanced collaboration (e.g., pooling data sets, undertaking joint analyses) towards improved understanding of connectivity issues relating to migratory species in the CMS context? If yes, please describe.

(i) Connectivity data needed for BIRDS

A. Migration systems - patterns and pathways of animal movements

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Discovering individual migratory bird movements	Movement distances/ranges	<ul style="list-style-type: none"> - Ringing recoveries - Colour marking observation records - Radio/satellite tracking data - GPS/GSM data (collected via loggers) - Light level and atmospheric pressure geo-locator data - Covariates of individually identified birds: e.g., sex- and age-classes, morphometrics, conditions (e.g., body mass, muscle and fat scores, moult phase). Availability of such variables at first capture and subsequent encounters
	Movement timings (departure/ stopover/ arrival; changes in these from year to year)	<ul style="list-style-type: none"> - Satellite tracking data - GPS/GSM data (collected via loggers) - Light level and atmospheric pressure geo-locator data
Describing whole migration systems, and mapping the pathways	Population-level movement patterns, in space and time	<ul style="list-style-type: none"> - Colour marking observation records - Satellite tracking data - GPS/GSM data (collected via loggers) - Light level and atmospheric pressure geo-locator data - Radar data - Nocturnal migration audio recordings - Genetic and stable isotope data - Digital flyway mapping representations, including both outer envelopes and pinch-points or 'bottlenecks' - Systematic monitoring counts of birds at migration passage "hotspots", and behavioural observation records, to illuminate the functioning of their migration patterns and particular connectivity vulnerabilities

B. Networks of areas, functioning to support connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Identifying areas that play a key role in the connectivity of bird migration systems	Location of relevant areas	<ul style="list-style-type: none"> - Ground and aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers)
	Extent/boundaries of areas	<ul style="list-style-type: none"> - Ground and aerial observation records
	Abundance of birds in areas	<ul style="list-style-type: none"> - Ground and aerial observation records
	Temporal use of areas	<ul style="list-style-type: none"> - Records of ground and aerial observations of areas/sites - Satellite tracking data - GPS/GSM data (collected via loggers) - Radio tracking data (nanotags)

	Ecological use of areas (feeding, roosting, etc.), and their relative importance	- Ground and aerial observation records
Identifying links and interdependencies between areas forming a network	Relationship between population-level movement patterns (see A above) and identified areas supporting migratory bird species	- Overlays of data on important areas with data on migration movements (from A above)
Strategies for conserving coherent networks of areas that function to support migratory bird connectivity	Sufficiency of coverage of protected and conserved areas vis-a-vis birds' occurrence (at population level) throughout the annual cycle	- Boundaries and coordinates of areas - Overlays of data on areas of importance with data on areas under protection/conservation
	Level of protection in place for each area	- Lists of areas nominated or designated under relevant frameworks
	Level of conservation management in place for each area	- Lists of areas covered by appropriate and effectively implemented management frameworks - Analyses of management effectiveness
	Conservation and management measures in individual areas that are aimed at supporting/ enhancing/ restoring connectivity	- Relevant extracts from area management plans - Case studies of projects for enhancement or restoration of connectivity for birds

C. Threats to connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Minimizing and mitigating threats to connectivity that result from obstacles and barriers to movement, such as infrastructure (including energy); illegal killing at 'bottleneck' sites or other migration 'hotspots'; avoidance zones created by light pollution, noise pollution or other disturbances; and other causes	Location and extent (existing and planned barriers)	- Infrastructure mapping - Development plans
	Type of resulting impact	- Mortality data: field observation records, Camera observation records - Behavioural data: field observation records; radio tracking data; satellite tracking data
	Population level of impact	- Bird demographic data including additive mortality: colour marking observation records, field observation records - Mortality statistics from illegal killing at 'bottleneck' sites or other migration "hotspots"
	Cumulative impacts across the range	- Bird demographic data including additive mortality: colour marking observation records, field observation records
Minimizing and mitigating threats to connectivity that result from habitat fragmentation that restricts movements of migratory bird species	Extent and severity of fragmentation impacts on migratory birds	- River fragmentation data related to migratory bird movements - Forest fragmentation data related to migratory bird movements - Fragmentation data for other ecosystems related to migratory bird movements
Minimizing and mitigating threats to connectivity that result from climate change-related causes	Effects on migratory birds of fragmentation and other habitat loss impacts on connectivity caused by climate change, e.g., through sea level rise, wildfire forest destruction, river dry-up, melting sea-ice, etc.	- Information on climate change-induced habitat changes, related to bird migration systems
	Phenological asynchrony effects, disrupting trophic chains	- Data on shifts in migration timing, related to shifts in timing of predators, prey, food & water sources, survivable temperature ranges, etc.
	Climate-related migration behaviour changes, e.g., shifts of range	- Ground and aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers)

Minimizing and mitigating threats to connectivity that result from inconsistencies in management across and beyond national jurisdictions	Compatibility of (or inconsistencies between) relevant management regimes between countries sharing any bird migration flyway in common	<ul style="list-style-type: none"> - Data on programmes to harmonize transboundary management regimes (including transboundary protected areas, transboundary river commissions, connectivity-related initiatives by CMS Family instruments, etc.) - Relevant sections in national reports to MEAs
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(ii) Connectivity data needed for MAMMALS

A. Migration systems - patterns and pathways of animal movements

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Discovering individual migratory mammal movements	Movement distances/ranges	<ul style="list-style-type: none"> - Mark/recapture data - Camera trap data - Radio/satellite tracking data - GPS/GSM data (collected via loggers)
	Movement timings (departure/ arrival; changes in these from year to year)	<ul style="list-style-type: none"> - Radio/satellite tracking data - GPS/GSM data (collected via loggers)
Describing whole migration systems, and mapping the pathways	Population-level movement patterns, in space and time	<ul style="list-style-type: none"> - Satellite tracking data - GPS/GSM data (collected via loggers) - Aerial monitoring - Digital migration route representations - Field observation records
	Links to habitat type/ ecological condition (rainfall seasons, ocean temperatures, etc.)	<ul style="list-style-type: none"> - Field observation records - Habitat mapping (for correlation to animal data) - Ecosystem seasonality data (for correlation to animal data)

