

Over half of threatened species require targeted recovery actions to avert human-induced extinction

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Averting human-induced extinctions will require strong policy commitments that comprehensively address threats to species. A new Global Biodiversity Framework is currently being negotiated by the world's governments through the Convention on Biological Diversity. Here we explored how the suggested targets in this framework could contribute to reducing threats to threatened vertebrates, invertebrates, and plants, and assessed the importance of a proposed target to implement recovery actions for threatened species. Although many of the targets benefit species, we found that extinction risk for over half (57%) of threatened species would not be reduced sufficiently without a target promoting recovery actions, including ex situ conservation, reintroductions, and other species-specific interventions. A median of 54 threatened species per country require such actions, and most countries of the world hold such species. Preventing future human-induced extinctions requires policy commitments to implement targeted recovery actions for threatened species in addition to broader efforts to mitigate threats, underpinned by transformative change.

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The world is facing an extinction crisis, with over 40,000 species documented as threatened (IUCN 2021a) and extrapolations indicating that one million species are at risk of extinction (Díaz *et al.* 2019). Governments committed to halting extinctions and reducing extinction risk under the auspices of UN Sustainable Development Goal 15 (UN 2015)

and Aichi Target 12 of the Convention on Biological Diversity (CBD) Strategic Plan for 2011–2020 (CBD 2010). This target was not achieved (CBD 2020a). Although some extinctions were averted (Bolam *et al.* 2020), others were not, including those of the Pinta giant tortoise (*Chelonoidis abingdonii*) and the Alagoas foliage-gleaner (*Philydor novaesi*) (IUCN 2021a).

Parties to the CBD are now negotiating a post-2020 Global Biodiversity Framework to address the continuing loss of biodiversity and degradation of nature. The latest draft, published in August 2021, includes four goals and 21 targets to achieve these goals (CBD 2021a). Goal A would commit countries to reducing the rate of extinctions at least tenfold, and halving the risk of species extinctions across all taxonomic and functional groups.

To achieve this goal, the targets must be sufficiently comprehensive and have adequate numeric thresholds. Relevant targets in earlier versions of the draft framework focused on area-based conservation and threat mitigation (CBD 2020b), but failed to recognize that some species also require targeted recovery actions (eg ex situ conservation, reintroductions, and other species-specific interventions such as vaccinations, supplementary feeding, or breeding site provision) in order to prevent their extinction. The latest draft now includes Target 4, to “Ensure active management actions to enable the recovery and conservation of species and the genetic diversity of wild and domesticated species, including through ex situ conservation, and effectively manage human–wildlife interactions to avoid or reduce human–wildlife conflict” (CBD 2021a). The

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importance of this target has not previously been quantified, nor has the contribution of different proposed targets to conserving at-risk species.

Here we assessed how individual targets potentially contribute to reducing threats to species and preventing their extinction. We quantified how many species would benefit from targets that address major drivers of species loss and how many require a target on species-specific recovery actions because the threats to their survival are not addressed by the other, more far-reaching targets or because species-specific recovery actions are critical for their survival. We therefore provide a rationale for the importance of this target for meeting relevant aspects of Goal A, and the need to retain its level of ambition during negotiations to finalize the post-2020 Global Biodiversity Framework.

Methods

Post-2020 targets considered

In the latest draft of the post-2020 Global Biodiversity Framework (CBD 2021a), we considered the first eight of the targets (Targets 1–8), which address threats to biodiversity and active species management. By way of comparison, the remaining targets (Targets 9–21) address meeting people's needs through sustainable use and benefit sharing, as well as tools for implementation and mainstreaming; therefore, Targets 9–21 do not directly address threats to species. Targets 1–8 aim to (1) implement spatial planning to retain existing intact ecosystems; (2) restore degraded ecosystems and ensure connectivity among them; (3) conserve land and sea areas, especially areas of particular importance for biodiversity, through protected areas and other effective area-based conservation measures; (4) ensure active management to enable species recovery, conserve genetic diversity, and reduce human–wildlife conflict; (5) ensure that harvesting, trade, and use of species are legal, sustainable, and safe; (6) prevent or reduce the introduction of invasive alien species, and (where introduced) control or eradicate them; (7) reduce pollution; and (8) minimize the impact of climate change on biodiversity.

