The Post-2020 Global Biodiversity Framework must safeguard the Tree of Life

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Abstract

Following our failure to fully achieve any of the 20 Aichi biodiversity targets, the future of biodiversity rests in the balance. The Convention on Biological Diversity's Post-2020 Global Biodiversity Framework (GBF) presents us with the opportunity to preserve Nature's Contributions to People (NCPs) for current and future generations through conserving biodiversity and averting extinction across the Tree of Life. Here we demonstrate that species extinctions can lead to unequal losses of biodiversity depending on their evolutionary history, and call attention to our need to conserve the Tree of Life to maintain its benefits. We highlight two indicators available for adoption in the post-2020 GBF to monitor our progress towards safeguarding the Tree of Life. The Phylogenetic Diversity indicator, adopted by IPBES, can be used to monitor biodiversity's capacity to maintain NCPs. The EDGE (Evolutionarily Distinct and Globally Endangered) Index monitors how well we are performing at averting the greatest losses across the Tree of Life by conserving the most distinctive species. By committing to safeguarding the Tree of Life post-2020, we can reduce biodiversity loss and preserve nature's contributions to humanity now and into the future.

1 Introduction

Current biodiversity policy has failed to stem declines across the board (Díaz et al. 2019), partially achieving only six of the 20 Aichi biodiversity targets (Secretariat of the Convention on Biological Diversity 2020a). As nations now work towards agreeing the post-2020 Global Biodiversity Framework (GBF) for the Convention on Biological Diversity (CBD), and its goals and targets for the coming decades, it is only by being highly ambitious that we can have any chance of improving the outlook for global biodiversity by 2050 (Díaz et al. 2020). At the heart of the post-2020 GBF (Secretariat of the Convention on Biological Diversity 2020b) is the recognition that we must value and maintain nature's contributions to people— all the benefits and impacts on people that come from nature both now and in the future (IPBES 2019), realised through conservation and sustainable use (draft Goal B), and achieved by protecting ecosystems and species (draft Goal A).

A critical and often overlooked aspect of biodiversity is the evolutionary heritage represented by a set of species across the Tree of Life, measured by Phylogenetic Diversity (PD; Faith 1992). PD represents the variety of different evolutionary features of species that give rise to both current benefits and as yet unexplored options for humanity, which we can effectively safeguard by preserving the Tree of Life (Forest et al. 2007; IPBES 2019b; Molina-Venegas et al. 2020). Maintaining possible future uses and benefits to society (the biodiversity option value measured by PD; Faith et al. 2018) is particularly important in the context of a changing environment and the challenges that biodiversity—and its contributions to humanity—faces going forward (IPBES 2019b).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) adopted PD as an indicator for Nature's Contributions to People (NCPs; Faith et al. 2018; IPBES 2019b): linking PD to the maintenance of options (the overall capacity of biodiversity to support a good quality of life into the future; NCP 18), and thus the continued provision of medicinal, biochemical and genetic resources (NCP 14), and learning and inspiration (NCP 15; Díaz et al. 2019; IPBES 2019b). This recognition of the link between the Tree of Life and nature's contributions to people provides an opportunity to address the significant challenge of maintaining these for current and future generations, to which the CBD is committed (Secretariat of the Convention on Biological Diversity 2021a). Indeed, Díaz et al. (2020) recognise that, if we wish to 'bend the curve' of biodiversity loss whilst securing a broad range of NCPs, we must set and attain highly ambitious goals that include prioritising the conservation of evolutionarily distinct lineages to effectively safeguard the Tree of Life.

Here we show that, when setting goals and targets linked to the maintenance of biodiversity and the associated contributions to people, focusing on species without considering their evolutionary history may lead to large biodiversity losses across the Tree of Life. However, much of this impending loss of PD could be averted by prioritising a small proportion of species for conservation. We outline the use of two related indicators suitable for the post-2020 GBF that uniquely interlink valuing nature's contributions to people (Goal B) with improving species' conservation status (Goal A) (Secretariat of the Convention on Biological Diversity 2020b): (i) the Phylogenetic Diversity indicator monitoring the status of PD and thus biodiversity's capacity to maintain contributions to people (adopted by IPBES); (ii) the EDGE (Evolutionarily Distinct and Globally Endangered) Index tracking the extinction risk of the world's most evolutionarily distinct and threatened species. Aside from these, no indicators currently listed in the draft monitoring framework capture these important aspects of biodiversity as values to conserve, nor explicitly articulate how biodiversity and nature's contributions to people are inextricably linked.