B. Networks of areas, functioning to support connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Identifying core areas and ecological corridors that play a key role in the connectivity of mammal migration systems	Location of relevant areas and corridors	<ul style="list-style-type: none"> - Ground/sea and aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers)
	Extent/boundaries of areas and corridors	<ul style="list-style-type: none"> - Ground/sea and aerial observation records
	Abundance of mammals in areas	<ul style="list-style-type: none"> - Ground/sea and aerial observation records
	Temporal use of areas and corridors	<ul style="list-style-type: none"> - Records of ground/sea and aerial observations of areas/sites - Satellite tracking data - GPS/GSM data (collected via loggers)
	Ecological use of areas (feeding, bathing, congregating, etc.), and their relative importance	<ul style="list-style-type: none"> - Ground/sea and aerial observation records

Identifying links and interdependencies between areas forming a network	Relationship between population-level movement patterns (see A above) and identified areas supporting migratory mammal species	- Overlays of data on important areas/corridors with data on migration movements (from A above)
Strategies for conserving coherent networks of areas that function to support migratory mammal connectivity	Sufficiency of coverage of protected and conserved areas vis-a-vis mammals' occurrence (at population and network level) throughout the annual cycle	- Boundaries and coordinates of areas and corridors - Overlays of data on areas of importance with data on areas under protection/conservation
	Level of protection in place for each area, including connecting corridors	- Lists of areas nominated or designated under relevant frameworks
	Level of conservation management in place for each area, including connecting corridors	- Lists of areas covered by appropriate and effectively implemented management frameworks
	Conservation and management measures in individual areas, including corridors, that are aimed at supporting/enhancing/restoring connectivity	- Relevant extracts from area management plans - Case studies of projects for enhancement or restoration of connectivity for mammals

C. Threats to connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Minimizing and mitigating threats to connectivity that result from obstacles and barriers to movement, such as infrastructure (including energy); poaching or other illegal killing at migration 'hotspots'; avoidance zones created by disturbance, underwater noise, etc.; and other causes	Location and extent (existing and planned barriers)	- Infrastructure mapping - Development plans
	Type of resulting impact	- Mortality data: field observation records, camera observation records - Behavioural data: field observation records; radio tracking data; satellite tracking data
	Population level of impact	- Mortality data - Population trends
	Cumulative impacts across the range	- Demographic data - Distribution change data
	Success of connectivity restoration initiatives	- Data on relevant restoration initiatives e.g., transport underpasses/overpasses, removal of fences, etc.
Minimizing and mitigating threats to connectivity that result from habitat fragmentation that restricts movements of migratory mammal species	Extent and severity of fragmentation impacts on migratory mammals	- Forest fragmentation data related to migratory mammal movements - Fragmentation data for other ecosystems related to migratory mammal movements
	Success of connectivity restoration initiatives	- Data on relevant restoration initiatives e.g., ecological corridor creation
Minimizing and mitigating threats to connectivity that result from climate change-related causes	Effects on migratory mammals of fragmentation and other habitat loss impacts on connectivity caused by climate change e.g., through sea level rise, wildfire forest destruction, river dry-up, melting sea-ice, etc.	- Information on climate change-induced habitat changes, related to mammal migration systems
	Phenological asynchrony effects, disrupting trophic chains	- Data on shifts in migration timing, related to shifts in timing of predators, prey, food & water sources, survivable temperature ranges, etc.
	Climate-related migration behaviour changes, e.g., shifts of range	- Ground and aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers)

Minimizing and mitigating threats to connectivity that result from inconsistencies in management across and beyond national jurisdictions	Compatibility of (or inconsistencies between) relevant management regimes between countries sharing any mammal migration pathway in common	<ul style="list-style-type: none"> - Data on programmes to harmonize transboundary management regimes (including transboundary protected areas, transboundary river commissions, connectivity-related initiatives by CMS Family instruments, etc.) - Relevant sections in national reports to MEAs
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(iii) Connectivity data needed for REPTILES

A. Migration systems - patterns and pathways of animal movements

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Discovering individual migratory reptile movements	Movement distances/ranges	<ul style="list-style-type: none"> - Tagging recoveries - Satellite tracking data - GPS/GSM data (collected via loggers)
	Movement timings (breeding/ dispersing, etc.)	<ul style="list-style-type: none"> - Records of field observations at nesting beaches - Satellite tracking data - GPS/GSM data (collected via loggers)
Describing whole migration systems, and mapping the pathways	Population-level movement patterns, in space and time; disaggregated by sex & age	<ul style="list-style-type: none"> - Satellite tracking data - GPS/GSM data (collected via loggers) - Digital migration route mapping representations/models

B. Networks of areas, functioning to support connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Identifying areas that play a key role in the connectivity of reptile migration systems	Location of breeding, nesting, nursery and other key areas used by migratory reptiles	<ul style="list-style-type: none"> - Ground/sea and aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers)
	Extent/boundaries of areas	<ul style="list-style-type: none"> - Ground/sea and aerial observation records
	Abundance of reptiles in areas	<ul style="list-style-type: none"> - Ground/sea and aerial observation records
	Temporal use of areas	<ul style="list-style-type: none"> - Ground/sea and aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers)
Identifying links and interdependencies between areas forming a network	Relationship between population-level movement patterns (see A above) and identified areas used by migratory reptile species	<ul style="list-style-type: none"> - Overlays of data on important areas with data on migration movements (from A above)
	The nature of ecological connectivity factors enabling/ restricting migratory movements of reptiles	<ul style="list-style-type: none"> - Correlations of migratory route data and life-cycle movements with data on e.g., ocean currents and other relevant factors
Strategies for conserving coherent networks of areas that function to support migratory reptile connectivity	Sufficiency of coverage of protected and conserved areas vis-a-vis reptiles' occurrence (at population level) throughout the annual cycle	<ul style="list-style-type: none"> - Boundaries and coordinates of areas - Overlays of data on areas of importance with data on areas under protection/conservation
	Level of protection in place for each area	<ul style="list-style-type: none"> - Lists of areas nominated or designated under relevant frameworks