Taxonomic groups included

We downloaded the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2020) information for all comprehensively assessed taxonomic groups at a global level (37,482 species) on 29 Mar 2021, and retained all species listed as “Vulnerable”, “Endangered”, and “Critically Endangered” (hereafter collectively referred to as “threatened”) or “Extinct in the Wild” (a total of 7784 species). These consisted of amphibians (2444 species); birds (1486); mammals (1325); selected dicot groups (688); marine lobsters and freshwater crabs, crayfish, and shrimps (484); sharks, rays, and chimeras (355); reef-forming corals (232); conifers (205); selected bony fishes

groups (204); cycads (196); selected reptile groups (100); selected marine gastropods (41); hagfish (9); cephalopods (5); Gnetopsida (5); coelacanths and lungfish (3); and horse-shoe crabs (2).

Matching threats to targets

To identify the number of species classified by the IUCN as threatened or Extinct in the Wild that would benefit from each of Targets 1–3 and Targets 5–8 in the post-2020 Global Biodiversity Framework, we matched threats to species with those that we judged would be addressed by each target. Threats are documented on the IUCN Red List using hierarchical classification schemes (Salafsky *et al.* 2008) and are grouped into 12 broad categories, including biological resource use, pollution, and climate change (Figure 1). Geological events such as volcanoes and earthquakes, which cannot be easily mitigated and threaten only 108 species, were excluded. Each threat record also lists corresponding stresses (that is, how the threat is affecting the species: for example, through ecosystem degradation or species mortality). Of the species we considered, 99% have at least one threat listed in their assessments, and most have two (WebFigures 1 and 2). The threats have corresponding stresses listed for 98% of species–threat records. Detailed analyses of the pattern of threats to species based on these data, and their associated caveats, were described previously in Joppa *et al.* (2016) and Maxwell *et al.* (2016).

We assumed that full implementation of each draft target would effectively address the threats they targeted or the conservation responses on which they focused. We then matched each threat–stress combination coded for threatened species to the draft targets (see WebTable 1 for rationale). We considered stresses in addition to threats because different stresses resulting from each threat may be addressed by different targets. For instance, a threat from “Human intrusions & disturbance: recreational activities” with “Ecosystem stresses” (eg damage to sensitive saltmarsh habitats by off-road vehicles) may be best addressed by Target 3 on protected areas, but the same threat with a stress of “Species disturbance” (eg disturbance of Javan hawk-eagle [*Nisaetus bartelsi*] nests near human populations) may be best addressed by Target 4 (through targeted nest-guarding efforts). We grouped Targets 1–3 (on spatial planning, restoration, and protected areas) together because their impacts on threats and stresses to species cannot be easily disentangled. Two of the authors (FCB and SHMB) independently matched the threats/stresses to the targets, and results were compared (following the approach of eg Ridley *et al.* 2020; Weiss *et al.* 2021). There was a high degree of consensus because the wording of several of the targets makes it very clear which threats they are intended to address, with a full match for 63% of species in each threat–stress combination and a partial match for a further

27%. The discrepancies between the two sets of scores were discussed by authors FCB, SHMB, and PJKM until consensus was achieved on the relationship. We then calculated the number of species affected by each threat–stress combination, and consequently the number of species potentially benefiting from implementation of each target. For example, we estimated that Target 6 on tackling invasive alien species may benefit 1999 species – those coded as threatened by “Invasive non-native/alien species/diseases” within the larger set of 2258 species coded as threatened by “Invasive & other problematic species, genes & diseases” (see WebTable 1 for further details). As documentation of stresses and conservation actions needed on the IUCN Red List may not be comprehensive, it is possible that the findings presented here underestimate the number of species that would benefit from attainment of each target.