2 Not all extinctions are equal

The extinction of a species represents the loss of the distinct features it embodied, the product of millions of years of evolutionary history, and results in a measurable reduction in global biodiversity, hence preventing extinction is fundamental to conservation (Díaz et al. 2020; Rounsevell et al. 2020). Preventing extinction is integral to draft Goal A in the GBF but, when considering each extinction event as of equal concern, we assume that each species contributes equally to the variety of life. This overlooks the importance of the variety of distinct features associated with differing evolutionary histories, also lost as part of a species' extinction. Thus, the extinction of a species that shares much of its evolutionary history and features with numerous extant close relatives intuitively represents a lesser reduction in global biodiversity (for as long as those close relatives survive), in comparison to the extinction of a species with few or no close relatives on the Tree of Life (Isaac et al. 2007; Díaz et al. 2020).

Phylogenetic Diversity approximates the features shared by, and unique to, species by measuring the branches of the Tree of Life that connect them: the greater the loss of PD, and therefore evolutionary history, the more distinct features we may lose (Faith 1992; Forest et al. 2007; Molina-Venegas et al. 2020). By measuring the reduction in PD associated with extinctions, we can estimate the reduction in biodiversity linked to the loss of features shaped by evolutionary history.

The extinction of 84 mammal species since 1500 (IUCN 2020) has resulted in the loss of around 250 million years of PD (0.7% of the mammal Tree of Life; Figure 1). If we were to lose all 1,244 currently threatened species (VU-CR on the IUCN Red List), we stand to lose around 4.5 billion years (11.9%) of the mammal Tree of Life (red line, Figure 1; Supporting Methods). Conservation efforts aim to avert the extinction of those species that are threatened, and thus the strategies adopted to prioritise species for conservation given our limited resources, will therefore also have a significant impact on the magnitude of biodiversity loss correspondingly averted. Given the scale of biodiversity loss that we face, it is clearly not enough to simply seek to prevent extinctions, we must seek to avert the extinction of species that will result in the greatest losses of PD and thus biodiversity.

Exploring the implications of different conservation strategies on the mammal Tree of Life, we show that conserving random sets of threatened mammals can save some threatened PD, but modelling a theoretical ideal selection that prioritises an equal number of threatened species that maximise PD can actually reduce this loss by as much as 65.6% (Figure 1; Table S1). As conservation in practice does not choose species to conserve based on a given sample size, we modelled the main PD-informed species conservation strategy in use globally, conserving Evolutionarily Distinct and Globally Endangered (EDGE) species (Box 1). This approach conserves greater amounts of PD than random sets of threatened species under all scenarios (from 26.2% increase in PD conserved under the most extreme extinction scenario (CR-VU) to 109.9% increase when only Critically Endangered species were considered at risk; 'High EDGE' strategy, Figure 1; Table S2).

BOX 1: Conserving evolutionarily distinct species

In 2012, the International Union for the Conservation of Nature (IUCN) adopted a resolution that recognised the importance of conserving threatened evolutionarily distinct lineages, the extinction of which results in the irreversible loss of irreplaceable genes and characteristics (IUCN 2012). Díaz et al. (2020) echo this resolution in their assertion that any truly ambitious post-2020 targets must aim to conserve distinct species in order to maintain the Tree of Life and the benefits to humanity it bestows. These values are embodied by the 'EDGE' (Evolutionarily Distinct and Globally Endangered) approach, which combines evolutionary distinctiveness with extinction risk to prioritise threatened species whose extinction would lead to the highest losses across the Tree of Life (Isaac et al. 2007; see Supporting Methods). To date, the EDGE approach continues to be the most established and best-known PD-informed conservation strategy (Owen et al. 2019), and has been applied to numerous animal and plant groups (e.g. Forest et al. 2018; Gumbs et al. 2018; Daru et al. 2019). By conserving high-ranking EDGE species, we can avert much of the impending losses across the Tree of Life (Figure 1, Figure S1), and we can track trends in the conservation status of priority EDGE species using simple metrics (Figure 3).

