

# **Guidelines for Using the IUCN Red List Categories and Criteria**

**Version 8.1 (August 2010)**

**Prepared by the Standards and Petitions Subcommittee  
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## 1. Introduction

The IUCN Red List Categories and Criteria were first published in 1994 following six years of research and broad consultation (IUCN 1994). The 1994 IUCN Categories and Criteria were developed to improve objectivity and transparency in assessing the conservation status of species, and therefore to improve consistency and understanding among users. The 1994 categories and criteria were applied to a large number of species in compiling the 1996 Red List of Threatened Animals. The assessment of many species for the 1996 Red List drew attention to certain areas of difficulty, which led IUCN to initiate a review of the 1994 categories and criteria, which was undertaken during 1998 to 1999. This review was completed and the IUCN Red List Categories and Criteria (version 3.1) are now published (IUCN 2001).

This document provides guidelines to the application of version 3.1 of the categories and criteria, and in so doing addresses many of the issues raised in the process of reviewing the 1994 categories and criteria. This document explains how the criteria should be applied to determine whether a taxon belongs in a category of threat, and gives examples from different taxonomic groups to illustrate the application of the criteria. These guidelines also provide detailed explanations of the definitions of the many terms used in the criteria. The guidelines should be used in conjunction with the official IUCN Red List Categories and Criteria booklet (IUCN 2001).

We expect to review and update these guidelines periodically, and input from all users of the IUCN Red List Categories and Criteria are welcome. We especially welcome IUCN Specialist Groups and Red List Authorities to submit examples that are illustrative of these guidelines. We expect that the changes to these guidelines will be mostly additions of detail and not changes in substance. In addition, we do not expect the IUCN Red List Criteria to be revised in the near future, because a stable system is necessary to allow comparisons over time.

## 2. An Outline of the Red List Categories and Criteria

### 2.1 Taxonomic level and scope of the categorization process

#### 2.1.1 *Taxonomic scale of categorization*

The criteria may be applied to any taxonomic unit at or below the species level. In these guidelines, the terms '*taxon*' and '*taxa*' are used to represent species or lower taxonomic levels, including forms that are not yet fully described. There is sufficient range among the different criteria to enable appropriate listing of taxa from the complete taxonomic spectrum, with the exception of micro-organisms. In presenting the results of applying criteria, the taxonomic unit used (species, subspecies, etc.) should be specified. It should be noted that taxa below the rank of variety (e.g., forma, morph, cultivar), are NOT included on the IUCN Red List, with the exception of assessments of subpopulations. Before assessments of taxa below the species level (subspecies, variety or subpopulation) can be included on the IUCN Red List, an assessment of the full species is also required.

*Subpopulations:* If a subpopulation assessed under the criteria is not isolated (i.e., if it may be exchanging individuals with other subpopulations), its assessments must follow the regional guidelines (IUCN 2003). In addition, it must be a biological subpopulation (i.e., not defined by political or national boundaries). Although the regional guidelines can in principle be applied at any geographical scale, application within very small geographical areas is strongly discouraged. The smaller the subpopulation as a proportion of the global population of the species, the more often the subpopulation will exchange individuals with other subpopulations. Therefore the assessment of extinction risk based on the criteria would become more unreliable (IUCN 2003). See also *Geographical scale of categorization* below.

*Newly described species:* The inclusion of newly described species on the IUCN Red List is addressed on a case-by-case basis. The designated IUCN Red List Authority and/or IUCN Species Programme staff (including staff from partner institutions working on Global Species Assessment projects) will consult with relevant experts to ascertain how widely accepted these are.

*Undescribed species:* The listing of undescribed species on the IUCN Red List is discouraged, but in exceptional circumstances these may be included. There must be a clear conservation benefit to justify the inclusion of such listings, or in the case of projects to completely assess a taxonomic group, undescribed species that are listed as Least Concern (LC) or Data Deficient (DD) may only be included if there is clear evidence that work is underway to describe the species concerned and that the new species will be widely accepted. The new species description should be published within four years of an undescribed species being included on the IUCN Red List; if it is not published or is not in press after that time, the assessment will be removed. For an undescribed species to be included on the IUCN Red List the following conditions must be met:

- There must be general agreement that the undescribed form is a clearly circumscribed species
- There must be a clear indication that work is underway to describe the species (e.g., a draft manuscript in preparation or a paper with the new description already submitted for publication)
- Clear distribution information must be provided
- Listing the undescribed species will potentially aid in its conservation
- Specimen reference numbers (voucher collection details) must be provided to enable the species to be traced without confusion
- The museum, herbarium or other institution holding the collection/s and the individual/s responsible for the proposal must be identified
- Undescribed species sometimes have a local common name, if so this should be provided, but if not a recognizable common name should be coined, so that it can be used to clearly indicate the identity of this taxon without any implication about scientific validity.

Undescribed species are presented on the IUCN Red List by using the generic name and the abbreviation sp. or sp. nov., sometimes followed by a provisional name in inverted commas (e.g., *Philautus* sp. nov. 'Kalpatta'). Voucher collection details (collector's name, specimen number and institution where housed) must be provided so that they can be cited under the

Taxonomic Notes section of the species' account on the Red List web site. Instances may arise where there are valid reasons for voucher collection details to be withheld. If this is clearly indicated and justified by the assessor(s) concerned, the voucher information will be suppressed from the public version of the species account. However, in such cases the voucher information must still be supplied in order for the assessment to be accepted, and this information will be held in confidence.

Undescribed species assessed as Least Concern (LC) or Data Deficient (DD) are not included on the IUCN Red List as there is little conservation benefit to such listings.

Undescribed infraspecific taxa are not included on the IUCN Red List.

In summary, assessments of the following taxa may be included on the IUCN Red List

- Species
- Subspecies
- Varieties (only for plants)
- Subpopulations (provided certain conditions as described above are met)
- Undescribed species (provided certain conditions as described above are met, and they are not listed as LC or DD)

Assessments of the following taxa may NOT be included on the IUCN Red List

- Taxa assessed locally, nationally or regionally are not considered for inclusion on the IUCN Red List unless they are global or subpopulation assessments (see “*Subpopulation*” above, and section 2.1.2)
- Hybrids (except for apomictic plant hybrids which are treated as 'species')
- Infraspecific ranks such as formas, morphs, subvarieties, varieties of subspecies, cultivars, etc.
- Domesticated taxa (in the case where a taxon comprises both domesticated and wild individuals, only the wild population may be assessed and included; feral animals derived from a domesticated source should not be included)
- Taxa known to have gone Extinct before 1500 AD
- Undescribed species assessed as Data Deficient or Least Concern (except in the case of complete global assessments for a taxonomic group, see above)
- Undescribed infraspecific taxa
- Assessments of higher taxa (i.e., above the species level).

### 2.1.2 Geographical scale of categorization

The IUCN criteria are designed for global taxon assessments. However many people are interested in applying them to subsets of global data, especially at regional, national or local levels. To do this it is important to refer to guidelines prepared by the IUCN/SSC Regional Applications Working Group (e.g., Gardenfors *et al.* 2001; IUCN 2003; Miller *et al.* 2007). When applied at national or regional levels it must be recognized that a global category may not be the same as a national or regional category for a particular taxon. For example, taxa classified as Least Concern globally might be Critically Endangered within a particular region where numbers are very small or declining, perhaps only because they are at the margins of their global range. Conversely, taxa classified as Vulnerable on the basis of their

global declines in numbers or range might, within a particular region where their populations are stable, not even nearly meet the criteria for Vulnerable, i.e. be Least Concern. Although this appears illogical, it is a result of the structure of the criteria. When such a situation occurs, interactions among sub-units should be carefully considered when planning recovery.

It is also important to note that taxa endemic to regions or nations will be assessed globally in any regional or national applications of the criteria, and in these cases great care must be taken to check that an assessment has not already been undertaken by a Red List Authority (RLA), and that the categorization is agreed with the relevant RLA (e.g., an SSC Specialist Group known to cover the taxon); see the regional guidelines.

### 2.1.3 *Introduced taxa*

The categorization process should only be applied to wild populations inside their natural range, and to populations resulting from benign introductions. Benign introductions are defined in the IUCN Guidelines for Re-Introductions (IUCN 1998) as ‘...an attempt to establish a species, for the purpose of conservation, outside its recorded distribution, but within an appropriate habitat and eco-geographical area. This is a feasible conservation tool only when there is no remaining area left within a species’ historic range’. If the only individuals left are in a naturalized population or a population resulting from a benign introduction, then the taxon should be considered Extinct in the Wild.

In some cases, taxa have successfully expanded their natural ranges into urban or semi-urban areas, e.g. primates, foxes and some birds. In these instances urban areas should be considered as part of the natural range, as the taxa have not been introduced. The original non-urban occurrence may only be assessed as a separate subpopulation (which then must be clearly indicated) if there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less) between the original and urbanized occurrences.

In addition to taxa within their natural range and subpopulations resulting from benign introductions (outside the taxon’s natural range), the criteria should also be applied to self-sustaining translocated or re-introduced subpopulations (within the taxon’s natural range), regardless of the original goal of such translocations or re-introductions. In such cases, the listing should indicate whether all or part of the assessed population has been introduced. Populations introduced for non-conservation purposes, outside the natural range of the taxon are not assessed globally, but they may be assessed regionally (see Regional Guidelines, page 11).

## 2.2 **Nature of the categories**

There are nine clearly defined categories into which every taxon in the world (excluding micro-organisms) can be classified (Figure 2.1). Complete definitions of the categories are given in Box 2.1. The first two categories in Figure 2.1 are relatively self-explanatory. **Extinct** means that there is no reasonable doubt that the last individual has died. **Extinct in the Wild** means that the taxon is extinct in its natural habitat (see Introduced taxa above). The following three categories, **Critically Endangered**, **Endangered** and **Vulnerable**, are

assigned to taxa on the basis of quantitative criteria that are designed to reflect varying degrees of threat of extinction. These criteria will be discussed further in the next section. The category **Near Threatened** is applied to taxa that do not qualify as threatened now, but may be close to qualifying as threatened. The category **Least Concern** is applied to taxa that do not qualify (and are not close to qualifying) as threatened or near threatened.

The remaining two categories do not reflect the threat status of taxa. The category **Data Deficient** highlights taxa for which sufficient information is lacking to make a sound status assessment. The inclination to assess taxa as Data Deficient may be very strong; it should be emphasised that assessors must use all data available in full when making a Red List assessment. Precise information on scarce taxa is usually lacking, and although the criteria are highly quantitative and defined, one can use projections, assumptions and inferences in order to place a taxon in the appropriate category. Since Data Deficient is not a category of threat, taxa placed in this category are not so obviously targets for conservation action, although their needs might be very great. Assessors should use whatever information is available and relevant to make assessments and place taxa into the Data Deficient category only when there is really no alternative. Guidance on handling uncertainty is especially relevant in the case of poorly known taxa (see section 3.2). The category **Not Evaluated** applies to taxa that have not yet been evaluated against the Red List Criteria.

Taxa in all of the IUCN Red List Categories, except LC and NE, are normally presented in the Red List and, consequently, are referred to as "red-listed". The 2003 update of the *IUCN Red List of Threatened Species* and all subsequent updates will include all taxa assessed as LC and information about them will be documented, although these taxa would not be referred to as "red-listed". This is especially important, for example, for taxa that were Red-listed in an earlier edition, but have since been down-listed.

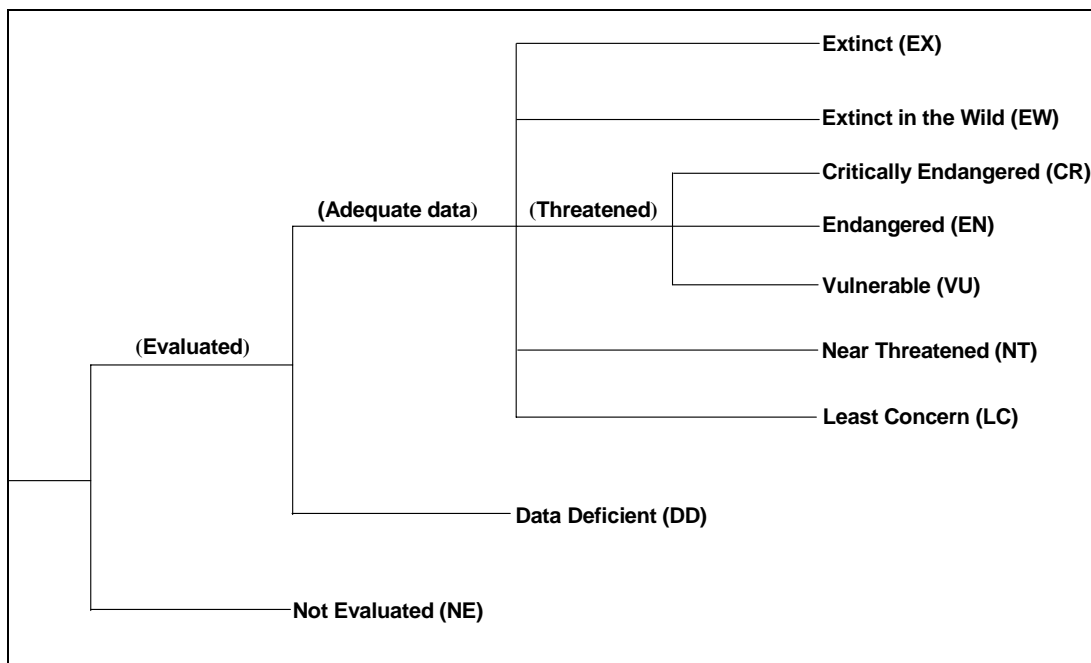


Figure 2.1. Structure of the IUCN Red List categories



**Box 2.1. The IUCN Red List Categories****EXTINCT (EX)**

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycles and life form.

**EXTINCT IN THE WILD (EW)**

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

**CRITICALLY ENDANGERED (CR)**

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.

**ENDANGERED (EN)**

A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.

**VULNERABLE (VU)**

A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.

**NEAR THREATENED (NT)**

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

**LEAST CONCERN (LC)**

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

**DATA DEFICIENT (DD)**

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, if a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

**NOT EVALUATED (NE)**

A taxon is Not Evaluated when it has not yet been evaluated against the criteria.

### 2.2.1 Transfer between categories

The following rules govern the movement of taxa between categories:

- A. A taxon may be moved from a category of higher threat to a category of lower threat if none of the criteria of the higher category has been met for five years or more. However, if the taxon is being moved from EW as a result of the establishment of a re-introduced population, this period must be 5 years or until viable offspring are produced, whichever is the longer.
- B. If the original classification is found to have been erroneous, the taxon may be transferred to the appropriate category or removed from the threatened categories altogether, without delay. However, in this case, the taxon should be re-evaluated against all the criteria to clarify its status.
- C. Transfer from categories of lower to higher risk should be made without delay.

D. The reason for a transfer between categories must be documented as one of the following:

*Genuine (recent)*. The change in category is the result of a genuine status change that has taken place since the previous assessment. For example, the change is due to an increase in the rate of decline, a decrease in population or range size or habitat, or declines in these for the first time (owing to increasing/new threats) and therefore new thresholds are met relating to the IUCN Red List Criteria.

*Genuine (since first assessment)*. This applies to taxa assessed at least 3 times, and is used to assign genuine category changes to the appropriate time period in order to calculate the Red List Index. The change in category is the result of a genuine status change that took place prior to the last assessment, but since the first assessment and that has only just been detected owing to new information or new documentation. If this new information had been available earlier, the new category would have been assigned during the previous assessment(s). When this code is used, the appropriate time period (between previous assessments) in which the status change occurred needs to be indicated. [See example below]

*Criteria revision*. The change in category is the result of the revision of the IUCN Red List Criteria (e.g., 1994 v. 2001 versions). These largely relate to criteria A2, A3, A4, D2 and the removal of the 'Conservation Dependent' category.

*Knowledge*. The change in category is the result of better knowledge, e.g. owing to new or newly synthesized information about the status of the taxon (e.g. better estimates for population size, range size or rate of decline).

*Taxonomy*. The new category is different from the previous owing to a taxonomic change adopted during the period since the previous assessment. Such changes include: *newly split* (the taxon is newly elevated to species level), *newly described* (the taxon is newly described as a species), *newly lumped* (the taxon is recognized following lumping of two previously recognized taxa) and *no longer valid/recognized* (either the taxon is no longer valid e.g. because it is now considered to be a hybrid or variant, form or subspecies of another species, or the

previously recognized taxon differs from a currently recognized one as a result of a split or lump).

*Mistake.* The previous category was applied in error.

*Other.* The change in category is the result of other reasons not easily covered by the above, and/or requires further explanation. Examples include change in assessor's attitude to risk and uncertainty (as defined in section 3.2.3) and changes in this guidelines document.

Determining the appropriate reason for change often requires careful consideration. Many category changes result from a combination of improved knowledge and some element of genuine deterioration or improvement in status. In such cases, "genuine" should only be assigned if the amount of genuine change (e.g., population size change, decline rate change, range size change, etc.) is sufficient on its own to cross the relevant Red List Category threshold. Genuine and non-genuine reasons for change should never be coded at the same time.

e.g. Species A previously qualified as Endangered (D) with a population estimated to be 150 individuals; it is reassessed as Vulnerable (D1) because its population is now estimated to number 400 individuals; the new estimate is partly a result of the discovery of a new stable subpopulation numbering 50 individuals, and partly because the previously known subpopulation increased from 150 to 350 individuals. The genuine increase is sufficient to have taken the total population over the threshold for Vulnerable, so the category change is coded as Genuine (recent), and Knowledge should not be coded in this case.

e.g. Species B previously qualified as Endangered (D) with a population estimated to be 150 individuals; it is reassessed as Vulnerable (D1) because its population is now estimated to number 400 individuals; the new estimate is partly a result of the discovery of a new stable subpopulation numbering 200 individuals, and partly because the previously known subpopulation increased from 150 to 200 individuals. The genuine increase in this case is insufficient to have taken the total population over the threshold for Vulnerable, (it should have qualified as Vulnerable in the previous assessment also) so the category change is coded as Knowledge, and Genuine should not be coded in this case.

In cases where a category change results from a combination of taxonomic splitting and genuine change, the change should be coded as Genuine (recent).

e.g. Species C previously qualified as Vulnerable(D1) with a total population estimated to number 600 individuals. It is then split into species D (540 individuals and stable) and species E (now only 40 individuals, having declined from 60 individuals in the previous assessment). This category change for species E (previously 'Not Recognised' but now Critically Endangered C1) should be coded as Genuine (recent). [Species D would be classified as Vulnerable (D), with "Taxonomy (newly split)" as its reason for change.]

All Genuine (recent) or Genuine (since first assessment) category changes should be supported with appropriate notes to justify why the change is coded as genuine.

e.g. Mauritius Kestrel *Falco punctatus* was downlisted from CR in 1988 to EN in 1994; this was coded as Genuine (recent) with the note: "Population increased from eight pairs in 1987–1988 to 56–68 pairs in 1994 as a result of a ban on hunting".

e.g. Montserrat Oriole *Icterus oberi* was uplisted from NT in 1994 to CR in 2000; this was coded as Genuine (recent) with the note: "In the early 1990s, this species occurred throughout the three main

forested hill ranges on the island, but volcanic eruptions in 1995-1997 destroyed two-thirds of remaining habitat. Recent evidence suggests that the decline may now have halted, and the population is estimated at c.100-400 pairs”.

e.g. Ethiopian Bush-crow *Zavattariornis stresemanni* was uplisted from Vulnerable to Endangered in 2005. This category change was coded as Genuine (since first assessment), with the genuine change assigned to the 1994–2000 period, and the note “Encounter rates declined 80% between 1989 and 2003. Assuming declines began in 1989, the cumulative decline would have exceeded 50% over 10 years for the first time during the period 1994-2000”.

### 2.3 Nature of the criteria

There are five quantitative criteria which are used to determine whether a taxon is threatened or not, and if threatened, which category of threat it belongs in (Critically Endangered, Endangered or Vulnerable) (Table 2.1). These criteria are based around the biological indicators of populations that are threatened with extinction, such as rapid population decline or very small population size. Most of the criteria also include subcriteria that must be used to justify more specifically the listing of a taxon under a particular category. For example, a taxon listed as “Vulnerable C2a(i)” has been placed in the Vulnerable category because its population is fewer than 10,000 mature individuals (criterion C) and the population is undergoing a continuing decline and all its mature individuals are in one subpopulation (subcriterion a(i) of criterion C2).

The five criteria are:

- A. Declining population (past, present and/or projected)**
- B. Geographic range size, and fragmentation, decline or fluctuations**
- C. Small population size and fragmentation, decline, or fluctuations**
- D. Very small population or very restricted distribution**
- E. Quantitative analysis of extinction risk (e.g., Population Viability Analysis)**

To list a particular taxon in any of the categories of threat, only one of the criteria, A, B, C, D, or E needs to be met. However, a taxon should be assessed against as many criteria as available data permit, and the listing should be annotated by as many criteria as are applicable for a specific category of threat. For example, Critically Endangered: A2cd; B1+2de; C2a(i). Only the criteria for the highest category of threat that the taxon qualifies for should be listed. For example, if a taxon qualifies for criteria A, B, and C in the Vulnerable and Endangered category and only criterion A in the Critically Endangered category, then only the criterion A met in the Critically Endangered category should be listed (the highest category of threat). Additional criteria that the taxon qualifies for at lower threat categories may be included in the documentation

Although the criteria for each of the categories of threat are based on quantitative thresholds, the system remains relatively flexible to ensure that taxa for which there is very little information can also be assessed. This has been achieved by incorporating inference and projection into the assessment process. Therefore, the person conducting an assessment is expected to use the best available information in combination with inference and projection to test a taxon against the criteria. However, if inference and projection are used, the assumptions made must be documented. If there is any reasonable concern that a taxon is

threatened with extinction in the near future, it should qualify for the criteria of one of the categories of threat.

The different criteria (A-E) are derived from a wide review aimed at detecting risk factors across the broad range of organisms and the diverse life histories they exhibit. The criteria are aimed at detecting symptoms of endangerment rather than causes. Consequently the criteria are applicable to any threatening process that results in symptoms such as past and future population decline, small population sizes, and small geographic distributions. A taxon may be classified as threatened even if a threatening process cannot be identified. Regardless of the nature of threats, assessments must follow IUCN (2001) and these guidelines to ensure valid application of the criteria. However, different threats, especially new threats or poorly understood processes such as global climate change may require further guidance in the application of definitions and criteria. Section 12 provides guidance specific to different threats.

The quantitative values presented in the various criteria associated with threatened categories were developed through wide consultation, and they are set at what are generally judged to be appropriate levels. Broad consistency between them was sought. The process and the technical background to the IUCN Red List system, and the fundamental biological processes underlying population decline and extinction that the criteria are based on, are described by Mace et al. (2008).

Some studies suggest that when taxa are evaluated under all 5 criteria, there is a tendency for them to be listed under criteria A to D rather than under E. There are several possible reasons for this. First, a reliable assessment under Criterion E generally requires more data and analysis, and in practice the process may often be incomplete. Second, even if each criterion on average corresponds to an identical risk of extinction, the probability that a specific species meets at least one of four criteria will be higher than the probability that it meets one criterion. Third, the thresholds in criteria A to D may be more precautionary. This would be justified because they are based on partial information and are often used in data-poor situations, whereas criterion E can (and should) incorporate all factors that influence population dynamics. In data-poor situations, where data permit only one or two of criteria A-D to be assessed, it would be very easy to 'miss' taxa that should be listed (Keith et al. 2000); in other words, the listing errors will be wider under A-D, so their thresholds should be more precautionary. Even so, it should be noted that while some studies suggest that criteria A-D are more precautionary than criterion E (e.g., Gardenfors 2000), other studies indicate that criteria A-D may not be very precautionary, particularly when data are limited (e.g. Keith et al. 2004).