Identifying species needing recovery actions

To identify species that require the proposed Target 4 (ensure active management to enable species recovery) even if all other targets were implemented fully, we counted the number of species in three subsets. First, we identified species that are affected by threats not addressed by any of the other targets (eg from “Problematic native species/diseases”). Second, we added species that require species-specific conservation actions (even if they would also benefit from implementation of other targets). To identify these, we analyzed data from the IUCN Red List on the conservation actions needed for each threatened and Extinct in the Wild species in the taxonomic groups considered, as coded against the IUCN Actions Classification Scheme (Salafsky *et al.* 2008). This information was available for 86% of the threatened species included in our analysis. We defined species-specific conservation actions as “Ex situ conservation”, “Species reintroduction”, and “Species recovery”. Third, we added species with very small population sizes, which renders them highly susceptible to inbreeding depression, Allee effects (inability to find mates), lack of genetic variation for adaptation, and stochastic events. Such species may not fully recover without the measures proposed in Target 4. Specifically, we identified (a) species with a minimum population size below 1000 mature individuals or number of individuals in each subpopulation below 1000 (ie those

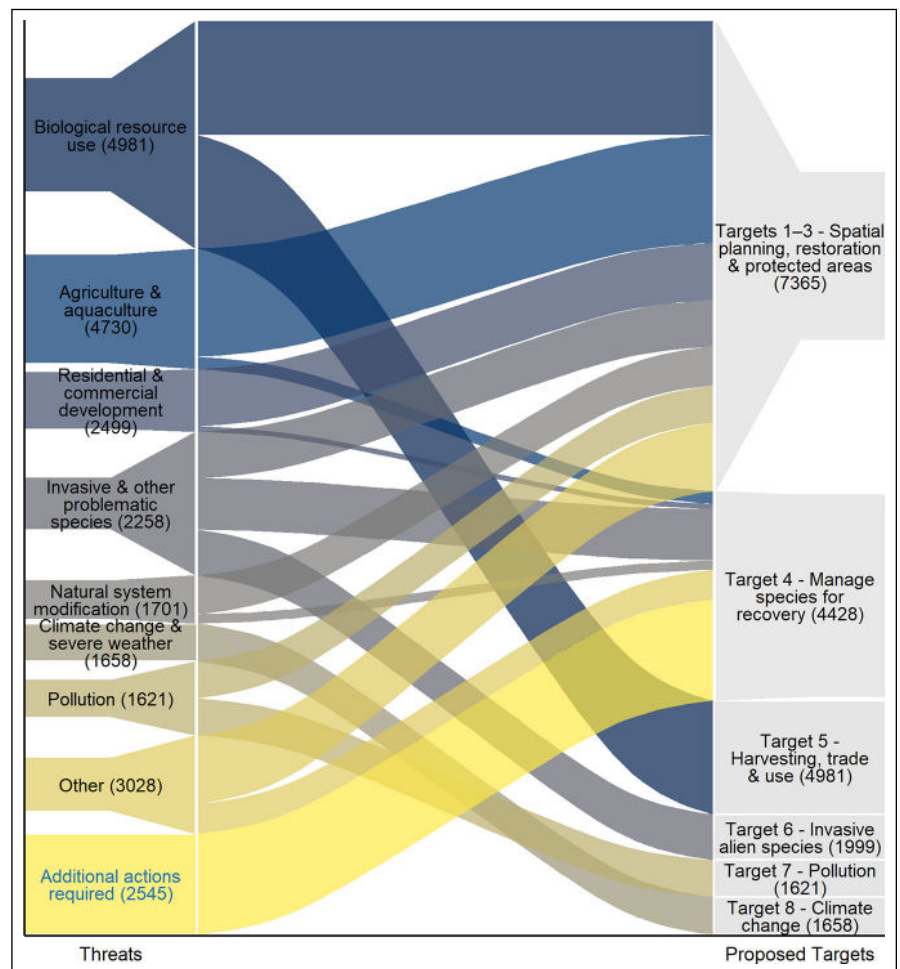


Figure 1. Number of threatened and Extinct in the Wild species whose threats are addressed by the proposed post-2020 targets for all comprehensively assessed species groups on the International Union for Conservation of Nature (IUCN) Red List ($n = 7784$ species). Species can be affected by more than one threat, and threats can be tackled by more than one target. Colors distinguish different threats. Threats are classes in level 1 of the IUCN Red List Threats Classification Scheme; “Other” includes the classes “Energy production and mining”, “Transportation and service corridors”, “Human intrusions and disturbance”, and “Other options”. “Additional actions required” refers to species requiring species-specific conservation actions as listed on the IUCN Red List Actions Classification Scheme (that is, “Ex situ conservation”, “Species reintroduction”, and “Species recovery”), and/or that require such actions because they have very small populations or ranges. Figures in parentheses indicate the number of species.

qualifying under IUCN Red List criterion D or D1, or assessed as Critically Endangered under criterion C, or Endangered or Vulnerable under criterion C2ai); and/or (b) species that have a small extent of occurrence or area of occupancy, severely fragmented ranges, and extreme fluctuations in extent of occurrence, area of occupancy, number of locations or subpopulations, or number of mature individuals (ie those qualifying under IUCN Red List criterion B_{ac}).