Modelling a scenario where PD is ignored demonstrates that there are sets of threatened species that can be prioritised for conservation that conserve even less of the Tree of Life than even random strategies ('Low EDGE', Figure 1). Hence, when the number of species extinctions remains constant, such as in each extinction scenario here (Figure 1; Supporting Methods), the associated PD loss demonstrates the scale of potential variation in the magnitude of biodiversity loss depending on those species selected for conservation. Thus, by failing to consider PD in conservation strategies we run the risk of losing distinct species that embody particularly large amounts of irreplaceable biodiversity (Chaudhary et al. 2018).

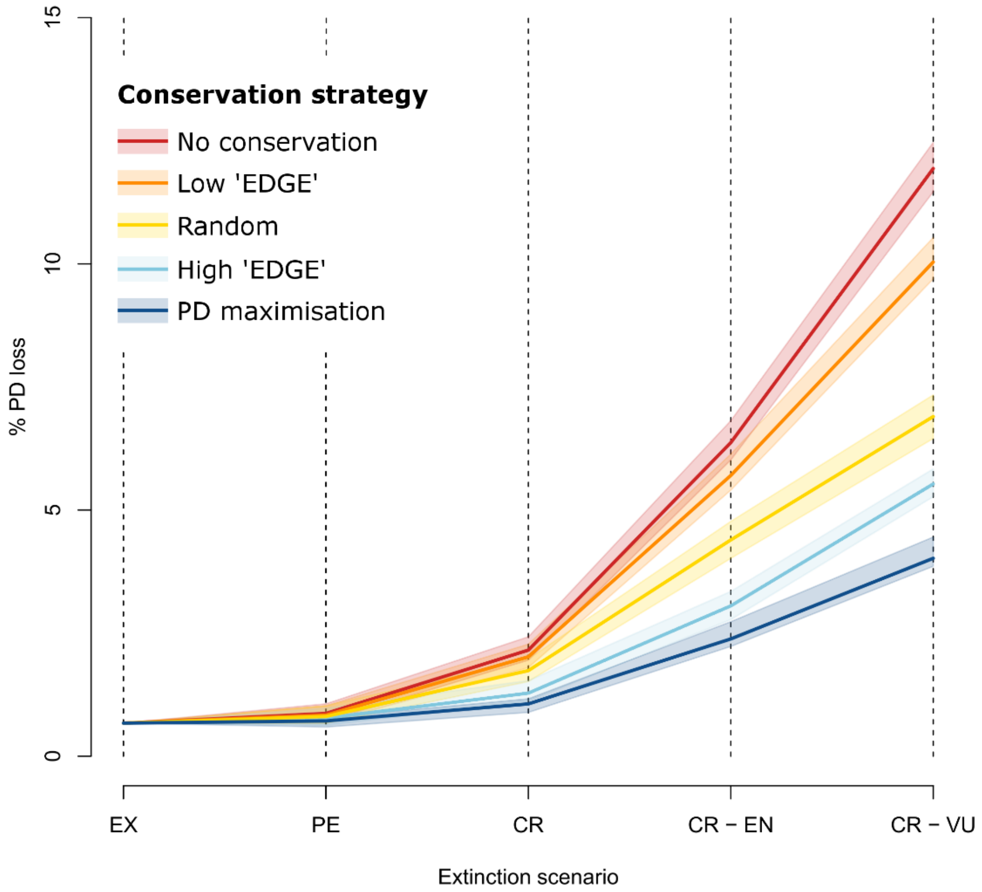


Figure 1: Variation in magnitude of expected loss of Phylogenetic Diversity (PD) under different conservation strategies selecting subsets of species, across four extinction scenarios for the world's mammals: 'PE': only Possibly Extinct and Extinct species on the IUCN Red List are lost; 'CR': Critically Endangered species are also lost; 'CR-EN': all Endangered species are also lost; 'CR-VU: all Vulnerable species are also lost. Coloured lines represent median values of PD lost under each of the five conservation strategies across each extinction scenario. "No conservation" = no species are conserved under each extinction scenario; "low 'EDGE'" = species in lowest quartile of expected PD loss contributions are conserved [low-ranking 'EDGE' Species] as a non-PD informed conservation model; "random" = a random set of species from those that meet the extinction scenario criteria, equal in size to one quartile, is conserved as our null model; "high 'EDGE'" = species in uppermost quartile of expected PD loss contributions are conserved [high-ranking 'EDGE' Species] as a PD-informed conservation model; "PD maximisation" = the theoretical ideal selection of species that optimise PD is conserved. PD loss was calculated across 100 mammalian trees - see Supporting Methods for details.

3 Tracking and averting phylogenetic diversity loss through time

i. Phylogenetic Diversity indicator