**Table 2.1.** Summary of the five criteria (A-E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A–E	Critically Endangered	Endangered	Vulnerable
<b>A. Population reduction</b>			
Declines measured over the longer of 10 years or 3 generations			
<b>A1</b>	≥ 90%	≥ 70%	≥ 50%
<b>A2, A3 &amp; A4</b>	≥ 80%	≥ 50%	≥ 30%
<p><b>A1.</b> Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible <b>AND</b> understood <b>AND</b> have ceased, based on and specifying any of the following:</p> <ul style="list-style-type: none"> <li>(a) direct observation</li> <li>(b) an index of abundance appropriate to the taxon</li> <li>(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality</li> <li>(d) actual or potential levels of exploitation</li> <li>(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.</li> </ul> <p><b>A2.</b> Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased <b>OR</b> may not be understood <b>OR</b> may not be reversible, based on (a) to (e) under A1.</p> <p><b>A3.</b> Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.</p> <p><b>A4.</b> An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased <b>OR</b> may not be understood <b>OR</b> may not be reversible, based on (a) to (e) under A1.</p>			
<b>B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)</b>			
<b>B1.</b> Extent of occurrence (EOO)	< 100 km <sup>2</sup>	< 5,000 km <sup>2</sup>	< 20,000 km <sup>2</sup>
<b>B2.</b> Area of occupancy (AOO)	< 10 km <sup>2</sup>	< 500 km <sup>2</sup>	< 2,000 km <sup>2</sup>
<b>AND at least 2 of the following:</b>			
(a) Severely fragmented, <b>OR</b>			
Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals.			
<b>C. Small population size and decline</b>			
Number of mature individuals	< 250	< 2,500	< 10,000
<b>AND either C1 or C2:</b>			
<b>C1.</b> An estimated continuing decline of at least:	25% in 3 years or 1 generation (up to a max. of 100 years in future)	20% in 5 years or 2 generations	10% in 10 years or 3 generations
<b>C2.</b> A continuing decline <b>AND</b> (a) and/or (b):			
(a) <b>i)</b> Number of mature individuals in each subpopulation:	< 50	< 250	< 1,000
<b>or</b>			
(a) <b>ii)</b> % individuals in one subpopulation =	90–100%	95–100%	100%
<b>(b)</b> Extreme fluctuations in the number of mature individuals.			
<b>D. Very small or restricted population</b>			
<b>Either:</b>			
Number of mature individuals	< 50	< 250	<b>D1.</b> < 1,000
			<b>AND/OR</b>
<b>VU D2.</b> Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.			<b>D2.</b> typically: AOO < 20 km <sup>2</sup> or number of locations ≤ 5
<b>E. Quantitative Analysis</b>			
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

## **2.4 Conservation priorities and actions**

The category of threat is not necessarily sufficient to determine priorities for conservation action. The category of threat simply provides an assessment of the extinction risk under current circumstances, whereas a system for assessing priorities for action will include numerous other factors concerning conservation action such as costs, logistics, chances of success, and other biological characteristics (Mace and Lande 1991). The Red List should therefore not be interpreted as a means of priority setting (IUCN 2001). The difference between measuring threats and assessing conservation priorities needs to be appreciated. However, assessment of taxa using Red List Criteria represents a critical first step in setting priorities for conservation action.

Many taxa assessed under the IUCN Red List Criteria will already be subject to some level of conservation action. The criteria for the threatened categories are to be applied to a taxon whatever the level of conservation action affecting it, and any conservation measures must be included with the assessment documentation. It is important to emphasise here that a taxon may require conservation action even if it is not listed as threatened, and that effectively conserved threatened taxa may, as their status improves over time, cease to qualify for listing.

## **2.5 Documentation**

All assessments should be documented. Threatened classifications should state the criteria and subcriteria that are met. For example, in a taxon listed as Endangered A2cd, the criterion A2 indicates that the taxon has declined by more than 50% in the last 10 years or three generations (whichever is longer) and the subcriteria indicate that the decline in mature individuals has been caused by a decline in the quality of habitat as well as actual levels of exploitation. Clearly listing the subcriteria provides the reasoning for placing a taxon in a specific category, and if necessary, the reasoning can be re-examined. It also enables people to understand the primary threats facing a taxon and may aid in conservation planning. No assessment can be accepted for the IUCN Red List as valid unless at least one criterion and any qualifying subcriteria are given. If more than one criterion or subcriterion is met, then each should be listed. If a re-evaluation indicates that the documented criterion is no longer met, this should not result in automatic reassignment to a lower category of threat (downlisting). Instead, the taxon should be re-evaluated against all the criteria to clarify its status. The factors responsible for qualifying the taxon against the criteria, especially where inference and projection are used, should be documented. All data used in a listing must be either referenced to a publication that is available in the public domain, or else be made available. Full documentation requirements are given in Annex 3 of the IUCN Red List Categories and Criteria (Version 3.1) (IUCN 2001).

## **3. Data Quality**

### **3.1 Data availability, inference and projection**

The IUCN Red List Criteria are intended to be applied to taxa at a global scale. However, it is very rare for detailed and relevant data to be available across the entire range of a taxon. For this reason, the Red List Criteria are designed to incorporate the use of inference and projection, to allow taxa to be assessed in the absence of complete data. Although the criteria are quantitative in nature, the absence of high-quality data should not deter attempts at applying the criteria. In addition to the quality and completeness of the data (or lack of),

there may be uncertainty in the data itself, which needs to be considered in a Red List assessment. Data uncertainty is discussed separately in section 3.2.

The IUCN criteria use the terms Observed, Estimated, Projected, Inferred, and Suspected to refer to the quality of the information for specific criteria. For example, criterion A allows inferred or suspected reduction, whereas criterion C1 allows only estimated declines and criterion C2 specifies “observed, projected, or inferred” declines. These terms are defined as follows:

**Observed:** information that is directly based on well-documented observations of all known individuals in the population.

**Estimated:** information that is based on calculations that may include statistical assumptions about sampling, or biological assumptions about the relationship between an observed variable (e.g., an index of abundance) to the variable of interest (e.g., number of mature individuals). These assumptions should be stated and justified in the documentation. Estimation may also involve interpolation in time to calculate the variable of interest for a particular time step (e.g., a 10-year reduction based on observations or estimations of population size 5 and 15 years ago). For examples, see discussion under criterion A.

**Projected:** same as “estimated”, but the variable of interest is extrapolated in time towards the future. Projected variables require a discussion of the method of extrapolation (e.g., justification of the statistical assumptions or the population model used) as well as the extrapolation of current or potential threats into the future, including their rates of change.

**Inferred:** information that is based on indirect evidence, on variables that are indirectly related to the variable of interest, but in the same general type of units (e.g., number of individuals or area or number of subpopulations). Examples include population reduction (A1d) inferred from a change in catch statistics, continuing decline in number of mature individuals (C2) inferred from trade estimates, or continuing decline in area of occupancy (B1b(ii,iii), B2b(ii,iii)) inferred from rate of habitat loss. Inferred values rely on more assumptions than estimated values. For example, inferring reduction from catch statistics not only requires statistical assumptions (e.g., random sampling) and biological assumptions (about the relationship of the harvested section of the population to the total population), but also assumptions about trends in effort, efficiency, and spatial and temporal distribution of the harvest in relation to the population. Inference may also involve extrapolating an observed or estimated quantity from known subpopulations to calculate the same quantity for other subpopulations. Whether there are enough data to make such an inference will depend on how large the known subpopulations are as a proportion of the whole population, and the applicability of the threats and trends observed in the known subpopulations to the rest of the taxon. The method of extrapolating to unknown subpopulations depends on the criteria and on the type of data available for the known subpopulations. Further guidelines are given under specific criteria (e.g., see section 5.8 for extrapolating population reduction for criterion A assessments).

**Suspected:** information that is based on circumstantial evidence, or on variables in different types of units, for example, % population reduction based on decline in habitat quality (A1c) or on incidence of a disease (A1e). For example, evidence of qualitative habitat



loss can be used to *infer* that there is a qualitative (continuing) decline, whereas evidence of the amount of habitat loss can be used to *suspect* a population reduction at a particular rate. In general, a suspected population reduction can be based on any factor related to population abundance or distribution, including the effects of (or dependence on) other taxa, so long as the relevance of these factors can be reasonably supported.

## 3.2 Uncertainty

The data used to evaluate taxa against the criteria are often obtained with considerable uncertainty. Uncertainty in the data should not be confused with a lack of data for certain parts of a species' range or a lack of data for certain parameters. This problem is dealt with in section 3.1 (Data availability, inference and projection). Data uncertainty can arise from any one or all of the following three factors: natural variability, vagueness in the terms and definitions used in the criteria (semantic uncertainty), and measurement error (Akçakaya *et al.* 2000). The way in which uncertainty is handled can have a major influence on the results of an evaluation. Details of methods recommended for handling uncertainty are given below.

### 3.2.1 Types of uncertainty

Natural variability results from the fact that species' life histories and the environments in which they live change over time and space. The effect of this variation on the criteria is limited, because each parameter refers to a specific time or spatial scale. However, natural variability can be problematic, e.g. there is spatial variation in age-at-maturity for marine turtles, and a single estimate for these taxa needs to be calculated to best represent the naturally occurring range of values. Semantic uncertainty arises from vagueness in the definition of terms in the criteria or lack of consistency in different assessors' usage of them. Despite attempts to make the definitions of the terms used in the criteria exact, in some cases this is not possible without the loss of generality. Measurement error is often the largest source of uncertainty; it arises from the lack of precise information about the quantities used in the criteria. This may be due to inaccuracies in estimating values or a lack of knowledge. Measurement error may be reduced or eliminated by acquiring additional data (Akçakaya *et al.* 2000; Burgman *et al.* 1999). Another source of measurement error is 'estimation error', i.e. sampling the wrong data or the consequences of estimating a quantity (e.g., natural mortality) based on a weak estimation method. This source of measurement error is not necessarily reduced by acquiring additional data.

### 3.2.2 Representing uncertainty

Uncertainty may be represented by specifying a best estimate and a range of plausible values for a particular quantity. The best estimate can itself be a range, but in any case the best estimate should always be included in the range of plausible values. The plausible range may be established using various methods, for example based on confidence intervals, the opinion of a single expert, or the consensus view of a group of experts. The method used should be stated and justified in the assessment documentation.

### 3.2.3 *Dispute tolerance and risk tolerance*

When interpreting and using uncertain data, attitudes toward risk and uncertainty are important. First, assessors need to consider whether they will include the full range of plausible values in assessments, or whether they will exclude extreme values from consideration (known as dispute tolerance). Uncertainty in the data is reduced when an assessor has a high dispute tolerance, and thus excludes extreme values from the assessment. We suggest assessors adopt a moderate attitude, taking care to identify the most likely plausible range of values, excluding extreme or unlikely values.

Second, assessors need to consider whether they have a precautionary or evidentiary attitude to risk (known as risk tolerance). A precautionary attitude (i.e., low risk tolerance) will classify a taxon as threatened unless it is highly unlikely that it is not threatened, whereas an evidentiary attitude will classify a taxon as threatened only when there is strong evidence to support a threatened classification.

### 3.2.4 *Dealing with uncertainty*

It is recommended that assessors should adopt a precautionary but realistic attitude, and to resist an evidentiary attitude to uncertainty when applying the criteria (i.e., have low risk tolerance). This may be achieved by using plausible lower bounds, rather than best estimates, in determining the quantities used in the criteria. It is recommended that ‘worst case scenario’ reasoning be avoided as this may lead to unrealistically precautionary listings. All attitudes should be explicitly documented. In situations where the spread of plausible values (after excluding extreme or unlikely values) qualifies a taxon for two or more categories of threat, the precautionary approach would recommend that the taxon be listed under the higher (more threatened) category.

In some rare cases, uncertainties may result in two non-consecutive plausible threat categories. This may happen, for example, when extent of occurrence (EOO) or area of occupancy (AOO) is smaller than the EN threshold and one subcriterion is definitively met, but it is uncertain whether a second subcriterion is also met. Depending on this, the category can be either EN or NT. In such cases, the category could be specified as the range EN–NT in the documentation (giving the reasons why), and the assessors must choose the most plausible of the categories, of which VU could be one. This choice depends on the level of precaution (see section 3.2.3) and should be justified.

Specific guidelines for dealing with uncertainty in assessing taxa with widely distributed or multiple subpopulations against criterion A are given in section 5.8. This section offers clear guidance on using uncertain estimates, uncertainty about the pattern of population decline and using data with different abundance units.

### 3.2.5 *Documenting uncertainty and interpreting listings*

The level of uncertainty associated with a particular taxon’s assessment is not apparent from the listing itself, potentially complicating and de-valuing interpretation of listings. When a plausible range for each quantity is used to evaluate the criteria, a range of categories may be obtained, reflecting the uncertainties in the data. However, only a single category, based on a specific attitude to uncertainty, will be listed along with the relevant criteria on the IUCN

Red List. It is important to note that the range of possible categories should also be indicated, along with the assessors' attitudes to uncertainty, in the documentation accompanying the assessment. The inclusion of information on uncertainty in the documentation, allows users of the Red List access to important information that will assist in the interpretation of listings, and inform debates over particular issues or listings.

### *3.2.6 Uncertainty and the application of the categories Data Deficient and Near Threatened*

The level of uncertainty in the data used for assessments may or may not affect the application of the categories Data Deficient and Near Threatened. Guidance on the application of these categories is given in section 10.

## **4. Guidelines for the Definitions of Terms Used in the Criteria**

The terms used in the IUCN Red List Categories and Criteria must be clearly understood to ensure that taxa are correctly assessed. The following terms are defined in the *IUCN Red List Categories and Criteria (version 3.1)* on pages 10-13 (IUCN 2001). These definitions are reproduced here, with additional guidelines to assist in their interpretation.

### **4.1 Population and Population Size (Criteria A, C and D)**

“The term ‘population’ is used in a specific sense in the Red List Criteria that is different to its common biological usage. Population is here defined as the total number of individuals of the taxon. For functional reasons, primarily owing to differences between life forms, population size is measured as numbers of mature individuals only. In the case of taxa obligately dependent on other taxa for all or part of their life cycles, biologically appropriate values for the host taxon should be used.” (IUCN 2001)

The interpretation of this definition depends critically on an understanding of the definition of ‘mature individuals’, which is given and discussed below in section 4.3.

### **4.2 Subpopulations (Criteria B and C)**

“Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).” (IUCN 2001)

The significance of subpopulations in the criteria relates to the additional risks faced by taxa where the population is either fragmented into many small units or where most individuals are concentrated into one unit. Operational methods for determining the number of subpopulations may vary according to the taxon; in the case of tree species, for example, a subpopulation can be defined as a spatially distinct segment of the population that experiences insignificant seed or pollen migration from other subpopulations within a generation.

Although subpopulations typically have little demographic or genetic exchange, this may or may not amount to their complete isolation in this regard.

### 4.3 Mature individuals (Criteria A, B, C and D)

“The number of mature individuals is the number of individuals known, estimated or inferred to be capable of reproduction. When estimating this quantity the following points should be borne in mind:

- Mature individuals that will never produce new recruits should not be counted (e.g., densities are too low for fertilization).
- In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals, which take this into account.
- Where the population size fluctuates, use a lower estimate. In most cases this will be much less than the mean.
- Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g., corals).
- In the case of taxa that naturally lose all or a subset of mature breeding individuals at some point in their life cycle, the estimate should be made at the appropriate time, when mature individuals are available for breeding.
- Re-introduced individuals must have produced viable offspring before they are counted as mature individuals.” (IUCN 2001)

#### 4.3.1 Notes on defining mature individuals

This definition of mature individuals differs slightly from that given in version 2.3 of the Red List Categories and Criteria (IUCN 1994). Some groups have found the more recent definition of mature individuals to be less conservative and less precise, leading to a potential down-listing of some taxa (e.g., obligate co-operative breeders) even though their extinction risk has not changed. It must be stressed that the intention of the definition of mature individuals is to allow the estimate of the number of mature individuals to take account of all the factors that may make a taxon more vulnerable than might otherwise be expected. The list of points given with the definition is not exhaustive and should not restrict an assessor’s interpretation of mature individuals, provided they are estimating the number of individuals known, estimated or inferred to be capable of reproduction. The ability of an assessor to estimate or infer which individuals are capable of reproduction is paramount and highly contingent on the particular features of the taxon or group. Juveniles, senescent individuals, suppressed individuals and individuals in subpopulations whose densities are too low for fertilization to occur will never produce new recruits, and therefore should not be counted as mature individuals. On the other hand, in many taxa there is a pool of non-reproductive (e.g., suppressed) individuals that will quickly become reproductive if a mature individual dies. These individuals can be considered to be capable of reproduction. In general, the judgement will be best made by assessors with insight into the species’ biology.

In the case of taxa obligately dependent on other taxa for all or part of their life cycles, biologically appropriate values of mature individuals for the host taxon might be used. This number may be much less than the total number of mature individuals of the host taxon, because generally other factors restrict the dependant taxon from utilizing all host individuals.

The number of mature individuals can be estimated using the equation  $d * A * p$ , where  $d$  is an estimate of population density,  $A$  is an estimate of area, and  $p$  is an estimate of the proportion of individuals that are mature. However, this approach often leads to gross overestimates of number of mature individuals. Therefore, great care should be taken when using this formula to ensure that: (a) the area is appropriately selected and  $d$  is an estimate of the average over the entire  $A$  (for example, the estimate will be positively biased if  $A$  is set to EOO and  $d$  is based on samples from areas of highest density), and (b)  $p$  should be selected based on knowledge of the taxon (or related taxa) rather than being set to a default value (such as 0.5) because the proportion of mature individuals in a population differs markedly among taxa. Bounds on the estimate of number of mature individuals can be obtained by placing bounds on each of  $d$ ,  $A$ , and  $p$ . The value from this approach will be an *estimate* if the values for  $d$ ,  $A$  and  $p$  are all estimates, but should be considered to be an *inference* if one or more of these values are based on inference.

#### 4.3.2 Colonial or modular organisms, such as corals, algae, bryophytes, fungi and many vascular plants

As opposed to a unitary organism, such as a vertebrate, an insect and many vascular plants, the growth and development of a colonial (modular) organism is an iterative process in which “modules” are added step by step to the existing structure. In principle, the growth of a modular organism never ends and it has no final shape, size or age. A modular organism (the genet) can sometimes exist in a form of many parts (ramets), which can become more or less isolated from each other. Consequently, what constitutes a ‘mature individual’ in a colonial or modular organism is not always clear. Still, it is important to define ‘mature individual’ for such organisms, since ‘mature individual’ is used under criteria C and D to capture the effects of threats and demographic stochasticity to a small population. In defining ‘mature individual’ for colonial organisms, it is important to identify entities that are comparable in extinction proneness to discrete mature individuals of animals and other organisms.

As a general rule, the ramet, i.e., the smallest entity capable of both independent survival and (sexual or asexual) reproduction should be considered a ‘mature individual’. For instance, in those cases where the organism appears in well-distinguishable units, each such unit would be counted as one mature individual. Examples may be a bryophyte tuft (e.g. of *Ulota*) or a discrete cushion (e.g. *Brachythecium*), a lichen thallus (e.g. *Alectoria*) or foliose patch (e.g. *Parmelia*), or a coral discrete entity (e.g. a brain coral *Diploria* or sun coral *Tubastrea*).

If the delimitation of ramets is not obvious, but the species lives in or on a discrete and relatively small substrate unit limited by a certain resource, e.g. a piece of cow dung, a leaf or a dead tree branch, each unit colonised by the species should be counted as a single mature individual. In many other cases, like reef-forming corals, cliff-growing lichens and ground-growing fungi, the organism grows in large, more or less continuous entities that could be divided into smaller pieces without obviously harming the organism. In principle, the smallest such entity (ramet) that an organism could be divided into without causing its death or preventing reproduction, should be counted as one mature individual. Obviously, what such an entity would be is often not known. Therefore, in such cases, it may be

necessary to adopt a pragmatic approach to defining ‘mature individuals’. Examples of possible interpretations of the definition of a mature individual are:

- For diffuse, wholly visible organisms in continuous habitats (e.g. corals, algal mats) assessors may assume an average area occupied by a mature individual and estimate the number of mature individuals from the area of occupied habitat. The area of occupied habitat should be estimated at a scale (grid size) that is as close as practicable to the area assumed to be occupied by a single mature individual (not necessarily 2x2km as recommended for estimation of AOO).
- For diffuse organisms, not wholly visible, in continuous habitats (e.g. subterranean mycelial fungi) assessors may assume that each recorded presence separated by a minimum distance represents an assumed number of individuals. For example, each visible fungal fruiting body may be assumed to represent ten mature individuals, so long as they are separated by at least 10 metres. This kind of assumption is necessary because the size or area of a fungal mycelium is rarely known.
- For diffuse organisms that occur in discrete habitat patches (e.g. fungi living more or less concealed in dead wood), each patch (trunk or log colonized by the species) could – if no better information exists – be counted as 2–10 mature individuals, depending on the size of the tree.

In any case, it is recommended that authors of Red List assessments specify the way they have used ‘mature individual’.

#### 4.3.3 Fishes

In many taxa of marine fish, reproductive potential is commonly closely related to body size. Since exploitation usually reduces the mean age and size of individuals, assessing declines in numbers of mature individuals may under-estimate the severity of the decline. When evaluating population decline, this factor should be kept in mind. One possible method is to estimate decline in the biomass of mature individuals rather than the number of such individuals when applying criterion A, where biomass is ‘an index of abundance appropriate to the taxon’.

#### 4.3.4 Sex-changing organisms

Many marine taxa have the capacity to change sex as they grow. In such taxa, the sex ratio may be highly biased towards the smaller sex. The criteria acknowledge that the number of mature individuals can take biased sex ratios into account, by using a lower estimate for the number of mature individuals. For sex-changing organisms it is also appropriate to consider changes in sex ratio as an indicator of population perturbation, which may be of additional conservation concern because the larger sex (already less numerous) is often subject to higher harvest mortality. In these cases, the number of mature individuals may be estimated by doubling the average number of individuals of the larger (or less numerous) sex.

#### 4.3.5 Trees

Individual trees that flower without producing viable seeds do not qualify as mature individuals. For example, *Bailonella toxisperma* first flowers at 50-70 years and does not fruit until roughly 20 years later. Conversely, *Sequoiadendron giganteum* may produce seed

at less than 20 years of age and continue to do so for 3000 years. However, not all trees between these ages may be mature individuals if the population includes some reproductively suppressed individuals. If little is known about age at fruiting, mature individuals should be counted as those of a typical reproductive size; e.g. estimates for canopy taxa should exclude sub-canopy individuals. Vegetative clones, apomictic taxa and self-fertilizing taxa may qualify as mature individuals, so long as they produce viable offspring and their survival is independent of other clones.

Where it is impossible to calculate the number of mature individuals, but information is available on the total population size, it may be possible to infer the number of mature individuals from the total population size.

#### 4.4 Generation (Criteria A, C1 and E)

“Generation length is the average age of parents of the current cohort (i.e., newborn individuals in the population). Generation length therefore reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual, except in taxa that breed only once. Where generation length varies under threat, such as the exploitation of fishes, the more natural, i.e. pre-disturbance, generation length should be used.” (IUCN 2001)

In general, time-based measures in the criteria are scaled for the different rates at which taxa survive and reproduce, and generation length is used to provide this scaling. The current definition of generation length has been widely misunderstood, and there are difficulties when dealing with very long-lived taxa, with taxa having age-related variation in fecundity and mortality, with variation in generation length under harvesting, with environmental changes and variation between the sexes. Some of the different acceptable methods for estimating generation length are included here.

It is also appropriate to extrapolate information such as a generation length from closely related well-known taxa and to apply it to lesser-known and potentially threatened taxa.

Formally, the definition of generation length requires age- and sex-specific information on survival and fecundity, and is best calculated from a life table. Depending on the taxon concerned, other methods may provide a good approximation. Care should be taken to avoid estimates that may bias the generation length estimate in a non-precautionary way, usually by under-estimating it. Generation length may be estimated in a number of ways:

1. the age at which 50% of total reproductive output is achieved
2. time taken for most (>50%) individuals to reach maximum reproductive output
3. the average age of parents in the population, based on the equation

$$G = \frac{\sum x l_x m_x}{\sum l_x m_x}$$

where the summations are from age ( $x$ ) 0 to the last age of reproduction;  $m_x$  is (proportional to) the fecundity at age  $x$ ; and  $l_x$  is survivorship up to age  $x$  (i.e.,  $l_x = S_0 \cdot S_1 \cdots S_{x-1}$  where  $S$  is annual survival rate, and  $l_0 = 1$  by definition)

4. 1/adult mortality + age of first reproduction (if fecundity and survival are independent of age above the age at maturity)

5. age of first reproduction +  $z$  \* (length of the reproductive period), where  $z$  is usually <0.5, depending on survivorship and the relative fecundity of young vs. old individuals in the population
6. for partially clonal taxa, generation length should be averaged over asexually and sexually reproducing individuals in the population
7. for plants with seed banks use juvenile period + either the half-life of seeds in the seed bank or the median time to germination. Seed bank half-lives commonly range between <1 and 10 years.

