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ANNEX A: OVERVIEW AND COMPARISON OF FOUR CLIMATE CHANGE VULNERABILITY ASSESSMENT METHODOLOGIES

(Prepared by JNCC)

Summary:

Report on climate change vulnerability assessment methodologies, based on a document prepared by the UK government and linked to the Migratory Species and Climate Change Expert Workshop, held from 11 to 13 February 2025 in Edinburg, United Kingdom. The information document supports document UNEP/CMS/COP15/Doc.28.12 on Climate Change and Migratory Species.

Annex A: Overview and comparison of four Climate Change Vulnerability Assessment methodologies

A literature review was carried out to identify published Climate Change Vulnerability Assessments (CCVAs) that assessed large numbers of species and that may be suitable for use or adaptation to address Decision 12.214(b). The review identified four trait-based or combination approaches:

CMS/ZSL Methodology (McNamara, 2010) (Foden *et al*. 2013)

IUCN CCVA Methodology (Foden *et al.* 2013)

NatureServe Climate Change Vulnerability Index (CCVI) (Young *et al*, 2012, 2015)

WWF Climate Change Vulnerability Assessment for Species.

An overview and comparison of these four published CCVA methodologies can be found below.

CMS/ZSL Methodology 2010

Context

ZSL were contracted by CMS to develop a methodology to assess migratory species' vulnerability to climate change. The resultant trait-based methodology was applied to 44 pilot species listed on CMS Appendix I and one species listed on Appendix II, and was presented to the CMS Scientific Council in 2010 (McNamara, 2010). However, it was not subsequently used to make further assessments of migratory species' climate change vulnerability.

Overview of the methodology

The ZSL methodology involves four phases:

Phase 1 involves a literature review of species' climate change threats and vulnerabilities.

Phases 2 and 3 comprise the climate change vulnerability assessment. Phase 2 involves consulting experts to devise vulnerability gradings for each species and using them to determine species' "*Initial gradings*" or rankings. Phase 3 involves further in-depth expert consultations to review the climate change vulnerability of priority species and assign species a vulnerability assessment of high, medium, or low vulnerability, to be used to inform management recommendations

Phase 4 involves compiling detailed reports for each species, identifying all potential threats, vulnerabilities and uncertainties, with the objective of feeding them into conservation management planning processes.

The ZSL methodology involves assigning each species a score from 1-5 across each of 12 'factors', classed under the following four headings: vulnerability of habitats, ecological flexibility, species interactions and synergistic threat processes. Scores are assigned according to qualitative criteria specific to each factor.

Assessment of sensitivity and adaptive capacity

Factors associated with species' sensitivity and adaptive capacity are included under four categories: vulnerability of habitats, ecological flexibility, species interactions, and synergistic threat processes.

The habitat vulnerability category consists of a single factor that considers whether the species' habitat is likely to be degraded due to climate change, taking into account any modelling that has been done on the impact of climate change on the species' habitat.

The ecological flexibility category represents adaptive capacity, and comprises five factors, including degree of specialisation (of diet or habitat), rate of reproduction, dispersal ability, environmental or phenological cues, and evidence of past adaptation (included to inform assessments but not included in species' overall scores for climate vulnerability). It was assumed that species will not be able to evolve fast enough to adapt to climate change, and so traits reflecting capacity for evolutionary adaptation were not included in the methodology.

The species interactions category contains two factors that consider whether the species is likely to be negatively affected as a result of climate-related changes to interspecific interactions, including predation, competition, mutualism, and symbiosis.

The synergistic threat processes category includes four factors that consider whether the species is likely to be negatively impacted by four other threats: habitat loss or fragmentation, exploitation, disease, and invasive species. Whilst the assessment criteria for disease and invasive species consider whether these threats are likely to increase as a result of climate change, those for habitat loss and exploitation consider whether these threats are likely to reduce the species' resilience to climate change, for example, by limiting dispersal, so they could be considered to be more reflective of species' adaptive capacity. It should be noted that other non-climate related anthropogenic threats that may affect species' adaptive capacity, such as over-harvest of the species' prey, or accidental mortality, are not taken into account.

Assessment of exposure

The methodology includes a factor that includes consideration of whether the species' habitat is projected to be degraded by climatic changes, thereby providing a measure of exposure. Other factors (such as dependency on phenological cues) only allow high scores where climate change is predicted to have an impact.