Goal B of the draft GBF aims to ensure that the benefits to all people provided by biodiversity (NCPs) are maintained or enhanced, with an explicit commitment to intergenerational equity – i.e. preserving the interests of future generations (Secretariat of the Convention on Biological Diversity 2020b). To achieve this, we need tools with which to monitor biodiversity's capacity to maintain NCPs. By preserving the Tree of Life we can capture both current benefits and future options (Forest et al. 2007; IPBES 2019b; Molina-Venegas et al. 2020), therefore monitoring the status of the Tree of Life is crucial to reliably quantify the capacity for biodiversity to provide NCPs through time (IPBES 2019b).

We can monitor the status of the Tree of Life by calculating the expected loss of PD as the amount of evolutionary history expected to be lost given current extinction risks to species (Faith et al. 2018). Specifically, the greater the proportion of long branches of the Tree of Life supported by threatened species—or groups of closely-related threatened species (e.g., pangolins, of which all eight species are threatened with extinction)—the greater the expected loss of PD. This approach underpins the PD indicator adopted by IPBES to monitor trends in NCPs (Faith et al. 2018), particularly the maintenance of options (Díaz et al. 2019). Initial approximations of the magnitude of expected loss of PD have been reported for several taxonomic groups in regional and global IPBES assessments (IPBES 2018, 2019b; Martín-López et al. 2018).

Our proposed use of the existing PD indicator used by IPBES incorporates an update to improve its accuracy and applicability for the post-2020 Global Biodiversity Framework and beyond. Specifically, this update incorporates the standardised extinction risk of all species in a given taxonomic group, for multiple time points where applicable (Henriques et al. 2020; IUCN 2020), to generate trends in expected PD loss. We apply this updated approach to three clades: mammals, birds and cycads (Supporting Methods). Given increased levels of extinction risk through time for each of the three groups, trends in their PD are worsening (Figure 2).