Methods 1 and 2 are more in way of definitions. Methods 3-5 are approximations in order of decreasing reliability. Methods 6 and 7 are for taxa with particular kinds of life histories

#### **4.5 Reduction (Criterion A)**

“A reduction is a decline in the number of mature individuals of at least the amount (%) stated under the criterion over the time period (years) specified, although the decline need not be continuing. A reduction should not be interpreted as part of a fluctuation unless there is good evidence for this. The downward phase of a fluctuation will not normally count as a reduction.” (IUCN 2001)

##### *4.5.1 Estimating reduction*

Percentage reductions in the number of mature individuals can be estimated in a number of ways, including ‘an index of abundance appropriate to the taxon’. In the case of exploited fishes, the catch per unit effort (CPUE) may be used. This measure should be used with caution because changes in CPUE may underestimate population declines. This may occur, for example, if the population aggregates even at small sizes so that catches remain high with the same level of effort, even if the size of the population is declining. It may also occur if increases in fishing efficiency are not fully taken into account. It is therefore preferable to assess exploited fish taxa using the results of fishery-independent survey techniques.

The population data from which a reduction can be calculated are likely to be variable, and it may not be obvious how a reduction should best be estimated. Depending on the shape of the data, a linear or exponential model may be fitted, and the start and end points of the fitted line used to calculate the reduction. Fitting a model in this way helps to eliminate some of the variability in the data that may be attributable to natural fluctuations, which should not be included. If a taxon is threatened by exploitation, and the hunting mortality (proportion of individuals taken) does not change as the population size declines, then the population is likely to be declining exponentially, and this model should be fitted. In some cases, a linear model will be more appropriate. This occurs when the number of individuals taken (rather than their proportion to the total population) may remain constant. For example, if a taxon is threatened with habitat loss, and a similar sized area of habitat is lost every year, this could lead to a linear decline in the number of individuals. No model need be fitted in cases where there are only two estimates of population size (at the start and end of the time period specified in the criteria) – the reduction can be calculated from those two points. If a model is fitted, the assumptions of the model must be justified by characteristics of life history,



habitat biology, pattern of exploitation or other threatening processes, etc. For more information, see section 5.8 below.

#### 4.5.2 *Inferring or projecting population reduction*

When it is necessary to extrapolate population trends (under criteria A3 or A4), the assumed pattern of decline (e.g., exponential or linear) can make an important difference to the assessment. Guidelines on this issue are given in section 5 (criterion A).

Population reduction over long generation times may be estimated from data over shorter time frames. However, assumptions about the rate of decline remaining constant, increasing or decreasing, relative to the observed interval must be justified with reference to threatening processes, life history or other relevant factors. Section 3 deals with incorporating uncertainty and using inference and projection.

Future population reduction can be projected using population models, provided that: (i) the model meets the requirements outlined in section 9 ("Guidelines for applying Criterion E"), (ii) the effects of future levels of threat are included in the population model, represented as changes in model parameters, and (iii) the model outputs are not inconsistent with expected changes in current or recent rates of decline. When using a population model to project a reduction under criterion A3, the median or mean of the projections for a range of plausible scenarios should be used to calculate a best estimate of the magnitude of the projected reduction. Assessments may be based on the best estimate, lower or upper bound but, for reasons of transparency, assessors must justify the rationale for their choice if a value other than the best estimate is used. The projected variability may be used to quantify uncertainty. For example, upper and lower quartiles of the projected magnitude of the future reduction (i.e., reductions with 25% and 75% probability) may be considered to represent a plausible range of projected reduction, and used to incorporate uncertainty in the assessment, as described in sections 3.2 and 5.8.2 of the Guidelines. The bounds of the plausible range should incorporate model uncertainty as well as measurement error; or a justification of the model structure, and why it is the most appropriate in the face of model uncertainty, should be provided.

## 4.6 **Continuing decline (Criteria B and C)**

“A continuing decline is a recent, current or projected future decline (which may be smooth, irregular or sporadic) which is liable to continue unless remedial measures are taken. Fluctuations will not normally count as continuing declines, but an observed decline should not be considered as a fluctuation unless there is evidence for this.” (IUCN 2001)

Continuing declines are used in two different ways in the criteria. Continuing declines at any rate can be used to qualify taxa under criteria B or C2. This is because taxa under consideration for criteria B and C are already characterised by restricted ranges or small population size. *Estimated continuing decline* (under criterion C1) has quantitative thresholds, and requires a quantitative estimate. The concept of continuing decline at any rate is not applicable under criterion C1 (or under criterion A).

Rates of continuing decline over long generation times (in the same way as reductions) may be estimated from data over shorter time frames. For example, evaluating a taxon under criterion C1 for the Vulnerable category requires estimating a continuing decline for 3 generations or 10 years, whichever is longer (up to a maximum of 100 years). When extrapolating data from shorter time frames, assumptions about the rate of decline remaining constant, increasing or decreasing, relative to the observed interval must be justified with reference to threatening processes, life history or other relevant factors.

Note that a continuing decline is not possible without a reduction (which, however, may not be large enough to meet any thresholds under Criterion A), but a reduction is possible without a continuing decline: if a reduction has ‘ceased’ under criterion A, there cannot be a continuing decline.

A potentially confusing aspect of the criteria is that “estimated continuing decline” under C1 is conceptually very similar to “moving window reduction” under A4. The differences are (i) A4 is always evaluated for 3 generations/10 years, whereas C1 is evaluated for 1, 2, or 3 generations, depending on the category, (ii) the thresholds are lower under C1 (e.g., for VU, 10% under C1 and 30% under A4), (iii) C1 also requires small population size, and (iv) under C1, the decline must be observed or estimated, whereas under A4, the reduction can be observed, estimated, inferred, projected or suspected.

#### **4.7 Extreme fluctuations (Criteria B and C2)**

“Extreme fluctuations can be said to occur in a number of taxa where population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude (i.e., a tenfold increase or decrease).” (IUCN 2001)

Extreme fluctuations are included in criteria B and C in recognition of the positive relationship between extinction risk and variance in the rate of population growth (Burgman et al. 1993). Populations that undergo extreme fluctuations are likely to have highly variable growth rates, and are therefore likely to be exposed to higher extinction risks than populations with lower levels of variability.

Population fluctuations may vary in magnitude and frequency (Figure 4.1). For the ‘extreme fluctuations’ subcriterion to be invoked, populations would normally need to fluctuate by at least 10-fold (i.e., an order of magnitude difference between population minima and maxima). Fluctuations may occur over any time span, depending on their underlying causes. Short-term fluctuations that occur over seasonal or annual cycles will generally be easier to detect than those that occur over longer time spans, such as those driven by rare events or climatic cycles such as El Niño. Fluctuations may occur regularly or sporadically (i.e. with variable intervals between successive population minima or successive population maxima).

The effect of extreme fluctuations on the extinction risk will depend on both the degree of isolation and the degree of synchrony of the fluctuations between subpopulations.

If there is regular or occasional dispersal (of even a small number of individuals, seeds, spores, etc) between all (or nearly all) of the subpopulations, then the degree of fluctuations

should be measured over the entire population. In this case, the subcriterion would be met only when the overall degree of fluctuation (in the total population size) is larger than one order of magnitude. If the fluctuations of different subpopulations are independent and asynchronous, they would cancel each other to some extent when fluctuations of the total population size are considered.

If, on the other hand, the subpopulations are totally isolated, the degree of synchrony between the population is not as important and it is sufficient that a majority of subpopulations each show extreme fluctuation to meet the subcriterion. In this case, if most of the subpopulations show fluctuations of an order of magnitude, then the criterion would be met (regardless of the degree of the fluctuations in total population size).

Between these two extremes, if dispersal is only between some of the subpopulations, then the total population size over these connected subpopulations should be considered when assessing fluctuations; each set of connected subpopulations should be considered separately.

Population fluctuations may be difficult to distinguish from directional population changes, such as continuing declines, reductions or increases. Figure 4.1 shows examples where fluctuations occur independent of, and in combination with, directional changes. A reduction should not be interpreted as part of a fluctuation unless there is good evidence for this. Fluctuations must be inferred only where there is reasonable certainty that a population change will be followed by a change in the reverse direction within a generation or two. In contrast, directional changes will not necessarily be followed by a change in the reverse direction.

There are two main ways that extreme fluctuations may be diagnosed: (i) by interpreting population trajectories based on an index of abundance appropriate for the taxon; and (ii) by using life history characteristics or habitat biology of the taxon.

- i) Population trajectories must show a recurring pattern of increases and decreases (Figure 4.1). Normally, several successive increases and decreases would need to be observed to demonstrate the reversible nature of population changes, unless an interpretation of the data was supported by an understanding of the underlying cause of the fluctuation (see ii). Successive maxima or minima may be separated by intervals of relatively stable population size.
- ii) Some organisms have life histories prone to boom/bust dynamics. Examples include fish that live in intermittent streams, granivorous small mammals of arid climates, and plants that respond to stand-replacing disturbances. In these cases there is dependence on a particular resource that fluctuates in availability, or a response to a disturbance regime that involves predictable episodes of mortality and recruitment. An understanding of such relationships for any given taxon may be gained from studies of functionally similar taxa, and inference of extreme fluctuations need not require direct observation of successive increases and decreases.

In all cases, assessors must be reasonably certain that fluctuations in the number of mature individuals represent changes in the total population, rather than simply a flux of individuals between different life stages. For example, in some freshwater invertebrates of intermittent water bodies, the number of mature individuals increases after inundation which stimulates emergence from larval stages. Mature individuals reproduce while conditions remain suitable, but die out as the water body dries, leaving behind immature life stages (e.g. eggs) until the next inundation occurs. Similarly, fires may stimulate mass recruitment from large persistent seed banks when there were few mature individuals before the event. As in the previous example, mature plants may die out during the interval between fires, leaving a store of immature individuals (seeds) until they are stimulated to germinate by the next fire. Such cases do not fall within the definition of extreme fluctuations unless the dormant life stages are exhaustible by a single event or cannot persist without mature individuals. Plant taxa that were killed by fire and had an exhaustible canopy-stored seed bank (serotinous obligate seeders), for example, would therefore be prone to extreme fluctuations because the decline in the number of mature individuals represents a decline in the total number.

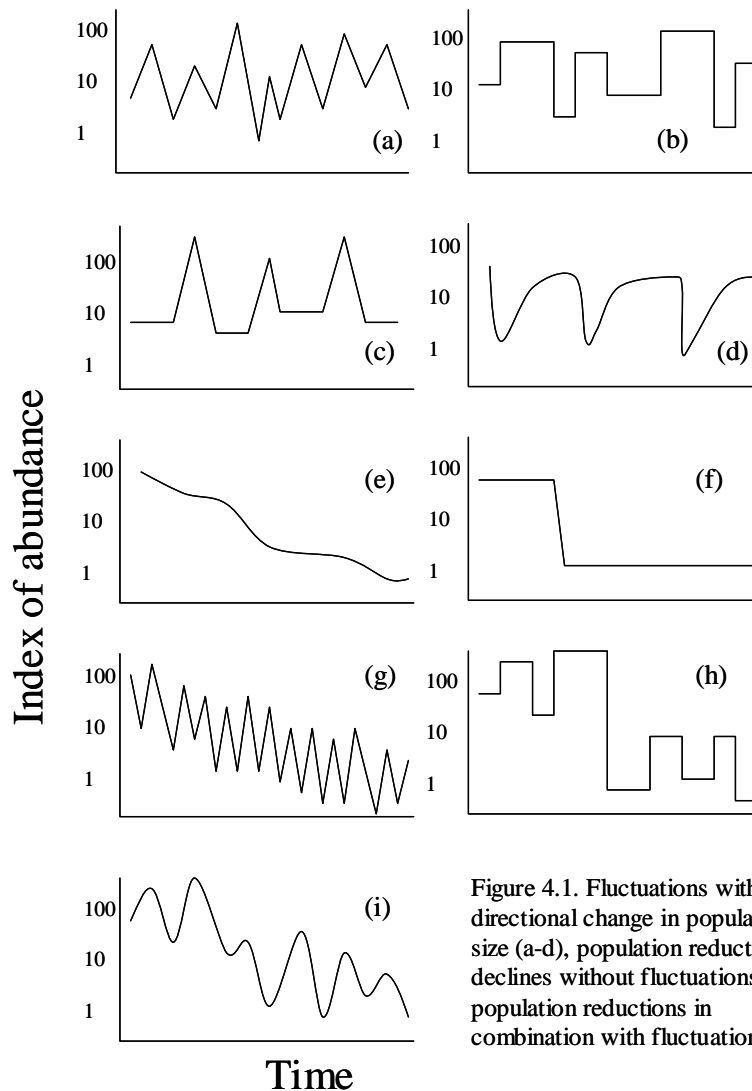


Figure 4.1. Fluctuations without directional change in population size (a-d), population reductions or declines without fluctuations (e-f), population reductions in combination with fluctuations (g-i).

#### 4.8 Severely fragmented (Criterion B)

“The phrase ‘severely fragmented’ refers to the situation in which increased extinction risks to the taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations (in certain circumstances this may be inferred from habitat information). These small subpopulations may go extinct, with a reduced probability of recolonization.” (IUCN 2001)

Fragmentation must be assessed at a scale that is appropriate to biological isolation in the taxon under consideration. In general, taxa with highly mobile adult life stages or with a large production of small mobile diaspores are considered more widely dispersed, and hence not so vulnerable to isolation through fragmentation of their habitats. Taxa that produce only small numbers of diaspores (or none at all), or only large ones, are less efficient at long distance dispersal and therefore more easily isolated. If natural habitats have been fragmented (e.g., old growth forests and rich fens), this can be used as direct evidence for fragmentation for taxa with poor dispersal ability.

In cases where data are available on (i) the distribution of area of occupancy (i.e., detailed maps of occupied habitat), (ii) some aspect of the dispersal ability of the taxon, (e.g., average dispersal distance), and (iii) average population density in occupied habitat (e.g., information on territory size, home range size, etc.), then the following criterion can be used to decide whether there is severe fragmentation: A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance

For (1), the area for a viable population should be based on rudimentary estimates of population density, and on the ecology of the taxon. For example, for many vertebrates, patches that can support fewer than a hundred individuals may be considered too small to be viable. For (2), the degree of isolation of patches should be based on dispersal distance of the taxon. For example, patches that are isolated by distances several times greater than the (long-term) average dispersal distance of the taxon may be considered isolated.

Note that the existence (or even a large number) of small and isolated patches is not sufficient to consider the taxon severely fragmented. For meeting this criterion, more than half of the individuals (or, more than half of the occupied habitat area) must be in small and isolated patches.

For many taxa, the information on population density and dispersal distance can be based on other similar taxa. Biologically informed values can be set by the assessors for large taxonomic groups (families or even orders) or for other groupings of taxa based on their biology. For example in bryophytes, information on the effects of isolation of subpopulations is often lacking. It is recommended that in most circumstances, a minimum distance greater than 50km between subpopulations of taxa without spore dispersal can indicate severe fragmentation, and a distance of between 100km and 1,000km for taxa with spores (Hallingbäck *et al.* 2000).

The definition of severe fragmentation is based on the distribution of subpopulations. This is often confused with the concept of "location" (see section 4.11), but is independent of it. A taxon may be severely fragmented, yet all the isolated subpopulations may be threatened by the same major factor (single location), or each subpopulation may be threatened by a different factor (many locations).

#### **4.9 Extent of occurrence (Criteria A and B)**

“Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g., large areas of obviously unsuitable habitat) [but see 'area of occupancy', section 4.10 below]. Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence).” (IUCN 2001)

Extent of Occurrence (EOO) is a parameter that measures the spatial spread of the areas currently occupied by the taxon. The intent behind this parameter is to measure the degree to which risks from threatening factors are spread spatially across the taxon’s geographical distribution. It is not intended to be an estimate of the amount of occupied or potential habitat, or a general measure of the taxon’s range. Other, more restrictive definitions of “range” may be more appropriate for other purposes, such as for planning conservation actions. Valid use of the criteria requires that EOO is estimated in a way that is consistent with the thresholds set therein.

In thinking about the differences between EOO and AOO (area of occupancy; discussed in section 4.10), it may be helpful to compare species that have similar values for one of these spatial parameters and different values for the other. All else being equal, larger EOOs usually result in a higher degree of risk spreading (and hence a lower overall risk of extinction to for the taxon) than smaller EOOs, depending on the relevant threats to the taxa. For example, a taxon with occurrences distributed over a large area is highly unlikely to be adversely affected across its entire range by a single fire because the spatial scale of a single occurrence of this threat is narrower than the spatial distribution of the taxon. Conversely, a narrowly distributed endemic taxon, with the same AOO as the taxon above, may be severely affected by a fire across its entire EOO because the spatial scale of the threat is larger than, or as large as, the EOO of the taxon.

In the case of migratory species, EOO should be based on the minimum of the breeding or non-breeding (wintering) areas, but not both, because such species are dependent on both areas, and the bulk of the population is found in only one of these areas at any time.

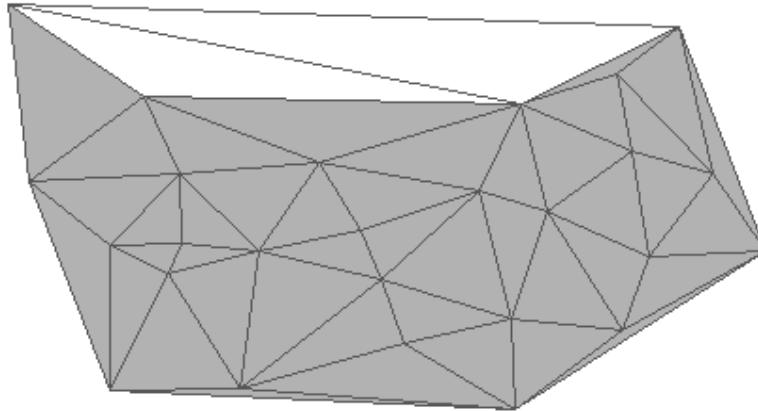
If EOO is less than AOO, EOO should be changed to make it equal to AOO to ensure consistency with the definition of AOO as an area within EOO.

EOO can be measured by a minimum convex polygon and may exclude “discontinuities or disjunctions within the overall distribution of the taxa”. However, for assessments of criterion B, exclusion of areas forming discontinuities or disjunctions from estimates of EOO

is discouraged except in extreme circumstances.. Exclusions are not recommended for criterion B, because disjunctions and outlying occurrences accurately reflect the extent to which a large range size reduces the chance that the entire population of the taxon will be affected by a single threatening process. The risks are spread by the existence of outlying or disjunct occurrences irrespective of whether the EOO encompasses significant areas of unsuitable habitat. Inappropriate exclusions of discontinuities or disjunctions within the overall distribution of a taxon will underestimate EOO for the purpose of assessing criterion B and consequently will underestimate the degree to which risk is spread spatially for the taxon. Further guidelines on the kind of discontinuities or disjunctions that should be excluded will be developed following a review of current assessments.

When there are such discontinuities or disjunctions in a species distribution, the minimum convex polygon (also called the convex hull) yields a boundary with a very coarse level of resolution on its outer surface, resulting in a substantial overestimate of the range, particularly for irregularly shaped ranges (Ostro *et al.* 1999). The consequences of this bias vary, depending on whether the estimate of EOO is to be used for assessing the spatial thresholds in Criterion B or whether it is to be used for estimating or inferring reductions (Criterion A) or continuing declines (Criteria B and C). The use of convex hulls is unlikely to bias the assessment of EOO thresholds under Criterion B, because disjunctions and outlying occurrences often do contribute to the spatial spread of risk (see above). However, the bias associated with estimates based on convex hulls, and their sensitivity to sampling effort, makes them less suitable as a method for comparing two or more temporal estimates of EOO for assessing reductions or continuing declines. If outliers are detected at one time and not another, this could result in erroneous inferences about reductions or increases. Therefore, a method such as the  $\alpha$ -hull (a generalization of a convex hull) is recommended for assessing reductions of continuing declines in EOO because it substantially reduces the biases that may result from the spatial arrangement of habitat (Burgman and Fox 2003). The  $\alpha$ -hull provides a more repeatable description of the external shape of a species' range by breaking it into several discrete patches when it spans uninhabited regions. For  $\alpha$ -hulls the estimate of area and trend in area also converges on the correct value as sample size increases, unless other errors are large. This does not necessarily hold for convex hulls. Kernel estimators may be used for the same purpose but their application is more complex.

To estimate an  $\alpha$ -hull, the first step is to make a Delauney triangulation of the mapped points of occurrence (Figure 4.2). The triangulation is created by drawing lines joining the points, constrained so that no lines intersect between points. The outer surface of the Delauney triangulation is identical to the convex hull.



**Figure 4.2.** Illustration of  $\alpha$ -hull. The lines show the Delauney triangulation (the intersection points of the lines are the taxon's occurrence locations). The sum of the areas of darker triangles is EOO based on the  $\alpha$ -hull. The two lighter colored triangles that are part of the convex hull are excluded from the  $\alpha$ -hull.

The second step is to measure the lengths of all of the lines, and calculate the average line length. The third step is to delete all lines that are longer than a multiple ( $\alpha$ ) of the average line length. (This product of  $\alpha$  and the average line length represents a “discontinuity distance”.) The value of  $\alpha$  can be chosen with a required level of resolution in mind. The smaller the value of  $\alpha$ , the finer the resolution of the hull. Experience has shown that an  $\alpha$  value of 2 is a good starting point for some species (however, the value to use for specific cases of assessing reductions in EOO should be based on a compromise between minimising the potential bias associated with incomplete sampling of outlying occurrences and minimising the departure from a convex hull). This process results in the deletion of lines joining points that are relatively distant, and may subdivide the total range into more than one polygon. The final step is to calculate the extent of occurrence by summing the areas of all remaining triangles. When this exercise is repeated to estimate EOO from a second temporal sample of points (and hence assess change in EOO), the same discontinuity distance between points should be used as a threshold for deleting lines (rather than the same value of  $\alpha$ ). This will reduce bias due to variation in sampling effort between the two surveys and the bias due to changing average line length with more or fewer occurrences.

Extent of Occurrence and Area of Occupancy are measures of the current distribution, i.e. they should not include areas where the species no longer exists. On the other hand, these measures should not only include the actually known sites, but also inferred sites. For instance, sites can be inferred from presence of known appropriate habitat, but where the species has not yet been searched for. In doing so, it will be important to judge to what extent the taxon has been looked for. Incorporating inferred sites results in a range of plausible values, which may give a range of plausible Red List categories (see sections 3.1 on *Data availability, inference and projection*, and 3.2 on *Uncertainty*).



#### **4.10 Area of occupancy (Criteria A, B and D)**

“Area of occupancy is defined as the area within its 'extent of occurrence' (see 4.9 above), which is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats. In some cases, (e.g., irreplaceable colonial nesting sites, crucial feeding sites for migratory taxa) the area of occupancy is the smallest area essential at any stage to the survival of existing populations of a taxon. The size of the area of occupancy will be a function of the scale at which it is measured, and should be at a scale appropriate to relevant biological aspects of the taxon, the nature of threats and the available data (see below). To avoid inconsistencies and bias in assessments caused by estimating area of occupancy at different scales, it may be necessary to standardise estimates by applying a scale-correction factor. It is difficult to give strict guidance on how standardization should be done because different types of taxa have different scale-area relationships.” (IUCN 2001)

Area of Occupancy (AOO) is a parameter that represents the area of suitable habitat currently occupied by the taxon. As any area measure, AOO requires a particular scale. In this case, the scale is determined by the thresholds in the criteria, i.e. valid use of the criteria requires that AOO is estimated at scales that relate to the thresholds in the criteria. These scales (see “Problems of scale” below) are intended to result in comparable threat status across taxa; other scales may be more appropriate for other uses. For example, much finer scales are appropriate for planning conservation action for plants, and larger scales may be appropriate for global gap analysis for large mobile species. However, such scales may not be appropriate for use with the criteria.

Area of Occupancy is included in the criteria for two main reasons. The first is to identify species with restricted spatial distribution and, thus usually with restricted habitat. These species are often habitat specialists. Species with a restricted habitat are considered to have an increased risk of extinction. Secondly, in many cases, AOO can be a useful proxy for population size, because there is generally a positive correlation between AOO and population size. The veracity of this relationship for any one species depends on variation in its population density.

Suppose two species have the same EOO, but different values for AOO, perhaps because one has more specialized habitat requirements. For example, two species may be distributed across the same desert (hence EOO is the same), but one is wide ranging throughout (large AOO) while the other is restricted to oases (small AOO). The species with the smaller AOO may have a higher risk of extinction because threats to its restricted habitat (e.g. degradation of oases) are likely to reduce its habitat more rapidly to an area that cannot support a viable population. The species with the smaller AOO is also likely to have a smaller population size than the one with a larger AOO, and hence is likely to have higher extinction risks for that reason.