	Level of conservation management in place for each area	- Lists of areas covered by appropriate and effectively implemented management frameworks
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C. Threats to connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Minimizing and mitigating threats to connectivity that result from obstacles and barriers to movement, such as coastal developments, bycatch and boating collision risk areas; avoidance zones created by light pollution or other disturbances; and other causes	Location and extent (existing and planned obstacles/ pressure zones)	- Mapping of aquatic human-reptile conflict zones - Development plans
	Type of resulting impact	- Mortality data - Behavioural data: field observation records; radio tracking data; satellite tracking data
	Population level of impact	- Mortality data - Population trends
	Cumulative impacts across the range	- Demographic data - Distribution change data
Minimizing and mitigating threats to connectivity that result from climate change-related causes	Effects on migratory reptiles of habitat loss impacts on connectivity caused by climate change e.g., through sea level rise (affecting the connections between nesting beaches and the sea)	- Information on climate change-induced habitat changes, related to reptile migratory life cycles
	Phenological asynchrony effects, disrupting trophic chains	- Data on shifts in migration timing, related to shifts in timing of food sources, survivable temperature ranges, etc.
	Climate-related migration behaviour changes, e.g., shifts of range	- Aerial observation records - Satellite tracking data - GPS/GSM data (collected via loggers) - Overlays of migration pathway data with data on e.g., ocean temperatures and currents
Minimizing and mitigating threats to connectivity that result from inconsistencies in conservation strategies and standards across and beyond national jurisdictions	Compatibility of (or inconsistencies between) relevant conservation strategies and standards between countries sharing any reptile migration system in common	- Data on programmes to harmonize relevant conservation regimes - Relevant sections in national reports to MEAs

(iv) Connectivity data needed for FISH

A. Migration systems - patterns and pathways of animal movements

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Discovering individual migratory fish movements	Movement distances/ranges	- Fish catch data - Sampling surveys (e.g., electrofishing) - Tagging/ marking recoveries - Telemetry (sonic, radio, satellite)

	Movement timings (spawning/ maturing/ leaving/returning etc.)	<ul style="list-style-type: none"> - Field observation records - Fish catch data - Sampling surveys (e.g., electrofishing) - Telemetry (sonic, radio, satellite)
Describing whole migration systems, and mapping the pathways	Population-level movement patterns, in space and time	<ul style="list-style-type: none"> - Aggregations of occurrence data (see above) - Digital migration route mapping representations/models

B. Networks of areas, functioning to support connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Identifying areas that play a key role in the connectivity of fish migration systems	Location of spawning, nursery, maturing and other key areas used by migratory fish	<ul style="list-style-type: none"> - Field observation records - Fish catch data - Sampling surveys (e.g., electrofishing) - Telemetry (sonic, radio, satellite)
	Extent/ boundaries of areas	<ul style="list-style-type: none"> - Field observation records - Fish catch data - Sampling surveys (e.g., electrofishing) - Telemetry (sonic, radio, satellite)
	Abundance of fish in areas	<ul style="list-style-type: none"> - Fish catch data - Sampling surveys (e.g., electrofishing)
	Temporal use of areas	<ul style="list-style-type: none"> - Field observation records - Fish catch data - Telemetry (sonic, radio, satellite)
Identifying links and interdependencies between areas forming a network	Relationship between population-level movement patterns (see A above) and identified areas used by migratory fish species	<ul style="list-style-type: none"> - Overlays of data on important areas with data on migration movements (from A above)
	The nature of ecological connectivity factors enabling/ restricting migratory movements of fish	<ul style="list-style-type: none"> - Correlations of migratory route data and life-cycle movements with data on e.g., ocean currents and other relevant factors
Strategies for conserving coherent networks of areas that function to support migratory fish connectivity	Sufficiency of coverage of protected and conserved areas vis-a-vis migratory fish occurrence (at population level) throughout the annual cycle	<ul style="list-style-type: none"> - Boundaries and coordinates of areas - Overlays of data on areas of importance with data on areas under protection/ conservation
	Level of protection in place for each area	<ul style="list-style-type: none"> - Lists of areas nominated or designated under relevant frameworks
	Level of conservation management in place for each area	<ul style="list-style-type: none"> - Lists of areas covered by appropriate and effectively implemented management frameworks
	Conservation and management measures in individual areas or river systems that are aimed at supporting/ enhancing/ restoring connectivity	<ul style="list-style-type: none"> - Relevant extracts from area management plans - Case studies of projects for enhancement or restoration of connectivity for fish

C. Threats to connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Minimizing and mitigating threats to connectivity that result from obstacles	Location and extent (existing and planned obstacles/ pressure zones)	<ul style="list-style-type: none"> - River infrastructure mapping - Development plans

and barriers to movement, such as river infrastructure (dams, weirs, hydroelectricity plants, etc.); overfishing at migration 'hotspots'; and other causes	Type of resulting impact	- Mortality data - Behavioural data: field observation records - Recruitment data
	Population level of impact	- Mortality data - Population trends
	Cumulative impacts across the range	- Demographic data - Distribution change data
	Success of connectivity restoration initiatives	- Data on relevant restoration initiatives e.g., fish passes, removal of dams, etc.
Minimizing and mitigating threats to connectivity that result from habitat fragmentation that restricts movements of migratory fish species	Extent and severity of fragmentation impacts on migratory fish	- River fragmentation data related to migratory fish movements
	Success of connectivity restoration initiatives	- Data on relevant restoration initiatives e.g., fish passes, removal of dams, environmental flow allocations, water quality improvements, riparian habitat restoration, other river/floodplain restoration efforts, etc.
Minimizing and mitigating threats to connectivity that result from climate change-related causes	Effects on migratory fish of habitat loss impacts on connectivity caused by climate change e.g., through drying of rivers	- Information on climate change-induced habitat changes, related to fish migratory life cycles
	Phenological asynchrony effects, disrupting trophic chains	- Data on shifts in migration timing, related to shifts in timing of predators or food sources, survivable temperature ranges, etc.
	Climate-related migration behaviour changes, e.g., shifts of range	- Field observation records - Overlays of migration pathway data with data on e.g., ocean temperatures and currents
Minimizing and mitigating threats to connectivity that result from inconsistencies in management across and beyond national jurisdictions	Compatibility of (or inconsistencies between) relevant management regimes between countries sharing any fish migration pathway in common	- Data on programmes to harmonize transboundary management regimes (including transboundary protected areas, transboundary river commissions, commitments to keep river sections/ swimways connected, connectivity-related initiatives by CMS Family instruments, etc.) - Relevant sections in national reports to MEAs

(v) Connectivity data needed for INSECTS

A. Migration systems - patterns and pathways of animal movements

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Discovering individual migratory insect movements	Movement distances/ranges	- Field observation records - Camera data
	Movement timings (departure/passage/arrival; changes in these from year to year)	- Field observation records - Camera data
Describing whole migration systems, and mapping the pathways	Population-level movement patterns, in space and time	- Field monitoring - Digital migration path mapping representations/ models
	Links to habitat type/ ecological condition (weather patterns, food plant distribution & emergence, etc.)	- Field observation records - Habitat mapping (for correlation to animal data)