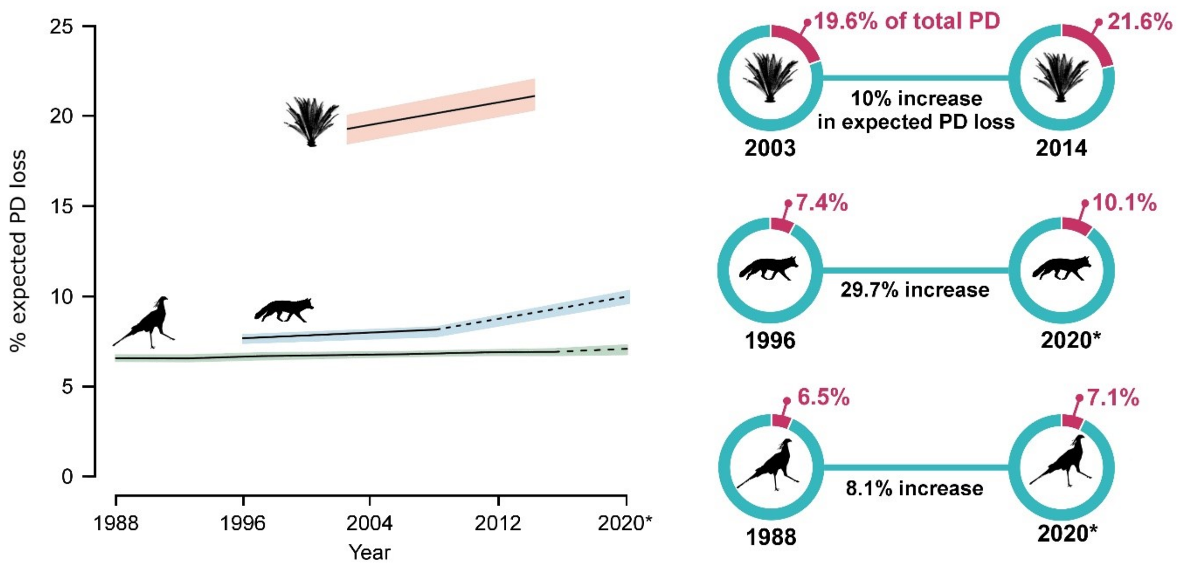


Figure 2: *The PD indicator: tracking PD loss through time. Left panel: trends in percentage of expected PD loss for the world's mammals (blue), birds (green) and cycads (pink), based on current and historical IUCN Red List assessments; right panel: detail of this change, baseline (left circle) and latest (right circle) estimations of expected PD loss for each clade, with the percent change in overall expected PD loss. *The 2020 timepoints displayed are not official Red List Index (RLI) timepoints of comprehensive assessments for all mammals and birds but represent the latest status of these assessments for both clades (see Supporting Methods); the trendlines from official RLI data to these 2020 timepoints are therefore dashed. The shaded regions around each trend line represent the range of values. There are insufficient repeated Red List assessments to produce a 2020 timepoint for cycads.*

Considering Phylogenetic Diversity's link to the provision of current and future benefits (Forest et al. 2007; IPBES 2019b; Molina-Venegas et al. 2020), and its adoption by IPBES to indicate the capacity of biodiversity to keep options open (Faith et al. 2018; Díaz et al. 2019; IPBES 2019a), it provides a unique and versatile tool with which to monitor NCPs while maintaining intergenerational equity. The PD indicator is therefore relevant to all aspects of Goal B of the draft GBF that relate benefits for people to biodiversity (Secretariat of the Convention on Biological Diversity 2020b, 2021a). The PD indicator is currently listed as a proposed complementary indicator for Goal B in the draft monitoring framework for the GBF (Secretariat of the Convention on Biological Diversity 2020c), however, it is demonstrably suitable as a headline or component indicator, for which it meets the criteria for global and national reporting (IPBES 2019b; Secretariat of the Convention on Biological Diversity 2021b).

ii. EDGE Index

To improve the status of the Tree of Life, we must improve the conservation status of threatened species whilst preventing the worsening of conservation status for non-threatened species, with a particular focus on distinctive species that embody a disproportionate amount of threatened PD. The loss of highly evolutionarily distinctive species, with few close relatives on the Tree of Life, results in the irreversible loss of not only their characteristics but also their potential benefits and should be avoided (Díaz et al. 2020). Without this recognition under draft Goal A on species, there is a significant risk that distinctive and threatened species will continue to be overlooked by conservation efforts (Owen et al. 2019), representing a significant potential loss of PD and consequently the reduction in options for humanity.

An established tool for identifying evolutionarily distinctive species whose conservation should be prioritised is the EDGE approach (Box 1), which prioritises the Tree of Life more effectively than alternative approaches (Figure S3; Supporting Methods). Using existing methods (Isaac et al. 2007; Faith et al. 2018), we present a simple EDGE indicator with several components to track trends in the extinction risk of priority EDGE species and thus monitor how well conservation efforts are performing at preventing the pruning of deep and long branches of the Tree of Life. We compiled the number of priority EDGE species (see Supporting Methods), their associated expected loss of PD, and trends in their global extinction risk through time for birds, mammals and cycads (Figure 3).

The EDGE index has multiple components, as follows (and see Supporting Methods):

a. i. Changes in the number of EDGE species, increasing as more highly distinctive species become threatened, or decreasing as highly distinctive species move into non-threatened Red List categories;

a. ii. Changes in the amount of associated expected PD loss according to EDGE species conservation status, indicating the effectiveness of conservation efforts in averting the greatest losses of PD;

a. iii. Number of EDGE species that have gone extinct;

b. Changes in the conservation status of EDGE species, transitions to worse Red List categories (‘uplistings’) indicate insufficient conservation efforts for the most distinctive and threatened species, whereas transitions to less severe Red List categories (‘downlistings’) indicates effective conservation efforts.

