1 **Clarifying misconceptions of extinction risk assessment with the IUCN Red List**
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33 **Abstract**
34 The identification of species at risk of extinction is a central goal of conservation. As
35 the use of data compiled for IUCN Red List assessments expands, a number of
36 misconceptions regarding the purpose, application and use of the IUCN Red List
37 categories and criteria have arisen. We outline five such classes of misconception; the
38 most consequential drive proposals for adapted versions of the criteria, rendering
39 assessments among species incomparable. A key challenge for the future will be to
40 recognise the point where understanding has developed so markedly that it is time for
41 the next generation of the Red List criteria. We do not believe we are there yet but,
42 recognizing the need for scrutiny and continued development of Red Listing,
43 conclude by suggesting areas where additional research could be valuable in
44 improving the understanding of extinction risk among species.
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Introduction

Quantitative criteria for the IUCN Red List of Threatened Species (hereafter Red List) were developed recognising the need for rigor and objectivity in the assessment of extinction risk of species [1]. With the Red List, IUCN fulfills its goal to "provide information and analyses on the status, trends and threats to species in order to inform and catalyse action for biodiversity conservation". Over 79,000 species have been assessed (Fig. 1), with growing coverage of less well-known groups of invertebrates, plants and fungi, to complement comparatively better-known groups of vertebrates. This resource for biodiversity conservation is being widely used to inform global and regional biodiversity targets, aid conservation planning, evaluate conservation actions and inform legislative frameworks to protect species [2].

We outline five classes of misconceptions that have arisen regarding the purpose, application, and use of the Red List categories and criteria. The most consequential misconceptions drive proposals for revised versions of the criteria, which would render assessments among different species incomparable.

1. Goals of criteria

The Red List criteria were established to measure the relative risk of extinction among a broad array of eukaryotic taxa. Species are allocated to broad categories of extinction risk by applying simple quantitative rules (Table 1), relating to population size, range area, and rate of decline of both. Misconceptions surrounding the goals of the criteria include the notion that the Red List represents a prioritization mechanism for species conservation; it explicitly does not. Conservation prioritization strategies seek to balance a variety of competing factors. Extinction risk may contribute to such decisions, alongside cost, chance of success, and other metrics (e.g. abundance, rarity, endemism). The Red List categories were designed to reflect likelihood of extinction under prevailing circumstances [1].

The Red List classifies extinction risk rather than rarity. Rarity is an important metric for biodiversity that is not directly reflected in the Red List classification. Species can be rare in markedly different ways, and rarity does not consistently lead to high extinction risk [3]. Extremely rare species (very small population size) are captured under criterion D, irrespective of population trend. Although criteria B and C incorporate different metrics pertaining to rarity (e.g. restricted range, few locations, severe fragmentation, small population size) the subcriteria recognise instances where rare species decline rapidly to extinction, and others where they maintain populations for long periods. Conversely, criterion A (population reduction) deals with species that are at risk because of a steep rate of decline, irrespective of whether they are currently abundant or rare. The criteria employ symptoms of high risk that may covary with rarity, in order to classify species consistently.

2. Structure of criteria

One of the most frequent misconceptions regarding structure is the perception that they cannot work consistently for species in different taxonomic groups [4]. The five criteria were, however, developed based on the principles of population dynamics and derived from a wide review of risk-promoting factors across a broad range of species with diverse life histories. The criteria were structured to recognize the major differences between species, and the symptoms indicative of risk [1].

