COMMENTARY:

Preventing species extinctions resulting from climate change

H. Resit Akçakaya, Stuart H. M. Butchart, James E. M. Watson and Richard G. Pearson

Recent studies show that current IUCN Red List assessment methods can identify species vulnerable to extinction because of climate change. But species must be assessed more completely and more regularly, and adaptation actions initiated swiftly once threatened species are identified.

There is a wealth of studies predicting increased extinction risk for species due to climate change[1,2], but these predictions are not reflected in the number of species identified as threatened because of climate change on the International Union for Conservation of Nature (IUCN) Red List. The Red List, which is widely regarded as the most authoritative system for classifying species according to extinction risk[3], identifies "climate change and severe weather" as a threat for only 2,334 (10.5%) of the 22,176 species listed as threatened. There are several reasons for this apparent mismatch. One is that the IUCN Red List criteria are based on symptoms, not causes, of endangerment[4], and, as a result, the causes of endangerment are not always identified comprehensively. Consequently, species can qualify as threatened without all the threats that affect them being identified or fully understood. Another reason is the challenge of applying the results of studies linking ecological niche models and climate change scenarios (the most commonly used approach to assessing climate change impacts on species) to red-listing. Although there are some guidelines addressing this[5], there has been a broad perception that the Red List criteria are not adequate for assessing species threatened with climate change[2,6,7]. One reason for this is that such studies often identify large numbers of species that are projected to undergo substantial range shifts and/or contractions by the end of the twenty-first century[8,9], but their generation length is too short for any inferred population declines to be sufficiently rapid to trigger the relevant IUCN Red List criteria[10], which consider declines over a three-generation period.

A set of recent studies[11–13], however, indicates that extinction risks due to climate change can be predicted simply by applying the current Red List criteria. Pearson *et al.*[11] show that extinction risk due to climate change can be predicted by information available in the present day, such as current occupied area and population size, much of which is used in the IUCN Red List criteria. Stanton *et al.*[13] and Keith *et al.*[12] go one step further and demonstrate that IUCN Red List criteria can identify species that would become extinct without conservation action, and can do so with decades of warning time (defined as the time between the point at which a species is first identified as threatened and its extinction, assuming no conservation action). This warning period is the time available for conservation measures (adaptation interventions) to prevent the extinction of a species.

These findings also suggest that applying the Red List criteria can overcome some of the shortcomings of many studies that assess vulnerability to climate change by using climate envelope modelling and related approaches. For example, these approaches are generally poor at incorporating the impacts of human adaptation to climate change, such as shifts in agriculture and urbanization, because these are difficult to predict[14,15]. As the Red List criteria *per se* do not distinguish between species' population declines or range contractions driven by climate change directly or by human responses, species threatened by the latter should be equally well detected.

Conservation recommendations

These recent studies highlight the importance of the quality and the amount of information used in climate vulnerability assessments. When assessing species with the IUCN Red List system, lack of information often results in only one criterion being used for assessing a species' status. This is problematic, as both Keith *et al.*[12] and Stanton *et al.*[13] demonstrate that using a single criterion results in shorter warning times. Stanton *et al.*[13] show that although average warning time is over 60 years when all criteria are used, it is as short as 20 years when only a single criterion is used.

Another important implication of these three studies is that conservation action should not be delayed for species identified as threatened. Stanton *et al.*[13] demonstrate that about half of the species may become extinct within 20 years of being listed at the highest threat category (Critically Endangered), even if the available information allows all criteria to be applied. Thus, conservation measures should be initiated at the latest when a species is listed as either Endangered or Critically Endangered, and preferably when it is listed as Vulnerable.

Increasing the taxonomic diversity and geographic representativeness of the species assessed in the IUCN Red List would probably allow many more species affected by climate change to be identified as threatened, as would improving knowledge of Data Deficient species to allow them to be re-evaluated. The nature of the threat from climate change means that it is also critical to regularly reassess species already listed on the Red List. In data-poor situations, assessments should be more frequent. Stanton *et al.*[13] demonstrate that when data are available to allow use of only one criterion, warning times can be substantially longer if assessments are made at annual or 5-year instead of 10-year intervals.

