POLICY FORUM

BIODIVERSITY

Set ambitious goals for biodiversity and sustainability

Multiple, coordinated goals and holistic actions are critical

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Global biodiversity policy is at a crossroads. Recent global assessments of living nature (*1*, *2*) and climate (*3*) show worsening trends and a rapidly narrowing window for action. The Convention on Biological Diversity (CBD) has recently announced that none of the 20 Aichi targets for biodiversity it set in 2010 has been reached and only six have been partially achieved (*4*). Against this backdrop, nations are now negotiating the next generation of the CBD's global goals [see supplementary materials (SM)], due for adoption in 2021, which will frame actions of governments and other actors for decades to come. In response to the goals proposed in the draft post-2020 Global Biodiversity Framework (GBF) made public by the CBD (*5*), we urge negotiators to consider three points that are critical if the agreed goals are to stabilize or reverse nature's decline. First, multiple goals are required because of nature's complexity, with different facets—genes, populations, species, deep evolutionary history, ecosystems, and their contributions to people—having markedly different geographic distributions and responses to human drivers. Second, interlinkages among these facets mean that goals must be defined and developed holistically rather than in isolation, with potential to advance multiple goals simultaneously and minimize trade-offs between them. Third, only the highest level of ambition in setting each goal, and implementing all goals in an integrated manner, will give a realistic chance of stopping—and beginning to reverse—biodiversity loss by 2050.

Achieving this will require prompt and concerted measures to address the causes of biodiversity loss (*6*), meaning that implementation will be crucial. The draft GBF (*5*) has advanced conceptually relative to its predecessor by highlighting the importance of outcome-oriented goals (i.e., what we want the state of nature to be in 2050 in terms of, for example, species extinction rates or ecosystem area and integrity). These outcome goals link the broad aspirational vision ("living in harmony with nature"; see SM) to the concrete actions needed to achieve it. The outcome goals—operationalized by more specific targets and assessed using indicators—provide a compass for directing actions and a way of checking their results; for example, whether meeting a set of action-based targets (e.g., designating X% of Earth's surface as protected areas) delivers on a desired outcome (e.g., "no net loss in the area and integrity of natural ecosystems") needed to realize the aspirational vision. It is more important than ever that the necessary outcomes are incorporated in the GBF and that they adequately cover the distinct facets of nature, are sufficiently ambitious, and are grounded in the best knowledge available.

Various proposals for the new CBD outcome goals have focused on individual facets of nature, such as ecosystems (*7*), species (*8*), or genetic diversity (*9*). What has been missing is a unified view on how these facets relate to each other in setting goals to achieve the CBD's 2050 vision. To address this gap, we surveyed, evaluated, and discussed published proposals of goals for ecosystems, species, genetic diversity, and nature's contributions to people (NCP) in relation to the empirical and theoretical knowledge in the scientific literature. Our evaluation addresses whether proposed goals encompass, are consistent with, or are opposed to each other; whether they are sufficiently ambitious such that meeting them will indeed curb and reverse biodiversity trends; and whether they contain all the elements needed to make them difficult to "game" (i.e., avoid making substantial contributions by exploiting weaknesses in wording) (see SM for details on our analysis).

DISTINCT GOALS

As the failure to achieve the CBD's single 2010 goal—to substantially reduce the rate of biodiversity loss—shows, having an "apex" goal does not guarantee success. Whereas the mission of the United Nations Framework Convention on Climate Change (UNFCCC) focuses on one main outcome—preventing dangerous climate change, for which one goal and indicator (well below 2°C) provide a reasonable proxy for the others—CBD's vision and mission have three components that are distinct, complementary, and often trade off with each other: conserving nature, using it sustainably, and (though we do not consider this component here) sharing its benefits equitably. The nature conservation component is itself complex because biodiversity includes variation in life at all levels, from genes to ecosystems. Recognizing this, the proposed formulation of the GBF (*5*) (see SM) started by proposing separate goals that explicitly covered ecosystems, species, genetic diversity, and the contributions to people derived from them. Whether this structure is retained, or the necessary outcomes for these facets are instead subsumed into more overarching goals, our analysis (see SM) shows that all these facets need to be addressed explicitly because of how they interrelate. If the facets were nested into one another like Russian dolls, or at least nearly so, then a single concise goal that specifies one number about the most encompassing facet could cover all of them. However, although the facets of nature are deeply interlinked, they are far from neatly nested and represent instead a "minimum set" (*10*, *11*). As a result, there is no single goal based on any one facet that would, if realized, guarantee by itself that the necessary outcome for the other facets would be achieved (*12*, *13*).

