The SAFE index is not safe

In a recent essay, Clements *et al.* (*Front Ecol Environ* 2011; **9[9]**: 521–525) proposed the SAFE index as a relative measure of threat to describe "species' ability to forestall extinction". While we recognize the paper's goal of developing a continuous measure of relative threat, we believe that the proposed index neither complements nor improves upon the current IUCN Red List system of Categories and Criteria, for the reasons discussed below.

Although the SAFE index is conceptually based on population viability, as presented and tested by Clements *et al.*, it simply measures how different the current population size of a species is from 5000 individuals. Thus, it is a continuous version of one of the five existing IUCN Red List criteria (criterion D; IUCN 2001, 2010). Population size, however, is only one measure or symptom of species' risk of extinction. Any index or assessment system based solely on population size ignores other factors – such as fluctuations in population size; fragmentation of, and trends in, species' spatial distribution; and life-history traits, such as dispersal ability and generation time – and thus provides an incomplete assessment of species' extinction risk. Consequently, some species assessed by the index as "safe" may be at substantial risk of extinction via other mechanisms. In contrast, the IUCN Categories and Criteria use all of these types of information to assess the threat category of a species (IUCN 2001, 2010; Mace *et al.* 2008).

Because the proposed index is based on the concept of minimum viable population (MVP), it could in principle incorporate some of the factors listed above, if the constant used in the formula was specific to each species rather than a fixed number applied to all. However, if there are sufficient data to calculate a species-specific MVP, then the same data can be used directly to estimate the risk of extinction. In such circumstances there is no need for indirect measures, such as the difference between the current population size and the MVP. Hence the SAFE index is incomplete if used with a generic constant and redundant if used with a species-specific constant.

Clements *et al.* claim that "the SAFE index provides a more meaningful and fine-grained interpretation of the relative threat of species extinction than do the IUCN threat categories alone". However, the reported analysis does not support this statement. It compares the proposed index to percent range reduction, and finds that the index predicts the IUCN Red List category better. Thus, the analysis considers the IUCN threat categories as the "truth" against which to compare alternative measures, and hence cannot support any claims comparing the SAFE index to IUCN categories.

Furthermore, the analysis that compares the SAFE index to percent range reduction is misleading because no widely used approach uses percent range reduction alone as a measure or symptom of extinction risk. Thus, percent range reduction is a "straw man". The analysis by Clements *et al.* only shows that population size alone predicts the IUCN Red List category of this particular set of species better than range size reduction alone. This may be because the Red List categories are also based on population size, among many other factors, for some of these mammal species, but the analysis has no relevance for assessing the suitability of the SAFE index as a general measure of extinction risk.

Clements *et al.* also claim that the SAFE index will be more readily understood by the general public, donors, and policy makers. Although different users of information on species status may have different preferences, we doubt that an index based on difference in $\log_{10}$ population sizes is any more intuitive than the Red List categories. Our experience from two decades of communicating the IUCN Red List system suggests that, for most target audiences, "Critically Endangered" is more easily comprehended and intuitively informative than, say, "SAFE = –2.76".

Finally, the authors assert that IUCN threat categories can be ambiguous and subjective, and have weak quantification, as well as that the "IUCN has yet to base its threat categories on predictions from population viability analyses because of inadequate data or models for most listed species". These claims are untrue. The basis for the IUCN Categories and Criteria in population viability and demographic theory has been well documented (Mace and Lande 1991; Mace *et al.* 2008; IUCN 2010), and the classification incorporates a wide variety of quantitative data and population viability methods so far as is possible, but application of quantitative models is generally constrained by lack of relevant information for most species.

In summary, we do not believe the proposed index adds anything useful to the existing IUCN Red List system, and the analysis presented by Clements *et al.* does not support their case.

