Guidelines for Using the IUCN Red List Categories and Criteria

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Prepared by the Standards and Petitions Subcommittee of the IUCN SSC Red List Programme Committee

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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 isolated 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.

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). 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.

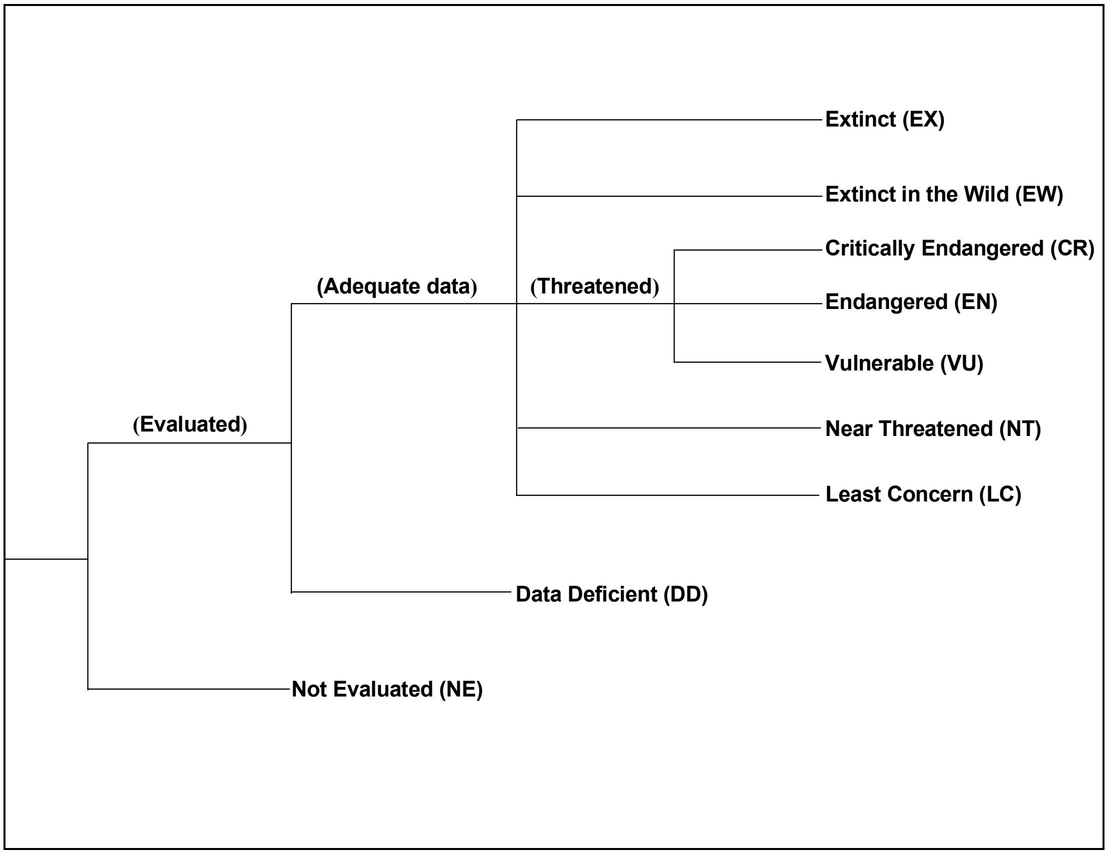


Figure 2.1. Structure of the IUCN Red List categories

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 is 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 change in the status of the taxon
- Criteria revision (due to differences between the 1994 and 2001 versions of the criteria)
- New information about the status of the taxon
- Errors in previous assessment
- Taxonomic changes (taxon is newly split, lumped, or recognized)

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 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.

Taxa that can be evaluated under all 5 criteria are more likely to be listed under criteria A to D than under E. The reason for this is that criteria A to D are designed to be more precautionary, because they are based on partial information and are often used in data-poor situations, whereas criterion E can (and should) incorporate all factors. In data-poor situations, it would be very easy to ‘miss’ taxa that should be listed; in other words, the listing errors will be wider under A-D, so their thresholds are necessarily more precautionary.