##### *4.10.1 Problems of scale*

Classifications based on the area of occupancy (AOO) may be complicated by problems of spatial scale. There is a logical conflict between having fixed range thresholds and the

necessity of measuring range at different scales for different taxa. “The finer the scale at which the distributions or habitats of taxa are mapped, the smaller the area will be that they are found to occupy, and the less likely it will be that range estimates ... exceed the thresholds specified in the criteria. Mapping at finer spatial scales reveals more areas in which the taxon is unrecorded. Conversely, coarse-scale mapping reveals fewer unoccupied areas, resulting in range estimates that are more likely to exceed the thresholds for the threatened categories. The choice of scale at which AOO is estimated may thus, itself, influence the outcome of Red List assessments and could be a source of inconsistency and bias.” (IUCN 2001)

Some estimates of AOO may require standardization to an appropriate reference scale to reduce such bias. Below, we first discuss a simple method of estimating AOO, then we make recommendations about the appropriate reference scale, and finally we describe a method of standardization for cases where the available data are not at the reference scale.

#### 4.10.2 *Methods for estimating AOO*

There are several ways of estimating AOO, but for the purpose of these guidelines we assume estimates have been obtained by counting the number of occupied cells in a uniform grid that covers the entire range of a taxon (see Figure 2 in IUCN 2001), and then tallying the total area of all occupied cells:

$$\text{AOO} = \text{no. occupied cells} \times \text{area of an individual cell} \quad (\text{equation 4.1})$$

The ‘scale’ of AOO estimates can then be represented by the area of an individual cell in the grid (or alternatively the length of a cell, but here we use area). There are other ways of representing AOO, for example, by mapping and calculating the area of polygons that contain all occupied habitat. The scale of such estimates may be represented by the area of the smallest mapped polygon (or the length of the shortest polygon segment), but these alternatives are not recommended.

If different grid locations (starting points of the grid) result in different AOO estimates, the minimum estimate should be used.

#### 4.10.3 *The appropriate scale*

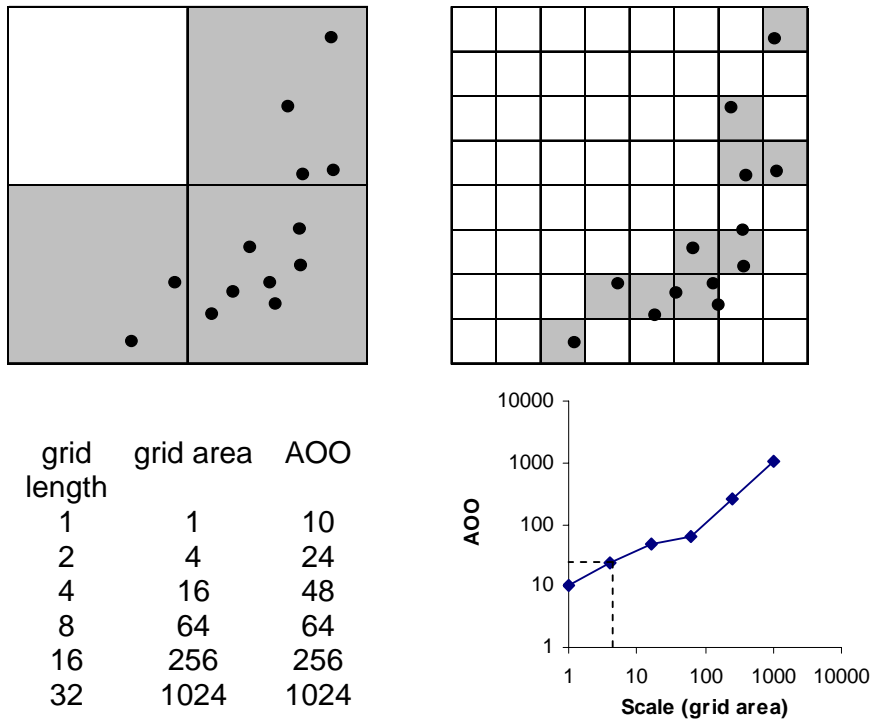
It is impossible to provide any strict but general rules for mapping taxa or habitats; the most appropriate scale will depend on the taxon in question, and the origin and comprehensiveness of the distribution data. However, we believe that in many cases a grid size of 2 km (a cell area of 4 km<sup>2</sup>) is an appropriate scale. Scales of 3.2 km grid size or coarser (larger) are inappropriate because they do not allow any taxa to be listed as Critically Endangered (where the threshold AOO under criterion B is 10 km<sup>2</sup>). Scales of 1 km grid size or smaller tend to list more taxa at higher threat categories than these categories imply. For most cases, we recommend a scale of 4 km<sup>2</sup> cells as the reference scale. If an estimate was made at a different scale, especially if data at different scales were used in assessing species in the same taxonomic group, this may result in inconsistencies and bias. In any case, the scale for AOO should not be based on EOO (or other measures of range area), because AOO and EOO measure different factors affecting extinction risk (see above).

***If AOO can be calculated at the reference scale of 4 km<sup>2</sup> cells, you can skip sections 4.10.4 and 4.10.5. If AOO cannot be calculated at the reference scale (e.g., because it has already been calculated at another scale and original maps are not available), then the methods described in the following two sections may be helpful.***

#### *4.10.4 Scale-area relationships*

We recommended reducing the biases caused by use of range estimates made at different scales by standardizing estimates to a reference scale that is appropriate to the thresholds in the criteria. This and the following section discuss the scale-area relationship that forms the background for these standardization methods, and describe such a method with examples. The method of standardization depends on how AOO is estimated. In the following discussion, we assume that AOO was estimated using the grid method summarised above.

The standardization or correction method we will discuss below relies on the relationship of scale to area, in other words, how the estimated AOO changes as the scale or resolution changes. Estimates of AOO may be calculated at different scales by starting with mapped locations at the finest spatial resolution available, and successively doubling the dimensions of grid cells. The relationship between the area occupied and the scale at which it was estimated may be represented on a graph known as an area-area curve (e.g., Figure 4.3). The slopes of these curves may vary between theoretical bounds, depending on the extent of grid saturation. A maximum slope = 1 is achieved when there is only one occupied fine-scale grid cell in the landscape (fully unsaturated distribution). A minimum slope = 0 is achieved when all fine-scale grid cells are occupied (fully saturated distribution).



**Figure 4.3.** Illustration of scale-dependence when calculating area of occupancy. At a fine scale (map on right)  $AOO = 10 \times 1 = 10$  units<sup>2</sup>. At a coarse scale (map on left)  $AOO = 3 \times 16 = 48$  units<sup>2</sup>. AOO may be calculated at various scales by successively doubling grid dimensions from estimates at the finest available scale (see Table). These may be displayed on an area-area curve (above).

#### 4.10.5 Scale correction factors

Estimates of AOO may be standardized by applying a scale-correction factor. Scale-area relationships (e.g., Figure 4.3) provide important guidance for such standardization. It is not possible to give a single scale-correction factor that is suitable for all cases because different taxa have different scale-area relationships. Furthermore, a suitable correction factor needs to take into account a reference scale (e.g., 2 km grid size) that is appropriate to the area of occupancy thresholds in criterion B. The example below shows how estimates of AOO made at fine and coarse scales may be scaled up and down, respectively, to the reference scale to obtain an estimate that may be assessed against the AOO thresholds in Criterion B.

##### *Example: Scaling Up*

Assume that estimates of AOO are available at 1 km grid resolution shown in Figure 4.3 (right) and that it is necessary to obtain an estimate at the reference scale represented by a 2 km grid. This may be done cartographically by simply doubling the original grid dimensions, counting the number of occupied cells and applying equation 4.1. When the reference scale is not a geometric multiple of the scale of the original estimate, it is necessary to calculate an area-area curve, as shown in Figure 4.3, and interpolate an estimate of AOO at the reference scale. This can be done mathematically by calculating a scale

correction factor (C) from the slope of the area-area curve as follows (in all equations below, "log" means logarithm to base 10):

$$C = \log(\text{AOO}_2/\text{AOO}_1) / \log(\text{Ag}_2/\text{Ag}_1) \quad (\text{equation 4.2})$$

where  $\text{AOO}_1$  is the estimated area occupied from grids of area  $\text{Ag}_1$ , a size close to, but smaller than the reference scale, and  $\text{AOO}_2$  is the estimated area occupied from grids of area  $\text{Ag}_2$ , a size close to, but larger than the reference scale. An estimate of  $\text{AOO}_R$  at the reference scale,  $\text{Ag}_R$ , may thus be calculated by rearranging equation 2 as follows:

$$\text{AOO}_R = \text{AOO}_1 * 10^{C * \log(\text{Ag}_R / \text{Ag}_1)}, \text{ or } \text{AOO}_R = \text{AOO}_2 * 10^{C * \log(\text{Ag}_R / \text{Ag}_2)} \quad (\text{equation 4.3})$$

In the example shown in Figure 4.3, estimates of AOO from 1x1 km and 4x4 km grids may be used to verify the estimate AOO at the reference scale of 2x2 km as follows:

$C = \log(48/10) / \log(16/1) = 0.566$ , and using equation 4.3 with this value of C, the AOO estimate at the larger scale ( $\text{AOO}_2=48$ ), and the grid sizes at the larger and reference scales ( $\text{Ag}_R=4$ ;  $\text{Ag}_2=16$ ), the AOO estimate at the reference scale is calculated as:

$$\text{AOO} = 48 * 10^{0.566 * \log(4/16)} = 22 \text{ km}^2$$

Note that this estimate differs slightly from the true value obtained from grid counting and equation 1 ( $24 \text{ km}^2$ ) because the slope of the area-area curve is not exactly constant between the measurement scales of 1x1 km and 4x4 km.

#### *Example: Scaling Down*

Scaling down estimates of AOO is more difficult than scaling up because there is no quantitative information about grid occupancy at scales finer than the reference scale. Scaling therefore requires extrapolation, rather than interpolation of the area-area curve. Kunin (1998) and He and Gaston (2000) suggest mathematical methods for this. A simple approach is to apply equation 4.3 using an approximated value of C.

An approximation of C may be derived by calculating it at coarser scales, as suggested by Kunin (1998). For example, to estimate AOO at 2x2 km when the finest resolution of available data is at 4x4 km, we could calculate C from estimates at 4x4 km and 8x8 km as follows.

$$C = \log(64/48) / \log(64/16) = 0.208$$

However, this approach assumes that the slope of the area-area curve is constant, which is unlikely to hold for many taxa across a moderate range of scales. In this case, AOO at 2x2 km is overestimated because C was underestimated.

$$\text{AOO} = 48 * 10^{0.208 * \log(4/16)} = 36 \text{ km}^2.$$

While mathematical extrapolation may give some guidance in estimating C, there may be qualitative information about the dispersal ability, habitat specificity and landscape patterns that could also provide guidance. Table 4.1 gives some guidance on how these factors may influence the values of C within the range of scales between 2x2 km and 10x10 km grid sizes.

**Table 4.1.** Characteristics of organisms and their habitat that influence the slope of the scale-area relationship, and hence the scale-correction factor, *C*, within the range of spatial scales represented by 2x2 km and 10x10 km grid cells.

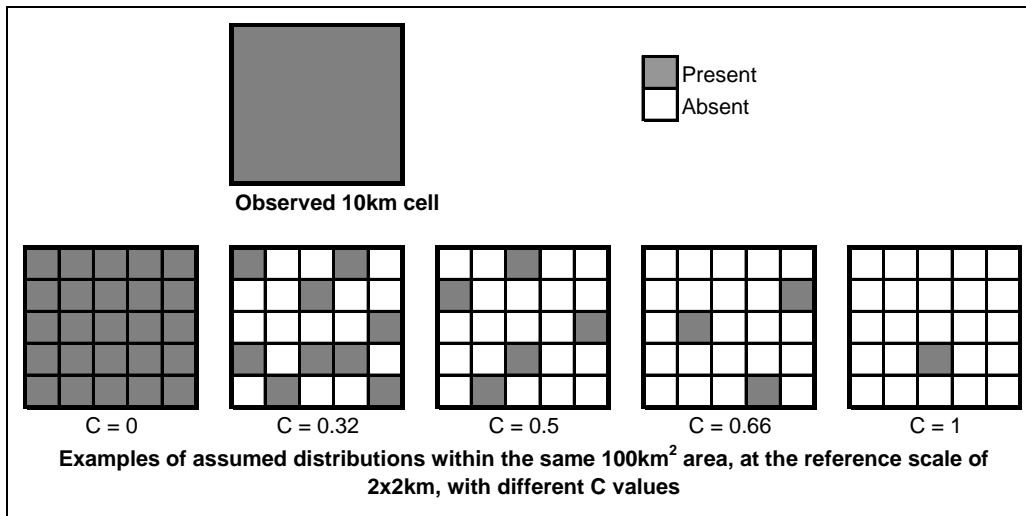
Biological characteristic	Influence on <i>C</i>	
	small (approaching 0)	large (approaching 1)
Dispersal ability	Wide	localised or sessile
Habitat specificity	Broad	Narrow
Habitat availability	Extensive	Limited

For example, if the organism under consideration was a wide-ranging animal without specialized habitat requirements in an extensive and relatively uniform landscape (e.g., a species of camel in desert), its distribution at fine scale would be relatively saturated and the value of *C* would be close to zero. In contrast, organisms that are either sessile or wide ranging but have specialized habitat requirements that only exist in small patches within the landscape (e.g., migratory sea birds that only breed on certain types of cliffs on certain types of islands) would have very unsaturated distributions represented by values of *C* close to one. Qualitative biological knowledge about organisms and mathematical relationships derived from coarse-scale data may thus both be useful for estimating a value of *C* that may be applied in equation 4.3 to estimate AOO at the reference scale.

Finally, it is important to note that if unscaled estimates of AOO at scales larger than the reference value are used directly to assess a taxon against thresholds in criterion B, then the assessment is assuming that the distribution is fully saturated at the reference scale (i.e., assumes *C* = 0). In other words, the occupied coarse-scale grids are assumed to contain no unsuitable or unoccupied habitat that could be detected in grids of the reference size (see Figure 4.4).

#### 4.10.6 "Linear" habitat

There is a concern that grids do not have much ecological meaning for taxa living in "linear" habitat such as in rivers or along coastlines. Although this concern is valid, for the purpose of assessing taxa against criterion B, it is important to have a measurement system that is consistent with the thresholds, and that leads to comparable listings. If AOO estimates were based on estimates of length x breadth of habitat, there may be very few taxa that exceed the VU threshold for Criterion B (especially when the habitats concerned are streams or beaches a few metres wide). In addition, there is the problem of defining what a "linear" habitat is, and measuring the length of a jagged line. Thus, we recommend that the methods described above for estimating AOO should be used for taxa in all types of habitat distribution, including taxa with linear ranges living in rivers or along coastlines.



**Figure 4.4.** Demonstration of the consequences of different assumed C values. The available map is at 10x10 km resolution, so a presence observed at this scale corresponds to 25 cells at the reference scale of 2x2 km. Assuming C=0 (i.e., using the unscaled estimate directly as AOO) assumes that all of these 25 cells are occupied. At the other extreme, a value of C=1 assumes that only one 2x2 km cell is occupied.

#### 4.10.7 AOO based on habitat maps and models

Habitat maps show the distribution of suitable habitat for a species. They may be derived from interpretation of remote imagery and/or analyses of spatial environmental data using simple combinations of GIS data layers, or by more formal statistical habitat models (e.g. generalised linear and additive models, decision trees, Bayesian models, regression trees, etc.). Habitat maps can provide a basis for estimating AOO and EOO and, if maps are available for different points in time, rates of change can be estimated. They cannot be used directly to estimate a taxon's AOO because they often map an area that is larger than the occupied habitat (i.e. they also map areas of suitable habitat that may presently be unoccupied). However, they may be a useful means of estimating AOO indirectly, provided the three following conditions are met.

- i) Maps must be justified as accurate representations of the habitat requirements of the species and validated by a means that is independent of the data used to construct them.
- ii) The mapped area of *suitable* habitat must be interpreted to produce an estimate of the area of *occupied* habitat.
- iii) The estimated area of occupied habitat derived from the map must be scaled to the grid size that is appropriate for AOO of the species.

Habitat maps can vary widely in quality and accuracy (condition i). A map may not be an accurate representation of habitat if key variables are omitted from the underlying model. For example, a map would over-estimate the habitat of a forest-dependent montane species if it identified all forest areas as suitable habitat, irrespective of altitude. The spatial resolution of habitat resources also affects how well maps can represent suitable habitat. For example, specialised nest sites for birds, such as a particular configuration of undergrowth or trees with hollows of a particular size, do not lend themselves to mapping at coarse scales. Any application of habitat maps to Red List assessment, should therefore be subject to an

appraisal of mapping limitations, which should lead to an understanding of whether the maps over-estimate or under-estimate the area of suitable habitat.

Habitat maps may accurately reflect the suitable habitat, but only a fraction of suitable habitat may be occupied (condition ii). Low habitat occupancy may result because other factors are limiting – such as availability of prey, impacts of predators, competitors or disturbance, dispersal limitations, etc. In such cases, the area of mapped habitat could be substantially larger than AOO and will therefore need to be adjusted (using an estimate of the proportion of habitat occupied) to produce a valid estimate of AOO. This may be done by random sampling of suitable habitat grid cells, which would require multiple iterations to obtain a stable mean value of AOO. Habitat maps are produced at a resolution determined by the input data layers (satellite images, digital elevation models, climate surfaces, etc.). Often these will be at finer scales than those required to estimate AOO (condition iii), and consequently scaling up will be required.

In those cases where AOO is less than the area of suitable habitat, the population may be declining within the habitat, but the habitat may show no indication of change. Hence this method could be both inaccurate and non-precautionary for estimating reductions in population change.

However, if a decline in mapped habitat area is observed (and the map is a reasonable representation of suitable habitat – condition i), then the population is likely to be declining at least at that rate. This is a robust generalisation because even the loss of unoccupied habitat can reduce population viability. Thus, if estimates of AOO are not available, then the observed decline in mapped habitat area can be used to invoke "continuing decline" in criteria B and C, and the rate of such decline can be used as a basis for calculating a lower bound for population reduction under Criterion A.

#### **4.11 Location (Criteria B and D)**

“The term ‘location’ defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat.” (IUCN 2001)

Justification for the number of locations used in Red List assessments should include reference to the most serious plausible threat(s). For example, where the most serious plausible threat is habitat loss, a location is an area where a single development project can eliminate or severely reduce the population. Where the most serious plausible threat is volcanic eruption, hurricane, tsunami, frequent flood or fire, locations may be defined by the previous or predicted extent of lava flows, storm paths, inundation, fire paths, etc. Where the most serious plausible threat is collection or harvest, then locations may be defined based on the size of jurisdictions (within which similar regulations apply) or on the level of access (e.g., ease with which collectors may reach different areas), as well as on the factors that determine how the levels of exploitation change (e.g., if collection intensity in two separate areas changes in response to the same market trends in demand, these may be counted as a single location).



If two or more subpopulations occur within an area that may be threatened by one such event, they must be counted as a single location. Conversely, if a single subpopulation covers an area larger than may be affected by any single event, it must be counted as more than one location.

Where the most serious plausible threat does not affect all of the taxon's distribution, other threats can be used to define and count locations in those areas not affected by the most serious plausible threat.

When parts of the distribution are not affected by any threat, the following options will be appropriate under different circumstances: (a) number of locations is not used (i.e., the subcriteria that refer to the number of locations consequently are not met), especially if the unaffected area is more than half the taxon's range; (b) number of locations in the unaffected areas is set to the number of subpopulations in those areas, especially if there are several subpopulations; (c) the number of locations is based on the smallest size of locations in the currently affected areas; (d) the number of locations is based on the most likely threat that may affect the currently-unaffected areas in the future. In any case, the basis of the number of locations should be documented.

In the absence of any plausible threat for the taxon, the term "location" cannot be used and the subcriteria that refer to the number of locations will not be met.

#### **4.12 Quantitative analysis (Criterion E)**

“A quantitative analysis is defined here as any form of analysis which estimates the extinction probability of a taxon based on known life history, habitat requirements, threats and any specified management options. Population viability analysis (PVA) is one such technique. Quantitative analyses should make full use of all relevant available data. In a situation in which there is limited information, such data as are available can be used to provide an estimate of extinction risk (for instance, estimating the impact of stochastic events on habitat). In presenting the results of quantitative analyses, the assumptions (which must be appropriate and defensible), the data used and the uncertainty in the data or quantitative model must be documented.” (IUCN 2001)

Quantitative analyses are used for assessing taxa under Criterion E. Guidelines for applying Criterion E are discussed in section 9. It is important to note that the risk-based thresholds of Criterion E should not be used to infer an extinction risk for a taxon assessed as VU, EN and CR under any of the criteria A to D.

### **5. Guidelines for Applying Criterion A**

The A criterion is designed to highlight taxa that have undergone a significant decline in the near past, or are projected to experience a significant decline in the near future. The criterion is split into the criteria A1, A2, A3 and A4.

Listing a taxon under criterion A requires specifying whether the reduction is based on (a) direct observation (A1, A2 and A4 only), (b) an index of abundance appropriate to the taxon,

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat, (d) actual or potential levels of exploitation, and/or (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

The difference between direct observation (a) and index of abundance (b), as well as the value of distinguishing between them, lies in the assumptions to be met to provide valid estimates of abundance. While “direct observation” requires only statistical assumptions (e.g., random sampling), indices of abundance require assumptions related to the biology of the species. For example, for a marine turtle species, use of “nesting females” to examine population change assumes that the proportion of mature individuals that breeds each year, and the number of visits to breeding sites per female per year are reasonably constant (or at least vary randomly) among years. If these assumptions are true, then “nesting females” is an appropriate index of mature individuals.

Direct observation (a) is the most relevant measure and, all things being equal, should be preferred. However, other measures may be used if they result in more reliable or more consistent (i.e., covering the 3 generation period more comprehensively) estimates of population size through time. For example, for species that are difficult to detect, direct counts may entail large sampling errors and be biased (i.e. systematically under or overestimate the change in population size). Alternatively, an index based on easily detectable traces (e.g., tracks, droppings, etc.) or resources that the taxon depends on exclusively may provide more reliable estimates of population reduction. Similarly, for a species that is censused very infrequently, or responds to habitat loss with a time lag, habitat change may be a more comprehensive estimate of reduction than direct observation (see section 5.7 on the relationship between habitat change and population change).

All applicable bases for reduction should be listed. Even if the reduction is calculated based on the best available data, for example, from direct observation, if others (such as decline in area of occupancy) are also observed, estimated, inferred or suspected, these should also be specified.

Criterion A1 deals with reductions in the past 10 years or 3 generations (whichever is longer) and is applicable to taxa in which the causes of reduction are clearly reversible AND understood AND ceased (see discussion below), based on (and specifying) any of (a) to (e), as discussed above.

Criterion A2 also deals with reductions in the past 10 years or 3 generations (whichever is longer) but for taxa where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

Criterion A3 deals with population reductions projected or suspected to be met in the future 10 years or 3 generations (whichever is longer, but up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

Criterion A4 deals with reductions observed, estimated, inferred, projected or suspected over any 10 year or 3 generation time period (up to a maximum of 100 years into the future), where the time period must include both the past and the future, and where the reduction or

its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

Under criterion A, a specific quantitative threshold indicating the population reduction must be met to qualify for one of the categories of threat. Under criterion A1, these thresholds are 90% (CR), 70% (EN) and 50% (VU). Under criteria A2, A3 and A4, these thresholds are 80% (CR), 50% (EN) and 30% (VU). These different rates reflect the understanding that taxa in which the causes of reduction are clearly reversible AND understood AND ceased are less at risk from extinction than those where the causes of reduction may not have ceased OR may not be understood OR may not be reversible. In order to use A1, three conditions must be met. (1) The reduction must be reversible. For example, the population size must not be so low that factors such as Allee effects make it impossible or unlikely to recover. It is the condition that must be reversible, not the cause of the deteriorated state. For example, loss of habitat may be irreversible even if the action that caused the loss has ceased. In contrast, a reduction in a forest-dependent species caused by logging could be considered reversible if changed management practices are leading to recovery of this species. (2) The causes of the reduction (the threatening factors) must be identified and their actions must be understood. Thus, it is not sufficient to simply list the threatening factors; it is also necessary to understand the scale and mechanism of their action (e.g., the magnitude and spatial distribution of overfishing, or the relationship between pollution and the population reduction). (3) The threatening factors must have ceased (e.g., overfishing has stopped). Examples of taxa that might qualify under criterion A1 are fish species that have suffered declines under exploitation but where the cause of reduction (e.g., over-exploitation) has ceased. This criterion may also be applicable to situations where the population is still being exploited, at lower levels of exploitation that do not cause additional population reductions. If any of the three conditions (reversible and understood and ceased) are not met in a substantial portion of the taxon's population (10% or more), then A2 should be used instead of A1.