To illustrate the importance for each country of Target 4, we mapped the number of species per country that require its implementation, as outlined above.

Results

We found substantial differences in the number of species that would benefit from each target, according to the threats coded for each species (Figure 1). Collectively, Target 1 (implement spatial planning to retain existing intact ecosystems), Target 2 (restore degraded ecosystems and ensure connectivity among them), and Target 3 (conserve land and sea areas, especially areas of particular importance for biodiversity through protected areas and other effective area-based conservation measures) will be particularly important, as 95% of threatened and Extinct in the Wild species (7365 species) would benefit from their implementation. This is followed by Target 5 (ensure harvesting, trade, and use of wild species are legal, sustainable, and safe) with 64% (4981 species), Target 6 (prevent or reduce the introduction of invasive alien species, and control or eradicate them) with 26% (1999 species), Target 8 (minimize the impact of climate change on biodiversity) with 21% (1658 species), and Target 7 (reduce pollution) with 21% (1621 species). Most species would benefit from multiple targets, with most benefiting from two (WebFigure 3).

At least 57% of threatened and Extinct in the Wild species (4428 species) would require Target 4 (ensure active management to enable species recovery and conserve genetic diversity) based on data from the IUCN Red List (Figure 1). These comprise (a) 3424 species that are affected

by threats not addressed in the other proposed targets (WebTable 1), (b) 1863 species that need targeted species recovery actions (including ex situ conservation for 1210 species; reintroduction for 256 species; and recovery actions, such as vaccinations, supplementary feeding, or breeding site provision, for 939 species; Figure 2), and (c) 1106 species that have very small population sizes or very small ranges that are severely fragmented or fluctuate in size, with overlaps between these three subsets (WebFigure 4). Species potentially requiring Target 4 occur in almost every country of the world, with a median of 54 species per country (Figure 3). Indonesia supports the largest absolute numbers of these species (490), followed by Mexico (449) and Australia (436), but the proportion of all species (in comprehensively assessed groups) in each country that such species comprise is highest in Ascension Island (20.4%), Saint Helena (20.4%), and Heard Island (20.0%) (WebFigure 5).

Discussion

Our analysis provides an indication of the relative importance of different proposed targets in the post-2020 Global Biodiversity Framework for achieving the goal of conserving at-risk species. Area-based conservation – encompassing spatial planning (Target 1), restoration (Target 2), and effective site-focused conservation efforts (Target 3), such as protected areas (if placed in the right locations, sufficiently large, adequately connected, resourced, and equitably