100 While the major drivers of extinction are known, risk changes non-linearly with these
101 pressures. Differences in ecology and geography have substantial influence and vary
102 among taxonomic groups [5]. These interactions were impossible to simplify for a
103 broadly applicable scheme [1]. Where high quality data are available, criterion E
104 enables quantification of interactions among different threats, although this criterion
105 has seldom been used (Fig. 2a). It is crucial to evaluate all criteria for which data are
106 available to exploit the ensemble properties of the criteria to identify species on
107 different pathways to extinction.
108
109 The *c*. 79,000 species assessments on the Red List suggest broad applicability.
110 Threatened vertebrates are assessed in broadly similar proportions under each of the
111 five criteria as threatened non-vertebrates, a pattern consistent for plants, arthropods,
112 and molluscs (Fig. 2b). The one exception is cnidarians, where criterion A was
113 applied more frequently because of the anticipated impact of a single threat.
114 Variations within major taxa likely reflect that certain variables are more readily
115 estimated for some taxa, e.g. area of occupancy for large sessile than small mobile
116 organisms; rates of decline for taxa with slow rather than rapid population turnover.
117
118 ***3. Use of standard metrics***
119 The argument that one type of risk assessment cannot work for all taxa tends to hinge
120 on two biological measures that differ markedly across species: life history and
121 geographic range. The argument is made that the criteria could be improved by
122 adopting different parameter thresholds for different taxa. However, this would
123 reduce generality. For example, broadcast spawning fish are viewed as more fecund
124 than most other species; however, high levels of fecundity do not consistently lead to
125 low extinction risk in marine fish [6], so idiosyncratic thresholds may not improve
126 assessments. Accounting for variability is important, and is accomplished by using
127 bespoke definitions to account for variation in biological characteristics. Failure to
128 consider correctly these definitions causes the majority of misconceptions regarding
129 standardized metrics. Species responses to threatening processes are scaled to
130 generation length to accommodate variation in population turnover [7] (although for
131 practicality, A3, A4, C1 and E limit the time horizon for future declines to 100 years,
132 regardless of generation length). Arbitrarily changing the time horizon would produce
133 inconsistent outcomes–extinction risk could not be compared among taxa [8]. An
134 alternative would be taxon-specific modified sets of parameters. These would render
135 cross-species comparisons invalid and make the large task of assessing a
136 representative set of species far more onerous [9].
137
138 A bespoke definition is used to calculate extent of occurrence (EOO)–area contained
139 within the shortest continuous boundary encompassing all the known, inferred, or
140 projected sites of occurrence of a species. EOO reflects the spatial spread of risk from
141 threats across the species range. It is therefore an index of insurance against spatially
142 explicit threats, and not intended as an accurate depiction of the range of a species
143 [10].
144
145 Comparable application of the criteria requires that EOO be estimated consistently
146 across different species. It remains unclear whether research that develops the
147 measurement of range size results in improved indices of risk-spreading, but applying
148 different measures to Red List thresholds compromises cross-taxon comparability.

149 Improved consistency in the measurement of EOO is leading to hundreds of bird,
150 mammal and amphibian species being down-listed [11].
151

4. Application of criteria

153 Most assessments are based on a range of quantitative estimates derived from a
154 variety of sources. A common misconception is that categories are assigned based on
155 unstructured expert opinion–listings are not assigned directly through expert opinion.
156 The Red List criteria are frequently applied by groups of assessors in workshops, in
157 which available data for a species are compared against the quantitative criteria
158 thresholds. Taking into account uncertainty, specialist expertise on the species or the
159 threats it faces are used to estimate parameter values based on incomplete data, or to
160 interpret certain qualifiers to these criteria (e.g. infer whether habitat degradation
161 observed in a species' range impacts that species and leads to a decline in habitat
162 quality–a qualifier in the B criterion). Quantitative thresholds ensure that these are
163 transparent and falsifiable.
164

165 Uncertainty (natural variability or measurement error) in estimation of parameters,
166 and the impacts that those uncertainties have on classification, can be incorporated in
167 a number of ways. Analytically, parameter estimates can be made using bounds and
168 best estimates together with fuzzy logic to assign a range of plausible categories [12].
169 Probably the largest source of variation in Red List assessments is due to variation in
170 risk tolerance of assessors. Attitudes to risk span a continuum from precautionary
171 (evidence needed to classify a species as non-threatened) to evidentiary (evidence
172 needed to classify as threatened). Inconsistency in risk tolerance is most evident when
173 assessing valuable exploited species [6].
174

175 Red Listing has proved controversial in the debate surrounding the risk faced by small
176 or range-restricted, stable populations (e.g. those on small oceanic islands) that
177 nominally meet the criterion B area thresholds. There are many examples of naturally
178 rare highly restricted species, but which have life history strategies to enable long-
179 term persistence [13], thus putting them at low risk of extinction; while others with
180 large ranges may be high risk. Hence, species cannot be listed solely on the basis of
181 size, and require other symptoms of risk to qualify for threatened status under
182 criterion B.
183