Another reason for having multiple goals is "Goodhart's law": Whenever a measure becomes a policy goal itself, it ceases to be a good measure of the true state of the system because it can be "gamed" (*14*). For example, incentives would favor actions to enhance the targeted metric irrespective of effects on the rest of nature. Given nature's multidimensionality, this approach would cause inefficient use of resources at best and possibly promote perverse outcomes (*14*). If the CBD enshrined an "apex" goal focusing on a single facet of nature, other facets may be relegated to the back seat. By incentivizing holistic actions, a framework with multiple

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Sustainability at the crossroads

Columns show different facets of nature and their contributions to people (NCP). Each cell shows a potential goal (in bold) at a particular level of ambition in attaining it and some consequences of reaching it, including effects on the other facets of nature and NCP. Only the scenario in green would contribute substantially to "bending the curve" of biodiversity loss. See supplementary materials for further details.

GOALS	ECOSYSTEMS	SPECIES	GENES	NATURE'S CONTRIBUTIONS TO PEOPLE
LOW AMBITION – DECLINE	**Lax "no net loss"** • Critical ecosystems lost • "Natural" ecosystems lose integrity and function • Unchecked extinction and loss of genetic diversity • Ecosystems less able to provide resilient flows of NCP	**Stabilize extinction rate and average abundance** • Continued rapid extinction of species and populations • Many ecosystems altered by, e.g., loss of megafauna • Threatened species lose adaptability	**50% conserved** • Critical ecosystems cannot adjust to climate change • Many species can no longer adapt and die out • Crops and livestock more vulnerable to pests and diseases, causing famines	**Few NCP secured** • Critical ecosystems cannot adjust to climate change • Many species can no longer adapt and die out • Crops and livestock more vulnerable to pests and diseases, causing famines
MEDIUM AMBITION – UNCERTAIN FUTURE	**Strict "no net loss"** • "Natural" and "managed" ecosystems keep functioning and delivering NCP • Critical ecosystems stabilized • Species currently with too little habitat will go extinct	**Reduce extinction rate and stop rare species declines** • Many species saved • Large or specialist species may still go extinct • Many ecosystems lose functions delivered by particular groups of species	**75% conserved** • Most species can adapt • Ecosystem adaptability safeguards many NCP, but others are diminished • Many species at risk from reduced adaptability to climate change	**Some NCP secured** • Some NCP secured but critical shortfalls in many • Ongoing deterioration of "natural" and "managed" ecosystems and species that deliver NCP • Climate risks remain
HIGH AMBITION – ROAD TO RECOVERY	**Strict "no net loss" and targeted protection and restoration** • Net increase in "natural" ecosystem area and integrity • Large numbers of species and much genetic diversity saved • NCP flow from "natural" and "managed" ecosystems secured	**Minimal loss of species and populations** • Stabilizes species abundance, including particular groups delivering ecosystem functions and NCP • Safeguards the "tree of life" • Saves culturally important species	**90% conserved** • Resilient ecosystems • Safeguards adaptability of most of rare species • Crops, livestock, and their wild relatives can adapt to pests, diseases, and climate change	**Broad range of NCP secured** • Food, water, health, and climate security for the most vulnerable people • More resilient "natural" and "managed" ecosystems • Nature-based solutions reduce climate risk

goals reduces the risk that the goals could be achieved without also achieving the overarching vision that they were intended to serve.

HOLISTIC ACTIONS

The interdependence of ecosystems, species, genetic diversity, and NCP offers the opportunity to design policies and actions that contribute to multiple goals simultaneously. This offers the possibility for mutually reinforcing goals, in which progress toward one goal also advances the others, even though each facet of nature will also require targeted actions to address its specificities (see SM). For example, restoring ecosystems that are species-rich, have many endemics, and store large amounts of carbon, such as tropical peatlands, contributes toward all goals. The downside of this interdependence is that failure to achieve one goal will likely undermine others in a negative mutually reinforcing cycle: Ongoing loss of area and integrity of tropical peatlands leads to global extinctions and reduces options for climate mitigation; climate change then causes further loss of ecosystems, species, populations, genetic diversity, and NCP (see SM).

Although the scientific and management communities have been long aware of interactions among biodiversity goals and targets, these linkages have not been sufficiently operationalized (*11*). We highlight the need for the connectedness, partial dependence, and imperfect nesting of nature's facets to be built right from the start in the design of outcome goals, targets, indicators, and actions. In addition to addressing different facets of nature, goals must be set across the whole gradient from "natural" to "managed" ecosystems, attending to the specificities of these different landscapes (see SM).