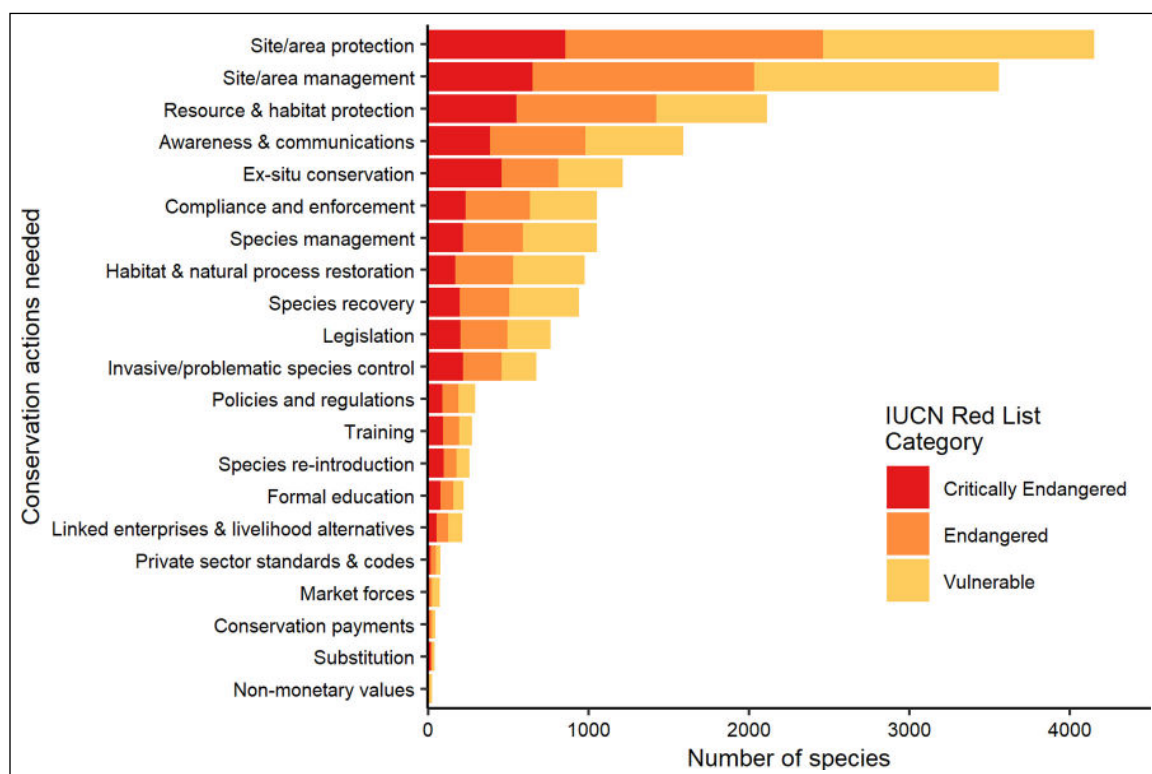


Figure 2. Number of threatened species that need different types of conservation actions, as identified on the IUCN Red List (IUCN 2020), sorted by IUCN Red List category. The 15 species listed as Extinct in the Wild were excluded, as there are too few to visualize in this figure. Species-specific conservation actions are defined as “Ex situ conservation”, “Species reintroduction”, and “Species recovery”.

managed; Maxwell *et al.* 2020) – will play a key role, given that 95% of species classified by the IUCN as threatened or Extinct in the Wild could benefit from these three targets collectively. Other key actions include managing unsustainable harvesting and trade (addressed by Target 5, benefiting 63% of species), and controlling invasive species (Target 6, benefiting 23% of species). However, Target 4 (active management) will be essential in ensuring the recovery of more than half of the current threatened and Extinct in the Wild species, because the threats these species face are not addressed by the other targets or because they require targeted species-specific actions. Our results emphasize that it is critical to retain such a target in further negotiations.

Tackling the most pervasive threats

The post-2020 Global Biodiversity Framework needs to stimulate the transformative change (ie fundamental, system-wide reorganization across technological, economic, and social factors; Díaz *et al.* 2019) required for halting species extinctions, by addressing the underlying drivers of species loss. Tackling threats is important for species currently under threat, but also for preventing additional species from becoming threatened. The new targets are intended to act synergistically in stimulating progress to achieving the Goals stated in the post-2020 Global Biodiversity Framework, as was the intention for the Aichi Targets (eg implementation of those Aichi Targets that focused on addressing threats enabled progress toward Target 12 on preventing extinctions and conserving threatened species; Marques *et al.* 2014). Our finding that 95% of threatened species require area-based conservation (through spatial planning, restoration, and site-focused efforts such as establishment of protected areas) highlights the importance of targets that aim to address the most pervasive threats to species, particularly overexploitation and land-use change resulting from agricultural conversion. There are transformative pathways demonstrating that ecosystems can be maintained and can recover while ensuring food security, such as by making food production more sustainable, changing consumption and diet choices to sustainable and healthy levels, and increasing protected area coverage (Leclère *et al.* 2020) – all of which are consistent with the draft targets.

However, to ensure that the proposed targets will halt extinctions, they must be fully and effectively implemented, address threats sufficiently to reduce extinction risk, and be implemented with urgency (Díaz *et al.* 2020). For instance, many threatened species need adequate representation in a well-placed network of protected areas and other effective area-based conservation measures (Coad *et al.* 2019; Maxwell *et al.* 2020).