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No safety in numbers

Clements *et al.* (*Front Ecol Environ* 2011; **9[9]**: 521–525) proposed a single metric that describes a "species' ability to forestall extinction" (referred to by the acronym "SAFE") as a "scientifically defendable rule of thumb for when complete demographic data are unavailable" to rank the relative threat status of a species. SAFE is calculated on a logarithmic scale and reflects the difference between a species' current population size and 5000, the estimate for a universal minimum viable population (MVP) promoted by Traill *et al.* (2010). Clements *et al.* advocated SAFE as a useful tool for triage to allocate resources in conservation, and as a measure of population viability that would be more easily understood by the public than the IUCN Red List categories (Mace *et al.* 2008). We believe that SAFE is not a useful metric to guide conservation planning for three main reasons.

First, a universal MVP of 5000 individuals, regardless of taxon or circumstance, is poorly supported (Flather *et al.* 2011). Studies promoting this benchmark overlooked substantial uncertainty in standardized MVP estimates that span several orders of magnitude for the same species, suggesting 5000 is likely to be a poor estimate for *any* specific population. Methods used to standardize MVP estimates across disparate studies were not robust (Flather *et al.* 2011). MVP estimates depend critically on the environmental context of a population and on the way that context interacts with decisions made in the population modeling process.

Second, theory and practice strongly suggest that metrics other than population size are equally or more important in determining a population's viability (Lande 1993; Caughley 1994; Flather *et al.* 2011). Viability of a species is a composite of many characteristics, such as the mean and variance of its growth rate, the number and connectivity of its populations, its range size and trends, and its life history, rather than simply its distance from 5000. Clements *et al.* implicitly acknowledge this by comparing the performance of their SAFE metric versus range change (both independent variables) to the IUCN Criteria (the dependent variable or "truth"), which is based on a complex series of factors combined to assess status. The ordinal logistic regressions only accounted for 6% of the deviance.

Third, SAFE offers little to inform the conservation of threatened species. Populations can only be conserved if the factors that cause them to decline are identified and those threats are ameliorated. Obtaining a reliable estimate of population size for comparison to the unreliable MVP estimate of 5000 suggests that sufficient information on species' ecology, habitat, and current threats is likely to exist to inform conservation. Triage decisions based on population size alone are pointless, ignoring circumstance, trends, taxonomic uniqueness, desirability, and other important factors that affect such decisions.

Population size is one indicator of population viability, much like a patient's body temperature is one indicator of health. However, there is no single number that represents a healthy temperature for all people, because time of day and many other circumstances affect it. Moreover, physicians do not use body temperature alone to determine a living patient's prognosis, make triage decisions, or diagnose cause of illness.

The way forward to develop measures that assist conservation planning is not through oversimplification. Classification systems, such as those developed by IUCN and others, are useful for ranking the degree of threat because they incorporate a wide range of information related to population viability. They do so because no single population characteristic is sufficient to describe population viability. Conservation planning advances when it combines comprehensive measures of population viability with knowledge of how these factors relate to threats, an understanding of social desires, and estimates of the cost of recovery.

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The SAFE index should not be used for prioritization

Clements *et al.* (*Front Ecol Environ* 2011; **9[9]**: 521–525) proposed the SAFE index to measure a "species' ability to forestall extinction". However, we believe that this index can, at best, only measure threat – not the ability to forestall extinction. We note and concur with other concerns regarding the index (letters by Akçakaya *et al.* and Beissinger *et al.*, this issue), but focus on the points below for the sake of brevity.

The SAFE index is simply a measure of how far the population size (*N*) is from the minimum viable population size (MVP). If the MVP were common to all species (although the evidence for this appears weak; Flather *et al.* 2011), then the SAFE index is merely a measure of *N*. The need for the logarithmic transformation in the SAFE index is unsupported. Clements *et al.* claim that the SAFE index improves communication of "distance" from extinction. However, the general public, donors, and policy makers will understand the implications of *N*, and how it departs from MVP, much more easily than those of log(*N*/MVP).

