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Supplementary information

Aiming higher to bend the curve of biodiversity loss

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Supporting information:

Aiming higher- bending the curve of biodiversity loss

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Contents

A. Existing targets

We use two internationally agreed policy commitments: (1) the Convention on Biological Diversity (CBD) Aichi Targets (2010-2020) https://www.cbd.int/sp/targets/ (Aichi Targets), and (2) United Nations Sustainable Development Goals (2015-2030) (http://www.un.org/sustainabledevelopment/sustainable-development-goals/) (SDGs). For a longer term (2050) policy goal we are adopting the CBD vision for 2050. Details of each of these follow:

CBD Aichi Target 12 (2020)

The CBD Strategic Plan for Biodiversity (2011-2020) is intended to be an overarching framework for biodiversity conservation, not only for the biodiversity-related conventions, but for the entire United Nations system and all other partners engaged in biodiversity management and policy development. It includes 20 Aichi targets to be delivered by 2020, which are classified into 5 strategic goals (A to E). The Goals cover a range of contextual necessities for achieving the shared vision whereby, "*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people*."

Goal C is to "*To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity*" and includes 3 targets. Target 11 concerns the global coverage of protected areas, Target 12 is directed at the conservation of species, and Target 13 concerns the conservation of genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives. Here we focus on Target 12, the most direct and straightforward measure of biodiversity and one where there are existing metrics at global scale that have already been adopted by the CBD in various assessment processes.

Target 12 states, "*By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained*"

The target is only directed at 'known threatened species" which will be the number of species listed as being Critically Endangered, Endangered or Vulnerable on the IUCN Red List (http://www.iucnredlist.org/). In 2017 this was just over 25,000 species, out of over 60,000 that have been assessed for the Red List. Note that this is only a small proportion of all known species (more than 1.3 million) and a sample that is strongly biased towards terrestrial and large-bodied vertebrates.

To meet Target 12, none of these threatened species should have gone extinct, and those species in steepest decline (presumably the Critically Endangered, Endangered and Vulnerable species) will show improvements in their status, i.e. should have at least moved to a category of lower threat – Endangered, Vulnerable or Least Concern respectively.

Achieving this target by 2020 will be challenging, in part because the driving forces of species decline and extinction are often systemic and hard to reverse within a few years, but also because the responses of species to improvements in their environment may, depending on their lifespans and reproductive rates, take many years to show improvements.

SDG 14 and 15 (2030)

On 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development came into force. Over the next fifteen years, the SDGs, also known as Global Goals call for action by all countries, poor, rich and middle-income to promote prosperity while protecting the natural environment.

Of the 17 goals, three are specifically directed at the natural environment. Goal 13 is addressed at climate change and reflects the 2015 Paris Agreement for action on climate change. Goal 14 is to "*Conserve and sustainably use the oceans, seas and marine resources*" and Goal 15 is to "*Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss*"; these two are summarised as Life Below Water (Goal 14) and Life on Land (Goal 15). Both Goals 14 and 15 have specific targets which are directed at reducing threats, securing ecosystem functions and services, and supporting the flows of benefits from biodiversity to people. One target in Goal 15 concerns the state of biodiversity itself ("*Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species*"). This target reflects Aichi target 12. There is no equivalent Target in Goal 14 (Life Below Water) but we infer from the headline for Goal 15 that species conservation is an intended component, and that therefore the target to "halt biodiversity loss" from Goal 15 (Life on Land) can be applied to species living in the oceans.

Halting biodiversity loss is a more ambitious target than the Aichi target of preventing the extinction and improving the status of known threatened species because it concerns all species, and is not restricted to extinction risk alone. "Halting the loss of biodiversity" should be interpreted to also halt the declines in abundance and distribution of species as well as the structure and functioning of biological communities.

Note that while the target for SDG 15 gives 2020 as an end date, most other SDG goals are geared to 2030. Given the implausibility of achieving even the less ambitious Aichi target for 2020 (see above) and taking heed of the 2030 end date for most other SDGs, we are adopting 2030 as the target date for the SDG related biodiversity target.

CBD Vision (2050)

There are no policy commitments beyond 2030 but a longer timescale is important given the long lag times that some kinds of species recovery require, and also because of threats that will certainly be acting, some at greater intensity, after 2030. Climate change targets are routinely set for 2050 and 2080 recognising the long term dynamics of the climate system. Climate is one potential threat to biodiversity, but species and ecosystems also demonstrate dynamics that may play out over decades to centuries. Hence we argue that a longer term goal is crucial. We adopt the CBD vision for 2050 ("*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people*."). While this currently has no specific indicators we adopt the scientifically-based assessments of biodiversity conditions that are required for a sustainable Earth system using the planetary boundaries framework (Mace *et al.* 2014; Steffen *et al.* 2015). The planetary boundary for biodiversity represents a safe operating space where biophysical conditions are such that the Earth life support systems are stable and supportive. In the latest formulation of the boundaries there are two metrics for biodiversity, one is that the extinction rate should be less than 10 extinctions per million species years (reflecting the maintenance of genetic diversity) and the other is that the functional ecological diversity should be maintained. Functional diversity means that the species composition within key areas (biomes or large regional areas) are maintained at close to historical levels. Steffen et al. (2015) recommend using the Biodiversity Intactness Index to measure this metric of the biodiversity boundary (see below).