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**
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	> 90%	> 70%	> 50%
A2, A3 & A4	> 80%	> 50%	> 30%

A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND ceased based on and specifying any of the following:
(a) direct observation
(b) an index of abundance appropriate to the taxon
(c) a decline in AOO, EOO and/or habitat quality
(d) actual or potential levels of exploitation
(e) effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on any of (a) to (e) under A1

A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on any of (b) to (e) under A1.

A4. 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 OR may not be understood OR may not be reversible, based on any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy)

B1. Either extent of occurrence	< 100 km^2	< 5,000 km^2	< 20,000 km^2
B2. or area of occupancy	< 10 km^2	< 500 km^2	< 2,000 km^2
and 2 of the following 3:			
(a) severely fragmented or # locations	=1	=2-5	=6-10

(b) continuing decline in (i) extent of occurrence (ii) area of occupancy, (iii) area, extent and/or quality of habitat, (iv) number of locations or subpopulations and (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 and (iv) number of mature individuals.

C. Small population size and decline

Number of mature individuals	< 250	<2,500	<10,000
and either **C1** or **C2**:			
C1. An estimated continuing decline of at least up to a maximum of 100 years	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline and (a) and/or (b)			
(a i) # mature individuals in largest subpopulation	< 50	< 250	< 1,000
(a ii) or % individuals in one subpopulation =	90-100%	95-100%	100%
(b) extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

Either (1) number of mature individuals	< 50	< 250	< 1,000
or (2) restricted area of occupancy	na	na	typically: AOO < 20km^2 or # locations ≤5

E. Quantitative Analysis

Indicating the probability of extinction in the wild to be at least	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. The Red List should therefore not be interpreted as a means of priority setting. 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.

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 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 an isolated population which experiences insignificant seed or pollen migration from other subpopulations within a generation length.

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.

4.3.2 Bryophytes

What constitutes a mature individual bryophyte is not always clear. It is recommended that authors of Red List assessments specify the way they have used 'mature individual'. The sort of individual within which all the shoots are connected to one another are often difficult to determine without extensive destruction of populations. However it is possible to use a pragmatic definition of an individual, in the case of those taxa that have a growth form that makes it easy to separate colonies or stands. For example, a single tuft of *Ulota* or a single discrete patch of *Brachythecium* can be regarded as a 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 it 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 fishes

Many fish 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 fishes 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 fishing 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)

All time-based measures in the criteria need to be scaled for the different rates at which taxa survive and reproduce, and generation length is used to provide this scaling. The current definition 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:

- the age at which 50% of total reproductive output is achieved
- time taken for most (>50%) individuals to reach maximum reproductive output
- age of maturity + 0.5*(length of reproductive period in life cycle)
- 1/adult mortality + age of first breeding (if fecundity and survival are independent of age above the age at maturity)
- for partially clonal plants, reflect the natural frequency of sexual and asexual reproduction, i.e. the greater the frequency of asexual reproduction the longer the generation length
- 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.

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.

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 may be inferred from population trajectories over appropriate time spans or from characteristics of life history or habitat biology that predispose organisms to such fluctuations. A plant taxon, for example, may exhibit extreme fluctuations if it only appears in years with high rainfall.

In determining whether fluctuations are extreme, assessors should consider the frequency ("how often"), duration ("how long"), and magnitude ("how much") of population changes, as well as the taxon's life history and dynamics of its habitat. For example, fluctuations that occur on average at least once over a 3-generation period, and cause a tenfold increase and then a decrease (or vice versa) within one generation might be considered extreme. A large decrease, if not followed by an increase may indicate a reduction and/or a continuing decline, rather than a fluctuation.

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 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).