Clements *et al.*'s result that the SAFE index correlates more strongly with IUCN classes than with historical range reduction is unsurprising. Population size, and hence the SAFE index, must correlate with IUCN classes because population size is one of the major criteria used in the IUCN classification. In contrast, historical range reduction will only correlate with IUCN classifications as far as it correlates with current reductions in range or population size, or with some other measure that is used in the IUCN criteria. A further concern is that the analysis was based on linear models. Apparent low correspondence for an index could arise from unmodeled non-linear relationships with IUCN classes.

Clements *et al.* also claim that "the SAFE index provides a more meaningful and fine-grained interpretation of the relative threat of species extinction than do the IUCN threat categories alone". Although IUCN classes are correlated with actual extinctions (Keith *et al.* 2004), Clements *et al.* provide no evidence that the SAFE index is "more meaningful" than assessments based on IUCN criteria because, for example, they did not analyze independent extinctions.

The acronym for the index ("species' ability to forestall extinction") implies that it measures whether it is worth trying to save a species. This implication is stated explicitly by Clements *et al.*: "Practitioners of conservation triage may want to prioritize resources on the Sumatran rhinoceros (*Dicerorhinus sumatrensis*) instead of the Javan rhinoceros (*Rhinoceros sondaicus*)" based on differences in their SAFE index values. This statement is not supported by the published paper, which focused on a measure of threat. Optimal prioritization depends on the management objective, the efficiency with which spending resources on different species meets that objective, the uncertainties in the measures of efficiency, and the available budget (McCarthy *et al.* 2008, 2010). For example, aiming to minimize the number of extinct species can lead to very different allocations from those obtained when aiming to minimize the number of threatened species, even in the absence of any other differences (McCarthy *et al.* 2008).

In conclusion, we argue that conservation prioritization based solely on population size is unsubstantiated and potentially misleading.

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Better SAFE than sorry

We welcome the debate that our proposed species' ability to forestall extinction (SAFE) index (*Front Ecol Environ* 2011; **9[9]**: 521–525, this issue) has attracted from our peers (see previous letters by Akçakaya *et al.*, Beissinger *et al.*, and McCarthy *et al.*), because it has further emphasized the need for a more heuristic measure of species extinction threat. The main points of contention can be summarized as follows: (1) SAFE merely echoes the existing IUCN Red List categorization and is therefore redundant; (2) SAFE should not be proffered as a replacement for the Red List; (3) SAFE simplifies mathematically to a measure of a species' abundance and therefore provides no additional risk information; and (4) minimum viable population (MVP) size, on which SAFE is based, is species-specific and so a threshold abundance applied to all species cannot be used. We outline below why each of these arguments is unsupported.

(1) SAFE merely echoes IUCN Red List categorization. Contrary to the implicit assertion in the three critiques, most Red List criteria on which threat categorizations are founded are not related to a population's size per se. Rather, the two most-used criteria are based on a measured or perceived *reduction* in population size (criterion A) or geographic range (criterion B). Criteria C (indicating small population size and decline or fragmentation) and D (small size only) also set population-size thresholds for long- and short-term persistence (Critically Endangered: 250 and 50 individuals; Endangered: 2500 and 250 individuals; Vulnerable: 10 000 and 1000 individuals [although Vulnerable D2 is based only on restricted area of occupancy], respectively). However, these thresholds are arbitrary and not derived from any empirical risk assessment (these are "set at what are generally judged to be appropriate levels, even if no formal justification for these values exists" [www.iucnredlist.org]). The abundance thresholds for Critically Endangered and Endangered are typically one to two orders of magnitude lower than nearly all quantitative MVP size estimates (Traill *et al.* 2010; Brook *et al.* 2011). Only criterion E is based on integrative modeling – population viability analysis (PVA) – which explicitly estimates extinction risk.