Scoring system

Each factor has qualitative assessment criteria, based around a choice of five scenarios, resulting in a score from one (low risk) to five (high risk). Scores for factors are integrated to provide a single score for each category (vulnerability of habitats, ecological flexibility, species interactions and synergistic threat processes), depending on how they are considered likely to interact to affect the species' overall climate vulnerability.

The overall species climate vulnerability score is determined according to criteria that take account of how many high, medium and low risk scores the species is assigned across the 12 factors. For example, a species would be classified as having high vulnerability if any factor receives a score of five (high risk), or if the total score exceeds a threshold. However, according to these criteria, a species may attain an overall high vulnerability score as a result of attaining a high score for a factor that reflects its ability to adapt to climate change, while attaining low scores across factors reflecting sensitivity to climate change, and so assessors are advised to review the interaction of factors when assigning an overall vulnerability score.

The rationale for the use of a qualitative scoring system was that the thresholds that would be required for a quantitative assessment are not sufficiently understood, and there would be insufficient data across relevant taxa with which to apply them.

Advantages and disadvantages

A list of some potential advantages and disadvantages of the ZSL methodology can be found in Table 1.

Table 1. Potential advantages and disadvantages of the ZSL methodology

Advantages	**Disadvantages**
All factors are scored using a system of five scenarios of increasing risk, so there is some consistency in the scoring method across factors.	Logical framework of the groups of factors included in the methodology is less clear than those of some other methodologies, with no specific assessment of exposure.
A standard set of 'factors' is used to assess all species.	Consideration of the impacts of other anthropogenic threats is partial, with only limited specific threats included.
Assessment criteria for most factors are not based purely on intrinsic traits, but take account of predicted climate impacts, which may reduce assumptions/generalisations made in relating traits to climate vulnerability.	A species may be assessed as having a high climate vulnerability based only on its degree of specialisation or dispersal ability, and in the absence of climate sensitivity or known impact mechanisms (N.B. see below).
The avoidance of quantitative thresholds for assigning scores eliminates the need for arbitrary thresholds and builds expert opinion and scrutiny into the scoring mechanism, which could improve confidence in the results.	Assessors are encouraged to consider the interaction of factors when assigning a score for overall vulnerability, which introduces subjectivity and potential inconsistency.
	Assessment criteria for most factors are not based purely on intrinsic traits, but take

	account of predicted climate impacts, which may limit usage of large species trait datasets and may require more extensive research. Assessment criteria are qualitative, and expert judgement is required to match species to scenarios, which may be more labour-intensive and may introduce inconsistencies and bias. It is not possible to batch-assess species or automate assessments; each species must be assessed independently in order to select and justify the most appropriate scenario for each factor. Traits are weighted equally and independently, but their impacts on species' climate vulnerability are unlikely to be equal and are likely to interact.

IUCN CCVA Methodology

Context

IUCN began developing a methodology in 2007, with the aim that it could be applied to large numbers of species across all taxa. The approach was piloted on all the world's birds, amphibians and warm-water reef-building corals, resulting in climate change vulnerability assessments of 16,857 species (Foden *et al*. 2013). The methodology has also been used at regional scales to assess other taxonomic groups including mammals, reptiles, plants and freshwater fishes (J. Carr *et al*. 2013; J. A. Carr *et al*. 2014).

Overview of the methodology

This methodology uses a trait-based approach to assess species' sensitivity and adaptive capacity and combines the results with a measure of exposure to climate change to identify the species with the greatest relative vulnerability to climate change. Sensitivity and adaptive capacity are assessed through assessment of seven standardised '*trait sets'*, each representing a broad intrinsic characteristic that may render a species sensitive or less able to adapt to climate change. The assessment of each of these trait sets, however, is not standardised and is tailored according to the availability of information relevant to that trait set for the taxonomic group being assessed. Scores for exposure were derived using GIS to project in relevant climatic variables across maps of the species' distributions.

Assessment of sensitivity and adaptive capacity

This methodology makes a distinction between traits used to assess sensitivity and those used to assess adaptive capacity.