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)

Under criterion B, extent of occurrence (EOO) has to be "estimated". Thus, inferred or suspected ranges would be inadequate to trigger this criterion. Thus, under Criterion B, EOO should be drawn to encompass all the known or projected (but not inferred or suspected) sites of occurrence.

In estimating the extent of occurrence (EOO), the definition allows the exclusion of "discontinuities or disjunctions within the overall distributions of taxa (e.g., large areas of obviously unsuitable habitat)" (IUCN 2001). When there are such discontinuities or disjunctions, 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). This bias increases with sample size and may be further exacerbated by errors in sites, and the spatial and temporal distribution of sampling effort.

In cases with discontinuities or disjunctions, the α-hull (a generalization of a convex hull) is recommended. This measure substantially reduces the biases that may result from the spatial arrangement of habitat, and may also be used to estimate extent of occurrence (Burgman and Fox 2003). The advantage of the α-hull is that it provides a more detailed description of the external shape of a species' habitat, and is capable of breaking habitat into several discrete patches when it spans uninhabitable regions. The estimate of area and trend in area also converges on the correct value as sample size increases, unless other errors are large. Kernel estimators may be used for the same purpose but their application is more complex.

To estimate an α-hull, the first step is to make a Delauney triangulation of the points in a sample. 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.

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 (α) of the average line length. The value of α can be chosen with a required level of resolution in mind. The smaller the value of α, the finer the resolution of the hull. Experience has shown that an α value of 2 is a good starting point. This process results in the deletion of lines joining points that are relatively distant, the space between which is unlikely to represent good habitat. In so doing, it may subdivide the total range into more than one polygon. The final step is to calculate the area of habitat by summing the areas of all remaining triangles.

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)

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)

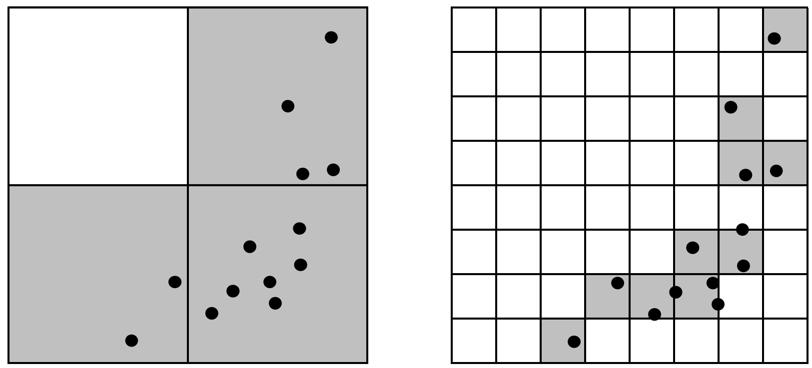
Some estimates of AOO may require standardization to an appropriate reference scale to reduce such bias. Below, we first discuss a simple method of estimating AOO, then we make recommendations about the appropriate reference scale, and finally we describe a method of standardization for cases where the 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 (Figure 4.1), and then tallying the total area of all occupied cells:

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

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.



grid length	grid area	AOO
1	1	10
2	4	24
4	16	48
8	64	64
16	256	256
32	1024	1024

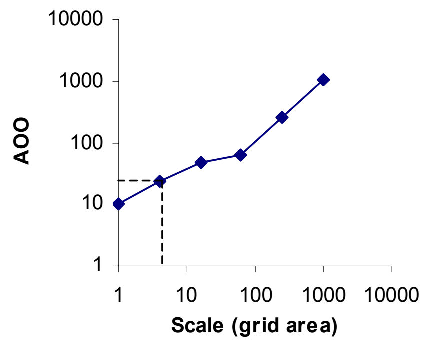


Figure 4.1. Illustration of scale-dependence when calculating area of occupancy. At a fine scale (map on right) AOO = 10 x 1 = 10 units^2. At a coarse scale (map on left) AOO = 3 x 16 = 48 units^2. AOO may be calculated at various scales by successively doubling grid dimensions from estimates at the finest available scale (see Table). These may be displayed on an area-area curve (above).