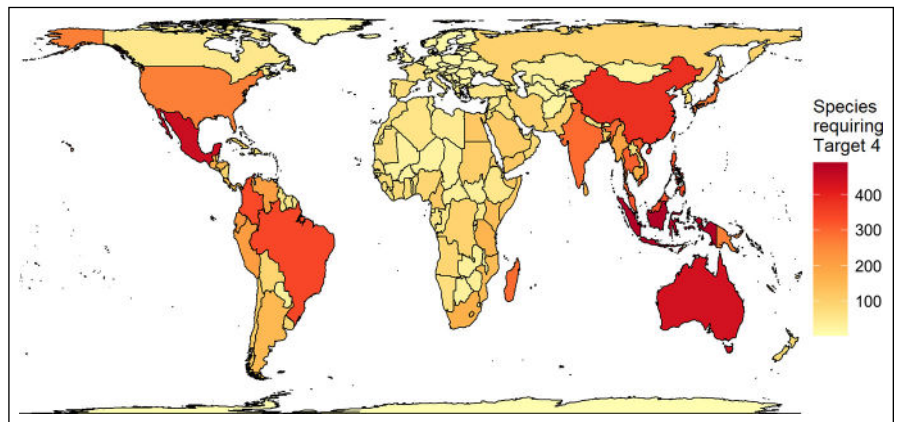


Figure 3. Number of species per country that require implementation of Target 4, illustrating the importance of this target for conserving threatened species in Australia, Indonesia, Mexico, and China, among others.

This could in large part be achieved by identifying and conserving Key Biodiversity Areas (“sites contributing significantly to the global persistence of biodiversity”, identified using a standardized set of criteria [IUCN 2016]), in particular those identified for threatened species under Key Biodiversity Area criterion A1 (Visconti *et al.* 2019), which identifies sites supporting proportions of the global population of one or more threatened species above particular thresholds. Such species not only need sufficient coverage by protected and conserved areas, but also require these to be effectively and equitably managed and adequately connected (Maxwell *et al.* 2020).

Species that require recovery actions to ensure their survival

Our analysis has demonstrated that in order to achieve Goal A in the post-2020 Global Biodiversity Framework, it is essential to retain Target 4 to ensure active management to enable species recovery. Target 4 will be necessary for 4035 species that are facing threats not addressed by other targets, or that will require species-specific recovery actions. Examples include 238 endemic Hawaiian plant species with fewer than 50 individuals remaining in the wild (Werden *et al.* 2020), such as the punaluu haha (*Cyanea truncata*), which requires intensive in situ recovery actions to manage the threat of invasive species as well as ex situ conservation to supplement the population. For other plant species, labor-intensive planting, watering, and protection of seedlings are necessary due to lack of natural regeneration, such as for the iconic oak (*Quercus brandegeei*) in Mexico (Denvir and Westwood 2016), and the Baishan fir (*Abies beshanzuensis*) in China (Yang *et al.* 2013). No more than 35 Lord Howe Island stick insects (*Dryococelus australis*) remain in the wild, but once invasive plants are removed from its range on a small island, conservation translocation efforts will be undertaken using stock from ex situ populations in zoos, which contain thousands of individuals (Rudolf and Brock 2017).

For some taxa – such as the 232 threatened coral species impacted by bleaching, the 571 threatened amphibian species impacted by chytridiomycosis, or those species whose mutualists (seed dispersers, pollinators, symbionts) have disappeared locally or globally – scientists do not yet fully understand how to tackle the threats they face. For such species, ex situ conservation may buy time while feasible interventions are devised, tested, and applied (da Silva *et al.* 2019), ensuring that species can be translocated or populations supplemented.

Our analysis focused on *known* threatened species, as was the case for Aichi Target 12, and as implied by reference to the IUCN Red List in the draft monitoring framework proposed by the CBD, and other supporting CBD documentation for the draft set of new goals and targets (CBD 2021b). Clearly, it is impossible to implement targeted recovery actions (those called for under Target 4) for species that have yet to be described by science or that are known but to an insufficient degree for their extinction risk (and actions needed) to be documented.

Effectively implementing recovery actions for species can be challenging, but there is evidence that such measures can succeed in averting extinctions, even for species on the brink (Bolam *et al.* 2020). For example, the Seychelles warbler (*Acrocephalus sechellensis*) was listed as “Threatened” (a former Red List category used prior to the adoption of quantitative Red List criteria) in 1988 but had recovered to Near Threatened by 2015 following translocations and habitat management (BirdLife International 2016).