Sensitivity to climate change is assessed according to traits categorized under five '*trait sets*':

a. Specialised habitat and/or microhabitat requirements
b. Environmental tolerances or thresholds that are likely to be exceeded due to climate change
c. Dependence on environmental triggers that are likely to be disrupted by climate change
d. Dependence on interspecific interactions that are likely to be disrupted by climate change
e. Rarity

Within each trait set, traits appropriate for particular taxonomic groups were selected, based on literature reviews, online databases and expert knowledge. For example, traits selected to reflect birds' and amphibians' habitat specialisation included the number of habitats in which they are known to occur, according to the information in their IUCN Red List assessments, as well as their dependence on microhabitats. Traits selected to assess the habitat specialisation of corals included their depth ranges. Environmental tolerances were assessed through spatial analysis of climatic variables across the species' range.

The methodology assesses adaptive capacity according to traits categorized under two '*trait sets*':

a. Poor dispersal ability
b. Poor evolvability

As per the assessment of sensitivity, within each trait set, traits appropriate for particular taxonomic groups were selected, based on literature reviews, online databases and expert knowledge. For example, traits selected to assess birds' dispersal ability included mean maximum dispersal distances and extrinsic barriers to dispersal. The assessment of birds' evolvability considered low genetic diversity, generation length and reproductive output. Amphibians were judged to have poor dispersal ability if they are not known to have become established outside their natural ranges, are not associated with flowing water, and have very small ranges.

Assessment of exposure

Species' exposure to climate change was assessed through spatial analysis. Species' range maps from their IUCN Red List assessments were refined by suitable habitat and elevation, and those for coral species were refined to only include areas intersecting a dataset of coral reefs. Projected changes in climate variables were then modelled across the resultant species range maps. Species' levels of exposure were ranked according to the magnitude of the projected changes in climatic variables across their range.

Scoring system

Species were assigned a score of '*high'*, '*low'*, or '*unknown'* risk for each trait or measure of exposure. The criteria or thresholds used to determine these scores varied according to the trait and were a mix of qualitative and quantitative criteria. For some traits, species' assessments were ranked, and 25% of species considered to have the highest degree of risk according to that trait were scored as high risk.

Species were then assigned a score for each of sensitivity, adaptive capacity, and exposure, according to the scores they received for traits reflecting that dimension of vulnerability. A species that scored '*high'* according to any trait reflecting that dimension would be also attributed a high score for that dimension.

Species were attributed an overall score of climate vulnerability depending on their scores for sensitivity, adaptive capacity and exposure, with a high score for each of these dimensions required in order for a species to be assigned a high score for overall climate vulnerability.

The authors state, "*due to the scarcity of direct evidence to support trait scoring thresholds, climate change vulnerability scores must be interpreted as relative measures, and comparison of percentages of climate change vulnerable species between taxonomic groups is not meaningful*".

Advantages and disadvantages

A list of some potential advantages and disadvantages of the IUCN methodology can be found in Table 2.

Table 2. Potential advantages and disadvantages of the IUCN methodology

Advantages	**Disadvantages**
Clear logical framework with separate assessment of each of the three dimensions of vulnerability (sensitivity, adaptive capacity, exposure), and species only assessed as vulnerable overall if they score highly across all three dimensions.	Does not take into account evidence of past/current climate change impacts.
Standard '*trait sets'* used to assess sensitivity and adaptive capacity across all species.	The traits used to assess sensitivity and adaptive capacity are specific to each taxonomic group and are not standardised, so comparison of percentages of climate change vulnerable species between taxonomic groups is not meaningful.
Scoring is semi-quantitative, which reduces the potential for assessor bias and enables assessment of some traits across batches of species.	Traits are weighted equally and independently, but their impacts on species' climate vulnerability are unlikely to be equal and are likely to interact.
Traits used to assess sensitivity and adaptive capacity are generally intrinsic and are not determined by species-specific evidence of	Many traits are scored through ranking species, and score thresholds are arbitrary.

climate impacts, so many can be collated from large datasets (e.g. the IUCN Red List). Exposure and some traits are assessed through spatial analysis, which ensures that these elements are scored consistently across species and with a robust scientific basis. At least some parts of assessments can be carried out across large batches of species, provided sufficient data are available, meaning that assessment of large numbers of species may be faster and less labour-intensive than methodologies that require more detailed species-specific assessments.	Assessment of exposure requires skills in spatial analysis. Reliance on intrinsic traits without scrutiny of their interplay with climate change mechanisms at species-level introduces assumptions.