		- Ecosystem seasonality data (for correlation to animal data)
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B. Networks of areas, functioning to support connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Identifying areas that play a key role in the connectivity of insect migration systems	Location of relevant areas	- Field observation records - Camera data
	Extent/ boundaries of areas	- Field observation records - Camera data
	Abundance of insects in areas	- Field observation records - Camera data
	Temporal use of areas	- Field observation records - Camera data - Sample trapping
	Ecological use of areas (feeding, egg-laying, overnight resting, etc.), and their relative importance	- Field observation records - Camera data - Sample trapping
Identifying links and interdependencies between areas forming a network	Relationship between population-level movement patterns (see A above) and identified areas supporting migratory insect species	- Overlays of data on important areas with data on migration movements (from A above)
Strategies for conserving coherent networks of areas that function to support migratory insect connectivity	Sufficiency of coverage of protected and conserved areas vis-a-vis insects' occurrence (at population level) throughout the annual cycle	- Boundaries and coordinates of areas - Overlays of data on areas of importance with data on areas under protection/ conservation
	Level of protection in place for each area	- Lists of areas nominated or designated under relevant frameworks
	Level of conservation management in place for each area	- Lists of areas covered by appropriate and effectively implemented management frameworks
	Conservation and management measures in individual areas that are aimed at supporting/ enhancing/ restoring connectivity	- Relevant extracts from area management plans - Case studies of projects for enhancement or restoration of connectivity for insects

C. Threats to connectivity

A. Conservation/ research objective	B. Key knowledge and understanding needed	C. Types of data and information sources required
Minimizing and mitigating threats to connectivity that result from habitat fragmentation that restricts movements of migratory insect species	Extent and severity of fragmentation impacts on migratory insects	- Ecosystem fragmentation data related to migratory insect movements
Minimizing and mitigating threats to connectivity that result from climate change-related causes	Effects on migratory insects of fragmentation and other habitat loss impacts on connectivity caused by climate change e.g., through wildfires, droughts, etc.	- Information on climate change-induced habitat changes, related to insect migration systems
	Phenological asynchrony effects, disrupting trophic chains	- Data on shifts in migration timing, related to shifts in timing of predators, food sources, survivable temperature ranges, etc.

	Climate-related migration behaviour changes, e.g., shifts of range	- Field observation records
Minimizing and mitigating threats to connectivity that result from inconsistencies in conservation strategies across and beyond national jurisdictions	Compatibility of (or inconsistencies between) relevant conservation strategies between countries sharing any insect migration pathway in common	- Data on programmes to harmonize relevant transboundary conservation regimes - Relevant sections in national reports to MEAs

3. CMS objectives and mandates that define needs for data on connectivity

A. Migration systems - patterns and pathways of animal movements

Resolution 12.26 (Rev.COP13) *Improving ways of addressing connectivity in the conservation of migratory species* in paragraph 1(i) urges Parties and invites others to give special attention to connectivity issues so that, inter alia, strategic conservation objectives may more often be expressed in terms of whole migration systems, and in terms of the requirements for the functioning of the migration process itself.

Resolution 12.26 (Rev.COP13) in paragraph 7 further invites Parties and others to use relevant databases for joint analyses of animal movements in an integrated way across the marine and terrestrial realms so as to improve understanding of the biological basis of migratory species connectivity.

Resolution 12.26 (Rev.COP13) in paragraph 9 also invites Parties to deploy appropriate tagging and transmitting equipment for tracking migratory species so as to improve knowledge about connectivity issues affecting these species.

B. Networks of areas, functioning to support connectivity

The Convention text in Article V(5)(f) suggests that CMS daughter Agreements should provide, inter alia, for maintenance of a network of suitable habitats “appropriately disposed in relation to the migration routes”.

Resolution 12.26 (Rev.COP13) *Improving ways of addressing connectivity in the conservation of migratory species* in paragraph 1 (ii) urges Parties and invites others to give special attention to connectivity when identifying, prioritizing, developing and managing protected areas and other effective area-based conservation measures, both within and beyond areas of national jurisdiction, taking account, inter alia, of the best available science, the need for connectivity to be a key factor in the definition of appropriate conservation management units, including at the landscape or seascape scale, and the need for actions to be addressed to the connections between places as well as to the places themselves.

Resolution 12.26 (Rev.COP13) in paragraph 1 (iii) urges Parties and invites others to enhance the design and functionality of ecological networks.

Resolution 12.26 (Rev.COP13) in paragraph 1 (iv) further urges Parties and invites others to evaluate the sufficiency and coherence of ecological networks in functional and qualitative terms as well as in terms of extent and distribution.

Resolution 12.7 (Rev.COP13) *The role of ecological networks in the conservation of migratory species* in paragraph 4 encourages Parties and others, when identifying areas of importance to migratory species, to take into account and make explicit the relationship between those areas and other areas which may be ecologically linked to them, in physical terms, for example as connecting corridors, or in other ecological terms, for example as breeding areas related to non-breeding areas, stopover sites, feeding and resting places.

Resolution 12.7 (Rev.COP13) in paragraph 5 invites Parties and others to collaborate to identify and designate comprehensive and coherent ecological networks of sites of importance for migratory animals, taking account of the best available science.

Resolution 12.7 (Rev.COP13) in paragraphs 8 and 9 further encourages Parties and others to select areas for conservation in such a way as to address the needs of migratory species as far as possible throughout their life cycles and migratory ranges, to enhance the connectivity

of protected areas, and to set network-scale objectives for the conservation of migratory species.

C. Threats to connectivity

The Convention text in Article II(4)(b) requires Parties to prevent or minimize the adverse effects of activities or obstacles that seriously impede or prevent the migration of Appendix I species for which they are Range States.

The Convention text in Article V(5)(h) suggests that CMS daughter Agreements should provide, inter alia, for elimination, to the maximum extent possible, of activities and obstacles which hinder or impede migration.

Resolution 12.26 (Rev.COP13) *Improving ways of addressing connectivity in the conservation of migratory species* in paragraph 3 encourages Parties and invites others to intensify efforts to address threats to migratory species which are manifested as threats to connectivity, including barriers to migration, anthropogenic additional mortality, fragmented resources and disrupted processes, genetic isolation, population non-viability, altered behaviour patterns, shifts in range caused by climate change or depletion of food or water resources, inconsistencies in management across and beyond national jurisdictions, and other factors.

Resolution 12.7 (Rev.COP13) *The role of ecological networks in the conservation of migratory species* in paragraph 8 encourages Parties and others to set network-scale objectives for protected and conserved areas, including objectives for the restoration of fragmented habitats and removal of barriers to migration.

Resolution 12.7 (Rev.COP13) in paragraph 18 further encourages Parties to implement practical guidance for avoiding infrastructure development projects that disrupt the movement of migratory species.