NEED TO AIM HIGH

Holistically designed goals on ecosystems, species, genetic diversity, and NCP are necessary to achieve the 2050 vision; whether they are sufficient will depend on the level of ambition that these goals reflect. Even perfect implementation cannot make up for outcome goals set too low or too narrowly at the start. Different levels of ambition are, for example, whether the curve of biodiversity loss will bend (high ambition) or merely flatten (low), or whether no net loss of ecosystems is specified with a lax (low) or strict (high) criterion for replaceability (see SM). The interdependence among facets of nature means that missing a goal for one facet risks also missing goals related to other facets, whereas achieving each goal at a sufficient ambition level can contribute to reaching the others. Our synthesis of the evidence (see the figure, and SM) illustrates that the CBD's 2050 vision is feasible only by aiming high with each of the goals. Lower levels of ambition will deliver inadequate outcomes, including loss in area and integrity of ecosystems, more global extinctions, reduced abundance and performance of many important species, loss of genetic diversity, and reduced benefits to people. This would not only compromise the objectives of the CBD but also undermine progress toward most of the United Nations Sustainable Development Goals and the Paris Climate Agreement (*1*). The stakes are high.

MULTIPLE GOALS, ONE VISION

Our arguments for setting multiple goals do not mean that there is no place for a compelling and unifying overarching vision. Collective action over more than a century offers a clear lesson: To gain political traction, any unifying vision needs to be a rallying cry—broad, normative, inspirational, and aspirational. The CBD process has already set such clear vision: "living in harmony with nature." The goals underpinning the vision, by contrast, need to be unambiguous and strongly based on the best available knowledge to make it possible to derive SMART (specific, measurable, assignable, realistic, time-related) operational targets (*15*) from them.

In sum, one compelling overarching vision, buttressed by facet-specific goals that are mutually reinforcing, scientifically tractable, and individually traceable, will deliver the overarching vision more reliably than any single-facet goal. Using a single-facet goal as the only flagship of global biodiversity policy is analogous to using blood pressure or body mass index as the sole surrogate for the vision of "vibrant health": simple but risky.

COP15 AND BEYOND

The main challenge ahead lies not in the number of goals but rather in making them happen. However many goals are in the GBF, their specific wording and the supporting framework of targets and indicators will be equally influential on global policy. This wording will be decided by the governments at the 15th Conference of the Parties (COP15) of the CBD in 2021. We summarize critical elements emerging from our analysis that we hope delegates will consider when establishing the GBF, intended to help maximize positive impacts of each goal and minimize perverse interpretations (see the box).

We have deliberately focused on how the different facets of nature and their contributions to people should look in 2030 and 2050 to achieve the CBD 2050 vision (with 2030 seen as reflecting crucial "stepping stones" in the right direction toward 2050). We have not evaluated the economic and political consequences of the proposed goals nor the governance and distributional challenges of their implementation. In the case of NCP, we focused on their generation rather than on how they are accessed to meet actual needs and therefore result (or not) in people's good quality of life. Implementing actions to achieve these outcomes without considering social and political issues would be a recipe for further failure. We thus provide just one piece of the formidable puzzle that must be resolved. But it is an essential piece: what could be effective from the biological perspective, provided that the right actions are implemented and all relevant actors are involved in pursuing them. Actions to implement these goals will need to tackle the indirect socioeconomic drivers (and underlying value systems) at the root of nature's decline as well as the direct proximal drivers on which conservation has mostly focused to date (*1*). Only then will the 2050 vision have a chance. We exhort the parties to be ambitious in setting their goals, and holistic in their actions afterward, to transition to a better and fairer future for all life on Earth. ■

Key considerations for 2050 biodiversity goals

The following key elements are essential for the new post-2020 Convention on Biological Diversity goals. If not fully expressed in the actual goals, they should structure the action targets and indicator framework. To clarify their ambition and enable tracking of legitimate progress, all goals need to have clear reference years (e.g., 2020). For detailed explanations and supporting references, see supplementary materials.

The ecosystems goal should:

- Include clear ambition to halt the (net) loss of "natural" ecosystem area and integrity.
- Expand ecosystem restoration to support no net loss by 2030 relative to 2020, and net gain of 20% of area and integrity of "natural" ecosystems and 20% gain of integrity of "managed" ecosystems by 2050.
- Require strict conditions and limits to compensation, including "like-for-like" (substitution by the same or similar ecosystem as that lost) and no loss of "critical" ecosystems that are rare, vulnerable, or essential for planetary function, or which cannot be restored.
- Recognize that improving the integrity of "managed" ecosystems is key to the continued provision of many of nature's contributions to people.
- Recognize that outcomes of conservation and restoration activities strongly depend on location and that spatial targeting is essential to achieve synergies with other goals.

The species goal should:

- Have clear ambitions to reduce extinction risk and extinction rate across both threatened and nonthreatened species by 2050, with a focus on threatened species in the short term.
- Focus on retaining and restoring local population abundances and the natural geographical extent of ecological and functional groups that have been depleted, and on conserving evolutionary lineages across the entire "tree of life."