A target for species recovery actions post-2020

The current wording of Target 4 includes reference to human-wildlife conflict. As this issue is conceptually distinct from the issue of species recovery, we suggest that it would be more appropriately included elsewhere in the framework. We also suggest that reference to domesticated species is inappropriate in this target, as it distracts from the focus on actions for wild species, and conservation of domesticated species falls within the remit of Target 10 on sustainable agriculture. Finally, we suggest that when the CBD develops explanatory text and guidance for Target 4 following its adoption, this should emphasize the importance of targeting active management actions particularly at those species whose recovery depends on them, as identified in our analyses (ie those impacted by threats not addressed by the other targets, those for which targeted actions have been identified as necessary on the IUCN Red List, and those requiring species-specific actions because they have small populations or ranges that are highly fragmented or fluctuate in size).

If implemented sufficiently, Target 4 would contribute to achieving the 2050 draft goal of reducing the number of species that are threatened. The target could be monitored using indicators based on the IUCN Red List, including the Red List Index (measuring trends in extinction risk for sets of species; Butchart *et al.* 2007), which draws on underlying monitoring of species’ distributions, abundance, and

habitats, as Essential Biodiversity Variables (Pereira *et al.* 2013). It could be informed by the establishment of science-based targets for species using the species threat abatement and restoration metric (Mair *et al.* 2021) and through IUCN Green Status of Species assessments (Grace *et al.* 2021). The effectiveness of its implementation could be increased by prioritizing and coordinating action across relevant stakeholders by developing and implementing “species action plans” (also known as “species recovery plans”) for the relevant species (Copsey *et al.* 2020). Evidence suggests that such plans are more effective when a diversity of participants are involved (Boersma *et al.* 2001). For stakeholders like zoos and botanical gardens, their contribution to achieving Target 4 could be maximized through coordinated action to establish or strengthen ex situ conservation of those species whose recovery depends on such programs (Collar and Butchart 2014; Westwood *et al.* 2020). Support to governments and others in implementing Target 4 effectively is being developed by IUCN as part of a “Global Species Action Plan” to outline the key actions needed, and link to key tools and resources to support these (IUCN 2021b).

The draft targets of the post-2020 Global Biodiversity Framework cover the key threats to species. In addition, Target 4 covers the interventions required for those species in need of additional recovery actions. It is therefore critical that all draft targets be retained in the final framework. Further human-induced species extinctions can be prevented, but only if all threats to species are mitigated and species recovery actions are implemented as a matter of urgency.

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Data Availability Statement

Data and code for reproducing numbers and figures shown are available at https://github.com/rbolam/Species_target.

References

BirdLife International. 2016. *Acrocephalus sechellensis*. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Gland, Switzerland: IUCN.