ANNEX 3

LINKAGES BETWEEN MIGRATORY SPECIES CONNECTIVITY AND ECOSYSTEM RESILIENCE - DECISION 13.114 (C)

1. The section that follows below explores the component parts of the linkages between migratory species connectivity and ecosystem resilience, and offers some initial specifics that address it in the particular context of climate change.

'Migratory species connectivity'

2. The accepted global definition of 'ecological connectivity' was originated through CMS and was formally adopted in CMS Resolution 12.26 (Rev.COP13) as "*the unimpeded movement of species and the flow of natural processes that sustain life on Earth*".
3. Such connectivity can be recognized in a 'structural' sense (where the configuration, distribution or physical connections between relevant areas/habitats provide the structural *enabling conditions* for organisms to move and ecological processes to flow), and in a 'functional' sense (where such movements and flows actually take place in practice). Importantly, for many migratory species, this 'functional' connectivity is not simply dependent on physical contiguity of suitable areas (for example the limited idea of 'ecological corridors'), but on the overall disposition of all of the areas (sometimes continents or oceans apart) that are required to support a species' entire migration system (reflected in the wider idea of 'ecological networks').
4. There is, in addition, a distinct and different concept of 'migratory connectivity', which has been defined in several different ways, but which broadly refers to the degree to which individuals or populations are associated with particular areas at different stages of their annual cycles. Its focus tends to be on connectivity as a property of animal populations rather than a property of the habitats or sites that they use. The science of this (including genetic studies) is still an emerging field, with various aspects still to be elaborated. Some discussion of this in the CMS context is given in Ambrosini and Spina (2017).¹
5. In this light, the reference in Decision 13.114 to "Migratory species connectivity" requires some interpretation. For the purposes of the present document, it has *not* been interpreted in the rather narrow and specialized (genetic/population) sense of 'migratory connectivity' as described above (i.e., *sensu* Ambrosini & Spina), but rather as an intention by the COP to refer to *ecological connectivity, as it applies to migratory species*.

'Ecosystem resilience'

6. Although not quite matching the term 'ecosystem resilience' in the Decision, there are numerous different definitions of 'ecological' resilience (or resilience in ecological systems) in the literature.
7. A foundation for many of these is attributed to Holling (1973),² who described the concept in terms of the persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes; the capacity of systems to absorb disturbances and to continue functioning; and the capacity of systems to adapt to disturbances by reorganizing into new states that persist thereafter, while still maintaining essentially the same structures and functions as before.

¹ Ambrosini, R and Spina, F (2017). The past, present and future of migratory connectivity. In CMS Scientific Council (2017). Migratory animals connect the planet: the importance of connectivity as a key component of migration systems and a biological basis for coordinated international conservation policies. Document UNEP/CMS/COP12/Inf.20 for the 12th meeting of the Conference of Parties to the CMS, Manila, Philippines, 23-28 October 2017.

² Holling, CS (1973). Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics 4: 1-23.

8. Other approaches invite a gauging of the degree of resilience in terms of the amount of disturbance that a system can withstand before its self-organized processes and structures alter, or the time taken for a system to return to its equilibrium state following a perturbation (see for example Gunderson 2000,³ Walker and Salt 2006⁴).
9. The glossary developed for the Kunming-Montreal Global Biodiversity Framework (Convention on Biological Diversity, 2022⁵), quoting the glossary for the IPBES Global Assessment Report on Biodiversity and Ecosystem Services (2019),⁶ defines 'resilience' as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (citing Walker *et al.*, 2004⁷).

Resilience of ecosystems? Or of the migratory species? Or of the migration systems?

10. "Ensuring the resilience of migration systems" is part of the overarching Mission statement in the Strategic Plan for Migratory Species 2015-2023, and Goal 3 in the Plan (echoing wording in the Rio+20 outcome document) to "improve the conservation status of migratory species and the ecological connectivity and resilience of their habitats". The concept is therefore strongly embedded in high-level CMS policy statements.
11. CMS Resolution 12.21 *Climate Change and Migratory Species* expresses a recognition that connectivity of habitats is one factor that supports the resilience of wild animals to change, and it refers to an earlier Resolution (10.19) that urged Parties to "[...] maximize species and habitat resilience to climate change through appropriate design of ecological networks, [...] strengthening physical and ecological connectivity between sites [...]". It further invites Parties and others to take resilience into account in designing and maintaining ecological networks. UNEP's ecosystem management programme for 2014-2017 also included an item on "increased use of connectivity management approaches to enhance [...] resilience" of ecosystems. The idea that connectivity contributes to ecological resilience has therefore been prominently acknowledged for some time, but it will be valuable to enhance the science underpinning this.
12. Resilience in ecosystems can be influenced by size and connectivity (in forests, for example, generally the larger and less fragmented they are, the more resilient they can be (Thompson *et al.* 2009⁸)). There are direct links to be made between resilience and habitat management for connectivity, spatial planning of infrastructure and protected and conserved areas. One study has specifically related ecological resilience to biological corridors linking protected areas in Bhutan (Wangchuk 2007⁹).
13. Meaningful investigation should, in any case, specify what is being expected to exhibit resilience (i.e., in terms of specified characteristics of the ecosystems of interest), and what impacts or perturbations are being considered. Examples might be whether a network of sites on a migratory route produce an overall surplus of the food required by particular migratory animals, such that unexpected inability to utilize one site to the normal degree can be compensated by 'spare' resource being available at other locations in the network; or areas of suitable habitat for a terrestrial migrant being connected with no impediments to free movement, such that variations in seasonal patterns (e.g., distribution of rainfall, temperature-

³ Gunderson, L (2000). Ecological resilience: in theory and application. *Annual Review of Ecology and Systematics* 31: 425-439.

⁴ Walker, B and Salt, D (2006). *Resilience thinking: sustaining ecosystems and people in a changing world*. Island Press, Washington, D.C.

⁵ Convention on Biological Diversity (2022). Updated Glossary for the draft post-2020 Global Biodiversity Framework. Document CBD/WG2020/5/4 for the fifth meeting of the Open-Ended Working Group on the post-2020 Global Biodiversity Framework, Montreal, Canada, 3-5 December 2022.

⁶ IPBES (2019). Glossary: Annex I to the Global Assessment Report on biodiversity and ecosystem services.

⁷ Walker, B, Holling, CS, Carpenter, SR and Kinzig, A (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9(2): 5.