4.10.3 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^2) 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^2). Scales of 1 km grid size or smaller tend to list more taxa at higher threat categories than these categories imply. However, if the available data were obtained as the result of high-intensity sampling, these finer scales may be appropriate. In other words, in order to use a finer scale of, say, 1 km grid size, the assessors should be reasonably certain that empty 1-km^2 cells represent real "absents" rather than "undetected presents". For most other cases, we recommend a scale of 4 km^2 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.

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. The following sections 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.

4.10.4 Scale-area relationships

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. 4.1). 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).

4.10.5 Scale correction factors

Estimates of AOO may be standardized by applying a scale-correction factor. Scale-area relationships (e.g,. Figure. 4.1) 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 1km grid resolution shown in Figure. 4.1 (right) and that it is necessary to obtain an estimate at the reference scale represented by a 2 km grid. This may 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. 4.1, 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:

$$C = (\log_{10}(AOO_2/AOO_1)/\log_{10}(Ag_2/Ag_1)) \qquad \text{(equation 4.2)}$$

Where AOO_1 is the estimated area occupied from grids of area Ag_1, a size close to, but smaller than the reference scale, and AOO_2 is the estimated area occupied from grids of area Ag_2, a size close to, but larger than the reference scale. An estimate of AOO_R at the reference scale, Ag_R, may thus be calculated by rearranging equation 2 as follows:

$$AOO_R = AOO_1 * 10^{C*\log(Ag_R / Ag_1)} \qquad \text{(equation 4.3)}$$

In the example shown in Figure 4.1, 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 from the as follows:

$C = (\log_{10}(48/10)/\log(16/1)) = 0.566$, and

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

Note that this estimate differs slightly from the true value obtained from grid counting and equation 1 ($24km^2$) 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 (1999) 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 (1999). 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 4x4 km is overestimated because C was underestimated.

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

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 C	
	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 (eg., 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.

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.

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. 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.

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. 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, so, for example, loss of habitat may be irreversible even if the action that caused the loss has ceased. (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.

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.

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 90% (CR), 70% (EN) and 50% (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.

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[1], 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.

[1] 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".

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, and the taxon cannot be assessed under another criterion, it should be listed as Data Deficient.

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.*

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)[2].

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*).

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[2] However, see "*Dealing with uncertainty*" below for a discussion of exceptions to this rule.

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)
Overall	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[a]	4403[a]	50% suspected reduction
Atlantic Ocean	8000 (1955)	9000 (1998)		7699[b]	9074[b]	17.9% estimated increase
Indian Ocean	?	2000 (1980)	70% (inferred)	4374[c]	1312[c]	70% inferred reduction
Overall				20880	14789	29.2% reduction

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

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

[c] Annual population change is 0.9801 [=$(1\text{-}0.7)^{(1/60)}$]. Population change from 1941 until the census in 1980 is 0.4572 [=$0.9801^{(1980\text{-}1941)}$]. Thus, population size in 1941 is 4374 (2000/0.4572). Population change from the census in 1980 to 2001 is 0.6561 [=$0.9801^{(2001\text{-}1980)}$]. 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 2nd 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 $exp(2881\text{-}2.887t+0.0007255t^2)$, 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.

Subpopulation	**Past**	**Present**
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[3]. For example, for the “Pacific” subpopulation, the minimum reduction can be estimated as a reduction

[3] 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.

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 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 1st generation, but increases to 43% for the 3rd generation.