184 Finally, applying the five criteria and listing under the highest-risk outcome has been
185 criticized for not using best available information. Alternatives include averaging
186 extinction risk across criteria, or ignoring some criteria based on differences in data
187 quality. However, the different criteria were derived from a wide review through wide
188 consultation with species experts aimed at detecting risk factors across the broad
189 range of organisms and the diverse life histories they exhibit [1], thus producing an
190 ensemble of criteria to identify the symptoms of risk. Broad consistency among them
191 was sought [10]. Adopting the highest category returned by any criterion (i.e. relying
192 on the worst symptoms with reliable data) ensures a more precautionary approach to
193 making urgent decisions based on limited information. This approach is akin to
194 emergency room doctors focusing their assessments of patients on the most severe
195 symptoms, instead of an average, where the best symptoms cancel out the worst ones.
196 Assessors are encouraged to document criteria under which a species meets lower
197 categories of risk, as such information is critical to recovery planning.
198

199   *5. Interpretation of classifications*
200   Subjectivity was a criticism of early unstructured versions of the Red List, and was
201   the principal motivation for development of quantitative criteria [1]. Clear guidelines
202   are given on how quantitative data are used to assign species to categories of risk
203   [10]. There is subjectivity in the establishment of boundaries among the categories of
204   risk, though there is no theoretical reason why they should not be subjective. These
205   boundaries divide extinction risk, a continuous metric, into categorical blocks. The
206   continuum could have been divided differently. However, the proportion of species in
207   the three threatened categories show that the current boundaries are reasonable: for
208   randomly or fully assessed groups, the proportion in each category is neither
209   negligible nor overwhelming, meeting the Red List's goal to provide an informative
210   index of extinction risk.
211
212   Criteria A–D are based on population size, geographic range size, and rates of
213   decline. Criterion (E) is based on quantitative models of extinction risk, e.g.
214   population viability analyses. Some researchers have assumed that species assessed
215   using criteria A-D (proxies of extinction risk) can be assigned the probability of
216   extinction thresholds in criterion E. Since E is the only criterion that can potentially
217   incorporate all factors and symptoms of extinction risk, and the only criterion that
218   includes quantitative thresholds of extinction probability, the thresholds of Criterion E
219   should not be used to infer the probability of extinction for species under any of the
220   criteria A–D [8]. Comparisons of thresholds across categories and criteria are
221   complex because of uncertainties in the relationship between extinction probability
222   (E) and extinction risk proxies (A-D) used to assess taxa.
223
224   **Future focus for the development of extinction risk measures**
225   The development of Red List criteria has promoted valuable thinking and empirical
226   research on extinction risk. The scrutiny that the scientific community continues to
227   bring to Red Listing is welcome, and much has been done to refine and develop the
228   existing framework in response to such scrutiny. However, we are not yet at the point
229   where understanding has developed so markedly that it is time for the next generation
230   of the Red List criteria. We conclude by identifying several key areas requiring
231   further research.
232
233   1. Further standardization of parameter estimation methods, particularly methods
234   that can use sparse, uncertain, and qualitative information to estimate robustly
235   variables such as population reduction.
236
237   2. Exploiting new data: remote sensing, genetic sampling, citizen science, and
238   social media. Effectively using these will require both fundamental research
239   and new practical methods for estimating the variables used in the criteria.
240
241   3. Assessment of risk under changing and interacting threats. Climate change is
242   expected to have profound effects on biodiversity. Novel combinations of
243   threats are also likely to occur. Although a recent study [14] suggested that the
244   Red List criteria can identify species that might go extinct due to climate
245   change, species may require more frequent and complete assessment. Methods
246   are required to facilitate use of future climate and land-use change scenarios,
247   e.g. through species distribution and population modeling.
248

5

249   4. Better understanding of the relationship between spatial structure and
250   population dynamics (common and rare species), in relation to the spatial
251   patterns of human impacts. Such research would lead to more specific
252   guidelines on determining the number of locations and degree of
253   fragmentation.
254