### **5.1 The use of time caps in criterion A**

Generation length is used in criterion A as a way of scaling the time frame over which reductions are measured with the life history of the taxon. Short-lived, faster-reproducing taxa have to suffer higher annual mortality rates than long-lived, slower-reproducing taxa to meet the same quantitative threshold (e.g., 80% reduction) over a set time period (e.g., 10 years). To put it another way, long-lived taxa might be unlikely ever to meet quantitative decline thresholds over a fixed time period, yet could be facing many years of population decline per recruitment opportunity. The three-generation time period is used to scale the decline rate threshold for the species' life history. This important scalar allows criterion A to be applied to a wide range of taxa. A minimum time cap of 10 years is specified because, although some taxa will have three-generation periods of less than 10 years, 10 years is the shortest time period of relevance to conservation planning and action. A maximum time cap has been introduced for assessments based on projections into the future, as it is felt that the distant future cannot be predicted with enough certainty to justify its use as a way of assessing whether a taxon is threatened. A maximum time cap is not applied to assessments based on past reductions, as it is felt that for long-lived taxa, it is important to use data for three generations, if it is available.

## 5.2 How to apply criterion A4

In order to decide whether a taxon can be listed under criterion A4, a “moving-window” reduction must be calculated. It is not possible to determine whether A4 is applicable only by looking at the qualitative pattern of the decline, or by calculating only past or only future reductions.

To calculate a “moving window” reduction, first create a time series of past population sizes and future projections. Then, calculate 3-generation reduction for all time frames that include at least one past time step and at least one future time step. The length of all those time frames (windows) must be 3-generations or 10 years (whichever is longer), but cannot extend more than 100 years into the future. Finally, find the maximum of these reductions, which is the number to use in criterion A4. Whether a taxon is listed under A4 or not, of course, depends on whether it qualifies under any of the other criteria.

In cases where reliable past data are available only for time periods of less than 3 generations, and/or reliable future predictions can only be made for less than 3 generations into the future, the 3-generation window to use in A4 can be set as the time period for which reliable data and predictions are available.

In general, if a taxon is listed under Criteria A2 and A3, it will also be listed under Criterion A4. However, this is not always the case, and the category of threat determined using a “moving window” can exceed that calculated from past and future declines. Therefore, species should always be evaluated against Criterion A4 as well as Criteria A2 and A3. See the workbook file (CriteriaA.XLS) accompanying these guidelines for a simple example of the use of Criteria A2, A3 and A4.

## 5.3 The ski-jump effect

Some widespread, long-lived taxa show very large long term declines as well as recent increases, and their population sizes are well above the thresholds for critical population size and distribution (under criteria B to D). This pattern has been termed the ‘ski-jump’ effect and affects any long-lived taxa that have declined in the past and are now stable or increasing. The question often asked is whether the long term historical declines or the more recent increases should take precedence in the assessment of threat in such taxa. However, the question is misleading; the IUCN criteria do not allow precedence among the criteria, or emphasizing one criterion over another. The correct interpretation is to assess the taxon against all the criteria. The point of criterion A is that long-term trends may indicate an underlying cause whereas recent trends may be temporary.

When applying criterion A to taxa showing these patterns, a couple of points should be remembered: (1) if the causes of reduction are clearly reversible AND understood AND ceased then the higher thresholds of criterion A1 (90% for CR, 70% for EN and 50% for VU) apply, which may lead to a down-listing of the taxon that would reflect the fact that it is currently stable or increasing, (2) uncertainty in the data (particularly long-term historical data) if properly incorporated into the assessment may affect the outcome of the listing (see section 3.2).

## 5.4 Severely depleted populations

Some taxa (particularly marine taxa) show persistence at very low fractions of their unexploited equilibrium or carrying capacity. These taxa may not qualify under criterion A1 or A2 because their declines occurred more than 3 generations ago, and they may be too widespread and abundant to qualify under any other criteria. Nevertheless, they may be more cause for concern because they are more susceptible to unforeseen catastrophic events and marine taxa may be harvested as bycatch in other fisheries. Such taxa are not currently being assessed as threatened under the criteria A1 and A2, although they may still qualify under criteria A3, A4, B, C, D or E.

Taxa in this situation may be assessed under criteria A3 or A4 based on projected or suspected population declines in the future, provided there is sufficient evidence for the threats faced by the taxon or the likely decline rate of the taxon to warrant such a listing. The category Near Threatened could also be used if a taxon nearly qualifies as Vulnerable under A3 or A4. It must be remembered however that the IUCN Red List Criteria are designed to identify taxa that exhibit symptoms of endangerment, and not simply depletion or conservation priority. The problem of assessing these taxa is also related to the scaling issues discussed under the definition of Area of Occupancy (section 4.10), which affects the application of criterion B. If an appropriate taxon-specific scaling factor is used, severely depleted marine taxa may qualify as threatened under criterion B.

## 5.5 Fisheries

Taxa that are the target of fisheries may show a decline in population size due to intentional management action. Under the Red List Criteria, such taxa could be assigned a threatened status under criterion A (declining population). Concern has been expressed that such a listing might not reflect extinction risk, especially if the decline is a consequence of a management plan designed to achieve a goal such as the maximisation of sustainable yield from a fishery. Such listings should not be problematic in the medium- to long-term because, if the fishery is managed effectively, although it currently exhibits symptoms consistent with endangerment, the population will eventually stabilize at a target level and the decline will end, such that the taxon would then no longer qualify for listing. If declines continued, there would be reason for concern, and the listing would still apply. In addition, fisheries that are being managed sustainably should be assessed under criterion A1, where the higher thresholds of 90% (CR), 70% (EN) and 50% (VU) make it less likely that they will be classified as threatened.

## 5.6 Trees

The generation length of some tree species can exceed 100 years. It is difficult to estimate population declines from a point in time before which the species populations or even the species itself may have been recorded. It is important to emphasise the point that the most significant declines, which are useful to record and which may be possible to reverse, are probably those that have been caused over the last 100 years.

## 5.7 Relationship between loss of habitat and population reduction

Under criterion A, a reduction in population size may be based on a decline in area of occupancy, extent of occurrence and/or quality of habitat. The assumptions made about the relationship between habitat loss and population reduction have an important effect on the outcome of an assessment. In particular, the simplest assumption, that the relationship is linear, is not often true and may lead to over- or under-listing. For example, a bird species may not be reduced by 50% if 50% of its habitat is lost (perhaps because it will colonise new habitats). Or, reduction may happen mostly in lower-density areas, leading to a faster decline in range than in population size. Conversely, if reductions occur predominantly in high-density areas, population reduction will be faster than can be deducted from range contraction (decrease in EOO) (Rodríguez 2002). Similarly, a coral reef fish may be reduced by more than 50% if 50% of its habitat is lost through fishing with explosives (perhaps because spawning areas have been destroyed).

The sensible use of inference and projection is encouraged when estimating population reductions from changes in habitat. For example, if a forest species' extent of occurrence has been 70% clear cut in the last five years it might be justified to infer a 50% decline in the population over the past ten years. The species would therefore qualify as Endangered A2c.

In all cases, an understanding of the taxon and its relationship to its habitat, and the threats facing the habitat is central to making the most appropriate assumptions about habitat loss and subsequent population reduction. All assumptions about this relationship, and the information used should be included with the assessment documentation.

Available population data may contradict habitat data (e.g., habitat seems to be declining in quality, but population numbers are stable). This can occur because: (1) one set of data is uncertain, biased, or dated, or (2) the population has a lagged response to loss of habitat (likely if generation time is long). In the first case, the assessors must use their judgement to decide which data are more certain. If it is decided that the abundance data are adequate to determine trends, the taxon should be listed under Criterion A2. The implications of a possible lagged response in abundance to loss of habitat should, however, be considered when evaluating the taxon under Criterion A3. For example, if population reduction in the last 3 generations is 30% based on abundance data, which are adequate to determine trends, then the species should be listed as VU A2, even if habitat loss in the same period was 60%. However, if a lagged response in abundance to loss of habitat is likely (i.e. the impact of habitat loss at present may lead to a future reduction in the number of mature individuals), then the population may be expected to decline further in the future (even if habitat loss has stopped), so an EN A3 or EN A4 listing should be considered as well, if the 60% loss of habitat is inferred to lead to 50% or more reduction in the number of mature individuals.

## 5.8 Taxa with Widely Distributed or Multiple Populations

This section addresses the issues related to the presentation and use of the information from subpopulations (or from parts of the range) of a widely distributed taxon, in assessing the taxon against IUCN's criterion A. For such taxa, it is recommended that the available data on past reduction be presented in a table that lists all known subpopulations (or parts of the range), and gives at least two of the following three values for each subpopulation:

1. the estimated abundance at a point in time close to 3 generations ago<sup>1</sup>, and the year of this estimate,
2. the most recent estimated abundance and its year,
3. suspected or inferred reduction (in %) over the last 3 generations.

If there are estimates of abundance for years other than those reported in (1) or (2), these should also be reported in separate columns of the same table. Any qualitative information about past trends for each subpopulation should be summarised in a separate column, as well as quantities calculated based on the presented data (see examples below).

There are three important requirements:

- (a) The values should be based on estimates or indices of the number of mature individuals. If the values are based on indices, a note should be included that explains how the index values are expected to relate to the number of mature individuals, and what assumptions are necessary for this relationship to hold.
- (b) The subpopulations should be non-overlapping. This does not mean that there is no or infrequent dispersal among subpopulations. The point of this requirement is to avoid double-counting as much as possible.
- (c) Together, the subpopulations should include all of the taxon. If this is not possible, a “subpopulation” named *Remainder* should include an estimate of the total number of mature individuals not included in the listed subpopulations. This estimate, like others, can be uncertain (see below).

If these requirements cannot be met, the taxon cannot be assessed under criterion A.

In this section, we refer to subpopulations, but the discussion applies to any type of non-overlapping subunits of the taxon, such as parts of the taxon’s range. In the next subsection on *Estimating reduction*, we discuss the basic methods of using such a data table for assessing a taxon under criterion A. In many cases, there will be uncertainty, because the abundances are not known precisely, are in different units for different subpopulations, or are available only from one or few subpopulations. These cases will be discussed later, in a subsection on *Dealing with uncertainty*. For a simple demonstration of the methods discussed in the following examples, see the workbook file (CriteriaA.XLS) accompanying these guidelines.

### 5.8.1 *Estimating reduction*

To assess a taxon against criterion A, it is necessary to estimate the overall reduction over the last 3 generations. All available data should be used to calculate a reduction as an average over all subpopulations, weighted by the estimated size of each subpopulation 3 generations ago. Inferences regarding reductions should not be based on information for any single subpopulation (whether it is the fastest declining, most stable, largest or smallest)<sup>2</sup>.

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<sup>1</sup> The criteria are defined in terms of the maximum of 10 years or three generations. However, for clarity of presentation, reference is only made in this section to “three generations”.

<sup>2</sup> However, see “*Dealing with uncertainty*” below for a discussion of exceptions to this rule.

The recommended methods for estimating reduction are explained below by a series of examples. All examples are for a taxon with a generation length of 20 years, assessed in 2001 (i.e., for these examples, the “present” is 2001 and “three generations ago” is 1941). All examples of this section are based on data with the same units for all subpopulations; the issue of different units is discussed in the next subsection (*Dealing with uncertainty*).

*Example 1: Estimates are available for past (3 generations ago) and current population sizes.*

Subpopulation	Past	Present
Pacific Ocean	10000 (1941)	5000 (2001)
Atlantic Ocean	8000 (1941)	9000 (2001)
Indian Ocean	12000 (1941)	2000 (2001)
<i>Overall</i>	30000 (1941)	16000 (2001)

In this (simplest) case, all past population sizes are added up (30000) and all present population sizes are added up (16000), giving an overall reduction of 46.7%  $[(30-16)/30]$ . Note that the changes in individual subpopulations are 50% reduction, 12.5% increase and 83.3% reduction. An average of these numbers, weighted by the initial population sizes, gives the same answer  $[(-0.5*10+0.125*8-0.833*12)/30]$ .

*Example 2: Estimates are available for various past population sizes.*

Subpopulation	Past	Present	Notes
Pacific Ocean	10000 (1930s)	7000 (1995)	most of the decline in the last 20 yr
Atlantic Ocean	8000 (1975)		believed to have been stable
Indian Ocean	10000 (1961)	4000 (1981)	

In this case, the “past” and “present” population estimates are not from the same year for all subpopulations. Thus, it is necessary to make projections in order to estimate reduction for each subpopulation in the same time period. There are several types of projection. For example it is necessary to project the population from the “past” census (in the 1930s) to 1941 (3 generations ago) as well as from the most recent census (in 1995) to the present.

Any information about past trends can be valuable in making such projections (as in the “Notes” in the example). For instance, given that most of the decline in the Pacific subpopulation has occurred in recent years, the estimate in the 1930s can be assumed to also represent the population in 1941 (3 generations ago). However, in this case, it is necessary to make a projection from the most recent estimate (in 1995) to 2001. If the estimated decline from 10000 to 7000 occurred in 20 years, then assuming a constant rate of decline during this period, annual rate of decline can be calculated as 1.77%  $[1-(7000/10000)^{(1/20)}]$ , giving a projected decline of about 10.1% in the 6 years from the last census (in 1995) to 2001, and a projected 2001 population of 6290  $(=7000*(7000/10000)^{(6/20)})$ . This means a 3-generation decline of 37% (10000 to 6290).

When there is no evidence that the rate of decline is changing, exponential decline can be assumed. For example, for the “Indian Ocean” subpopulation, the 20-year reduction from 1961 to 1981 is 60% per generation; corresponding to 4.48% per year [-



$0.0448=(4000/10000)^{(1/20)}-1$ . Thus, 3-generation decline can be estimated as 93.6% [ $-0.936=(4000/10000)^{(60/20)}-1$ ]. Another way to calculate the 3-generation decline is based on annual rate of change, which is 0.9552 (1-4.48%). Thus, 60-year population change is  $0.9552^{60}=0.064$ ; i.e., only 6.4% of the population will remain after 60 years, which is a 93.6% decline]. The population size 3 generations ago can thus be estimated as 25000 [ $=10000/(1-0.6)$ ], and the current population as 1600 [ $=4000*(4000/10000)$ ].

It is important to note that the assumption of the pattern of decline can make an important difference to the estimated reduction, and that exponential decline is not the only possible assumption. See the discussion in the next subsection (*Dealing with uncertainty*).

The “Atlantic” subpopulation has been stable, so a reduction of 0% is assumed. Combining the three estimates, the weighted average of reduction for the taxon is estimated as 63% [ $(-0.37*10+0*8-0.936*25)/43$ ].

When such projections are used in estimating the overall reduction, the projected declines and projected subpopulation sizes should be given in different columns of the table than those that are used for the data (see completed table below).

Subpop.	Past	Present	Notes	Population 3 gen. ago (est.)	Current population (est.)	Estimated 3-generation reduction
Pacific Ocean	10000 (1930s)	7000 (1995)	Most of the decline in the last 20yr	10000	6290	37.1%
Atlantic Ocean	8000 (1975)		Believed to have been stable	8000	8000	0%
Indian Ocean	10000 (1961)	4000 (1981)		25000	1600	93.6%
Overall				43000	15890	63.0%

*Example 3: Estimates are available for various past population sizes for some subpopulations only.*

Subpopulation	Past	Present	Reduction	Notes
Pacific Ocean	unknown	5000 (1990)	50%	suspected reduction over 3 generations
Atlantic Ocean	8000 (1955)	9000 (1998)		
Indian Ocean	unknown	2000 (1980)	70%	inferred reduction over 3 generations

In this case, for some regions, there is no information about the past subpopulation size, but there is a suspected or inferred reduction. In this case, such suspected or inferred values must be averaged, weighted by the population size 3 generations ago. Since this number is not known, it must be projected using the present estimates and the reduction amount, using the methods discussed under Example 2. Assuming exponential decline or growth, the table is completed as follows.

Subpop.	Past	Present	Reduction	Population 3 gen. ago (est.)	Current population (est.)	3-generation change
Pacific Ocean	?	5000 (1990)	50% (suspected)	8807 <sup>a</sup>	4403 <sup>a</sup>	50% suspected reduction
Atlantic Ocean	8000 (1955)	9000 (1998)		7699 <sup>b</sup>	9074 <sup>b</sup>	17.9% estimated increase
Indian Ocean	?	2000 (1980)	70% (inferred)	4374 <sup>c</sup>	1312 <sup>c</sup>	70% inferred reduction
Overall				20880	14789	29.2% reduction

<sup>a</sup> Annual proportional population change is 0.9885  $[(1-0.5)^{(1/60)}]$ , which is a 1.15% decrease per year. Population change from 1941 until the census in 1990 is 0.5678  $[=0.9885^{(1990-1941)}]$ . Thus, population size in 1941 is 8807 (5000/0.5678). Population change from the census in 1990 to 2001 is 0.8807  $[=0.9885^{(2001-1990)}]$ . Thus, population size in 2001 is 4403 (5000\*0.8807).

<sup>b</sup> Population change from 1955 to 1998 is 1.125  $(=9000/8000; 12.5\% \text{ increase})$ . Thus, annual change is 1.00274, or 0.27% increase per year  $[=1.125^{1/(1998-1955)}]$ . Population size in 1941 is 7699  $[=8000/1.00274^{(1955-1941)}]$ . Population size in 2001 is 9074  $[=9000*1.00274^{(2001-1998)}]$ .

<sup>c</sup> Annual population change is 0.9801  $[(1-0.7)^{(1/60)}]$ . Population change from 1941 until the census in 1980 is 0.4572  $[=0.9801^{(1980-1941)}]$ . Thus, population size in 1941 is 4374 (2000/0.4572). Population change from the census in 1980 to 2001 is 0.6561  $[=0.9801^{(2001-1980)}]$ . Thus, population size in 2001 is 1312 (2000\*0.6561).

*Example 4: Multiple estimates are available for various past population sizes.*

Subpopulation	Past-1	Past-2	Past-3	Present
Pacific Ocean	10000 (1935)	10200 (1956)	8000 (1977)	5000 (1994)
Atlantic Ocean	8000 (1955)			9000 (1998)
Indian Ocean	13000 (1946)	9000 (1953)	5000 (1965)	3500 (1980)

In this case, as in example 2, the “past” and “present” population estimates are not from the same year for all subpopulations. However, there are estimates for additional years, which provide information for making projections. For example, for the Pacific Ocean subpopulation, the annual rate of change has changed from a 0.09% increase in the first period (1935 to 1956) to a 1.15% decrease in the second and a 2.73% decrease in the third period, suggesting an accelerated decline. One option is to assume that the final rate of decline will apply from 1994 to 2001 as well. Another option is to perform a non-linear regression. For example, a 2<sup>nd</sup> degree polynomial regression on the natural logarithms of the four population estimates predicts population size as  $exp(-1328+1.373t-0.0003524t^2)$ , where  $t$  is year from 1935 to 2001. This equation gives a 1941 population of 10389 and a 2001 population of 3942, which correspond to a 62% decline. The Indian Ocean subpopulation shows a different pattern; the annual rate of decline decelerates from 5.12% in the first period to 4.78% in the second and 2.35% in the third period. The same regression method predicts population size as  $exp(2881-2.887t+0.0007255t^2)$ , giving a 1941 subpopulation of 18481 and a 2001 subpopulation of 3538, which correspond to a 80.9% decline (thus, the regression has predicted a slight increase from 1980 to 2001). The completed table is below.

To decide what form of decline curve to apply over the three-generation period, assessors should use the best information they have about the processes that contribute to these changing rates. For example, if other information suggests that threat processes have increased in severity over time and that these are affecting the population in an increasingly severe manner, then it will be appropriate to assume an accelerating decline rate. If, however, recording intensity has changed over time and is emphasizing recent declines, then

it will be appropriate to use the best estimate of decline rate overall. Assessors should indicate the basis on which they have decided the form of the decline function.

Subpop.	Past-1	Past-2	Past-3	Present (closest to 2001)	Population 3 gen. ago (1941; est.)	Current population (2001; est.)	Estimated 3- generation change
Pacific Ocean	10000 (1935)	10200 (1956)	8000 (1977)	5000 (1994)	10389	3942	62.1% reduction
Atlantic Ocean	8000 (1955)			9000 (1998)	7699	9074	17.9% increase
Indian Ocean	13000 (1946)	9000 (1953)	5000 (1965)	3500 (1980)	18481	3538	80.9% reduction
Overall					36569	16554	54.7% reduction

### 5.8.2 Dealing with uncertainty

In many cases, data from some or even most of the subpopulations (or, regions) will be unavailable or uncertain. Even for taxa with very uncertain data, we recommend that the available data be organized in the same way as described above.

#### *Using uncertain estimates*

Uncertain values can be entered as plausible and realistic ranges (intervals). In specifying uncertainty, it is important to separate natural (temporal or spatial) variability from uncertainty due to lack of information. Because criterion A refers to a specific period, temporal variability should not contribute to uncertainty. In other words, the uncertainty you specify should not include year-to-year variation. Criterion A refers to the overall reduction of the taxon, so spatial variability should not contribute to uncertainty. For example, if the reduction in different subpopulations ranges from 10% to 80%, this range ([10,80]%) should not be used to represent uncertainty. Instead, the estimated reduction in different subpopulations should be averaged as described above.

This leaves uncertainty due to lack of information, which can be specified by entering each estimate as an interval, as in the following table.

<b>Subpopulation</b>	<b>Past</b>	<b>Present</b>
Pacific Ocean	8000-10000 (1941)	4000-6000 (2001)
Atlantic Ocean	7000-8000 (1941)	8000-10000 (2001)
Indian Ocean	10000-15000 (1941)	1500-2500 (2001)

In this case, a simple approach is to calculate the minimum and maximum estimates for the reduction in each subpopulation using the lower and upper estimates<sup>3</sup>. For example, for the “Pacific” subpopulation, the minimum reduction can be estimated as a reduction from 8000 to 6000 (25%) and the maximum reduction can be estimated as 60% (from 10000 to 4000). If “best” estimates for past and present populations are also available, they can be used to estimate the best estimate for reduction. Otherwise, the best estimate for reduction can be

<sup>3</sup> This is the method used in RAMAS Red List to calculate reduction based on abundances, when you click the “Calculate” button in the Value editor window for past or future reduction.

estimated as 44% (9000 to 5000), using the midpoints of the intervals for the past and the present population sizes.

If similar uncertainty exists for all subpopulations (as in this example), a simple approach is to add all lower and all upper bounds of estimates. In this case, the total population size would be 25000-33000 in the past and 13500-18500 in the present. Using the same approach as outlined above, the best estimate of reduction can be calculated as 45% (29000 to 16000), with plausible range of reductions from 26% (from 25000 to 18500) to 59% (from 33000 to 13500).

An alternative method is to use a probabilistic (Monte Carlo) approach. If the uncertainty of past and present population sizes are given as probability distributions, and the correlation between these distributions are known, then the probability distribution of the reduction can be estimated by randomly selecting a pair of past and present population sizes (using the given distributions), calculating the reduction based on this pair, and repeating this with hundreds of randomly selected pairs.

#### *Uncertainty about the pattern of decline*

When it is necessary to extrapolate population trends, the assumed pattern of decline can make an important difference. Here, we briefly discuss various assumptions, and where they might be applicable. Suppose for a subpopulation of the same taxon discussed in the examples above, population size was estimated as 20000 in 1961 and 14000 in 1981 (these are shown as square markers in the graphs below). We need to extrapolate back in time to 1941 and forward to 2001. The simplest assumptions are those that involve no change in early or late years. For example, if it is assumed that decline did not start until the early 1960s, the reduction can be based on the initial population of 20000. If it can be assumed that the decline stopped before 1981, then 14000 can be used as the current population size. However, if some decline is also suspected to have occurred outside this period, then it is necessary to make an assumption about the pattern of decline. The documentation should include a rationale for the assumed pattern of decline.

#### *Exponential decline*

Exponential decline can be assumed in cases where the proportional rate of decline of the population is believed to be constant. For example, if the taxon is threatened by exploitation, and the hunting mortality (proportion of individuals taken) does not change as the population size declines, then exponential decline can be assumed.