NatureServe Climate Change Vulnerability Index (CCVI)

Context

First developed in the early 2010s, and revised several times subsequently, the NatureServe Climate Change Vulnerability Index (CCVI) is available as an Excel spreadsheet, and is widely used in North America to assess species' vulnerability to climate change and to provide input for planning documents, such as State Wildlife Action Plans (Young *et al*. 2012, 2015) . It can be used for animals, plants or fungi, and is designed to provide a rapid, cost-effective means of estimating a plant, fungus, or animal species' relative vulnerability to climate change.

Overview of the methodology

The method uses a trait-based approach to assess species' sensitivity and adaptive capacity. Exposure is assessed by uploading or drawing a map of the species' range in an online tool, which calculates projected changes in temperature and drought within the species' range, or by using standard US state-level exposure values. Uncertainty can be accounted for by entering a range of responses, and the tool will carry out a Monte Carlo simulation to produce a measure of confidence. Each species is placed on a five-category scale of climate change vulnerability.

Assessment of sensitivity and adaptive capacity

Species' capacity to adapt to climate change is assessed through 37 factors that focus on intrinsic adaptive capacity (as opposed to extrinsic factors such as geographic barriers), as defined by Thurman *et al.* (2020). These factors are grouped under seven categories:

- Distribution - includes measures of the size of the species' range, its habitat specialisation and degree of tolerance of human influences.

- Movement - includes measures of a species' ability to disperse or migrate, including dependence on an environmental cue, dispersal distance, site fidelity, migration timing and distance.

- Evolutionary potential - contains measures of the species' genetic diversity and population size.

- Ecological role – includes consideration of species interactions that are likely to be impacted by climate change and diet breadth.

- Abiotic niche – includes seasonal phenology, breadth of climatic niche, physiological tolerances, the ability of individuals to change their behaviour in effort to reduce exposure to climate stressor, and tolerance of changes in ecological disturbance events due to climate change.

- Life history – includes dependence of reproductive events on environmental cues, mating system, fecundity, sex ratio, sex determination and parental investment.

- Demography – includes lifespan, generation length and recruitment.

A separate section takes into account extrinsic factors that may influence a species' ability to adapt to climate change, including barriers to dispersal, land use change and other threats that are likely to increase due to climate change.

Assessment of exposure

Species' exposure to climate change is assessed via an online tool that performs a spatial analysis of projected climate change across the species' range, based on two climate change scenarios. The tool calculates the changes in temperature and climatic water deficit across the geographic area assessed for the taxon of interest, rescales both variables to a number ranging from zero to one, then averages the two figures to gain an overall exposure value. The user may upload a map file, draw a map or use a built-in map of a US state. To assess exposure to sea level rise, assessors are instructed to use a tool on the website of the National Oceanic and Atmospheric Administration.

Documented or modelled responses to climate change

This methodology has an optional section that can be used to take into account documented or modelled responses of the species to climate change. Questions cover documented and modelled impacts on the species' population or range, overlap of current range with modelled future range, and occurrence of protected areas in the modelled future range.

Scoring system

All variables except for exposure are scored on a scale of up to five categories ranging from low to high, with the number of possible options varying. Thresholds are a mix of quantitative and qualitative.

The scores for each variable relating to adaptive capacity are summed and the final score is adjusted using the score for extrinsic factors and the exposure score to produce an overall vulnerability score, which is placed into one of five categories representing levels of vulnerability. The overall vulnerability score is then adjusted according to the score for documented or modelled responses to climate change.

Advantages and disadvantages

A list of some potential advantages and disadvantages of the NatureServe methodology can be found in Table 3.

Table 3. Potential advantages and disadvantages of the NatureServe methodology

Advantages	**Disadvantages**
User-friendly spreadsheet makes it very easy to complete an assessment. Takes account of documented climate change impacts. Takes account of modelled climate change impacts. Takes account of protected areas within projected range under climate change. Includes a measure of uncertainty. A standard set of questions is applicable to all species (with a few alternate options for animals vs plants/fungi), so all species can be assessed consistently.	Assessment of exposure is designed for use in North America – may need further development to be applicable to other regions. There may be limited data available for some of the variables included in the methodology (such as genetic diversity). Cannot be used to batch-assess multiple species at once. The assessment of exposure considers few climatic variables and does not take account of changes in seasonal temperatures, or increased frequency of extreme events such as storms or wildfires, which may be important mechanisms of climate change impact. The score thresholds are arbitrary. Many of the assessment criteria are qualitative, and expert judgement is required to select appropriate scores, which may be more labour-intensive and may introduce inconsistencies and bias. All adaptive capacity variables are treated equally in score calculations, but their true effects on climate vulnerability are likely to differ and to interact. Does not allow for assessment of seasonal exposure for migratory species (although seasonal ranges could be assessed separately).