The genetic diversity goal should:

- Include maintenance of genetic diversity—the raw material for evolutionary processes that support survival and adaptation; population size is not an adequate proxy for this.
- Be set at the highest ambition level (e.g., above 90% of genetic diversity maintained).
- Focus on populations and their adaptive capacity and include wild species and domesticated species and their wild relatives.

The nature's contributions to people (NCP) goal should:

- Be addressed directly in a goal that recognizes NCP (e.g., food, medicines, clean water, and climate regulation) and avoids conflation with a good quality of life (e.g., food security or access to safe drinking water), which results from other factors as well as from NCP.
- Encompass spatial and other distributional aspects, such as provision from both "natural" and "managed" ecosystems, and inter- and intragenerational equity to ensure benefits to all.

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SUPPLEMENTARY MATERIALS

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Supplementary Materials for

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This PDF file includes:

- Supplementary Text: Author Affiliations
- Disclosures
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Supplementary Text: Author affiliations

Supplement S1. A New Global Intergovernmental Framework for Biodiversity

Supplement S2. Co-benefits of holistic action

Supplement S3. Goals for “natural” and “managed” ecosystems

Supplement S4. Different levels of ambition in setting individual goals for nature

Supplement S5. Formulating biodiversity goals for a better planet - A science-based annotated checklist

References (refs 1 to 164)

Supplementary Materials for

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Supplementary Materials for

Set ambitious goals for biodiversity and sustainability

Supplement S1. A New Global Intergovernmental Framework for Biodiversity

The CBD is an intergovernmental treaty that entered into force in December 1993. It has 196 Parties (195 countries and the European Union) with the aim of conserving and ensuring the sustainable and equitable use of biodiversity. At the beginning of each decade, its Conference of the Parties (COP) defines a new global biodiversity policy framing for national governments, which is also taken as guidance by other stakeholders, such as regional governments, NGOs, educators and scientific bodies and the wider UN system. The first policy framing of this century was the Strategic Plan of 2002, which aimed to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth" *(16)*. It was declared unachieved in 2010 *(17)*. Then followed the ten-year Aichi Biodiversity Targets, established in 2011, together with the CBD's overarching Vision for 2050, "Living in Harmony with Nature", and expressed more explicitly as "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people."*(16)*. The Aichi Targets were due in 2020 and the Global Biodiversity Outlook 5 concluded that a minority of them (6 out of 20) showed some degree of achievement *(4)*. The Conference of the Parties (COP 15) charged with defining the new strategic plan for the decade 2021-2030, termed the post-2020 Global Biodiversity Framework (GBF), has been postponed due to the Covid-19 pandemic and will be held in 2021 in China. As a result, the consultation phase for the GBF has been extended considerably, allowing for greater inputs through submissions and comments from CBD Parties and Observers, including from consultative workshops.

The GBF is being developed through a consultative drafting process. The Zero Draft *(5)* was released in January 2020 and identified five broad goals in pursuit of the 2050 Vision. Four of them corresponded to three major aspects of biodiversity – ecosystems, species and genetic diversity within species – and the benefits that people derive from these. The fifth Goal concerned the fair and equitable sharing of benefits from the use of genetic resources and associated traditional knowledge. In an updated version released in August 2020 the three 'biodiversity' goals were combined into a single goal, so that the three goals in the updated Zero Draft correspond to the three objectives of the Convention (conserving nature, sustainable use and equitable sharing of benefits), thus also aligning the GBF more effectively with the Vision for 2050 set for the Convention, of "Living in Harmony with Nature".

To accommodate potential further changes to final text of the GBF, in this article we use the term 'goal' with a lower-case "g" in parallel with the term 'outcome', recognizing that Parties may select final goals for the Framework based on multiple other considerations. Our findings will be relevant in any reorganization of the Framework if the elements we suggest as critical are retained in some element of the final Framework.

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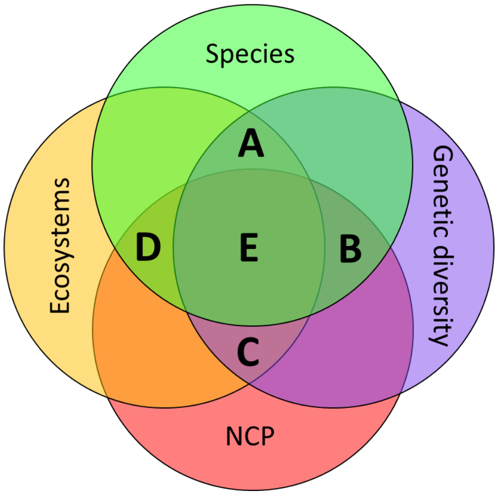