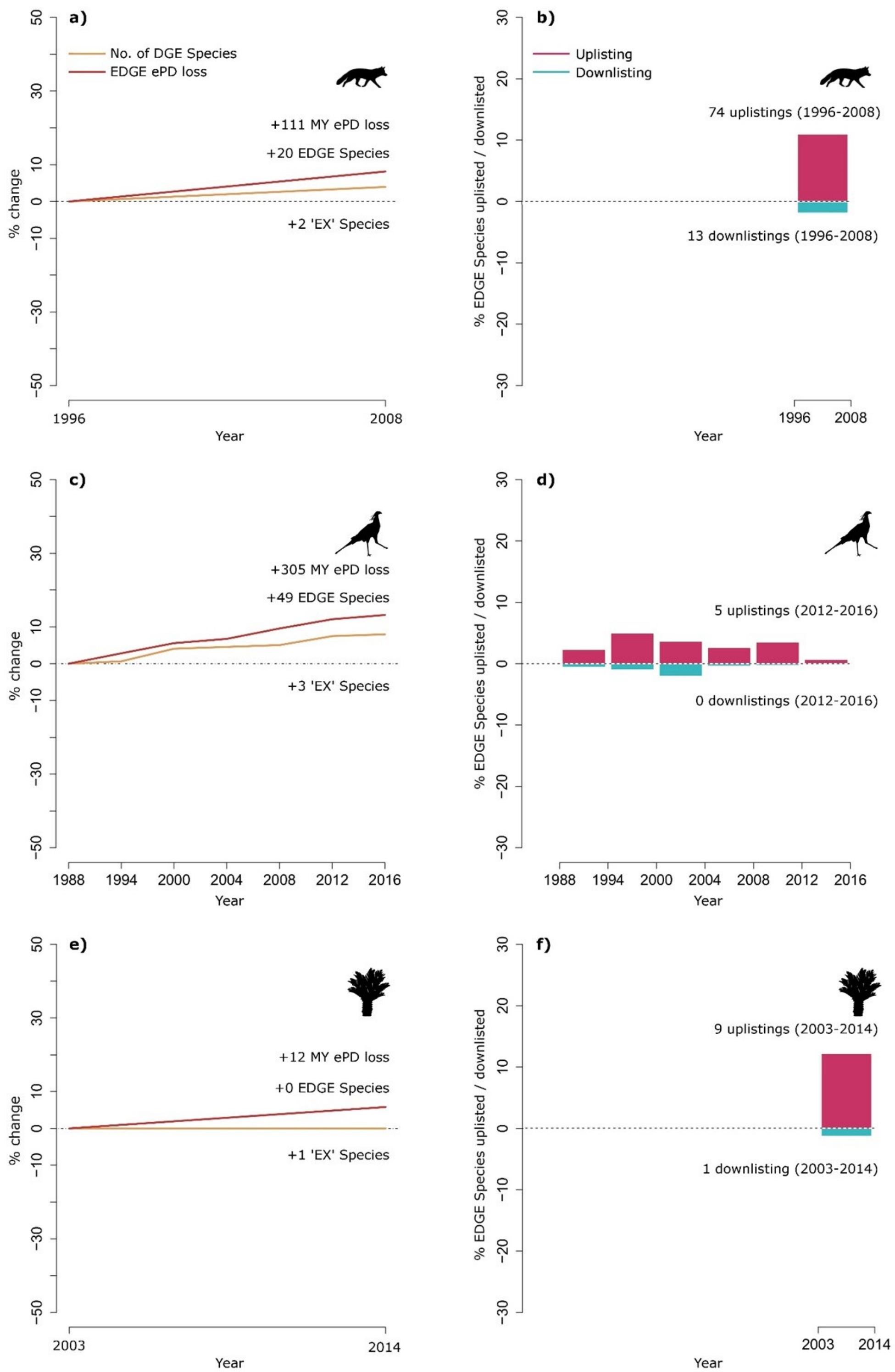


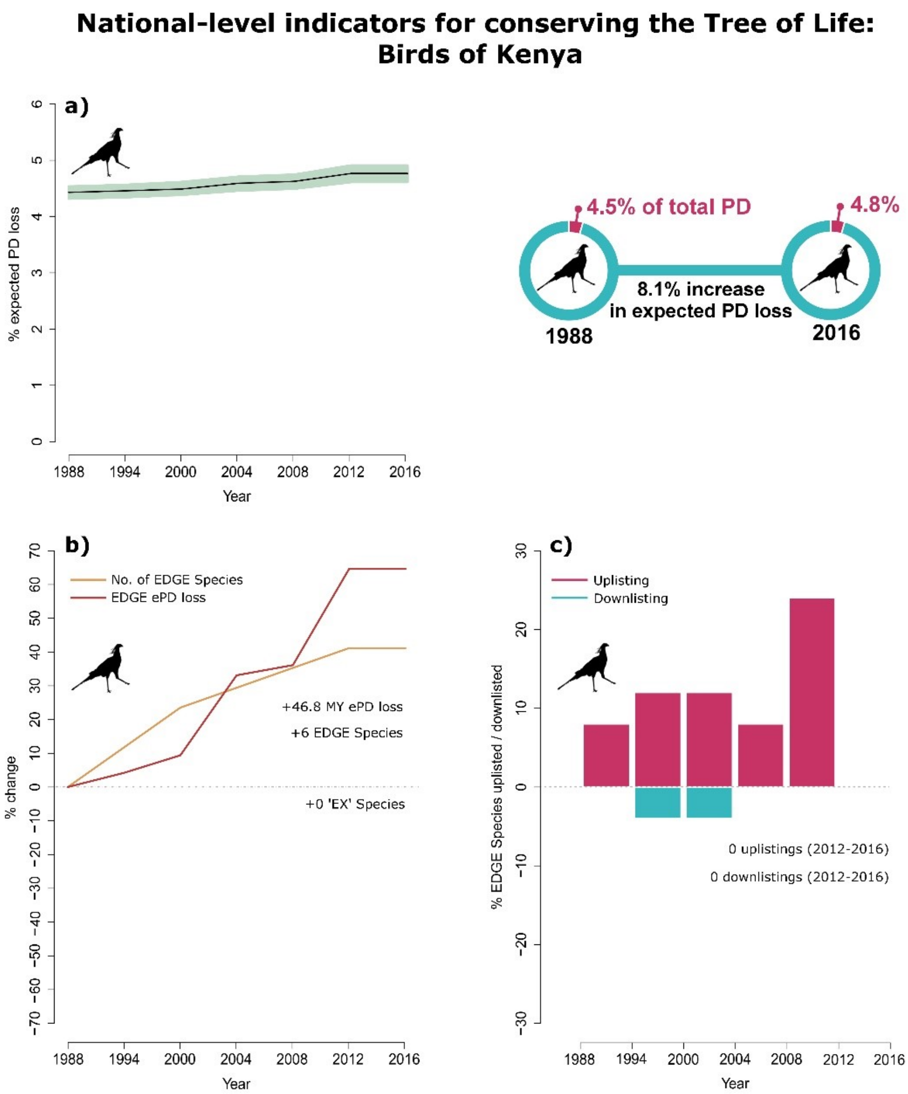
Figure 3: *The EDGE Index: monitoring trends in extinction risk for priority EDGE Species. Left panels: tracking changes through time in the total number of EDGE species, associated expected PD loss (ePD loss), and extinctions (EX Species), of priority EDGE Species per clade; and (right panels) the changes in extinction risk (uplistings and downlistings: species moving into higher or lower Red List categories) within sets of EDGE Species, for: a-b) mammals, c-d) birds, and e-f) cycads. Changes in total number of*

EDGE species, associated expected PD loss, and extinct species, are cumulative from baseline timepoint (dotted line). Number of uplistings and downlistings is for each time period between time points.