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315

316   **Captions**

317   **Table 1.** The IUCN Red List categories and criteria for CR, EN, VU.
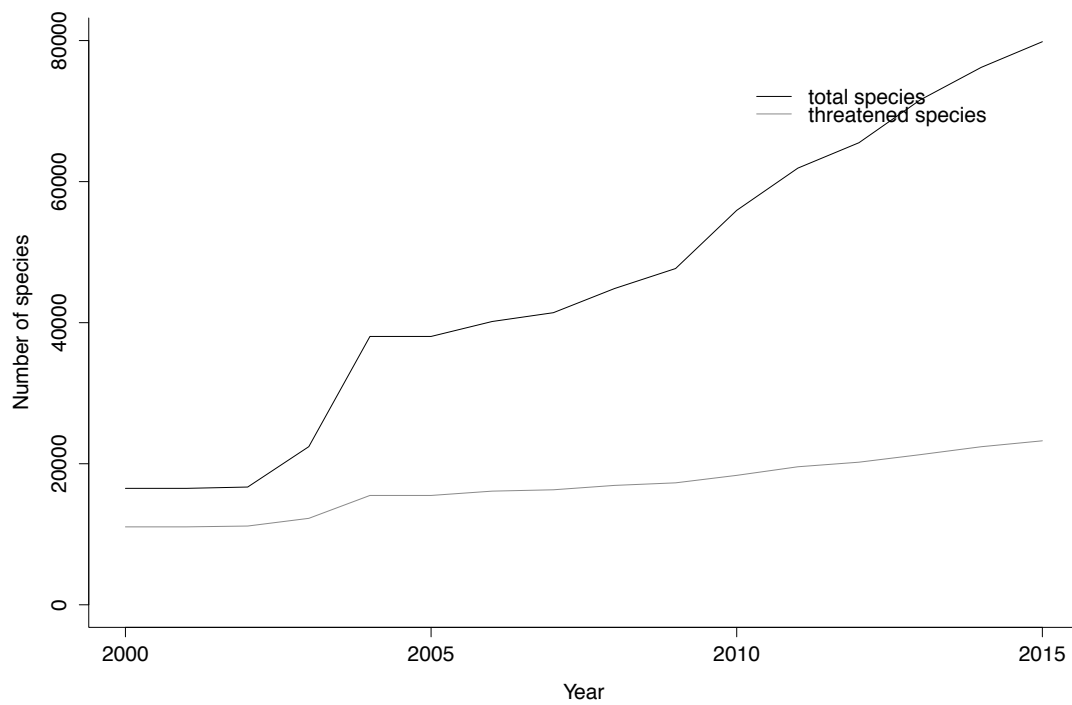318   **Figure 1.** Temporal trend in assessments on IUCN Red List
319   **Figure 2.** Proportion of threatened species meeting each criteria a) vertebrates and
320   non-vertebrates, b) non-vertebrates subdivided.
321

Tables & Figures
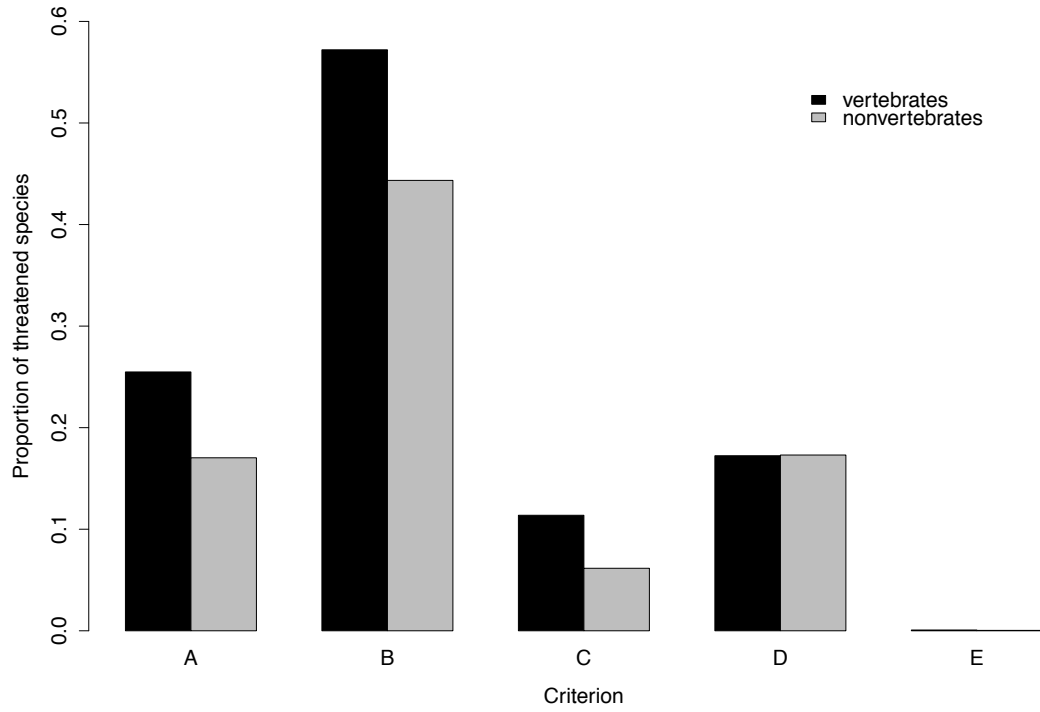
323 **Table 1.** The IUCN Red List categories and criteria for CR, EN, VU.
324