Of the 95 mammal species we assessed for the SAFE index, 63 are IUCN threat-listed. Of these, 51% are not assessed by the IUCN on population size thresholds at all, and only one assessment is even partially based on PVA. Indeed, based on our recent (July 2011) examination of Critically Endangered, Endangered, or Vulnerable species, not one of 1370 mammal or 1288 bird species relies entirely on criterion E data, and only 4 mammal and no bird assessments include any PVA information. Hence, the assertion that the SAFE index (a measure of distance from MVP) simply reproduces the Red List is demonstrably incorrect. It is debatable to what extent the Red List categories predict real extinction risk (O'Grady *et al.* 2004); regardless, they must largely invoke reductions in geographic range and population size to do so.

(2) SAFE replaces the Red List. Under no circumstances did we assert that the SAFE index should replace the Red List, or that conservation-based prioritization should be based "solely on population size". We clearly called for SAFE to be used in conjunction with the Red List to provide a more heuristic measure of relative species-extinction threat. We agree that assessments made on population size (and their distance to MVP) alone are inadequate to explain all elements of risk – claiming otherwise would be astonishingly naïve (Brook *et al.* 2011). The contribution of SAFE to the existing Red List categories is that, in addition to reflecting susceptibility to stochastic extinction processes, it provides a continuous measure both *among* and *within* risk categories (somewhat analogous to RAMAS software's Red List fuzzy-number categorization method [www.ramas.com/redlist.htm]). This is pertinent given the ambiguous nature of categorical terms like "endangered", "threatened", and "vulnerable" that are often confused by lay persons and used interchangeably or inconsistently in national-level legislation. In a triage context, the choice to invest in conserving particular species can be informed, at least partially, by MVP (Traill *et al.* 2010) and SAFE by indicating how urgently a species requires attention.

*(3) SAFE simplifies to population size (*N*)*. We incorporated a logarithmic transformation in SAFE to ease interpretability for our "distance from extinction and to MVP" concept across many species, and for standardization purposes. For example, take hypothetical species A and B – comprising 200 and 2 000 000 individuals, respectively – and assume a threshold MVP target of 5000. Even for specialists, explaining the relative risk as "species A is 4800 individuals away from the threshold target", and "species B is 1 995 000 individuals above the threshold" becomes a confusing mix of largely irrelevant numbers and qualifiers. We maintain that it is far easier to infer whether species A is in trouble based on a negative SAFE index (–1.40, in this case), and that species B is at far less risk based on its positive SAFE value (2.60). As we originally stated in our paper, the threshold MVP value need not necessarily be 5000; if one has sufficient data to estimate, for instance, a taxon-specific MVP, then different denominator values could be used for different taxa (Traill *et al.* 2010; Brook *et al.* 2011). This process would act to normalize comparisons of SAFE-based extinction risks among groups (taxa or otherwise) with intrinsically different MVP sizes. Commonly used biodiversity evenness metrics such as Shannon's Index also use logarithms to make large and small sample sizes comparable.

(4) MVP size is not generalizable. Several authors took exception to our concept of a generalizable MVP size for use as a target threshold, based mainly on arguments raised in a recent critique (Flather *et al.* 2011). We have addressed these concerns elsewhere (Brook *et al.* 2011), but summarize our principal defense here. Although MVP does vary among species, the key emergent result is that thousands, and not hundreds, of individuals are needed to minimize the risk of stochastic extinction – this is the essence of the MVP "rule of thumb" (Traill *et al.* 2010). PVAs are unavailable to estimate MVPs for most species, so generalizations are required in most instances. The alternative – to argue that the problem is too intractable and uncertain and that all species are unique – leads nowhere in terms of practical conservation management.

In conclusion, we are surprised that a heuristic concept designed to enhance conservation decision making has evoked such spirited criticisms from the progenitors of the Red List (Akçakaya *et al.*) and other conservation decision-theory specialists (Beissinger *et al.* and McCarthy *et al.*). Putting aside arguments about uncertainty and relative merit, the real test of the SAFE concept's utility will be determined by whether it can contribute usefully to on-the-ground conservation decisions.

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