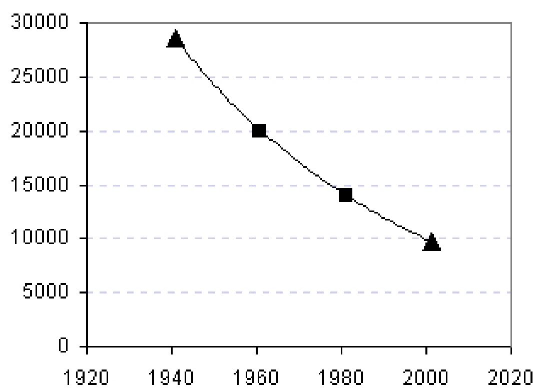

Figure 5.1. Exponential decline

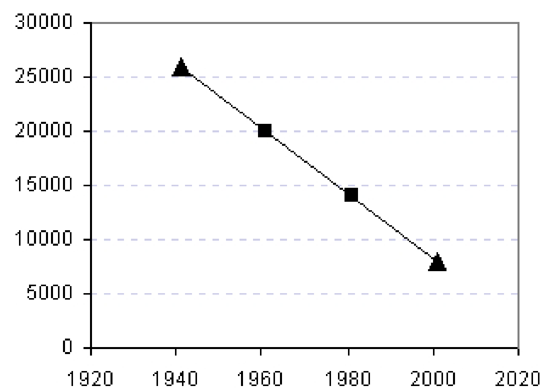

Figure 5.2. Linear decline

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 1st generation to 30% in the 2nd and 60% in the 3rd. 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.

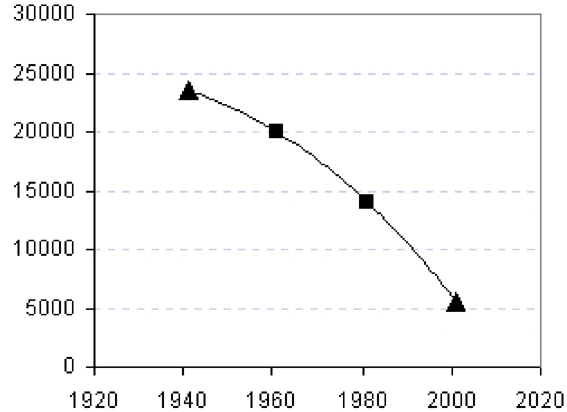

Figure 5.3. Accelerated decline

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. Thus 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%*0.4)+ (80%*0.6), or 72%. The low estimate would be (60%*0.7)+(80%*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^2, 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.

Some of the problems encountered when applying criterion B are dealt with elsewhere in this document, i.e. defining extent of occurrence (section 4.9) and defining 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 less than 1,000 mature individuals. A taxon qualifies for Vulnerable D2 if the area of occupancy is very restricted (typically less than 20km^2) or exists at typically five or fewer locations. This criterion is provided for taxa that are not decreasing, but are characterised by an acute restriction in their number of mature individuals, area of occupancy or in their number of locations.

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 20km^2 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 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.

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 recognizable threats and the area is relatively well known, Vulnerable D2 is appropriate. If people have searched for the taxon and no more individuals were found, then the taxon would be listed as Critically Endangered D (an appropriate time interval for the taxon must be used). If any significant threats can be identified, then Critically Endangered under the **B** and **C** criteria may be appropriate.

8.2 Example of applying criterion D

The New Caledonian Lorikeet (*Charmosyna 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.

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 (which ever 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 Is there enough 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. For example, to qualify as Vulnerable under criterion D, a taxon must have less than 1,000 mature individuals. If a population had 1,500 mature individuals it should be listed as Near Threatened. 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, if a taxon meets the area requirements under criterion B for Vulnerable and is declining, but the population is not severely fragmented and occurs at twelve locations.

10.2 Not Evaluated and Data Deficient

Listing in the categories of Not Evaluated and Data Deficient indicates that no assessment of extinction risk has been made, though for different reasons. Until such time as an assessment is made, taxa listed in these categories should not be treated as if they were not threatened. It may be appropriate (especially for Data Deficient forms) to give them the same degree of attention as threatened taxa until their status can be assessed.

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. 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.

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