We use both extinction rate and functional diversity targets for 2050 reflecting the levels recommended by the planetary boundaries framework as a representation of the CBD 2050 vision.

B. Defining the metrics

Overview of biodiversity metrics

Biodiversity indicators are now being widely reviewed in the Aichi and IPBES processes (Kim *et al.* 2018). The multiplicity of indicators is inevitable given the many dimensions of biodiversity change. However, different metrics that are in common use have different properties and their responses to pressures vary (Hill *et al.* 2016) and so it is important to select metrics that are relevant and fit-for-purpose. We suggest that the measurement of progress towards the CBD vision and the CBD and SDG targets can be based on a minimum of three biodiversity dimensions. These are measures of conservation status (the global extinction rate), changes in species abundance (local and global), and changes to local biodiversity (abundance and composition representing function). Three metrics that are effective proxies for these are described here.

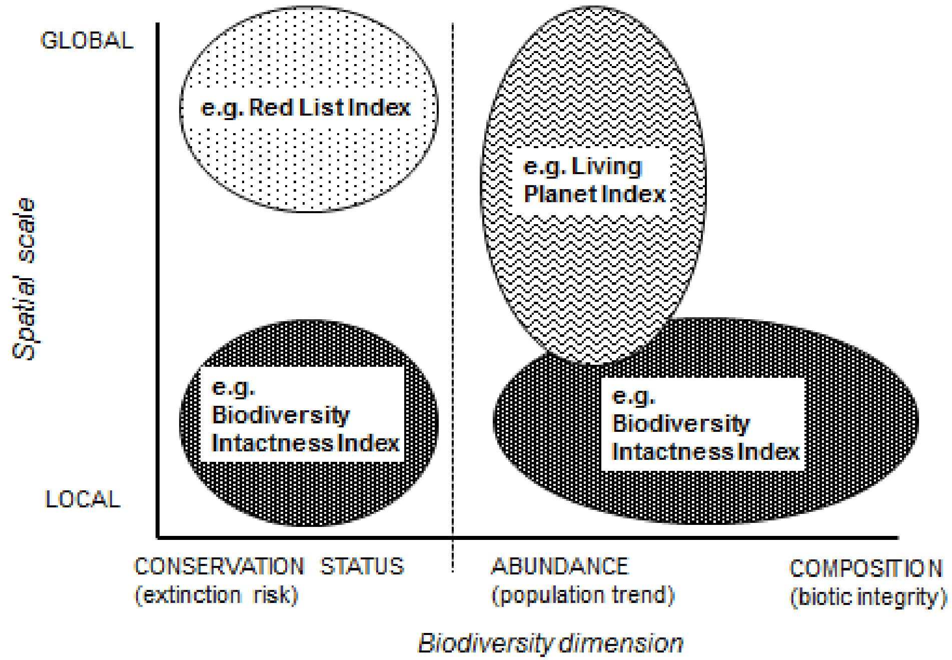

Figure S1:

Diagrammatic representation of the attributes of biodiversity metrics needed to represent targets in the CBD and SDG goals. Changes to species richness at global level represent the overall extinction rate, and changes to population abundance of wild species at large to global scales measure overall population declines. Local level species richness, abundance and composition contribute to ecosystem functions and services.

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The Red List Index (RLI)

The Red List Index (RLI), based on the IUCN Red List of Threatened Species, is based on the conservation status of major species groups, and measures trends in global extinction risk over time so showing loss of global species richness (Butchart *et al.* 2004; Butchart *et al.* 2007). Its value varies from 1.0, when all species are Least Concern according to the IUCN Red List category classification system, to 0 when all species are Extinct. The number of species in the threat categories of Critically Endangered, Endangered and Vulnerable determines the value of the Index between 0 and 1, and as the conservation status of species improves they move towards lower categories of threat and the value of the index increases. By conducting conservation assessments at regular intervals, changes in the threat status of species in a taxonomic group can be used to monitor trends in extinction risk. RLIs have been calculated from comprehensive data for birds, mammals, corals and amphibians, using changes in threat status for species in each of the groups. The current value ranges from about 0.75 (amphibians) to just over 0.9 (birds) with all trends being downwards since 1980 or later. Where data are incomplete because not all species have been assessed the RLI can be calculated using a sampled approach (Baillie *et al.* 2008). See http://www.iucnredlist.org/about/publication/red-list-index for details.