Figure S2. Co-benefits of holistic actions. The interdependence among the different facets of nature means that actions aimed at any one of them –ecosystems, species, genetic diversity and nature's contributions to people (NCP)– can be designed to simultaneously contribute to others and minimize trade-offs. Letters indicate intersections across three (**A-D**) or all (**E**) of the facets; actions across these intersections will be necessary to achieve the 2050 Vision in addition to other goal-specific actions. Illustrative examples of such actions are: **A**. Effective conservation of places harbouring threatened species and ecosystems *(18)*; **B**. Protecting domesticated breeds and varieties in situ through traditional agricultural practices *(19)*; **C.** Restoration of ecosystem functioning, and the contributions to people that result, by reintroducing locally extinct species with important ecological roles *(20)*; **D**. Ecological intensification of agricultural landscapes *(21)*; and **E**. Restoring species-rich high-endemism high-carbon ecosystems *(22)*. Although actions in the intersections help progress towards multiple goals simultaneously, no single action can achieve the 2050 Vision. For example, restoring ecosystems that are species-rich, have many endemics and store large amounts of carbon contributes towards all goals (section **E**) but would, by itself, do nothing for many NCP unrelated to climate, for all other ecosystems, or for the species, populations and genetic diversity unique to them. However, a failure to conserve ecosystems represented in section **E** would –because of the interdependence among nature's facets– jeopardize all four goals: continued loss of area and integrity of such ecosystems will drive global extinctions *(23)* and reduce options for climate mitigation; climate change will then drive further loss of ecosystems, species, populations, genetic diversity and NCP *(24)*. The interdependence means that failure to achieve one goal can propagate to the others. Ongoing reductions in area and integrity of ecosystems result in smaller populations, less genetic diversity and, in ecosystems with high endemism, global extinction of many species (see S3 annotation **c**)**.** Local extinction of keystone species —for instance, top predators, large herbivores, habitat-forming species such as large trees and corals— can substantially erode ecosystem integrity and capacity to generate NCP (see S3 annotation **i**). Loss of genetic diversity undermines wild species survival and increases risk of extinction, with effects at the level of ecosystems and NCP. Continued extinction of varieties and domesticated breeds of plants and animals, and over-reliance on narrow genetic stock from a few lineages in agriculture, forestry and fisheries reduce future food security and results in dramatic declines in NCP (see S3, annotation **k**). While these examples focus on direct drivers of nature decline, achieving the 2050 Vision also requires strong emphasis on tackling the indirect drivers – the socioeconomic factors that are the root causes of biodiversity loss *(1, 2, 25)*. Tackling indirect drivers rather than direct drivers is more likely to make progress towards multiple goals.

Supplementary Materials for

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Supplement S3. Goals for "natural" and "managed" ecosystems

On land and in water, ecosystems span a wide gradient of human influence, from those with relatively low human imprint (sometimes called wilderness) to those almost entirely assembled by humans, such as croplands, aquaculture ponds or green urban spaces. Goals need to be set across the whole gradient, attending to the specificities and values of these different landscapes. A pragmatic distinction between "natural" and "managed" ecosystems is needed to accommodate the different approaches these require in global goal-setting, policy and action, and also to avoid perverse outcomes from substitution among them *(26)* (see S4, annotations **b-d**).

"Natural" ecosystems, in the context of this article, are those whose species composition is predominantly native and determined by the climatic and geophysical environment. This is not to say they are devoid of human influence. The majority of "natural" ecosystems have been reconfigured by people to a significant extent, although not to a degree that would make them "human-made" in the same way that "managed" ecosystems are. Even those that would qualify as "wilderness" *(7)*, such as the Amazonia, the great Western Woodlands of Australia, the Congo forests of central Africa, or the Canadian Arctic Archipelago, do not necessarily exclude human habitation, management and use, sometimes for millennia *(27-29)*. Moreover, many of them are strongly managed to maintain their perceived natural state *(30, 31)*. "Natural" ecosystems are not only reservoirs of biodiversity per se; even those at the most intact extreme have high practical value to people. For example, large areas of carbon-dense old-growth forest, quintessential examples of "human-less" nature, are crucial to global climate stability: halting their conversion and loss is essential to protecting nature and to achieving the Paris Climate Agreement *(32)*.

"Managed" ecosystems, in the context of this article, are those whose biotic composition is the result of deliberate manipulation by people, this often being a stronger factor than climate or substrate. In many cases the main plant or animal assemblages are designed anew for the purposes of serving human ends, such as providing food, fibers, energy or recreation. Obvious examples are agricultural fields, orchards, urban parks, aquaculture ponds, artificial reefs, rice paddy terraces, and many plantations. "Managed" landscapes and seascapes should not be considered as "lost for nature"; they host the greatest proportion of the world's biodiversity of domesticated organisms *(33)* and also a significant proportion of wild biodiversity, including wild relatives of crops *(33, 34)*.