This indicator complements existing broader species measures, meeting the need to prioritise evolutionarily distinct species to conserve the Tree of Life as part of any efforts to reduce extinction rate and risk (Secretariat of the Convention on Biological Diversity 2021b, 2021a), making it relevant to the preventing extinctions component of draft Goal A and any proposed improvements (Williams et al. 2020).

iii. National contributions to global biodiversity goals

Given the impetus—and desire—for nations to quantify their own values and monitor their individual progress towards both national and global targets (Rounsevell et al. 2020), it is essential that biodiversity indicators adopted in the post-2020 framework can be disaggregated to regional and national levels. In fact, the capability to monitor the status of global values of biodiversity at a national level is particularly important given that current local-scale conservation efforts can often neglect these species (Owen et al. 2019). Indeed, the benefits to humanity bestowed by species of medicinal importance, or those species that inspire awe for the natural world, transcend both political borders and generations. The indicators proposed here can be effectively disaggregated to national levels. To illustrate the simplicity of this, we generated the expected PD loss indicator and EDGE Index (all components) for the birds of Kenya (Figure 4; see Supporting Methods), just one example of a biodiverse country.



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254 ***Figure 4:*** *Example of national disaggregations for the two indicators for the birds of Kenya. The*
255 *expected PD loss of Kenyan bird species (a) is calculated as a percentage of the total PD associated*
256 *with bird species present in Kenya. The EDGE Index for Kenyan birds (b-c) is subset from the global pool*
257 *of priority EDGE birds to ensure national priority species align with those of global value. See*
258 *Supporting Methods for methods underpinning this national disaggregation approach.*

259

260 4 Conclusions

261 Here we have demonstrated how conservation strategies that do not incorporate evolutionary history
262 will inevitably fail to avert the greatest losses of irreplaceable biodiversity (Figure 1, S1), and we have
263 highlighted two indicators that can be used to track and prioritise conservation efforts to prevent
264 these losses within the post-2020 Global Biodiversity Framework. These indicators present a unique

opportunity to incorporate the Tree of Life—and the benefits it provides—into global biodiversity policy, while complementing existing species measures.

The PD indicator, adopted by IPBES (Díaz et al. 2019), is unique in its capacity to link the preservation of biodiversity to the maintenance of nature's contributions to people, bolstering intergenerational equity. The EDGE Index and its components utilise the well-established EDGE approach to monitor the conservation status of the world's most evolutionarily distinct species, the conservation of which must underpin any ambitious post-2020 framework (Díaz et al. 2020). Despite continued advances in our capability to map extinction risk across the Tree of Life (ter Steege et al. 2015; Jin & Qian 2019), more resources are needed to ensure any global biodiversity indicators are applicable to more than a narrow set of well-studied species groups, and regularly compiled to allow an effective monitoring of the current state of biodiversity. Baselines of these indicators are in production for terrestrial and marine vertebrates, gymnosperms and corals, and under the Global Strategy for Plant Conservation the required data will soon be available for all vascular plants, aiding their inclusion (Borsch et al. 2020). The IUCN SSC Phylogenetic Diversity Task Force has committed to generating the two indicators outlined here at global and national levels on a regular basis (Owen et al. 2020), which can effectively assist nations in tracking and reporting progress towards the goals of the post-2020 Global Biodiversity Framework.

To be truly ambitious, the post-2020 global biodiversity framework must aim to safeguard the Tree of Life (Díaz et al. 2020). If we fail to do so, we risk great losses of evolutionary history including the loss of their associated options and benefits for current and future generations. But if we succeed, we can preserve much of the global value of nature's contributions to humanity now and into the future.

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Author's contributions

All authors conceived the idea and analyses. RG conducted all analyses and generated all figures with input from all authors. RG and NRO led the writing of the manuscript with input on drafts from all authors. All authors contributed to the preparation of the manuscript and approved the final version for submission.

Data accessibility statement

Extinction risk data underpinning all analyses taken from Henriques et al. (2020) for historic assessments and IUCN Red List for 2020 mammal assessments and www.birdlife.org for 2020 bird assessments. Underlying phylogenetic data for birds and mammals available from www.vertlife.org, and for cycads upon request from F. Forest.

Conflict of interest

The authors declare no competing interests