Using the method discussed in Example 2 above, exponential decline would give a population size of 28571 for 1941 and 9800 for 2001 (triangle markers in Figure 5.1 below), giving a 3-generation reduction of about 66%.

#### *Linear decline*

In some cases, the number of individuals taken (rather than their proportion to the total population) may remain constant. For example, if a species is threatened with habitat loss, and a similar sized area of habitat is lost every year, this could lead to a linear decline in the

number of individuals. Note that this means that the rate of decline is increasing every year, because the same amount of habitat is lost out of a decreasing amount of remaining habitat.

With linear decline, the population size would be estimated as 26000 for 1941 and 8000 for 2001 (triangle markers in Figure 5.2 below), giving a 3-generation reduction of about 69%. In this case, the rate of decline is only 23% for the 1<sup>st</sup> generation, but increases to 43% for the 3<sup>rd</sup> generation.

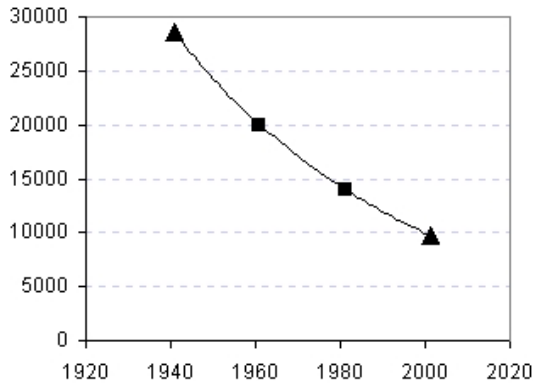


Figure 5.1. Exponential decline

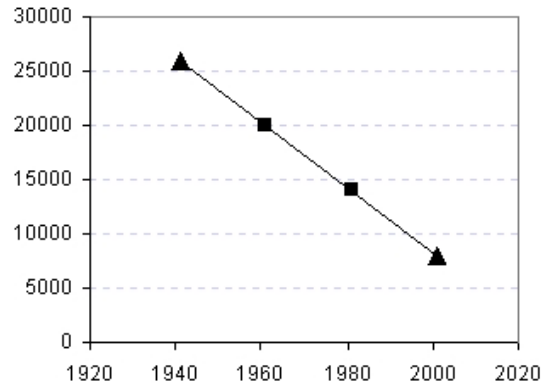
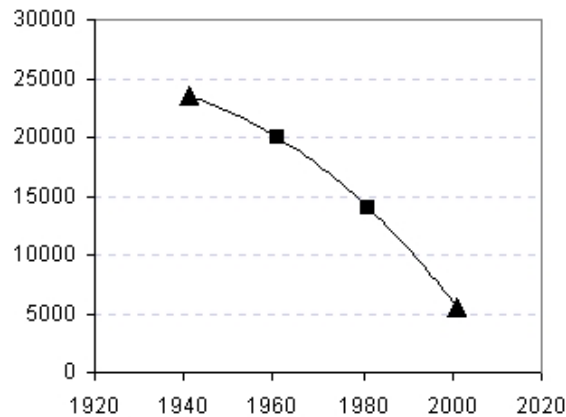


Figure 5.2. Linear decline

### *Accelerated decline*

Although a linear decline in the number of individuals means that the rate of decline is increasing, this increase can be even faster, leading to an accelerated decline in the number of individuals. This may happen when the exploitation level increases, for example when the number of individuals killed is larger every year because of increasing human population, or improving harvest efficiency.

To extrapolate under an assumption of accelerated decline, it is necessary to know or guess how the rate of decline has changed. For instance, in the above example, the observed 1-generation decline (from 1961 to 1981) is 30%. One assumption might be that the rate of decline doubled in each generation, from 15% in the 1<sup>st</sup> generation to 30% in the 2<sup>nd</sup> and 60% in the 3<sup>rd</sup>. This assumption would give a population of 23529 for 1941 ( $20000/(1-0.15)$ ) and 5600 for 2001 ( $14000*(1-0.6)$ ), giving a 3-generation reduction of about 76% (Figure 5.3). Of course, different assumptions about how the rates of decline may have changed in the past might give very different results.



**Figure 5.3. Accelerated decline**

The same approach can be used to make the calculation based on an assumption of decelerating decline.

It is also possible to assume different patterns of decline for different periods. For example, decline can be assumed to be zero until the first observation, and then exponential. This would give a population of 20000 for 1941 and 9800 for 2001, giving a 3-generation reduction of about 51%.

When there is no basis for deciding among various patterns of decline, the rate of decline can be specified as an uncertain number, based on the declines predicted by the different patterns. For example, in the examples above, the rate of decline can be expressed as the interval 66%-69%, if both exponential and linear patterns of decline are considered plausible, or as the interval 51%-76%, if all 4 possibilities discussed above are considered plausible.

#### *Using data with different units*

All the examples discussed above assumed that the population data were in the same units (number of mature individuals). In some cases, data from different populations may be in different units (such as CPUE or other indices). In such cases, we recommend that a separate table be prepared for each data type. If the past and current population sizes are in the same units for any subpopulation, they can be used to calculate (perhaps with extrapolation as discussed above) the reduction for that subpopulation. Such a calculation assumes that the index is linearly related to the number of mature individuals. The assessment should discuss the validity of this assumption, and make the necessary transformation (of the index to one that linearly relates to the number of mature individuals) before reduction is calculated (also see requirement (a) at the beginning of this section).

It is also important that an effort be made to combine the tables by converting all units to a common one. This is because it is necessary to know the relative sizes of the subpopulations in order to combine the reduction estimates, unless the subpopulations are known to be similar sizes or have declined by similar percentages. If the percent reduction is similar (within 1 or 2 percentage points) for different subpopulations, their relative sizes will not

play an important role, and a simple (arithmetic) average can be used instead of a weighted average. If population sizes were known to be similar three generations ago (e.g., the smallest subpopulation was not any smaller than, say, 90% of the largest), again a simple average can be used.

If population sizes and reduction amounts are different among subpopulations, then reductions (in percent) based on different units can be combined only if relative sizes of the subpopulations can be estimated. However, this need not be a very precise calculation. Ranges (intervals) can be used to calculate uncertain results. For example, suppose that the estimates of reduction in two subpopulations are 60% and 80%, and that precise estimates of relative population sizes are not available (because these reduction estimates are based on different indices). In this case, crude estimates of relative sizes can be used. If the relative size of the first subpopulation is estimated to be between 0.40 and 0.70 of the total population, then the overall reduction can be calculated as follows. The high estimate would be  $(60\% \times 0.4) + (80\% \times 0.6)$ , or 72%. The low estimate would be  $(60\% \times 0.7) + (80\% \times 0.3)$ , or 66%. Thus, the overall reduction can be expressed as the interval 66%-72%.

#### *Using data from a few subpopulations*

In some cases, reliable data exist from only one or few subpopulations. In such cases, the available data can be used under the following conditions.

1. If the subpopulation for which a reduction estimate is available was by far the largest subpopulation three generations ago, then this estimate can be used for the whole taxon. This process can also be formalised using the methods outlined above. For example, suppose that the largest subpopulation has declined by 60%, and that it had represented 90 to 99% of the mature individuals in the taxon three generation ago. If there is no information on the rest of the subpopulations (representing 1-10% of mature individuals), these subpopulations can be assumed to have declined by 0 to 100% (although, of course, this range does not include all the possibilities, as it excludes the possibility that the other subpopulations have increased). With these assumptions, the low estimate would be 54% (if the rest of the subpopulations had 10% of the individuals, and declined by 0%), and the high estimate would be 64% (if the rest of the subpopulations had 10% of the individuals, and declined by 100%). Thus, the overall reduction can be expressed as the interval 54%-64%, which includes the estimate (60%) based on the largest subpopulation, but also incorporates the uncertainty due to lack of knowledge from other subpopulations.

2. If it can be assumed that all (or all the large) subpopulations are declining at the same rate, then the reduction estimated for a subset of the subpopulations can be used for the whole taxon. In this case, it is important to document any evidence that indicates that the rates are the same, and discuss and rule out various factors that may lead to different rates of reduction in different subpopulations.

## **6. Guidelines for Applying Criterion B**

The B criterion has been designed to identify populations with restricted distributions that are also severely fragmented, undergoing a form of continuing decline, and/or exhibiting extreme fluctuations (in the present or near future). It is important to pay particular attention

to criterion B, as it is the most commonly misused criterion. To qualify for criterion B, the general distributional threshold must first be met for one of the categories of threat, either in terms of extent of occurrence (EOO) or area of occupancy (AOO). The taxon must then meet at least TWO of the three options listed for criterion B. The options are (a) severely fragmented or known to exist in no more than  $x$  locations, (b) continuing decline, or (c) extreme fluctuation (Table 2.1). Therefore, if a taxon has met the distributional requirement for the Endangered category and option (c) extreme fluctuation, but none of the other options, it would not qualify as Endangered (or Vulnerable) under the B criterion. To qualify, it would also have to meet either (a) or (b). An example of the proper use of the B criterion is Endangered: B1ab(v). This means that the taxon is judged to have an extent of occurrence of less than 5000 km<sup>2</sup>, the population is severely fragmented or known to exist at no more than five locations, and there is a continuing decline in the number of mature individuals.

Subcriterion (a) requires severe fragmentation and/or limited number of locations. The numbering in the criteria does not allow distinguishing between these two conditions. We recommend that assessors make this distinction by explicitly specifying in their documentation: (1) whether the taxon is severely fragmented, and (2) the number of locations.

Some of the problems encountered when applying criterion B are dealt with elsewhere in this document, i.e. definitions of "subpopulations" (section 4.2), "location" (section 4.11), "continuing decline" (section 4.6), "extreme fluctuations" (section 4.7), "severely fragmented" (section 4.8), "extent of occurrence" (section 4.9) and "area of occupancy" (section 4.10).

## **7. Guidelines for Applying Criterion C**

Criterion C has been designed to identify taxa with small populations that are currently declining or may decline in the near future. For criterion C the small population threshold must be met as well as one of the two subcriteria that describe decline. For example, to qualify for Endangered under criterion C, the population must be estimated to number less than 2500 mature individuals, and to either (1) have an estimated continuing decline of at least 20% within 5 years or 3 generations (whichever is longer, up to a maximum of 100 years) or (2) have a continuing decline in the number of mature individuals and either (a) a restricted population structure or (b) extreme fluctuations in the number of mature individuals (see Table 2.1 for details).

Few taxa have data on both population size and decline rates at the necessary resolution to apply subcriterion C1. There is also some overlap between criteria A and C1, the difference being that criterion C applies only to small populations, the time frame over which the decline is measured is shorter (except for the Vulnerable category) and the decline rate thresholds are lower, because the populations are already small.



## 8. Guidelines for Applying Criterion D

This criterion identifies very small or restricted populations. A taxon qualifies for criterion D if the population of mature individuals is smaller than the threshold set for each of the categories of threat. Under the Vulnerable category there are two options, D1 and D2. A taxon qualifies for Vulnerable D1 if the population size is estimated to number fewer than 1,000 mature individuals. A taxon qualifies for Vulnerable D2 if the area of occupancy is very restricted (typically less than 20 km<sup>2</sup>) or exists at typically five or fewer locations, and if there is a plausible natural or anthropogenic threat. This criterion is provided for taxa that may not be decreasing, but are characterised by an acute restriction in their number of mature individuals, area of occupancy or in their number of locations thereby rendering them particularly susceptible to a plausible threat.

The subcriterion D2 under Vulnerable was intended to be used for taxa with very small distributions. However, the thresholds for area of occupancy and the number of locations, although given as indicators (i.e., typically less than 20 km<sup>2</sup> or typically five or fewer locations), are frequently interpreted too literally. Some people have argued that the subcriterion is too inclusive and results in massive over-listing, while others argue that it is too exclusive (e.g., many marine species) and so leads to under-listing. It must be emphasised that the restricted area of occupancy under criterion D2 is defined such that the population is prone to the effects of human activities or stochastic events within a very short time period (e.g., within 1 or 2 generations) in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period. The numerical thresholds are given more by way of example and are not intended to be interpreted as strict thresholds.

The focus of subcriterion D2 is not the area or the location count (for which many taxa could qualify), but the risk that the taxon could suddenly become Critically Endangered or Extinct (i.e., if the plausible threat is realized, then the species will within a very short time qualify for listing in one of these categories under, for example, criterion A or B). So, simply meeting the suggested (or any other) threshold for AOO or number of locations is not sufficient. It is necessary that this restriction makes the species capable of becoming CR or EX within a very short time, because of the effects of human activities or stochastic events. There must be a substantial possibility of these activities or events actually occurring. Thus, unlikely events (e.g., eruption of an inactive volcano), non-specific events that were not observed in similar species (e.g., an unspecified disease epidemic), events unlikely to cause extinction (e.g., because the species has survived many hurricanes, or is likely to adapt to global warming, etc.), or events unlikely to take place rapidly enough to result in a CR or EX listing in a very short time would not qualify for listing under criterion D2. The stochastic events or human activities that lead to this listing must be specified in the justification for listing (see example below). If the taxon is highly restricted, and there are plausible threats that can cause the species to become VU or EN in a short time, then the taxon should be considered for listing as NT.

### 8.1 Taxa known only from the type locality

If a taxon is only known from its type locality and there is no information on its current status or possible threats, the taxon should be listed as DD. If there are no plausible threats, and the area is relatively well known, Least Concern is appropriate, unless criterion A, B or C is met. If people have searched for the taxon, both at the type locality and at a reasonable number of other potential localities, and no more than 50 mature individuals are estimated, then the taxon would be listed as Critically Endangered D (an appropriate time interval for the taxon must be used). If any significant or plausible threats can be identified, then a full assessment will be necessary to determine the most appropriate classification (e.g., Critically Endangered under criteria B or C, or Vulnerable under criterion D2).

### 8.2 Example of applying criterion D

The New Caledonian Lorikeet (*Chamosyna diadema*) is a very rare bird described from two female specimens collected in 1859 and an observation in 1913 on New Caledonia. The species was thought to be extinct in 1978, however islanders reported that it may still exist, and in 1980 two birds were reported by an experienced bushman. It is thought that this unobtrusive and easily overlooked species may survive in the cloud forest of Mount Humboldt and the Massif of Koualoué. Obviously very little is known about this species, but it is safe to estimate, given the limited sightings many years ago and the likelihood that bird watchers would have seen it, that the population contains less than 50 mature individuals. Therefore the New Caledonian Lorikeet is listed as Critically Endangered: D.

### 8.3 Example of applying criterion D2

Chatham Island Snipe (*Coenocorypha pusilla*) is confined to only four predator-free islands in the Chatham Islands, New Zealand, where it is common and considered stable. The historical range of this species was reduced as the result of the introduction of predators such as cats, rats *Rattus* spp. and Weka *Gallirallus australis*. Birds attempting to colonise neighbouring Pitt Island are killed by cats and *G. australis*. The accidental introduction of alien species to the predator-free islands could easily cause local extinction. Thus, the number of locations is estimated as 4 (because it is unlikely that such introductions would occur on more than one island at any given time), and the species is classified as VU under Criterion D2.

## 9. Guidelines for Applying Criterion E

To qualify under the E criterion a quantitative analysis such as a Population Viability Analysis (PVA) must be conducted to determine a species' probability of extinction over a given time period. For example, Critically Endangered E, would mean that the taxon has at least a 50% probability of going extinct in the wild in the next 10 years or three generations (whichever is longer).

### 9.1 What is extinction?

Extinction is defined as population size reaching zero. Population size is the number of all individuals of the taxon (not only mature individuals). In some cases, extinction can be defined as population size reaching a number larger than zero. For example, if only females

are modelled, it is prudent to define extinction as one female (instead of zero) remaining in the population. More generally, an extinction threshold greater than zero is justified if factors that were not incorporated into the analysis due to a lack of information (for example, Allee effects, sex structure, genetics, or social interactions) make the predictions of the analysis at low population sizes unreliable.

For Criterion E, extinction risk must be calculated for up to 3 different time periods:

- 10 years or 3 generations, whichever is longer (up to a maximum of 100 years)
- 20 years or 5 generations, whichever is longer (up to a maximum of 100 years)
- 100 years

For a taxon with a generation length of 34 years or longer, only one assessment (for 100 years) is needed. For a taxon with a generation length of 20 to 33 years, two assessments (for 3 generations and 100 years) are needed. For a taxon with a generation length less than 20 years, all three assessments are needed.

## 9.2 Which method can be used?

One of the commonly used techniques of quantitative analysis is population viability analysis (PVA), which is a collection of methods for evaluating the threats faced by populations of species, their risks of extinction or decline, and their chances for recovery, based on species-specific data and models. For an introduction to PVA, see Boyce (1992), Burgman *et al.* (1993), Akçakaya and Sjögren-Gulve (2000). Types of models used in a PVA will be discussed below.

In some cases, Criterion E can be used without a full PVA, using instead a quantitative analysis that does not necessarily include demographic information. For example, if a species is restricted to a small area, it may be possible to estimate the probability of the destruction of its entire remaining habitat. Such estimations may be based on past weather records, or other information about trends and locations of past habitat loss. It is important to remember, however, that such estimates can only be considered as lower bounds on the risk of extinction as it would have been estimated using a PVA. This is because a PVA incorporates such stochastic effects on habitat as well as other factors such as demographic variability, and other threats such as direct exploitation. Whatever the method used, the analysis must be numerical (i.e., a qualitative assessment such as “high probability of extinction” is not sufficient).

Which method is appropriate depends on the availability of data and the ecology of the taxon. The model structure should be detailed enough to use all the relevant data, but no more detailed. Assessments that use all the available and relevant data are more reliable than those that ignore part of the relevant information. However, including more detail than can be justified by the quality of the available data may result in increased uncertainty.

If the only available data are presence-absence information from a number of locations, occupancy models can be used (see Sjögren-Gulve and Hanski 2000). If census information from a number of years is available, then a scalar (unstructured) dynamic model can be used (see Dennis *et al.* 1991; Burgman *et al.* 1993). If data are available for different age classes or stages (e.g., juvenile and adult), then a structured model can be used (see Akçakaya

2000). If detailed data are available at the individual level (for example, pedigree data), then an individual-based model can be used (see Lacy 2000). If data on the spatial distribution are available, a metapopulation model or other spatially explicit model should be considered (note that scalar, structured and individual-based models can all be spatially structured).

The second important consideration in selecting a model is the ecology of the species. The model structure and assumptions should be realistic with respect to the ecology of the species. The documentation should list all the assumptions (even the most obvious ones) related to model structure, parameters and uncertainties. In cases where the available data and the ecology of the species allow more than one type of model, comparative modelling (e.g., Kindvall 2000, Brook *et al.* 2000) and other types of validation (McCarthy *et al.* 2001) may strengthen the conclusions.

### 9.3 Are there sufficient data?

The types of data that can be used in an assessment include spatial distributions of suitable habitat, local populations or individuals, patterns of occupancy and extinction in habitat patches, presence-absence data, habitat relationships, abundance estimates from surveys and censuses, vital rate (fecundity and survival) estimates from censuses and mark-recapture studies, as well as temporal variation and spatial covariation in these parameters. Not all of these types of data are required for any one model. For more information about data needs of particular types of PVA models, see the references mentioned above.

When there is not sufficient data, or when the available information is too uncertain, it is risky to make a Criterion E assessment with any method, including PVA. In order to decide whether the available data are sufficient to make a Criterion E assessment, we suggest the following procedure. First, select a model structure based on the discussion in the previous section. Then, estimate the model parameters (see below), incorporating the uncertainties in the data. A simple way to do this is to make a best estimate for each parameter, as well as an “optimistic” and a “pessimistic” estimate. The more uncertain a parameter is, the wider the difference will be between the “optimistic” and the “pessimistic” estimates. Use these estimates to create a range of models, which should give a range of extinction risk estimates. The range of these estimates indicates whether the results are useful (and, hence, whether there is enough data). See also “Incorporating uncertainty” below.

Remember that Criterion E does not require very specific predictions. Even very uncertain results may be useful. For example, if the minimum estimate for the risk of extinction in 100 years is 10%, then the taxon is at least Vulnerable, regardless of the most pessimistic predictions. The criteria also allow incorporating uncertainty in the form of a range of categories presented in the documentation, while a single category should always be specified in the Red List (see Annex 1 of IUCN 2001). So, for example, if the generation length is 10 years, and the extinction risk is 20-60% in 100 years, 10-30% in 50 years, and 5-10% in 30 years, the taxon could be classified as (VU-EN) in the documentation, while either has to be chosen for the Red List.

## 9.4 Model components and parameters

It is very important that model parameters are estimated without bias. However, it is difficult to provide detailed guidelines on parameter estimation because the components and parameters of a model depend on its structure. Thus, although we provide some general guidelines and specific examples in this section, these are not comprehensive.

### 9.4.1 Density dependence

Density dependence is the relationship between demographic parameters (such as survival, fecundity, population growth rate, etc.) and the size or density of the local population. The relationship can be negative (also called compensation), with demographic parameters decreasing as density increases, or it may be positive (also called depensation), with demographic parameters decreasing as density decreases. The former type of density dependence may result, for instance, from overcrowding and interspecific competition, and the latter may result from Allee effects, social structure, and inbreeding depression. Both types of density dependence have important effects on extinction risks, so models should address both. In other words, whether the model includes or excludes these types of density dependence, the choice should be justified.

Compensation is especially important to include in cases where habitat loss is a threat. Depensation can be incorporated by setting an extinction threshold greater than zero (see above).

Because density dependence affects demographic parameters such as survival and fecundity, estimates of these rates should include description of the population sizes or densities during the time period when the data for these estimates were obtained.

### 9.4.2 Temporal variability

Because the criteria are in terms of probabilities, it is essential that all relevant forms of variability are included in the assessment. Thus the following types of variability should be considered: environmental fluctuations (in the form of random changes in one or more model parameters), demographic stochasticity, expected future trends in the average values of model parameters (e.g., as a result of deteriorating habitat), genetic stochasticity, random changes in the sex ratio, and low-probability, high-impact events (disturbances or catastrophes).

In modelling environmental fluctuations, the estimates of the variances of model parameters should include only temporal variation; variation due to demographic stochasticity, measurement error, spatial variation, etc. should be subtracted. For example, if survival rates are based on census data, binomial variance representing demographic stochasticity can be subtracted from total observed variance (Akçakaya 2002); if the survival rates are based on a mark-recapture analysis, methods described by Gould and Nichols (1998) and White *et al.* (2002), or in the help file of Program MARK (<http://www.cnr.colostate.edu/~gwhite/mark/mark.htm>) can be used to remove demographic/sampling variance.

If catastrophes are included in the model, only data from non-catastrophe years should be used when estimating the mean and variance of the model variable (such as survival, fecundity, or carrying capacity) that the catastrophe affects.

When probabilistic results are based on simulations, the number of replications or iterations determines the precision of these results. In most cases, the randomly sampled model parameters are statistically representative if the number of replications is in the 1000 to 10000 range.

#### 9.4.3 *Spatial variability*

If different subpopulations of the taxon are spatially separated or have different demographic rates, these should be incorporated by making the model spatially explicit. Modelling such a taxon with a single-population model may underestimate the extinction probability. When multiple populations are included in the model, the correlation among the different populations is an important factor; ignoring it (i.e., assuming all populations to be independent) may underestimate the extinction probability.

### **9.5 Incorporating uncertainty**

We suggest that all parameters be specified as ranges that reflect uncertainties in the data (lack of knowledge or measurement errors). In addition, uncertainties in the structure of the model can be incorporated by building multiple models (e.g., with different types of density dependence). There are various methods of propagating such uncertainties in calculations and simulations (Ferson *et al.* 1998). One of the simplest methods is to build best-case and worst-case models (e.g., Akçakaya and Raphael 1998). A best-case (or optimistic) model includes a combination of the lower bounds of parameters that have a negative effect on viability (such as variation in survival rate), and upper bounds of those that have a positive effect (such as average survival rate). A worst-case or pessimistic model includes the reverse bounds. The results from these two models can be used as upper and lower bounds on the estimate of extinction risk, which in turn can be used to specify a range of threat categories (see Annex 1 of IUCN 2001).

### **9.6 Documentation requirements**

Any Red List assessment that relies on Criterion E should include a document that describes the quantitative methods used, as well as all the data files that were used in the analysis. The document and accompanying information should include enough detail to allow an evaluator to reconstruct the methods used and the results obtained.

The documentation should include a list of assumptions of the analysis, and provide explanations and justifications for these assumptions. All data used in estimation should be either referenced to a publication that is available in the public domain, or else be included with the listing documentation. The uncertainties in the data should be documented.