⁸ Thompson, I, Mackey, B, McNulty, S and Mosseler, A (2009). Forest resilience, biodiversity, and climate change. A synthesis of the biodiversity/ resilience/ stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43.

⁹ Wangchuk, S (2007). Maintaining ecological resilience by linking protected areas through biological corridors in Bhutan. *Tropical Ecology* 48(2): 176-187.

related timing of fodder emergence) can be accommodated by the animals moving to a different location.

14. The status of migratory species and the functioning of migration systems (and the connectivity on which these depend) might be one category of ecosystem variables in which it would be desirable to see resilience exhibited. In other words, the contribution that connectivity makes to ensuring resilient populations of migratory species could be one issue to study.
15. Resilience in the species themselves may relate to the ability to adapt behaviours, reproductive productivity or other factors in response to environmental change. The influence of connectivity on these factors, related for example to the size of isolated populations, could be one subject to investigate. The point at which the scale or speed of environmental change (or the nature of it, for example novel events) exceeds the species' ability to adapt, would be the important 'threshold' issue to know in order to inform conservation actions.
16. At the same time, the continuing or recovered functioning of migration systems and favourable conservation status of migratory species, supported by connectivity, might be one category of structures and processes that help an ecosystem to be resilient. This would be a different kind of question to study.
17. For the purposes of the Scientific Council's work in response to Decision 13.114 (c), it would appear that resilience of the migratory species themselves (and even perhaps the migration systems of which they are a part), should be understood as a key focus of the question, rather than necessarily just the narrower issue of resilience as exhibited by 'ecosystems' per se.

Connectivity and resilience in the context of climate change

18. There could be several dimensions of the linkages between ecological resilience and connectivity (in the migratory species context) that would be worth investigating. The most promising area to focus on at this stage may be the relationships between connectivity, resilience and climate change. Such a focus offers synergies with the Scientific Council's work on climate change more generally, under Resolution 12.21 and the annexed Programme of Work on Climate Change and Migratory Species (due to be revisited at COP14), as well as Decisions 13.126 *Climate Change and Migratory Species*, 13.114 (d) (needs for connectivity research) and 13.114 (e) (needs for connectivity guidance).

Collaboration with the UK, on a 'migratory species and climate change' initiative

19. The UK, through a project funded by the Department for Environment, Food and Rural Affairs (DEFRA), managed by the Joint Nature Conservation Committee (JNCC) and sub-contracted to the British Trust for Ornithology (BTO),, has been reviewing the impact of climate change on migratory species and the ecosystem services they provide (Martay et al., in prep¹⁰). The opportunity has therefore been taken during 2023 to establish a link between this work and the CMS Scientific Council's task concerning connectivity and resilience.
20. Part of the context for the UK project was initial analyses of the implications of climate change for migratory species developed in 2005 (Robinson et al., 2005¹¹) and 2010 (McNamara et al., 2010¹²), and the desire to update these. Components of the new work have covered a review of the impacts of climate change on migratory species and their habitats; the role of migratory

¹⁰ Martay, B, Macphie, K, Pearce-Higgins, J and Robinson, RA (in prep). Climate change impacts on migratory species: a review. JNCC report, Peterborough, UK.

¹¹ Robinson, RA, Learmonth, JA, Hutson, AM, Macleod, CD, Sparks, TH, Leech, DI, Pierce, GJ, Rehfisch, MM and Crick, HQP (2005). Climate Change and Migratory Species. A report for the UK Department of Environment, Food and Rural Affairs. British Trust for Ornithology, Research Report 414.

¹² McNamara, A, Atkinson, J, Baillie, J, Breach, K, Froy, H, Khela, S, Mukherjee, A, Peet, J and Smith, R (2010). Climate change vulnerability of migratory species - species assessments, preliminary review. Zoological Society of London; report for Convention on Migratory Species.

species in nature-based solutions to help adaptation to and mitigation of climate change effects; and some work on mitigation measures and the role of migratory species as indicators.

21. Only certain parts (a minority) of the UK work touch on the specific issues of connectivity and/or resilience. The points listed below therefore present an extraction of/reflection on these specific elements of the evolving work, as a contribution to the Scientific Council's specific task under Decision 13.114 (c):

- The work suggests that migratory species populations are most resilient to the effects of climate change where the animals concerned can (with unimpeded (new) movements) shift ranges or change migratory behaviour to adapt to climate change-driven loss of favourable environments/favourable conditions (e.g., too dry/too wet/too hot/or lost to sea level rise, ice melt, etc.).
- Such connectivity-related resilience can happen *either* of its own accord because of the *inherent* capabilities of the animals and the existing availability of requisite areas and resources, *or* it can be '*conservation enabled*' by e.g., barrier-removal, habitat enhancement, translocation projects, behavioural imprinting or other actions.
- Resilience is compromised when adaptive movements are impeded by *pre-existing barriers* (limited extent/distribution of suitable habitat; hotspots of predation pressure; existing anthropogenic barriers e.g., dams, sea walls, fences, energy infrastructure, etc.).
- Resilience is compromised when adaptive movements are impeded by *new climate change-induced losses of connectivity* (drying rivers, burning forests, flooded grasslands, melting sea-ice, etc.).
- Resilience is compromised when adaptive movements are impeded by *human responses to climate change* (shifting agricultural intensification, renewable energy developments, new reservoirs, higher sea walls and other flood defences preventing shift of suitable habitats e.g., nesting beaches, shifting areas of direct take when human populations are displaced, etc.).
- Resilience is compromised when populations are *scattered/fragmented to the extent that social learning about shifting migration routes cannot be properly transmitted* between individuals.
- Resilience is compromised when *site fidelity/migration route fidelity behaviours prevent adaptive shifts*, even when the requisite habitat connectivity is available. (Such situations could potentially be a trigger for translocation actions, for example).
- Resilience is compromised when climate-related condition-reducing effects in e.g., birds in the wintering areas '*carries over*' to reduced productivity in the breeding areas (this relationship between *effects in one area and impacts in another* could be viewed as a special form of connectivity).
- Resilience is compromised where *continuity of required conditions* is required along an entire migratory route, but this becomes fractured (e.g., water availability for bats; correct salinity for certain sharks: although a question would be how '*continuous*' these conditions need to be in reality to sustain the systems concerned).
- Resilience might, in some cases, be *improved* by climate change-induced changes in connectivity – e.g., melting sea-ice reducing the travel distance between penguin colonies and their food source has been found to improve productivity. Such situations however may be complex, involving a mix of positive and negative effects – in the penguin instance for example, closer food may also mean closer predators, and the observed productivity gain

has seemingly not been enough to offset the loss of productivity from climate change-induced reduction in prey volumes.