WWF Climate Change Vulnerability Assessment for Species

Context

WWF developed a trait-based climate change vulnerability assessment tool in 2014 (Advani, 2014, 2023), based on methods used by several existing tools (including that developed by Foden *et al.* in 2013). The tool was designed to be easy to use and to highlight species' areas of vulnerability to climate change so that these can be addressed through adaptation management recommendations in species conservation strategies. The tool does not assign species an overall score or grading for climate change vulnerability.

Overview of the methodology

The WWF methodology assesses species' vulnerability according to traits reflecting their sensitivity, adaptive capacity and exposure, as well as other threats (incorporating indirect climate change impacts). Traits relating to each of these are ranked as high, medium, low or unknown. The method does not require spatial analysis, and exposure is assessed using observed changes and near-term projections in weather and climate across the species' range.

Assessment of sensitivity and adaptive capacity

Sensitivity is assessed via thirteen traits that take into account IUCN Red List Category, geographic range, population size, temperature tolerance, reliance on environmental cues, symbiotic interspecific relationships, specialisation of diet or habitat, abundance of food source, freshwater requirements and susceptibility to diseases that may increase due to climate change. Assessors are also advised to assess tolerance of pH, salinity and oxygen levels for marine species.

Adaptive capacity is assessed via four traits: dispersal ability, generation time, reproductive rate and genetic variation.

The methodology also includes a question to reflect the influence of any other threats on the species' climate change vulnerability, with examples of habitat destruction, poaching, human-wildlife conflict, pollution, as well as human responses to climate change that may exacerbate these threats.

Assessment of exposure

Exposure is assessed via a single multiple-choice question: "*What level of change in temperature and precipitation is projected across the species' range?*". Guidance suggests that exposure to observed and projected changes to temperature, precipitation, and extreme weather events should be considered, and that the IPCC and World Bank may be useful resources. No further specification for an assessment method is provided.

Scoring system

Users are asked to assess species' traits "*relative to those of other similar species*" and select one of several available responses to each question. Some traits present a choice of three options (high, medium, or low; or large, medium and small) relating to different levels of vulnerability, as well as a '*don't know*' option, whilst some traits are assessed via a simple '*yes/no*' response. There is very little guidance provided on how to select the most appropriate response, so there is likely to be a large amount of assessor bias in how the questions are answered. The responses for traits are not combined or processed further, but the methodology is intended to act as a framework to aid identification of areas of vulnerability for inclusion in species' conservation strategies.

Advantages and disadvantages

A list of some potential advantages and disadvantages of the WWF methodology can be found in Table 4.

Table 4. Potential advantages and disadvantages of the WWF methodology

Advantages	**Disadvantages**
Straightforward to fill in. Does not require technical skills in spatial analysis or modelling. Highlights areas of vulnerability to be taken into account in species conservation plans. Clear logical framework, with separate sections for sensitivity, adaptive capacity and exposure (as well as other threats). Broad questions allow for the inclusion of a wide range of climate change impact mechanisms. Assessment of exposure is able to take into account the full range of climatic variables that may affect species, including extreme weather events. Assessment of 'other threats' may take into account the full range of interactions of other threats, including human responses to	Does not produce overall vulnerability score. Asks users to assess traits "*relative to those of similar species*", so is not consistent across all species There is very little guidance provided on how to select the most appropriate response, so there is likely to be a large amount of assessor bias in how the questions are answered. The incorporation of IUCN Red List Status could potentially introduce a degree of '*double-counting*', since the Red List assessment may already take current and/or projected climate change impacts into account. Assessment of exposure is via a single multiple-choice question, which leaves the decisions of how to make the assessment down to the assessor. This may introduce inconsistencies between species.

climate change, with climate change impact mechanisms. The same questions are used across all terrestrial species, although assessors are advised to add several additional traits for marine species.	The question pertaining to other threats is extremely broad and unlikely to be answered consistently by different assessors. It is also likely to duplicate consideration of threats that are included in species' Red List assessments, as included in the assessment of sensitivity.

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