Methods used in estimating model parameters and in incorporating uncertainties should be described in detail. Time units used for different model parameters and components should be consistent; the periods over which parameters are estimated should be specified.

## 10. Guidelines for applying the categories DD, NT, and NE

### 10.1 When to use the category Near Threatened

To qualify for the Near Threatened category, the taxon should be close to qualifying for the Vulnerable category. The estimates of population size or habitat should be close to the Vulnerable thresholds, especially when there is a high degree of uncertainty, or possibly meet some of the subcriteria. This may be combined with biological susceptibility and threat. The category Near Threatened is not specified by its own criteria, but instead by the proximity of a species to the criteria for the category Vulnerable. For taxa listed as Near Threatened on the IUCN Red List, assessors are asked to indicate as part of the justification, which criteria were nearly met. For example, NT listing would be justified in the following cases (in each case, any criteria not specifically mentioned are not met and are not nearly met):

- Population has declined by an estimated 20-25% in the last 3 generations.
- The taxon meets the area requirements under criterion B for threatened ( $EOO < 20,000 \text{ km}^2$  and/or  $AOO < 2,000 \text{ km}^2$ ) and is declining, but the population is not severely fragmented, occurs at twelve locations, and there are no extreme fluctuations.
- The taxon meets the area requirements under criterion B for threatened ( $EOO < 20,000 \text{ km}^2$  and/or  $AOO < 2,000 \text{ km}^2$ ) and is severely fragmented, but the population is not declining, occurs at more than 10 locations, and there are no extreme fluctuations.
- The taxon is declining and occurs at ten locations, but has an EOO of  $30,000 \text{ km}^2$  and/or an AOO of  $3,000 \text{ km}^2$ , which are uncertain estimates.
- The taxon is declining and severely fragmented, but has an EOO of  $30,000 \text{ km}^2$  and/or an AOO of  $3,000 \text{ km}^2$ , which are uncertain estimates.
- The taxon is declining and severely fragmented, but has an EOO of  $22,000 \text{ km}^2$  and/or an AOO of  $3,000 \text{ km}^2$ , which are highly certain estimates.
- Population has declined by an estimated 10% in the last 3 generations, and is continuing to decline, and has about 15,000 mature individuals.
- The taxon exists in a single subpopulation of about 15,000 individuals and is declining.
- The population has about 1500 mature individuals.
- The best estimate of population size is 2000 mature individuals, but this estimate is very uncertain, and as low as 1000 mature individuals cannot be ruled out.
- The taxon exists at 3 sites, occupying an area of  $12 \text{ km}^2$ ; the population is being harvested but is not declining; there are no current threats, but there are plausible events that may cause the species to decline, but these are unlikely to make the species Extinct or Critically Endangered in a short time.

The following are examples of species that should not be listed as NT (or any of the categories of threat), unless other criteria apply:

- Population has declined by an estimated 10% in the last 3 generations, and there are more than 20,000 mature individuals.
- Population has declined by an estimated 30% as part of fluctuations.

- The taxon meets the area requirements under criterion B for CR ( $EOO < 100 \text{ km}^2$  and/or  $AOO < 10 \text{ km}^2$ ), but is not declining, not severely fragmented, there are no extreme fluctuations, and there are no obvious threats.
- The taxon is long-lived and slow growing, but does not meet any criteria A-E.
- The population has more than 2000 mature individuals.
- The taxon exists at 3 sites, occupying an area of  $30 \text{ km}^2$ ; the population is not declining; there are no current threats, and the species is very unlikely to become Extinct or Critically Endangered in a short time.

A taxon may also qualify for the Near Threatened category if it is the focus of a continuing taxon-specific or habitat-specific conservation programme targeted towards the taxon in question, the cessation of which would result in the taxon qualifying for one of the threatened categories above within a period of five years. In these cases, the listing justification must explicitly state that the taxon is listed as NT because it is conservation-dependent. The conservation programmes that focus on the taxon must be described as part of the documentation requirements (see IUCN 2001; Annex 3).

## 10.2 Not Evaluated and Data Deficient

Listing in the categories of Not Evaluated (NE) and Data Deficient (DD) indicates that no estimation of extinction risk has been made, though for different reasons. NE indicates that no attempt to evaluate the current status of the taxon has been made. DD indicates that the taxon was evaluated using available data, which were found to be insufficient to place the taxon into a category. Taxa listed in these categories should not be treated as if they were not threatened.

## 10.3 When to use Data Deficient

If a taxon is known, but there is no information about its current status or possible threats, then it is obviously Data Deficient (DD). A Data Deficient listing does not imply that a taxon is not threatened.

The issue becomes more complex when there is very little information known about a taxon, but the available information indicates that the taxon may be threatened. The question then becomes how far is it acceptable to take inference and projection? This is discussed in greater detail in Sections 3.1 and 3.2 (Data availability, inference and projection, and uncertainty).

When data are very uncertain, the category of Data Deficient may be assigned. However, in this case the assessor must provide documentation showing that this category has been assigned because data are inadequate to determine a threat category. If the data are so uncertain that both CR and LC are plausible categories, the taxon can be listed as DD. If plausible categories range from NT to threatened categories, see section 3.2 about guidance to select the most plausible category while documenting the uncertainty. It is important to recognize that taxa that are poorly known can often be assigned a threat category on the basis of background information concerning the deterioration of their habitat and/or other causal factors; therefore the liberal use of Data Deficient is discouraged.



Data Deficient species may be flagged with one or more of the following tags:

1. Unknown provenance. The taxon is known only from one or more specimens with no or extremely uncertain locality information, so that it is not possible to make any further inference about its status.

Examples:

Bogata Sunangel *Heliangelus zusii* is a hummingbird known from a single trade-skin purchased in 1909 in Bogotá, and speculated to have been collected on the East Andes or possibly the Central Andes of Colombia, within a few hundred kilometres of the capital. However, some "Bogotá" specimens came from as far away as Ecuador. Since no other specimen is known, it is assumed to be (or have been) a relict species of restricted range.

*Rheocles pellegrini* is a freshwater fish known only from the type collection made in 1930 one day west of Andapa which is somewhere along the northeast coast of Madagascar. This species has not been collected again since the 1930s, largely because its exact type locality is not known. There are therefore no data available upon which to base statements about the quality of its habitat or the size of its population, but it is assumed to be (or have been) a relict species of restricted range.

*Anthurium parambae* is a hemi-epiphytic aroid plant endemic to Ecuador. It is known only from the type collection made in an unknown locale by L. Sodiro a century ago. The lack of information prevents any evaluation of the species' conservation status and this is further compounded by taxonomic problems with many species of *Anthurium* that were described by Sodiro.

2. Uncertain taxonomic status. The taxon's validity at the species level has been questioned or is unconfirmed, e.g., it may represent a hybrid, ecophenotype or aberrant individual.

Where a species name is widely accepted as containing multiple taxa that may deserve species-level recognition (a 'species complex'), this species name should be categorized as Data Deficient and tagged as Uncertain taxonomic status if there is good evidence that one or more of the constituent taxa would qualify as threatened. [In situations where none of the constituent taxa of the 'species complex' are considered to be likely to qualify as threatened, the species name should be categorized as Least Concern.]

Examples:

*Doratogonus bilobatus* is a species of millipede supposedly confined to the provinces of KwaZulu-Natal and Mpumalanga in South Africa. The taxonomic status of this species requires attention. It has been suggested that it is synonymous with *D. castaneus*, and it also resembles *D. rugifrons* to some extent.

West Mexican Knobtail *Epigomphus crepidus* is a dragonfly endemic to the Pacific slope of southern Mexico (Nayarit and Oaxaca). There is a question about the extent of occurrence for *E. crepidus*. It may be that more than one species is included in this taxon: a specimen from Oaxaca in the Paulson collection apparently differs in morphology from the type series from Nayarit. Further study is needed to determine if the two known subpopulations are the same species or not.

3. Insufficient information. There is inadequate information on the population size/structure, trend or range to apply the Red List criteria.

Examples:

Red Sea Swallow *Hirundo perdita* is known only from the type-specimen, found dead in May 1984 at Sanganeb lighthouse, north-east of Port Sudan, Sudan. The species's preferred habitat is unknown, but its morphology is similar to the 'cliff swallow' group of species, whose other members prefer open country (e.g. grassland or mountainous areas), often near to cliffs and/or water and/or human habitation. It is therefore judged most likely to be found in the Red Sea hills of Sudan or Eritrea, or possibly (because two pale-rumped swallows were seen flying out over the Red Sea towards Jeddah, just before the discovery of the type) in the coastal hills of western Saudi Arabia north of Jeddah. Unidentified cliff swallows, possibly of this species, have been seen at Lake Langano (c.20 birds) and in Awash National Park (3-8 birds) in the Rift Valley in Ethiopia, plus three more recent sites, although they are more likely to represent an undescribed taxon. There is no other information on the species' range, population size and trend, preferred habitat and potential threats.

Obscure Berrypecker *Melanocharis arfakiana* is known from two specimens and a series of recent unconfirmed sight records from New Guinea (Papua, formerly Irian Jaya, Indonesia, and Papua New Guinea). The specimens were collected in 1867 in the Arfak Mountains and in 1933 from 950 m near the upper Angabunga River. The recent sightings have been from 640-1,100 m in the Tabubil area, where it is not uncommon, Boana on the Huon peninsula, where it is common in degraded forest, and the Kokoda Trail near Port Moresby. Specimens from Tabubil and Boana differ slightly in plumage but are probably both of this species. It may be a genuinely extremely rare species, perhaps compressed into a narrow altitudinal belt between ecologically similar congeners. Forests in these geographical and altitudinal ranges are under some threat from logging and clearance for agriculture. However, its tolerance of degraded forest and recent discovery in widely scattered sites suggest that it is not threatened.

Parissi's slit-faced bat *Nycteris parisii* is a poorly known species of bat, known from only three records: northern Cameroon, near the border with Nigeria; southern Ethiopia, near the border with Kenya; and from southern Somalia. West African records probably represent a separate species (*N. benuensis*) but the taxonomy needs clarification. Nothing is known about its general biology or specific threats. Found at low elevations in riverine and riparian woodland. Population details are unknown. Roosts have never been found. The species was last collected in the 1980s.

*Doratogonus liberatus* is a species of millipede endemic to the Free State province of South Africa. This species has only been collected from two localities, one in the suburban area of Bloemfontein, and one approximately 100 km away in the Caledon Nature Reserve. The habitat between the two localities is not entirely transformed by agriculture and urbanisation but it is not known whether this species does occur more widely, or whether the population is fragmented. The taxonomy of the genus *Doratogonus* was revised in 2000. Species within this genus are large-bodied (8–20 cm long), conspicuous, and occur in forest habitat. The species in this genus may reflect patterns of endemism and threat commonly found in ground-dwelling, flightless invertebrates.

## 11. Guidelines for applying the extinct categories and tag

### 11.1 The extinct categories (EX and EW)

The category of Extinct is used when ‘there is no reasonable doubt that the last individual has died’. However, extinction—the disappearance of the last individual of a species—is very difficult to detect. Listing of a species as Extinct requires that exhaustive surveys have been undertaken in all known or likely habitat throughout its historic range, at appropriate times (diurnal, seasonal, annual) and over a timeframe appropriate to its life cycle and life form. Listing as Extinct has significant conservation implications, because protective measures and conservation funding are usually not targeted at species believed to be extinct. Therefore, a species should not be listed in the Extinct (EX) or Extinct in the Wild (EW) categories if there is any reasonable possibility that they may still be extant, in order to avoid the ‘Romeo Error’ (Collar 1998), where any protective measures and funding are removed from threatened species in the mistaken belief that they are already extinct. This term was first applied to the case of Cebu Flowerpecker *Dicaeum quadricolor*, which was rediscovered in 1992 after 86 years without a record (Dutson *et al.* 1993), having been written off as extinct at least 40 years earlier on the presumption that none of its forest habitat remained on the island of Cebu (Magsalay *et al.* 1995). An evidentiary approach to classifying extinctions is appropriate in order to encourage continuing conservation efforts until there is no reasonable doubt that the last individual of a species has died. However, if assessments of EX or EW are too evidentiary, then extinction rates based on the Red List are likely to be under-estimated. To avoid this bias, it is necessary to include possibly extinct species in estimates of numbers of extinct taxa and extinction rates.

### 11.2 ‘Possibly Extinct’ tag for Critically Endangered taxa

Although an evidentiary approach to classifying extinctions is appropriate, this approach biases analyses of recent extinctions when based only on those species classified as Extinct or Extinct in the Wild (when individuals survive only in captivity). For example, the number of recent extinctions documented on the IUCN Red List is likely to be a significant underestimate, even for well-known taxa such as birds. The tag of ‘possibly extinct’ has therefore been developed to identify those Critically Endangered species that are likely already Extinct, but for which confirmation is required. Taxa tagged as possibly extinct would then be included within bounded estimates of the number of recent extinctions to indicate plausible uncertainty in contemporary rates of extinction.

#### 11.2.1 Identifying Possibly Extinct species

Critically Endangered (possibly extinct) taxa are those that are, on the balance of evidence, likely to be extinct, but for which there is a small chance that they may be extant. Hence they should not be listed as Extinct until adequate surveys have failed to record the species and local or unconfirmed reports have been investigated and discounted. ‘Possibly Extinct in the Wild’ correspondingly applies to such species known to survive in captivity.

Note that ‘possibly extinct’ is a tag, and not a new Red List Category.

Different standards of evidence are required from assessors when deciding to assign a taxon to the Extinct or Critically Endangered (possibly extinct) categories. Assignment to the Extinct category requires evidence beyond reasonable doubt that the last individual of the taxon has died. Assignment of the ‘possibly extinct’ tag requires that on the balance of evidence, the taxon is likely to be extinct, but there is a small chance that it may be extant. Relevant types of evidence supporting a listing of extinction include:

- For species with recent last records, the decline has been well documented.
- Severe threatening processes are known to have occurred (e.g. extensive habitat loss, the spread of alien invasive predators, intensive hunting, etc.).
- The species possesses attributes known to predispose taxa to extinction, e.g. flightlessness (for birds)
- Recent surveys have been apparently adequate and appropriate to the species’ detectability, but have failed to detect the species.

Such evidence should be balanced against the following considerations:

- Recent field work has been inadequate (any surveys have been insufficiently intensive/extensive, or inappropriately timed; or the species’ range is inaccessible, remote, unsafe or inadequately known).
- The species is difficult to detect (it is cryptic, inconspicuous, nocturnal, nomadic, silent or its vocalisations are unknown, identification is difficult, or the species occurs at low densities).
- There have been reasonably convincing recent local reports or unconfirmed sightings.
- Suitable habitat (free of introduced predators and pathogens if relevant) remains within the species’ known range, and/or allospecies or congeners may survive despite similar threatening processes.

Similar considerations apply when assigning a taxon to either the Extinct in the Wild or Critically Endangered (possibly extinct in the wild) categories.

Guidelines for interpretation of the standards of evidence supportive of Extinct and Critically Endangered (possibly extinct) classifications and Extinct in the Wild and Critically Endangered (possibly extinct in the wild) classifications are under development.

The documentation for each taxon assessed as Extinct, Extinct in the Wild, Critically Endangered (possibly extinct) and Critically Endangered (possibly extinct in the wild) should explicitly justify the application of the Extinct categories and ‘possibly extinct’ tag. The documentation must summarise the lines of evidence for and against extinction, describe surveys carried out to search for the species and specify the date and relevant details of the last confirmed record.

The status of all taxa assigned ‘possibly extinct’ tags must be reviewed at 5-year intervals. For further discussion of the application of the Possibly Extinct tag, see Butchart *et al.* (2006).

### 11.2.2 Examples of Critically Endangered (possibly extinct) species

Alaotra Grebe *Tachybaptus rufolavatus* is a near-flightless bird that was restricted to the Lake Alaotra area in Madagascar. It underwent a well-documented decline owing to incidental mortality in

monofilament gill-nets and predation by introduced carnivorous fish, compounded by hybridisation with Little Grebe *T. ruficollis*. The last confirmed records were in 1985, with individuals showing some characters of the species seen in 1986 and 1988 (Hawkins *et al.* 2000). In all probability the species is now extinct, but there is a slim chance that individuals could survive at Lake Amparihinandriambavy, where unidentified grebes were seen in 2000 (BirdLife International 2004). The species is tagged as Possibly Extinct until further surveys determine the identity of the birds at Lake Amparihinandriambavy.

Nukupu'u *Hemignathus lucidus* is a bird endemic to the Hawaiian Islands where it has not been recorded since 1995–1996 despite extensive survey effort in a large proportion of its historic range (Pratt *et al.* 2001). It is in all likelihood extinct as a result of habitat loss and degradation combined with introduced diseases such as avian malaria spread by introduced mosquitoes. However, given the last record was within the last decade, the species is tagged as Possibly Extinct until further surveys confirm that no individuals remain.

Guadalupe Storm-petrel *Oceanodroma macrodactyla* is a bird endemic to the Mexican island of Guadalupe. It has not been recorded since 1912 despite several searches, following a severe decline owing to predation by introduced cats and habitat degradation by introduced goats (BirdLife International 2004). Only the difficulty of detecting storm-petrels at their breeding colonies at night (when the birds are active) and the continued survival of other storm-petrels on the island point to the possibility that some individuals survive. It is therefore classified as Possibly Extinct until further surveys confirm that the no individuals remain.

Spix's Macaw *Cyanopsitta spixii* is a parrot endemic to Brazil. It underwent a severe decline owing to unsustainable and intensive exploitation for the cagebird trade (Juniper 2003), and the last known individual disappeared in 2000. Searches have not led to the discovery of any other populations, although it is conceivable, if unlikely, that further individuals survive.

Oloma'o *Myadestes lanaiensis* is a bird endemic to the Hawaiian Islands. It was last recorded in 1980, with an unconfirmed report in 1988. There have been no subsequent records despite further surveys in most of the historical range. It is likely to have been driven extinct by disease spread by introduced mosquitoes, and as a result of habitat destruction (Reynolds and Snetsinger 2001). However, the remote Oloku'i Plateau has not been surveyed recently and could still harbour some birds.

*Atelopus planispina* is a species of Harlequin Toad endemic to the eastern slopes of the Ecuadorian Andes, from Volcan Reventador to the south, to Cordillera de Cutucu. The population has declined dramatically (more than 80%) in the last three generations probably due to the impacts of the disease chytridiomycosis, which has affected many other montane species of *Atelopus*. The last record of the species was in July 1985 (an amplexant pair) despite repeated visits to known (El Reventador) or inferred localities (within its extent of occurrence) (Bustamante 2002).

Hispaniolan Crestless Toad *Bufo fluviaticus* is a toad with a very restricted range (two known localities) in northwestern Dominican Republic. It was found in xeric habitats with broadleaf gallery forest, typically in close proximity to streams. It is not known whether animals stay close to streams or spread out into xeric habitats. The species is threatened by habitat destruction from agriculture and cattle grazing. The Hispaniolan Crestless Toad has not been encountered by any herpetologist in the three decades since it was first discovered, including by experts who have collected extensively on the island. Because toads often breed (and are seen) sporadically, additional efforts should be made to locate this species before it is considered extinct. No specimens have been collected since the type series. A scientist looked for it in 2003 and did not find it (M. Hernandez, pers. comm.).

Ethiopian Amphibious Rat *Nilopegamys plumbeus* is known only from one specimen trapped near the source of the Little Abbai River in northwestern Ethiopia. It is a water-adapted, insectivorous rodent and is therefore likely to occur at low densities. The species occurs in an area where the habitat has been destroyed through overgrazing by livestock. The habitat was already severely degraded when the type specimen was collected in the 1920s and L. Lavrenchenko (pers. comm.) confirms that the type locality area today is pure pastureland. The population status is unknown, possibly extinct. L. Lavrenchenko (pers. comm.) has attempted to recollect this species on two occasions, D. Schlitter (pers. comm.) has also tried, but without any success.

Pondicherry Shark *Carcharhinus hemiodon* is a very rare Indo-West Pacific shark species known from about 20 specimens in museums, obtained from widely separated sites. It occurs inshore on continental and insular shelves. All of the sites where it is known from are subject to large, expanding and unregulated artisanal and commercial 'catch all' fisheries. The population of this species is thought to have been severely depleted as a result of this exploitation. The species was last recorded in 1979 (in India), and it has not been reported since, despite detailed market surveys in much of its range in recent years (in Borneo, Philippines and Indonesia). Given that it has not been observed in over 20 years, that most known specimens were captured before 1900, and that its previously known habitat and extent of occurrence faces expanding unregulated fisheries, this species is listed as Critically Endangered (Possibly Extinct). Future survey work should attempt to locate the species.

## 12. Guidelines for Threatening Processes

As discussed in an earlier section, the criteria aim to detect symptoms of endangerment rather than causes (see also Mace et al. 2008). Consequently, they are applicable to any threatening process that results in symptoms such as population decline, small population sizes, and small geographic distributions. A taxon may be classified as threatened even if a threatening process cannot be identified. Regardless of the nature of threats, assessments must follow IUCN (2001) and these guidelines to ensure valid application of the criteria. However, different threats, especially new or poorly understood processes such as global climate change may require further guidance in the application of definitions and criteria.

The purpose of this section is to provide such specific guidance. In this version, we focus on global climate change; future versions will provide further guidance on how the criteria may be interpreted to assess taxa affected by other threats. It is important to note that the guidance in this section is not an alternative to previous sections.

One aspect of a Red List assessment involves listing the major threats in the required documentation, as described in IUCN (2001; Annex 3), using a standard classification scheme available at [iucnredlist.org](http://iucnredlist.org). The guidance given here does not relate to this process; instead the focus is on the application of the Red List categories and criteria.

### 12.1 Global climate change

There are several difficulties in applying the criteria to species impacted by global climate change, which have resulted in several misapplications of the criteria (Akçakaya et al. 2006). Here we discuss issues related to time horizon of Red List assessments, applications of various definitions and criteria, and use of different types of models. Although we discuss particular criteria in this section, this does not mean that these are the only applicable ones.

As with any other threat, the taxon should be assessed against all the criteria as available data permit.

#### *12.1.1 Time horizons*

An important issue in the application of the criteria to species impacted by climate change concerns the time horizons over which the assessments are made.

The time horizons used in the criteria serve several purposes. First, the generation time is used as a surrogate for turnover rates within populations and as a biologically relevant scaling factor that corrects for the variation in rates at which different taxa survive and reproduce. Second, the time horizon is set to a minimum of 10 years because measuring changes over shorter time periods is difficult and does not reflect time scales for human interventions. Third, the time horizon is set to a maximum of 100 years into the future, because of the uncertainties in predicting population sizes for a long time from the present day (Mace et al. 2008).

The global climate is projected to continue to change for several centuries, even if CO<sub>2</sub> emissions are stabilized (although more slowly after the first 100 years; see IPCC 2007; Chapter 10). The effects on biological systems will certainly continue for a long time. Thus, for many species, especially short-lived ones, Red List assessments are based on time horizons much shorter than the long periods over which we now expect the world's climate and its effect on species will change. This by itself may not make climate change fundamentally different: other threats, such as habitat loss may also continue for a long time.

However, the nature of change in biological systems caused by climate change is thought to be different than changes caused by other threats. Thuiller et al. (2005), for example, argued that, "the recognized time scales for assigning species IUCN Red List categories are not suited to evaluating the consequences of slow-acting but persistent threats," suggesting that the projected climate change impacts are thought to be of a more deterministic nature than other threats. In addition, some amount of climate change-related impact is irreversible (already committed) because of the lag between greenhouse gas emissions and climate change (and subsequent biological change).

While stochastic events (catastrophic fires, ENSO events, etc.) that contribute to the variability and hence the risk of extinction of populations clearly operate at different time scales than climate change, there are other processes that also are slow-acting and persistent. For example, it is debatable whether threats such as habitat loss and fragmentation are any less persistent or any more uncertain than climate change. Although climate change may be persistent, the predictions are also very uncertain. For example, IPCC (2007) makes most of its predictions only until 2100 because general climate models tend to produce very different outputs towards the end of the 21st century.

The criteria recognize that some threats may be irreversible (as explicitly noted in criterion A). For example, in many cases, habitat loss brought about by urban sprawl is not reversible. Various threats may involve time lags similar to that of climate change. For example, human populations have a momentum, and thus there is often a lag between a

change in the human population growth rate and resulting changes in human pressures on natural systems.

Thus, the assessment of species with short generation times is not fundamentally different under climate change and under other threats. Although short-lived species may not be listed under criterion A initially, if they are affected by climate change they will be listed (likely under criteria B or C) as their ranges and populations change as a response to climate change. They can also be listed under criterion E (see below).