The RLI is calculated using only the total number of species in each of the 5 threat categories in the IUCN Red List (Least Concern, Vulnerable, Endangered, Critically Endangered and Extinct). Each of these categories can describe quite a broad range of population sizes and geographical range areas, as well as recent rates of decline, extent of fragmentation etc. Hence, improvements and degradations in the conservation status of species can take place without there being any signal in the RLI. The RLI is also a slow-moving index because many of the quantitative criteria are measured relative to species generation times (in order to reflect the real dynamics of species extinctions) and not to years. Hence trends in the RLI are difficult to interpret over short periods of time (5 years or less).

The Living Planet Index (LPI)

The Living Planet Index (LPI) is an indicator based on trends in the abundance of vertebrate populations of species from around the world. The global LPI is calculated using over 14,000 of these population time-series which are gathered from a variety of sources such as journals, online databases and government reports. A generalized additive modelling framework is used to determine the underlying trend in each population time-series. Average rates of change are calculated and aggregated to the species level (Collen *et al.* 2009). Between 1970 and 2012 the index fell by 58% according to the latest analyses reported by WWF in the Living Planet Report 2016 http://wwf.panda.org/about_our_earth/all_publications/lpr_2016/.

Because the LPI measures changes in population abundance it can change quite rapidly with trends in threats. However it does not necessarily reflect species extinction risks. In fact if, as is likely, the species in most rapid decline are more likely to go extinct, then the LPI could increase with species extinctions unless extinct species were somehow kept within each updated calculation, perhaps by giving them an arbitrary but very small population size. There are no plans to do this at present. This may be less of a problem if more common species are also likely to be affected by the threats driving extinctions, but it is clear that the LPI and RLI are best used together to gain an understanding of overall changes in both species numbers and species abundances (Hill *et al.* 2016).

The Biodiversity Intactness Index (BII)

The Biodiversity Intactness Index (BII) measures the average abundance of originally present species across a broad range of species relative to their abundance in an undisturbed habitat (Scholes & Biggs 2005). BII reflects functional diversity inasmuch as it reflects human impacts on community composition across a very wide range of functional groups, rather than being at all taxon-specific; the lack of comprehensive data on species' functional ecology precludes any direct trait-based indicators of functional diversity. BII also differs from most indicators in being calculated as an average across local communities, which is the appropriate scale for a measure of the biodiversity underpinning ecosystem function. It is the proposed metric for area-based measures of loss of functional biodiversity suggested by Steffen et al (2015), who suggested a safe limit for the planetary boundary be placed at a precautionary 10% reduction, but note that it could be up to 70%. One key uncertainty when estimating safe limits is the role played by species that are now present but were not in the undisturbed system. These non-native species could benefit or be a detriment to ecosystem functioning. The BII has been implemented most recently in the PREDICTS global biodiversity modelling framework (Hudson *et al.* 2014; Newbold *et al.* 2015; Purvis *et al.* 2018), where the BII was estimated across the terrestrial land surface at 1km^2 grid cell scale (Newbold *et al.* 2016). They estimated both overall net change (correct if novel species contribute fully to ecosystems) and—using estimates of species turnover among land uses to exclude novel species—they also measured change only in species originally present (correct if novel species play no role) (Newbold *et al.* 2016). The BII can be measured at a range of spatial scales or for other defined areas such as biomes, countries or ecoregions although there are technical issues that complicate the metrics at both large and small spatial scales and the metric is also strongly affected by the weighting applied in the calculation of the metric .

For the purpose here, to reflect the CBD vision for 2050, we propose estimating the BII at two spatial scales. The smaller scale (ecoregion (Olson et al. 2001)) representing the influence that local ecosystem functions have on people, and a larger (biome) scale representing the influence that large scale biomes have on earth system stability (Mace *et al.* 2014). The PREDICTS model estimates BII using pressure-response relationships derived from observations and here will include land use and its intensity, the proximity of roads and human population density. The BII is an interim metric in the absence of an effective control variable being identified for each biome. We recognise that the 90% threshold is very precautionary; but justify this on the ground that the BII is quite permissive; the model may underestimate impacts (Newbold *et al.* 2015; Newbold *et al.* 2016; Purvis *et al.* 2018). The BII is based in estimates that exclude non-native species and is abundance weighted.