- Boersma PD, Kareiva P, Fagan WF, *et al.* 2001. How good are endangered species recovery plans? The effectiveness of recovery plans for endangered species can be improved through incorporation of dynamic, explicit science in the recovery process, such as strongly linking species' biology to recovery criteria. *BioScience* **51**: 643–49.
- Bolam FC, Mair L, Angelico M, *et al.* 2020. How many bird and mammal extinctions has recent conservation action prevented? *Conserv Lett* **14**: e12762.
- Butchart SHM, Akçakaya HR, Chanson J, *et al.* 2007. Improvements to the Red List index. *PLoS ONE* **2**: e140.
- CBD (Convention on Biological Diversity). 2010. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets. Decision X/2. Montreal, Canada: CBD.
- CBD (Convention on Biological Diversity). 2020a. Global Biodiversity Outlook 5. Montreal, Canada: CBD.
- CBD (Convention on Biological Diversity). 2020b. Zero draft of the post-2020 Global Biodiversity Framework. Montreal, Canada: CBD.
- CBD (Convention on Biological Diversity). 2021a. First draft of the post-2020 Global Biodiversity Framework. Montreal, Canada: CBD.
- CBD (Convention on Biological Diversity). 2021b. Post-2020 Global Biodiversity Framework: scientific and technical information to support the review of the updated goals and targets, and related indicators and baselines. Montreal, Canada: CBD.
- Coad L, Watson JEM, Geldmann J, *et al.* 2019. Widespread shortfalls in protected area resourcing undermine efforts to conserve biodiversity. *Front Ecol Environ* **17**: 259–64.
- Collar NJ and Butchart SHM. 2014. Conservation breeding and avian diversity: chances and challenges. *Int Zoo Yearbook* **48**: 7–28.
- Copsey J, Lees C, and Miller P (Eds). 2020. A facilitator's guide to species conservation planning (v1.0). Apple Valley, MN: International Union for Conservation of Nature Species Survival Commission Conservation Planning Specialist Group.
- da Silva R, Pearce-Kelly P, Zimmerman B, *et al.* 2019. Assessing the conservation potential of fish and corals in aquariums globally. *J Nat Conserv* **48**: 1–11.
- Denvir A and Westwood M. 2016. *Quercus brandegeei*. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Gland, Switzerland: IUCN.
- Díaz D, Settele J, Brondízio ES, *et al.* 2019. Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* **366**: aax3100.
- Díaz S, Zafra-Calvo N, Purvis A, *et al.* 2020. Set ambitious goals for biodiversity and sustainability. *Science* **370**: 411–13.
- Grace MK, Akçakaya HR, Bennett EL, *et al.* 2021. Testing a global standard for quantifying species recovery and assessing conservation impact. *Conserv Biol* **35**: 1833–49.
- IUCN (International Union for Conservation of Nature). 2016. A global standard for the identification of Key Biodiversity Areas, Version 1.0. First edn. Gland, Switzerland: IUCN.
- IUCN (International Union for Conservation of Nature). 2020. The IUCN Red List of Threatened Species (v2020-3). Gland, Switzerland: IUCN.
- IUCN (International Union for Conservation of Nature). 2021a. The IUCN Red List of Threatened Species (v2021-3). Gland, Switzerland: IUCN.
- IUCN (International Union for Conservation of Nature). 2021b. Global Species Action Plan briefing paper. Gland, Switzerland: IUCN.
- Joppa L, O'Conner B, Visconti P, *et al.* 2016. Filling in biodiversity threat gaps. *Science* **352**: 416–18.
- Leclère D, Obersteiner M, Barrett M, *et al.* 2020. Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature* **585**: 551–55.
- Mair L, Bennun LA, Brooks TM, *et al.* 2021. A metric for spatially explicit contributions to science-based species targets. *Nat Ecol Evol* **5**: 836–44.
- Marques A, Pereira HM, Krug C, *et al.* 2014. A framework to identify enabling and urgent actions for the 2020 Aichi Targets. *Basic Appl Ecol* **15**: 633–38.
- Maxwell S, Fuller R, Brooks TM, and Watson JEM. 2016. Biodiversity: the ravages of guns, nets and bulldozers. *Nature* **536**: 143–45.
- Maxwell SL, Cazalis V, Dudley N, *et al.* 2020. Area-based conservation in the twenty-first century. *Nature* **586**: 217–27.
- Pereira HM, Ferrier S, Walters M, *et al.* 2013. Essential Biodiversity Variables for global Earth observation. *Science* **339**: 277–78.
- Ridley FA, McGowan PJ, and Mair L. 2020. The scope and extent of literature that maps threats to species: a systematic map protocol. *Environ Evidence* **9**: 23.
- Rudolf E and Brock P. 2017. *Dryococelus australis*. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Gland, Switzerland: IUCN.
- Salafsky N, Salzer D, Stattersfield AJ, *et al.* 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conserv Biol* **22**: 897–911.
- UN (United Nations). 2015. Transforming our world: the 2030 agenda for sustainable development. New York, NY: UN.
- Visconti P, Butchart SHM, Brooks TM, *et al.* 2019. Protected area targets post-2020. *Science* **364**: 239–41.
- Weiss KCB, Iacona GD, Tuñas Corzón Á, *et al.* 2021. Aligning actions with objectives in endangered species recovery plans. *Conserv Sci Pract* **3**: e473.
- Werden LK, Sugii NC, Weisenberger L, *et al.* 2020. Ex situ conservation of threatened plant species in island biodiversity hotspots: a case study from Hawai'i. *Biol Conserv* **243**: 108435.
- Westwood M, Cavender N, Meyer A, and Smith P. 2020. Botanic garden solutions to the plant extinction crisis. *Plants People Planet* **3**: 22–32.
- Yang Y, Zhang D, Luscombe D, *et al.* 2013. *Abies beshanzuensis*. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Gland, Switzerland: IUCN.

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