	Critically Endangered	Endangered	Vulnerable
A. Population reduction	Declines measured over the longer of 10 years or 3 gens.		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%
B. Geographic range either EOO or AOO			
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (A00)	< 10 km²	< 500 km²	< 2,000 km²
and 2 of the following			
(a) Severely fragmented or # locations	= 1	≤ 5	≤ 10
(b) Continuing decline in: (i) EOO; (ii) AOO; (iii) area, extent and/or quality of habitat; (iv) # of locations or subpopulations; (v) # of mature individuals			
(c) Extreme fluctuations in: (i) EOO; (ii) AOO; (iii) # of locations or subpopulations; (iv) # of mature individuals			
C. Small population size and decline			
# of mature individuals	< 250	< 2,500	< 10,000
& either **C1** or **C2**:			
C1. Estimated continuing decline: 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. Continuing decline and (a) and/or (b):			
(i) # mature individuals in all sub-populations:	≤ 50	≤ 250	≤ 1,000
(ii) % individuals in one sub-population >	90-100%	95-100%	100%
(b) extreme fluctuations in the number of mature individuals			
D. Very small or restricted population			
(1) no. mature individuals	< 50	< 250	< 1,000
OR			AOO < 20 km² or # locations ≤ 5
(2) restricted AOO	na	na	
E. Quantitative Analysis			
Indicating probability of extinction in the wild:	≥ 50% in 10 yrs or 3 gens. (100 yrs max)	≥ 20% in 20 yrs or 5 gens. (100 yrs max)	≥ 10% in 100 years

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326

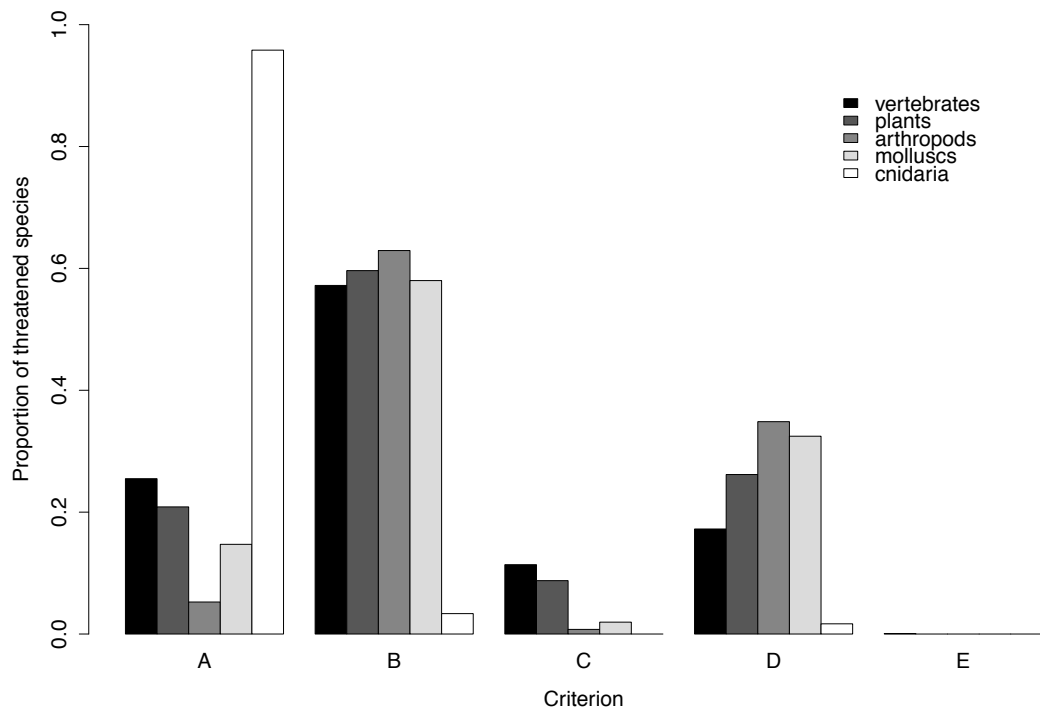327   **Figure 1.** Temporal trend in assessments on IUCN Red List

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329

330 **Figure 2.** Proportion of threatened species meeting each criteria a) vertebrates and
331 non-vertebrates, b) non-vertebrates subdivided.
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