Other biodiversity metrics

The three indicators we have selected here were chosen because they are well-established, globally relevant and robust. By this we mean that they have all already been used by intergovernmental biodiversity processes and are widely applied for biodiversity assessments, with some of the indicators being developed to meet the defined need of CBD implementation. Each has a methodology that is published in a peer-reviewed journal, and has been well used and adapted by groups other than the developers for multiple purposes. There is extensive data behind each one, with global coverage. All of these indicators also have open-access methods and datasets that are being actively maintained by well-founded institutions (IUCN, WWF, NHM London). We do not propose that that these are the only suitable indicators, and we anticipate that linking clearly to existing goals and targets will stimulate the development of improved metrics. Other models and indicators are already available and are being actively developed in IPBES, who have also published a useful review of biodiversity modelling (Kim *et al.* 2018) including BILBI/BHI for conservation status (Hoskins *et al.* 2018) and MSA for biotic integrity (Alkemade *et al.* 2009).

C. The targets and required levels for metrics:

Target	Target text	Object	Target for Conservation status (e.g. Red List Index RLI)	Target for Population trend (e.g. Living Planet Index LPI)	Target for Biotic Integrity (e.g. Biodiversity Intactness Indicator)
CBD Aichi target 12	By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.	Known threatened species i.e. the ~25,000 species on the IUCN global Red List. An improvement in conservation status would entail a species increasing in population to a point where it moves into a lower IUCN Red List Category threat category. This means the LPI should not decline further for threatened species. Also there should be no further extinctions.	Should be at least level by 2020 for threatened species – i.e. The threat status of all threatened species (CR, EN and VU) is at least stabilised. No CR species are EX. May continue to decline for all species beyond 2020 (as species may still *become* threatened)	Population trends for threatened species (CR, EN and VU) should be stabilised, possibly resulting in a slowing of overall trends.	No relevant target. Threatened species are very rare and abundances are low. Therefore they do not feature in the BII.
SDG 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt	The overall target is to halt biodiversity loss – so it is arguably all species and not just known, threatened species. The sub-target reiterates Aichi 12, but has the more general frame to halt	The RLI index should be stable by 2030, no more extinctions and species not moving into higher threat categories. The Index should start to head upwards.	The LPI should stabilise by 2030 and start to turn around.	Headline target has terrestrial ecosystems being restored and used sustainably by 2030, so in certain areas BIIs should improve by 2030.

	biodiversity loss (15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species)	biodiversity loss, so no further loss of abundance			For the 15.5 target. Both abundance and richness metrics of BII level off and show no further decline across the spatial areas being analysed.
Planetary boundary for biosphere integrity[1] NB. We align this to the CBD vision: "*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits*	a) <u>Genetic diversity</u>: Extinction rate; < 10 E/MSY (10–100 E/MSY) but with an aspirational goal of ca. 1 E/MSY (the background rate of extinction loss). (E/MSY = extinctions per million species-years) b) <u>Functional diversity</u>: Biodiversity Intactness Index (BII) Maintain BII at 90% (90–30%) or above, assessed geographically by biomes/large regional areas (e.g. southern Africa), major marine ecosystems (e.g., coral	All species, though (b) is in theory about function, there is no recommendation for functional groups being treated separately. Area-based metrics are meaningful for function and we use ecoregions (for smaller scale reflecting ecosystem functions affecting people) and biomes (for larger scale reflecting biome influences on earth system stability) (see text above)	a) Recovery of RLI. It should show positive movement towards 1.0 b) Recovers to close to 1.0	a) Population sizes are increasing, potentially to 1970 levels. b) it is likely that the LPI measure of abundance will respond positively where BII trends move to a better state.	a) not relevant b) small and large scale Ecoregions. Use 90% threshold. By 2050 70% of ecoregions are above the threshold, and it is improving. Biomes. By 2050, all biomes are above the threshold with low risk that any of them will drop below.

[1] From Table 1 Steffen et al 2015

essential for all people.	reefs) or by large functional groups.				

Trajectories for biodiversity to 2050

Figure 2 in the main paper illustrates recovery curves for the three categories of biodiversity metrics based in the LPI, RLI and BII indicators. The curves are plotted based on recent data and analyses by the authors, but are necessarily approximate, and so the axes are left unlabelled. Future work will improve the quality of the data and the nature of target levels. In the figure shown here the following data were used.

	RLI			LPI			BII (proportion above 90%	
year	**all**	**threatened**	**year**	**all**	**threatened**	**year**	**biomes**	**ecoregions**
2010	0.95	0.72	2010	0.41	0.18	2010	0.36	0.45
2020	0.87	0.73	2020	0.25	0.15	2020	0.30	0.40
2030	0.85	0.75	2030	0.25	0.15	2030	0.45	0.45
2040	0.90	0.82	2040	0.41	0.30	2040	0.75	0.60
2050	0.97	0.92	2050	0.92	0.85	2050	1.00	0.70

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