Bioclimatic Ecosystem Resilience

22. One approach to interpreting ecosystem resilience in relation to climate change is the recently developed Bioclimatic Ecosystem Resilience Index (BERI) (Ferrier et al., 2020¹³). This is included in the Monitoring Framework for the Kunming-Montreal Global Biodiversity Framework as one of the complementary indicators for Goal A and for Target 2, and as a component indicator for Target 8. (Goal A and Target 2 together include objectives for maintaining, enhancing and restoring the integrity, connectivity, resilience and functioning of ecosystems; Target 8 includes an objective of increasing the resilience of biodiversity in relation to climate change).
23. The index uses a modelling approach to project changes in terrestrial species composition under a plausible range of climate scenarios, and relates these to a grid-based spatial representation of connectedness of suitable habitat, to indicate the capacity of terrestrial ecosystems to retain biological diversity under climate change. Connectivity is assumed to be a positive factor in allowing shifts of organisms (plants, invertebrates and vertebrates) in response to climatic factors; and scores are assigned to cells in the spatial grid according to each cell's habitat condition and its connectedness to surrounding areas that are projected to support a similar composition of species under changes in climate.
24. While the BERI index works with (projected) changes in species composition at the ecosystem level, in a theoretical way, the UK research project described in the previous section addresses impacts and implied resilience factors for a range of species and taxonomic groups in turn, using more empirical data. Both of these perspectives can complement each other, and both are relevant to CMS interests in this subject.

¹³ Ferrier, S, Harwood, TD, Ware, C and Hoskins, AJ (2020). A globally applicable indicator of the capacity of terrestrial ecosystems to retain biological diversity under climate change: the bioclimatic ecosystem resilience index. *Ecological Indicators* 117: 106554.

PRIORITIES FOR FUTURE RESEARCH ON CONNECTIVITY - DECISION 13.114 (D)

[Note: the sequence in which the items below are presented does not imply any order of importance, and consideration will be given to this at a later stage].

Climate change

1. Decision 13.114 (d) highlights climate change as one area for attention. CMS has a Programme of Work on climate change, one of the core objectives of which is defined as assessing and developing distribution models for selected species for current situations and expected future scenarios, as well as assessing the vulnerability of critical sites to climate change. This therefore, in broad terms, already defines two key research priorities.
2. A central concern in researching the links between climate change and connectivity relates to the contribution that connectivity makes to enabling (some) species to respond to climate change, by increasing the chance that they may escape from areas that are rendered unsuitable and move to inhabit other areas where they can survive. The issue of ecological resilience and its relationship to connectivity in this context has been discussed in relation to Decision 13.114 (c) in the preceding section of this document.
3. It has also been noted that one application of the Eurasian-African Bird Migration Atlas is to analyse changing migration patterns to shed light on migratory birds' strategies for adapting to changing environmental conditions, and the proposed Global Atlas on Animal Migration would further extend the ability to conduct such analyses, in relation to species for which sufficient data exist.
4. It may be possible to research clear cases where lack of connectivity is hampering the ability of species to respond to climate-related trends and events. The Scientific Council, for example, has previously drawn attention to the case of the Mongolian Gazelle, where extreme weather conditions in 2016 triggered a migration of the animals in search of food, but railway infrastructure posed a barrier to this and led to a mass mortality in the population. The Global Initiative on Ungulate Migration (GIUM) has noted that thinning ice in the Arctic has effectively posed a barrier to migrating caribou, leading similarly to mass mortality events. GIUM also notes that droughts affecting ungulates are becoming more common, and that as well as movements driven by scarcity of forage and water, linked ecosystems along altitudinal gradients are required to enable thermal refuge as temperatures increase.
5. Research on connectivity associated with the Global Land Outlook points out a need for connectivity along gradients of aspect (north or south-facing) for similar thermal refuge reasons; and cites the climate-related increase in wildfires as a cause of connectivity loss where forest connections are destroyed.
6. Priorities for future research on these issues might therefore include, among others:
 - modelling predicted spatially-related effects of climate change on migratory species (for example identifying where species ranges, defined by climatically suitable conditions, may shift over time);
 - investigating the scope for migratory animals to adapt (e.g., mapping corridors, linked to studies of behaviour and population dynamics, etc.);

- strategies for effective design of ecological networks to support connectivity-based resilience/adaptation to climate change;
- methods for mitigating the barriers that most impede climate-responsive connectivity, and assessing the effectiveness of these;
- buffering and increasing the resilience of areas of known importance for ecological connectivity to climate-caused destruction; and
- identifying refugia that allow animals to escape extreme fire and flood events, droughts and changing water temperatures, and the means of ensuring access to these locations.

Ecological networks

7. Resolution 12.7 (Rev.COP13) includes an annex that contains a list of “useful areas for further work” synthesized from a strategic review document (COP11 Document 23.4.1.2), and the list includes some relevant research items. Three of these items in particular recommend the following:
 - Assess existing individual ecological networks in relation to the conservation needs of migratory species, using the recommendations and good practice points in this Annex as a guide, and addressing both (i) the functionality of the network for supporting migratory species and migration, and (ii) provisions in relevant governing frameworks and guidance for ensuring that migratory species aspects are taken fully into account.
 - Explore options for obtaining globally synthesized information about the results of the implementation of actions defined in Resolution 10.3 paragraph 7 (to assess whether Parties are addressing as effectively as possible the needs of migratory species throughout their life cycles and migratory ranges by means of ecological networks and enhanced habitat connectivity) and paragraph 9(i) (to assess the extent to which and the manner in which existing major protected area systems and initiatives aimed at promoting ecological networks address the needs of migratory species throughout their life cycles and migratory ranges).
 - Seek opportunities to direct relevant research (for example on animal distributions, movement patterns, gap analyses of networks) towards further improving knowledge and understanding of the design and implementation of ecological networks in ways which provide optimal benefits for migratory species.
8. Resolution 12.26 (Rev.COP13) urged Parties and invited others to give special attention to connectivity issues when, inter alia, evaluating the sufficiency and coherence of ecological networks in functional and qualitative terms as well as in terms of extent and distribution, and when monitoring and assessing the effectiveness of the protection and management of relevant areas and networks. COP11 Document 23.4.1.2, mentioned above, refers to methods used by the Bern Convention and the OSPAR and HELCOM Conventions to evaluate sufficiency and coherence of ecological networks, and there are several methods in use around the world for assessing management effectiveness of protected and conserved areas. A useful research priority to enhance the use of such evaluations and assessments would be to explore ways in which they might be able to factor in functional connectivity parameters.
9. One of the connectivity indicators proposed for monitoring relevant targets in the Kunming-Montreal Global Biodiversity Framework (‘ProtConn’) addresses (on a modelling basis) the structural connectivity of protected area systems. The two main

scientific papers that present the analyses this indicator can produce (Saura et al. 2017¹⁴ and Saura et al. 2018¹⁵) mention the desirability of further work to cover aspects they have not covered, including the needs of species (such as migratory birds) that require international networks of non-contiguous suitable areas, and the specific “connectivity performance of protected area management” (that latter point echoing one of those made in the preceding paragraph above). Further application of these methods to aquatic species would also be desirable.