While the "wildest" extreme of "natural" ecosystems and the most artificial extreme of "managed" ecosystems are starkly different, the limits between the highest-integrity "managed" ecosystems and the most heavily reconfigured "natural" ecosystems are necessarily arbitrary. Many traditional cultural landscapes lie in the transition zone. Examples include traditionally burned hunting and grazing lands in Africa and Australia *(35)*, "dehesas" in southern Europe *(36)*, hay and sheep grasslands in Europe and Asia *(37, 38)*, and "vegas" (wet meadows) in the high Andes *(39)*. This practical and somewhat artificial distinction therefore should not be conflated with unhelpful dichotomies such as "natural (=human-less) ecosystems for nature" versus “managed ecosystems for people”. Such dichotomies often underestimate the societal value of nearly intact ecosystems *(7)*, promote their value as “human-free paradises” and thus alienate the ancestral rights of inhabitants *(29)*, or place no conservation value (and therefore no biodiversity management or safeguards) in “managed” ecosystems *(40)*. A conservation focus solely on “natural” ecosystems also misses the fact that most NCP are co-produced by people and nature and thus often require proximity to people for their effects to be realized (e.g., flood regulation, recreation) or to agricultural crops (e.g., habitat for pollinators), so they must happen predominantly in “managed” ecosystems. Moreover, biodiversity goals that exclude inhabited and everyday landscapes may further separate people from nature and lead to a lack of public support and awareness.

Safeguarding the higher-integrity “natural” ecosystems and enhancing “managed” ones therefore represent complementary strategies *(41)*; only by setting clear goals and actions for the whole range of ecosystems can all facets of biodiversity be addressed and unintended consequences avoided *(26)*.

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Supplement S4. Different levels of ambition in setting individual goals for nature. In order to deliver the CBD's 2050 Vision, each of the high-level goals needs to be unpacked in quantitative targets. The achievement of the goals will directly depend on whether such targets, and the efforts to materialize them, are set ambitiously or cautiously. The tables summarize levels of ambition, alignment with the 2050 Vision, feasibility, and associated benefits or risks of goals for ecosystems, species and genetic diversity.

Goal	**Level of ambition**	**Alignment to 2050 Vision**	**Benefit/Risk for biodiversity and NCP**
ECOSYSTEMS			
No net loss in area or integrity between 2020 and 2030 (any loss balanced by restoration)			
Without safeguards to avoid substitution between ecosystems	**Low -** improvement over current trends needed	Poor	Insufficient to prevent perverse outcomes that negatively affect biodiversity and NCP
With safeguards avoiding substitution between ecosystems	**Medium -** requires dedicated action to balance losses	Good	Possible to largely meet goal, but still lose many species and critical ecosystems and related key NCP
With safeguards avoiding substitution between ecosystems and a no loss of critical ecosystems	**High -** requires dedicated action to balance losses and expand full protection to all critical ecosystems	Very good	Necessary to prevent loss of critical ecosystems and maintain NCP provision. Some residual loss of species and genetic diversity possible
Net gain by 2050 (net gain of area and integrity of ecosystems through retention and restoration)			
0% net gain	**Low -** improvements over current trends needed	Poor	Bending the curve *(42)* for goals b, c and d cannot be achieved without net gain
20% net gain of area and integrity (not targeted)	**High-** transformative change needed to make land and sea available to achieve area expansion of 'natural' ecosystems	Good	Will strongly contribute to achieving goals b, c and d but there is high variation in the contribution depending on the targeted areas and ecosystems
20% net gain of area and integrity targeted through integrated planning	**Very high -** requires transformative change and adoption of integrated land and sea use planning. Integrated planning helps to	Very good	Secures optimal outcomes towards achieving goals on other facets of nature