New research directions

Given the recent findings that existing extinction risk assessment methods can provide decades of warning time, especially if applied frequently and using multiple criteria, the most urgent research needs involve assessment of the efficacy of specific climate adaptation actions, based on species-specific life history characteristics. There is a need to test the ability of conservation actions (such as assisted colonization, actions targeted at ecosystems or geographic features rather than species, conserving climate refugia, increasing habitat connectivity between existing protected areas, and protected area planning that anticipates shifts driven by climate change) in preventing species extinctions. Such tests can be implemented using the same type of simulation-based scenarios used in the recent studies[11–13], but would require evidence from current actions to validate the analyses.

In addition, planning of conservation measures would benefit from analyses to determine how long a warning time is sufficient for preventing extinctions resulting from climate change. Sufficient warning time would be longer than the sum of latency time and response time (Fig. 1). Latency time (and to some extent the response time) depends on social and economic factors determining the society's response to the warning. The response time depends on ecological factors, such as generation length, determining the species' response to conservation, as well as resources available for the project. There is no systematic review of latency times and response times for different types of conservation actions. Stanton *et al.*[13] cite two sources reporting response times averaging 20 years or shorter for reintroduction projects. But there is no standard method of defining and reporting the initiation time of a conservation project and the time of a positive conservation outcome (for example a change in the status or trend of the species). We recommend an analysis of latency times and response times of previous conservation efforts to determine what warning time is necessary for different types of conservation actions, and for different life histories and demographic characteristics (for example generation length, Allee effects, dispersal ability or degree of fragmentation).

There is also a need to further develop species-specific assessment tools based on the IUCN Red List criteria, in order to increase warning times, especially in data-poor situations. Further development is also necessary if conservation actions to adapt to climate change are found to take longer times (latency plus response time), and thus would require a longer warning time. One approach might be based on the Red List criterion E, which has a 100-year time horizon for the lowest threat category, regardless of the generation time of the species. This criterion sets thresholds of extinction probability for the three threatened categories (Critically Endangered, Endangered and Vulnerable) in the IUCN Red List system. The statistical model developed by Pearson *et al.*[11] estimates the probability of extinction based on species-specific data on life history and spatial characteristics. Using the same approach for a wide variety of other taxa would allow development of a similar statistical model that is more widely applicable, and that can be implemented as a software tool that allows categorizing a species based on the probability thresholds of criterion E.

We conclude that recent research identifies the need for a change in focus of conservation research activities related to climate change. Understanding the impacts of human-induced climate change on biodiversity is neither just about trying to identify signals of climate change[16] nor about trying to predict overall potential extinction rates[2]. It now needs to encompass improving assessment tools (such as the Red List) to identify specific vulnerable species and then developing and testing management strategies that can help such species survive in a future that has a rapidly changing climate. ☐

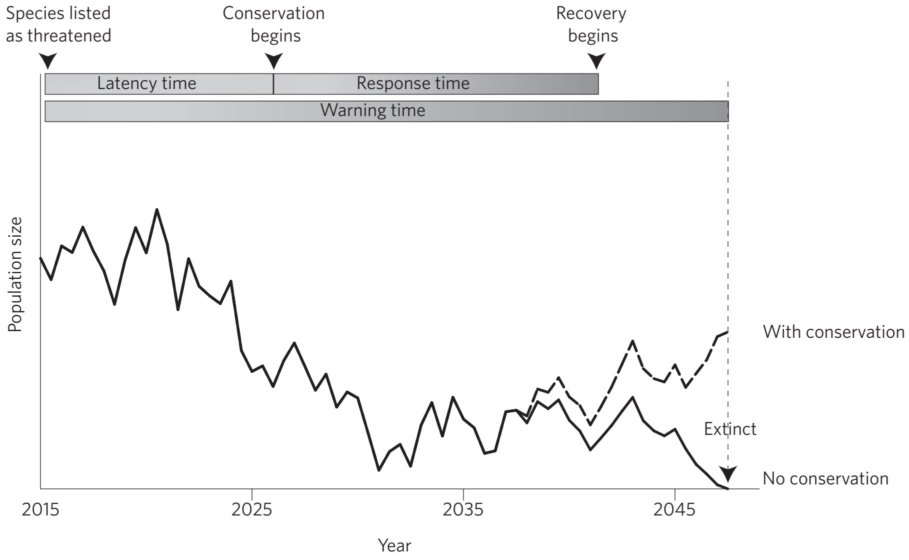

Figure 1 | Illustration of warning, latency and response times. For a species that would become extinct without conservation actions, warning time is the number of years it would be continuously listed as threatened before it becomes extinct. Latency time is the number of years between the listing of a species as threatened and initiation of conservation actions. Response time is the number of years from initiation of conservation to the start of the species' recovery.

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