Linear and other infrastructure

10. COP Decision 13.131 requested the Scientific Council to establish a working group on linear infrastructure, to [inter alia] review available information relevant to linear infrastructure development and potential impacts on migratory species; identify areas where further assistance is needed to enhance consideration of effects involving impediments to migration and impacts on migratory patterns or on migratory ranges; and provide recommendations on the future direction of work under the Convention to support Parties in addressing the impact of linear infrastructure on migratory species.
11. The Working Group was established in 2021 and held a meeting in 2022, at which it developed recommendations to be considered at COP14, which are contained in Document UNEP/CMS/COP13/Doc.28.3.1. *Linear and other Infrastructure Development*.
12. Decision 13.132 also requested the Scientific Council to identify the types of infrastructure that have not been addressed under CMS and are of particular relevance to the conservation of CMS-listed species, and to provide advice on possible actions that could be taken to address such infrastructure. When that work is done it could also generate recommendations for future research, in particular on types on infrastructure other than the ‘linear’ types addressed by the Working Group.

‘Migratory connectivity’

13. The distinct concept of ‘migratory connectivity’ has been defined in several different ways, but broadly refers to the degree to which individuals or populations are associated with particular areas at different stages of their annual cycles. Its focus tends to be on connectivity as a functional property of animal populations rather than a property of the habitats or sites that they use. The science of this is still an emerging field, with various aspects still to be elaborated. Some discussion of this in the CMS context is given in Ambrosini and Spina (2017).¹⁶
14. Research priorities for the Convention on this issue might concern issues such as the implications of different degrees of intermixing of populations, vulnerabilities related to geographically narrow dispersal of sub-populations, timing and distance structures within a given migration system, and potential changes to these in response to genetic or environmental factors.
15. Linked to this could be research studies on genetics and stable isotope markers to improve knowledge about the connectivity structure of migration systems, clarifying

¹⁴ Saura, S, Bastin, L, Battistella, L, Mandrici, A and Dubois, G (2017). Protected areas in the world’s ecoregions: how well connected are they? *Ecological Indicators* 76: 144–158.

¹⁵ Saura, S, Bertzky, B, Bastin, L, Battistella, L, Mandrici, A and Dubois, G (2018). Protected area connectivity: shortfalls in global targets and country-level priorities. *Biological Conservation* 219: 53–67.

¹⁶ Ambrosini, R and Spina, F (2017). The past, present and future of migratory connectivity. In CMS Scientific Council (2017). *Migratory animals connect the planet: the importance of connectivity as a key component of migration systems and a biological basis for coordinated international conservation policies*. Document UNEP/CMS/COP12/Inf.20 for the 12th meeting of the Conference of Parties to the CMS, Manila, Philippines, 23-28 October 2017.

distribution patterns, population relatedness and trends of change, including where intermixing or once continuous populations are becoming fragmented.

Connectivity indicators

16. Work on connectivity indicators has assumed particular importance in the context of the Monitoring Framework for the Kunming-Montreal Global Biodiversity Framework (GBF), and it requires significant further development. Some of this may take place through the Convention on Biological Diversity's Ad Hoc Technical Expert Group on GBF indicators, where input on connectivity in particular will be important.
17. A series of collaborative processes in recent years involving a range of organizations and networks, including CMS, IUCN and UNEP-WCMC, has identified over 20 possible measures or indices that could function as indicators for some part of the connectivity objectives expressed in the GBF. In most cases however, the formulation, data management, potential scaling-up and specific applied relevance of these remains to be worked out.
18. The role of CMS and the Scientific Council on this is discussed further in the separate section of the present document on 'Connectivity in the Global Biodiversity Framework'.

Connectivity and insect migration

19. Decision 13.129 requested the Scientific Council to address a number of issues relating to insect decline and its threat to migratory insectivorous animal populations; but by including work to collect information on the causes of insect decline, in principle this mandate also covers threats to insect species themselves, in cases where these are migratory and of conservation interest for the Convention. Results of such work are included in Document UNEP/CMS/COP14/Doc.28.4.2, *Insect Decline and its threats to Migratory Insectivorous Animal Populations*.
20. According to Hobson (2017),¹⁷ who discusses two such examples (the Monarch Butterfly, listed in CMS Appendix II; and the Globe Skimmer, a dragonfly species), there would appear to be a need for better understanding of insect migration in relation to population estimates, reproductive success and survivorship at each stage of the annual cycle, to allow more informed modelling of connectivity threats and targeting of conservation efforts.

Noise and light as barriers to connectivity

21. Decision 13.60 requested the Scientific Council to consider information and future needs concerning best practices and technologies for mitigating noise impacts on migratory species in the marine environment. Decision 13.139 requested the Council to consider issues concerning light pollution in relation to all affected groups of migratory animals. Results of such work are included in Document UNEP/CMS/COP14/Doc.28.4.4 *Light Pollution* and UNEP/CMS/COP14/Doc.25.2.1 *Marine Noise* respectively.
22. As the potential for problems to be caused for migratory species by noise pollution and light pollution becomes more appreciated, it will be important through research to

¹⁷ Hobson, KA (2017). Insect Migration and Connectivity. In CMS Scientific Council (2017). Migratory animals connect the planet: the importance of connectivity as a key component of migration systems and a biological basis for coordinated international conservation policies. Document UNEP/CMS/COP12/Inf.20 for the 12th meeting of the Conference of Parties to the CMS, Manila, Philippines, 23-28 October 2017.

develop a greater understanding of the role they might play as barriers to connectivity, for example by creating avoidance zones or causing disorientation.

Negative effects of increased connectivity

23. In a context particularly of efforts to enhance or restore connectivity, in addition to the benefits of doing so, any potential risks of increasing connectedness should also be considered. Methods may need to be developed for assessing and managing risks, for example of unwanted spread of pathogens, problematic predators, ecological competitors or invasive species.