	maximize outcomes and reduces overall costs, which might make it more achievable		
SPECIES			
Extinction rates			
Halt increase (0% change) in extinction rates through 2030 and 2050	**Low** - but better than business-as-usual	Very poor	Many species are lost, loss of evolutionary history, degradation and/or collapse of ecosystems and many NCP, before 2050 and/or beyond
Reduction in extinction rates – 10% by 2030, 50% by 2050	**High** - requires transformative change	Intermediate	Many species are lost, loss of evolutionary history, degradation of ecosystems and many NCP, before 2050 and/or beyond
90% reduction in extinction rates	**Very high** - requires **major** transformative change Likely the upper bound of what is achievable	Very good	Some functionally important or evolutionarily distinct species may still be lost, potentially compromising ecosystem function and NCP
Evolutionarily distinct prioritized	**Very high** - supplementary to options above	Very good, supports maintenance of diversity across Tree of Life	Ensures maintenance of evolutionary options. Might de-prioritise, and increase risk for other species with important functions and NCP
Extinction rate down to natural background levels by 2050	**Extremely high –** likely unachievable except for some well-known groups	Extremely good	Maintains natural long-term patterns and dynamics in multiple facets of nature and associated flows of NCP
Extinction risk			
Extinction risk is stabilized by 2030 and 2050	**Low**	Poor	Species would continue to go extinct at current very high rates
Extinction risk is reduced for 20% of threatened species by 2030 and for 50% of species by 2050	**High** - requires substantial increase in conservation efforts and associated resources	Intermediate/ Poor	Species that can recover quickly would be favoured, as large, long-lived organisms require longer periods to reduce extinction risk
Extinction risk is reduced for 50% (or more) of threatened species by 2030 and for all species by 2050	**Very high** - requires transformative change and drastic increase in conservation efforts and associated resources	Very good	Better spread of outcome across species, but some large, long-lived organisms still compromised

Abundance			
Average species population abundance stabilized, by 2030 and through 2050	**Medium to high** -depending on which species are targeted	Poor / Intermediate	Rare, threatened and functionally important species continue to decline if these declines are compensated by increases of generalist species, resulting in further losses of biodiversity, ecosystem functioning and associated NCP
Species population abundance has increased on average by 10% by 2030	**High to very high**[1] - depending on which species are targeted for recovery	Intermediate	
Population abundance of species in key functional groups stabilized by 2030 and functional role recovered by 2050	**High to very high -** requires transformative change and drastic increase in conservation efforts and associated resources	Good	Local loss of biodiversity, ecosystem function and NCP if relevant conservation-dependent species are not correctly identified and conserved across their range
Population abundance stabilized by 2030 and functional role recovered by 2050 across the entire distributional range of species	**Extremely high**	Very good	Facilitates optimal outcomes towards achieving goals on other facets of nature
GENETIC DIVERSITY			
X% Genetic diversity of the species of all major taxonomic groups is maintained			
50% (on average)	**Very low** – This may have been already achieved	Poor – Allows loss of genetic diversity in the other half and thus reduces functional diversity critical for ecosystem stability and benefits to people	High risk to many threatened species important for ecosystem integrity and NCP. Undermines the potential for evolutionary adaptation for coping with environmental change
75%	**Low** – Not ambitious enough to retain the diversity necessary to maintain the capacity of species to adapt to changing conditions and other threats	Poor	NCP will be highly diminished. Low probability that natural populations of species harbour sufficient diversity, including functional diversity that contributes to ecosystem resilience
90%	**High** – requires transformative change and drastic increase in conservation efforts and associated resources	Good –Would sustain species survival in the wild	High level of NCP to the majority of people. Ensures adequate adaptive capacity in populations and species to cope with climate change
100%	**Extremely high** – Most likely	Very good – Full	Species will have full

	unachievable	breadth of genetic diversity in all species	evolutionary capacity to cope with changes in environmental conditions and to maintain ecosystem stability, enabling full realization of potential NCP
X% Genetic diversity of domesticated species and their wild relatives is maintained			
50% (average)	**Low** – For many domesticated species (e.g. major crops) this may already have been exceeded	Poor	This level would reduce NCP by not providing the necessary trait variants to cope with changed environmental conditions, and would undermine the potential to respond to pests and diseases
75%	**Medium** – Not ambitious enough to retain the diversity necessary to maintain the capacity of species to adapt to environmental change and other threats	Poor	NCP will be highly diminished Low probability that natural populations of species harbour sufficient diversity, including functional diversity that ensures ecosystem stability and resilience
90%	**High** —For major crops this will require concerted action	Good-	Would provide high level of NCP to the majority of people and provide adequate adaptive capacity to cope with climate change
100%	**Extremely high** – Most likely unachievable	Very good	Would provide maximum level of NCP such as food production and the maintenance of options that depends on species evolutionary capacity

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Supplement S5. Formulating biodiversity goals for a better planet - A science-based annotated checklist

A suggested checklist of critical elements in order to achieve the 2050 Vision, to be considered in the final formulation of the post-2020 Global Biodiversity Framework by CBD COP 15, and more generally in global biodiversity goal formulation during the incoming decade. Recognizing that not all elements may be practical in a concise outcome goal, these elements should, at a minimum, provide the primary structure for derived action targets, implementation and monitoring. **The letters in brackets point to annotations with rationale and empirical evidence in support of each element in the list**.