In summary, many of the issues related to time horizons are not specific to global climate change. Although future versions of this document may provide further guidance on this issue, for the time being, the horizons for each of the criteria should continue to be applied as they are currently specified, regardless of the nature of the threatening factor, including global climate change.

#### *12.1.2 Definition of "Location" under climate change*

Using the number of locations in Red List assessments requires defining the most serious plausible threat(s). In some cases, the most serious plausible threat will be climate change, but it may not be correct to assume that species threatened by climate change occupy a single location. In general, it is not possible to identify climate change as the main threat (for purposes of defining locations) without knowing something about how the effects of climate change are likely to be played out through the proximate causes or direct threats. For most species susceptible to climate change, the climate change itself (e.g., increasing temperatures or changes in precipitation) is not the direct threat. Rather, the process through which climate change is expected to affect species involves a large variety of threats or proximate causes, such as changes in fire frequency, hydrology, species interactions, habitat suitability, diseases, that affect the species vital rates (these proximate causes can be inferred using knowledge of species ecology and predicted changes in relevant climatic variables). Thus, even when the ultimate cause of endangerment is climate change, the locations occupied by a species should be defined (and counted) in terms of these direct threats. Climate change should only be used to define the number of locations when it is the direct threat (e.g. where survival rates are reduced by thermal stress and are likely to be the principal direct cause of population declines or when suitable habitat is reduced due to changes in temperature and precipitation).

In some cases, climate change may threaten different parts of a species' range through different proximate factors, or not affect some parts at all (for example, part of the range may be expanding). In such cases, the most serious plausible threats should be used to define locations in different parts of the species range in accordance with section 4.11 (options a–d).

Examples of estimating the number of locations for species susceptible to climate change:

Species 1 is restricted to a single climatic zone affected by severe hurricanes that cause episodes of high mortality. The frequency of severe hurricanes in the region is projected to increase by at least 20% over the next 100 years. A single severe hurricane is unlikely to affect the entire range of the species, but two severe hurricanes could cover the entire range.



The species is correctly estimated to occur at two locations based on severe hurricanes as the proximate threat (the minimum number of independent hurricanes that could affect its entire range). It would be incorrect to interpret the species as occupying a single location based on the single climatic zone occupied in which severe hurricane frequency is projected to increase.

Species 2 is restricted to three coastal freshwater wetlands potentially affected by saltwater incursion associated with sea level rise. Two of the wetlands occur on the same floodplain, one at a low-lying site 0.5 metres above sea level, and another perched on the upper floodplain 5 metres above sea level. The third wetland also occurs at 5 metres above sea level, but in another region where there is a very large inter-tidal range. Sea level is projected to rise, on average by 1.0 metre by year 2100. The low-lying wetland will certainly be affected by sea-level rise. The nearby perched wetland is very unlikely to be affected by sea-level rise. The third wetland could be affected by saltwater incursion during extreme spring tides under projected future climate, but this is uncertain. Incursion by saltwater is the most serious plausible threat at the low-lying (first) site and the distant (third) site with the high inter-tidal range. These two sites could be interpreted as a single location if they are both threatened by the same regional sea-level rise. However, if sea level rise could lead to different outcomes at the two sites they could be interpreted as two separate locations. For example, the same amount of sea-level rise may inundate the first wetland but only sporadically affect the third wetland, causing different types of impacts at the two wetlands (total habitat loss in one and temporary population reduction in the other). If the independence of threat outcomes at the two wetlands is uncertain, then a bounded estimate of [1-2] locations is appropriate (see section 3). The second wetland is very unlikely to be affected by sea level rise, and hence the most serious plausible threat for this wetland is not sea level rise. If this site is subject to other threats, the most serious plausible one will govern how many locations are represented at that site. For example, if the entire wetland is threatened by polluted runoff, then it should be counted as a single location and the total number of locations for the species is [2-3]. Alternatively, if the second wetland is not threatened, then the number of subpopulations at that site could be used as a proxy or the number of locations may not be applicable to the assessment of the species (i.e. the subcriteria for number of locations cannot be met, see section 4.11).

Species 3 is restricted to the highest altitudes of two mountain ranges separated by a plain of 100 km. The two mountain ranges have a seasonal cover of winter snow that extends above a similar threshold altitude (1800 m above sea level), although the summits of their mountains are at different elevations. Seasonal snow cover affects breeding success by providing insulation during cold winters. The extent of snow cover is projected to decline stochastically over the next 30 years. The most serious plausible threat is the risk of a year in which there will be very low or no winter snow cover, which causes an episode of very high mortality in the species population. The chance of this occurring in the same year on both mountain ranges is about 30%, based on correlation of minimum snow extent over previous years. Despite their geographic separation, the two mountain ranges are interpreted as a single location for the species because they may be affected by the same 'low-snow cover' event.

### *12.1.3 Inferring population reduction and continuing decline from results of bioclimatic models*

Bioclimate envelope models (or bioclimate models) are often used to predict changes in a taxon's range as defined by climatic variables (see section 12.1.8 for detailed guidance on developing these models). The results of bioclimate envelope models will be a series of habitat suitability maps. In order to infer population reduction (for use in criteria A3 or A4) from these maps, it is necessary to calculate the expected population size from the current map and from the map for the time step that corresponds to 3 generations in the future. If climate data are not available for the year that corresponds to 3 generations in the future, it should be created by interpolation from the available layers.

Even if the current population size of the taxon is known, the same method of estimation should be used for both the "current" and the "future" maps. This is because the quantity of interest is the proportional change in population size, and using the same methods allows removing some of the effects of the assumptions involved in making this conversion from habitat suitability (HS) to population size.

The relationship between population reduction and habitat loss may not be linear (see section 5.7). However, in the absence of more specific information, it is an allowable assumption. With this assumption, the conversion from habitat suitability to population size will involve summing all the HS values in each map, and calculating the proportional change in 3 generations. One important correction to this calculation is to use a threshold, such that only HS values above a set threshold are added up. This allows for excluding areas that are unlikely to support a population because of low suitability. Another correction that should be made is to exclude patches that are too small to support a viable subpopulation (because of demographic stochasticity or Allee effects), or too isolated to be colonized by dispersers from occupied patches. Note that these corrections require species-specific information, and must be made separately for each taxon.

For species with limited dispersal ability, it is important to examine the overlap between successive habitat maps, projected at 1-generation intervals. The degree of overlap between each successive pair of habitat maps determines the relationship between habitat loss and population reduction. If there is little overlap, population reduction is likely to be larger than the projected habitat loss.

Projected change in habitat can also be used to infer continuing decline in habitat quality (e.g., B1b(iii)).

### *12.1.4 Using criterion D2*

When climate change is a plausible threat, a VU D2 classification may be appropriate for a taxon with restricted range or few locations. This classification is only permissible if the effects of climate change are such that the taxon is capable of becoming Critically Endangered or Extinct in a very short time period after the effects of the threat become apparent.

Example 1. A species that currently does not meet the area thresholds under criterion B may be classified as VU D2 if bioclimate models (see section 12.1.8) predict that a range reduction could correspond to a population reduction of 80% or more (and other information indicates that there are few locations; see above). In this case, the start of the decline may not occur soon, but the decline is plausible, and once it begins it is expected to cause a population reduction in a very short period of time (e.g., within 1 to 2 generations or 10 years) so that the species will be classified as CR A3c, so it now meets VU D2.

Example 2. A species of coral currently has restricted area of occupancy (less than 20 km<sup>2</sup>) but does not satisfy the criteria for classification under criterion B. Climate change models predict increases in ocean temperatures, greater than the typical seasonal variation, across the entire range of the species. This temperature increase is expected to cause coral bleaching such that the area of occupancy will be reduced to less than 10 km<sup>2</sup> within 10 years of the start of bleaching. It is highly uncertain when the temperature increase or the onset of the bleaching will occur, but there is a reasonable chance that it will occur in the future. Once the bleaching starts, the species will meet CR B2ab within a short time, so it now meets VU D2.

Example 3. A small mammal with an AOO > 500 km<sup>2</sup> occurs in a single location (see example of Species 3 above) where it is dependent on snow cover (for insulation and predator avoidance during the winter). Climate change is expected to increase the probability of a series of years with no or inadequate snow cover. If this occurs, the species is expected to decline by 80% or more due to mortality from exposure and predation. Although having a number of years with no snow cover is a stochastic process and cannot be exactly predicted, in this case the climate models indicate that it is a plausible event. The species meets VU D2 because this plausible event, once it occurs, will cause the species to be listed as CR.

Example 4. A species has AOO < 20 km<sup>2</sup>, but is not declining or under any specific threat or experiencing extreme fluctuations. It is expected that future climate change will affect this species, but the effects are expected to cause gradual and slow decline, which will not trigger any criteria for CR or cause extinction within 3 generations. Thus, this species does not meet VU D2.

Example 5. A fish species known only from a single oceanic archipelago, where it occurs from 1 to 30m depth. It lives in small recesses on slopes and walls of rocky reefs. In this region, localized declines, including the complete loss of at least one other endemic fish species, have occurred after strong El Niño-Southern Oscillation (ENSO) events that result in shallow waters that are too warm and nutrient poor for extended periods of time. The frequency and duration of ENSO events in this region appears to be increasing. Given the restricted distribution of the species and its specialised shallow water habitat, oceanographic environmental changes, such as those associated with future ENSO events, may cause the extinction of this species in a short period of time (as has happened for a similar species). Thus, it meets VU D2.

### *12.1.5 Severe fragmentation*

If a taxon is not currently severely fragmented (see section 4.8), but the results of bioclimatic models (see section 12.1.8) predict that the future distribution of the taxon will become severely fragmented, this result cannot be used to meet the severe fragmentation subcriteria (e.g., B1a). However, projected future fragmentation can be used to infer continuing decline, if certain conditions are met. Continuing decline is recent, current or projected future decline (see section 4.6). Severe fragmentation can for some species cause local extinctions of subpopulations inhabiting the smallest habitat fragments. If the population density and the projected distribution of fragments justify a prediction of increasing rate of local extinctions in the near future, this may be used to infer continuing future decline in population size.

The same conditions may also allow inferring population decline or reduction under criterion A3 (or C1), but this requires a quantitative prediction. Suppose that a bioclimatic model (see section 12.1.8) predicts that EOO of a taxon will decline by 20% in the next 3 generations due to climate change. Assuming that the population reduction will be at least as large as the EOO reduction (but see section 12.1.3), this can be used to infer a 20% population reduction, but would not by itself meet the VU threshold for A3. However, suppose that a simple population dynamic model predicts that populations smaller than a certain size have 50% risk of extinction. If the bioclimatic model also predicts that 40% of the population will be in fragments that support populations of this size or smaller, then we can infer that the population will undergo a further 20% reduction due to increased local extinction of smaller populations. Combined with the 20% reduction due to range contraction, this result can be used to infer a total of 40% population reduction, listing the species as VU A3.

### *12.1.6 Extreme fluctuations*

One of the predictions of many climate models is an increase in the frequency of extreme weather events (such as droughts, heat waves, etc.). This may increase population fluctuations to extreme levels (see section 4.7). If a taxon is not currently experiencing extreme fluctuations, but is predicted to do so in the future as a result of climate change, this prediction cannot be used to meet the extreme fluctuation subcriteria (e.g., B1c). However, a projected future increase in population fluctuations can be used to infer continuing decline, if certain conditions are met. Continuing decline is recent, current or projected future decline (see section 4.6). Extreme fluctuations can for some species lead to an increase in rate of local extinctions of subpopulations (especially if combined with severe fragmentation; see above). If the population sizes and the projected increase in fluctuations justify a prediction of increasing rate of local extinctions in the near future, this may be used to infer continuing future decline in population size.

A prediction of future extreme fluctuations can also contribute to a VU D2 listing if projected local extinctions could cause it to meet the criteria for CR in a very short period of time (see above).

### *12.1.7 Criterion E*

Because of its time horizon for VU of 100 years (regardless of generation time), criterion E can be used to list species with short generation times that are predicted to be threatened by

climate change. However, the difficulties with using criterion E (see section 9) are increased when climate change is the main threat, because of the need to take into account multiple types of stochastic and deterministic changes in the taxon's environment, demography and habitat that are caused or exacerbated by climate change.

When adequate data are available for developing both bioclimate models (see section 12.1.8) and population models (see section 9), new approaches that link outputs of global circulation models (GCMs, or climate models) to species habitat models and metapopulation models can be used to estimate risks of extinction (Keith et al. 2008; Anderson et al. 2009; Brook et al. 2009). Preliminary findings from these studies showed that extinction risks under climate change are subject to complex dependencies between species life history, distribution patterns and landscape processes (Keith et al. 2008).

It is very important not to ignore other threats, which may interact with, or supersede, climate change impacts when predicting species vulnerability to climate change. Approaches that focus on climate change alone may therefore lead to underestimation of extinction risks (Brook et al. 2009).

#### *12.1.8 Using bioclimate models*

Some of the guidance in the preceding sections refers to variables that may be calculated from outputs of bioclimate envelope models (or, bioclimate models). This section will summarize methodological guidance in the use of these models for the purposes of Red List assessments. It is important to note that the use of these models is not necessary for all assessments of species threatened with climate change. Future versions of this document may include guidelines for other types of predictive modelling (such as eco-physiological models) that may be useful for Red List assessments.

Bioclimate envelope models have been widely applied to explore potential impacts of climate change on species distributions (for reviews of this field see: Guisan and Zimmerman 2000, Guisan and Thuiller 2005, Heikkinen et al. 2006; for a practical introduction see Pearson 2007). These models commonly utilize associations between environmental variables and known species' occurrence records to identify climatic conditions within which populations can be maintained. The spatial distribution that is suitable for the species in the future can then be estimated under future climate scenarios. Advantages and disadvantages of this modeling approach have been widely debated in the literature, and multiple uncertainties make it essential that the model outputs are carefully interpreted (Pearson and Dawson, 2003; Hampe 2004; Araújo & Guisan 2006; Thuiller et al. 2008).

Bioclimate envelope models may provide useful information for red listing by identifying species that are more or less likely to experience contractions in the area of suitable climate space in the future and by estimating the degree to which potential distributions in the future might overlap with current observed distributions. The guidelines here are intended as a list of methodological issues that must be carefully considered in applications of these models for red listing under climate change. It is important that methodologies are well justified within the context of any particular study, and with respect to the biology of the taxon being assessed. Assessments that rely on bioclimate models will be reviewed by the SPSC, so

sufficient detail must be provided to allow the SPSC to determine if the model follows these guidelines.

Results of bioclimatic envelope models can be used in various ways to help with species assessments under the Red List Categories and Criteria. These uses include inferring population reduction under A3 and continuing decline (see section 12.1.3), linking bioclimate and demographic models for criteria E (section 12.1.7), inferring continuing decline from projected increases in fragmentation (see section 12.1.5), and projecting plausible threats for use in criterion D2 (see section 12.1.4). Although the interpretation of the results from these models for Red List assessments relies on a number of assumptions, they do allow a tentative solution to the problem of incorporating the long-term impacts of climate change. A number of alternative modelling approaches are being developed to explore the relationship between climate change and species endangerment (see section 12.1.7), which will allow more comprehensive guidelines for assessing the risk of extinction due to climate change.

#### *Quality of species occurrence data*

Bioclimate envelope models rely on observed occurrence records for characterizing species limits of tolerance to climate predictors so it is essential that these data are of good quality. Confidence in the accuracy of georeferencing and species identifications of occurrence records should be high. It is important that georeferencing of occurrence records is accurate to a degree that is relevant to the resolution of the environmental variables (e.g., accuracy should be within a few tens of meters if the resolution of analysis is 1 km<sup>2</sup>). Ideally, occurrence records should be associated with vouchered specimens and/or should have been identified by experts in the taxonomic group of interest. Data extracted from distributed databases (e.g., GBIF, HerpNET) should be carefully checked for accuracy, coverage and sampling intensity prior to use.

#### *Selection of environmental predictor variables*

Predictor variables need to be carefully selected. It is important to select variables that are expected to exert direct influence on the distributions of species (e.g., minimum temperature of the coldest month, maximum temperature of the warmest month, spring precipitation) through known eco-physiological mechanisms, and avoid indirect variables (e.g. altitude, topographic heterogeneity) (e.g., Guisan and Zimermann 2000). Often, there are several candidate variables for modelling the distributions of species but they tend to be correlated amongst each other. When this is the case, it is often advisable to investigate the correlation amongst them and select a reduced number of uncorrelated variables (to avoid problems of co-linearity; Araújo and Guisan 2006). One possible approach is to use Principal Components Analysis (PCA) to identify a reduced number of significant axes and then select a sub-set of ecologically meaningful variables that are associated with each one of the significant axis. Note that the number of predictor variables should not exceed the number of species occurrence records that are used. As a general rule, no more than one predictor variable for every five observations should be used. Some methods (e.g., Maxent, Phillips et al. 2006; Boosted Regression Trees, Elith et al. 2008) select a parsimonious number of variables automatically in which case the above rule would not apply. One reason to aim for

parsimony in variable selection is to avoid overfitting of the models, thus increasing generality.

#### *Land-use masks*

In addition to the climatic predictor variables, current and future land-use also constrains the distribution of species. This is especially crucial for species whose bioclimatic envelope is predicted to shift through human-dominated landscapes. Assessments that rely on climate data alone are prone to over-predict areas of suitable habitat because climate may be suitable but land cover may be unsuitable (Pearson et al. 2004). A land use map can be used as a mask to exclude such unsuitable areas from current and projected habitat.

#### *Choosing an appropriate spatial resolution*

Bioclimatic models have been fitted with data of varying resolutions, for instance ranging from 1 ha cells in Switzerland (Randin et al. 2009), to 2 degree latitude-longitude cells at a global level. There is commonly a trade-off between the geographical extent of the study area and the resolution of the data: studies across large areas are likely to use data at coarser resolutions than studies across smaller regions. Similarly, it is often necessary to use data at finer resolution when modelling the bioclimate envelope of restricted range species, whereas wide-ranging species may be effectively modelled using data at coarser resolutions. Also, when modelling species across regions with low spatial heterogeneity (e.g., flat terrain), coarser resolution data are less of a problem than when models are used across areas of high heterogeneity (e.g., rugged terrain). It is important to bear in mind, however, that analyses at coarse resolutions may not account for microclimates that may be important for species persistence (Pearson et al. 2006; Trivedi et al. 2008; Randin et al. 2009).

#### *Model selection*

A large number of bioclimatic modelling techniques exist, and it has been shown that agreements between predicted and observed distributions are often greater with models allowing complex response curves (e.g., Elith et al. 2006). There is an ongoing debate as to whether more complex models are more adequate for modelling species ranges under climate change (Araújo & Rahbek, 2006), so it is difficult at this point to provide unequivocal guidelines with respect to the choice of the modelling techniques. However, it is important that assessments of species range changes are based on established methodologies that have been used and verified by several independent research groups.

#### *Assessing the robustness of model projections*

Studies have shown that projections from alternative models can be so variable as to compromise assessment of whether species potential distributions should contract or expand for any given climate scenario (e.g., Araújo et al. 2005; Araújo et al. 2006; Pearson et al. 2006). Assessments of the temporal trends in the sizes of species potential distributions should, therefore, include an assessment of the robustness of the projections by comparing results of a range of bioclimatic modelling techniques. We suggest that at least three modeling techniques should be compared and be as independent as possible with regards to how they link the response and the predictor variables (e.g., GAM and GLM are conceptually similar and tend to produce similar results). Various strategies may be employed in cases when models forecast inconsistent trends. One such strategy is to

investigate the cause of the discrepancies. Typically, this would involve investigation of the species response curves obtained with each one of the methods, evaluating if there is any clear error, and then selecting the projections by the method producing more reasonable results. This approach is useful for species with well-known ecologies where expert judgements can be made and contrasted with the model outputs. The downside of the approach is that it involves subjective judgement that may yield non repeatable results. An alternative strategy is to run ensembles of forecasts using a number of established approaches and then combine the individual model projections through consensus methodologies (for a review see Araújo & New 2007). The disadvantage here is that potentially significant ecological knowledge is not being used.

#### *Background/pseudo-absence in the species distribution data*

Species distribution data may be either presence-only (i.e., records of localities where the species has been observed) or presence/absence (i.e., records of presence and absence of the species at sampled localities). Alternative modeling approaches have been developed to deal with each of these cases. Some approaches that use presence-only data also utilize 'background' (e.g., Maxent, Phillips et al. 2006) or 'pseudo-absence' (e.g., Elith et al. 2006) data. In these cases, model results are sensitive to the extent of the study region from which background or pseudo-absence samples are taken. It is therefore important to select an appropriate study region. In general, background and pseudo-absence records should not be selected from areas where the species is absent due to non-climatic factors, such as dispersal limitation or inter-species competition (because such records provide a false-negative signal that will lead to poorer characterization of the species' climatic requirements; Anderson and Raza, in press). Where possible, selection of the extent of the study region should therefore take into account factors including the dispersal capacity of the species and distributions of competitors.

#### *Capturing entire species ranges and avoiding model extrapolation*

It is necessary to include occurrence records from throughout the species range in order to avoid artificially truncating response curves when modeling the species' niche (Elith and Graham 2009; Thuiller et al. 2004). For example, models based on data from only one country within a multi-national species range will generally be unacceptable. It is possible that response curves could be adequately characterized using part of the range provided that excluded localities do not represent parts of the niche that are represented by other occurrence records, but such cases must be well justified. Caution must also be exercised when extrapolating model results under future climate scenarios (i.e., extrapolating in environmental space beyond the range of data used to build the model; Pearson et al. 2006). Extrapolation should be avoided where possible (e.g., Pearson et al. 2002), or else the behavior of the model (i.e., the shape of response curves when extrapolating) should be known and well justified.

#### *Model testing*

Testing model performance is an important step in any modeling exercise. Multiple tests have been employed to assess the performance bioclimate envelope models (e.g., AUC, Kappa, TSS; Fielding and Bell 1997), but it is important to note that testing of bioclimate models remains problematic for at least three reasons. First, models aim to predict the



distribution of potentially suitable climates, yet data against which this can be tested are not available (use of species absence records is unsatisfactory because predictions of ‘presence’ in areas that are climatically suitable but unoccupied for non-climatic reasons will be classified as model ‘errors’) (Peterson et al. 2010). Second, performance of the models is usually inflated because studies use data for training the models that are not independent from the data used for testing them (Araújo et al. 2005). Finally, projections are made for events that have not yet occurred, so any attempts to test the models must focus on examination of the internal consistency of the models rather than their predictive accuracy (Araújo & Guisan 2006). So, although standard testing methodologies are an important part of model building, it should be noted that the predictive skill of the bioclimatic models under climate change remains untested.

#### *Using appropriate metrics of species range changes*

Bioclimate models may be useful to assess trends in the availability of suitable climate conditions for species. There are two possible measures that are likely to be useful. One is based on combining probabilities or suitability indices from the models, and the second is based on measuring the potential area occupied by the species after transforming probabilities (or suitabilities) into estimates of presence and absence. To make such a transformation, it is necessary to use thresholds (see, for example, Liu et al. 2005). For instance, use of the lowest presence threshold (e.g., Pearson et al. 2007) may be justified in cases with few occurrence records, but balancing sensitivity and specificity may be more appropriate when a larger number of presence/absence records are available. Sensitivity of conclusions to the selection of alternative methods for defining thresholds should be examined. However, it should be noted that the measures of change in climate suitability that are relevant to red listing are relative measures (of proportional change in time) and these are, in principle, robust to alternative methods for defining thresholds. The absolute areas (of range or potential habitat) should not be used as part of assessments of species extinction risk under climate change because estimates of change from bioclimate models are very sensitive to the thresholds used. Note that thresholds may also be used when converting habitat suitability to population size (see section 12.1.3).

#### *Future emission scenarios*

Climate models are based upon socio-economic scenarios. Each of these scenarios makes different assumptions about future greenhouse gas emissions, land-use and other driving forces. Assumptions about future technological and economic developments are built into families of ‘storylines’, each of which describing alternative pathways for the future because there is no theoretical basis for long-term socio-economic forecasting. The IPCC Third (TAR) and Fourth (AR4) assessment reports proposed six families of scenarios: A1FI, A1B, A1T, A2, B1, and B2 (IPCC Fourth Assessment Report, 2007). In order to account for uncertainty in predictions of future climate change, studies should explore a range of plausible scenarios of climate change (e.g., the A1F1 and B2 scenarios in IPCC 2007), and the broader the range of scenarios considered the better. The set of scenarios selected should be justified. Furthermore, as emission scenarios are revised in future, so should the relevant red list assessments based on them be revised also.

### 13. References

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