Ecosystems:

- Take 2020 as reference year for evaluating no net loss (**a**, **b**), achieving no net loss between 2020 and 2030 (**b**).
- Require strict conditions and limits to compensation, including like-for-like compensation by having a clear ecosystem definition and no substitution between different ecosystems (**b**).
- Explicit recognition of limits to replaceability, including the consideration of time lags (**b**).
- Ensure achieving no loss of critical ecosystems, i.e., ecosystems that are rare, vulnerable or essential for planetary function, or which cannot be restored (**c**).
- Aim for no net loss of both area and integrity in “natural” ecosystems and no net loss of integrity of “managed” ecosystems (**d**).
- Integrity of “managed” areas to be increased to ensure recovery of nature’s contributions to people (**d**).
- Maintain a restoration ambition (20% increase of area and integrity of “natural ecosystems” and 20% gain of integrity of managed ecosystems by 2050) as part of the goals (“net gain in area and integrity”) with implementation through integrated planning to optimize benefits for nature and people (**e**).

Species:

- Focus on threatened species to 2030 to prioritize species needing urgent attention, but for 2050, reduce extinction risk across both threatened and non-threatened species, not just the former (**f**).
- Reduce the rate of extinction progressively by 2030 and 2050 (**g**).
- Focus on retaining and restoring local population abundances and natural geographical extent of ecological and functional groups that have been depleted, and on conserving evolutionary lineages across the entire “Tree of Life”, in order to ensure persistence of the full breadth and depth of evolution, maintain viability, local adaptation and

evolutionary potential, and maintain ecosystem functioning and continued NCP provision (**h, i**).

Genetic diversity:

- Maintain a distinct goal focused on genetic diversity (**j**).
- Consider populations and their adaptive capacity explicitly (**j**).
- Make explicit mention of all wild and domesticated species, including their wild relatives (**k**).
- Estimating precise quantitative targets for maintaining genetic diversity may be difficult, but current knowledge suggests a minimum of 90% by 2050 (**l**, **m**).
- Avoid "on average" (as previously proposed in "zero draft") when referring to the maintenance or enhancement of genetic diversity, since this is very likely to set the bar too low (**n**).

Nature's contributions to people (NCP):

- Focus the goals on the outcome (nature's contributions to people), not on actions needed to achieve it (e.g. sustainable management) or quality of life (which results from NCP interacting with other factors, particularly anthropogenic assets not directly associated with living nature, and outside the CBD's mandate) (**o**).
- Consider the capacity of both "natural" and "managed" ecosystems to augment, secure and stabilize the provision of multiple NCP (**p**).
- Consider inter- and intragenerational equity in the distribution of wellbeing derived from benefits (**q**).

Annotations:

The importance of where and when

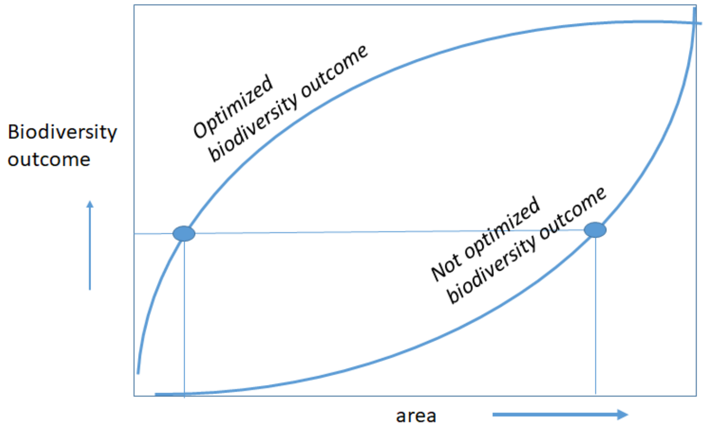
(a) "No net loss" (NNL) policies, if not qualified, carry high risk of harmful outcomes. NNL policies, i.e. those that only allow conversion or deterioration of ecosystems if compensated for by a similar amount or quality improvement elsewhere *(43)*, have existed for decades, but examples of successful outcomes are rare *(43, 44)*. In addition, the risk of undesirable outcomes or perverse incentives is high, e.g., through exacerbating baseline biodiversity declines, winding-back non-offsetting conservation actions or poor regulatory/legislative governance *(45)*. Goal-setting that includes NNL can be expressed in a way that limits such potential risks, by clearly defining year and ecosystem of reference **(b)**, not allowing any further loss of critical ecosystems **(c)**, and making sure area and integrity are not mutually substitutable **(d)**.

(b) Define reference year and ecosystem. The 'net' component of NNL implies that gains in area and integrity of ecosystems can counterbalance losses *(43)*; depending on the definition of "ecosystem", this wording makes room for the loss of irreplaceable ecosystems. Substitution of one ecosystem with an ecosystem of another type - for example, conserving coral reefs to compensate for destruction of abyssal habitats by deep-sea mining *(46)*; or allowing one native habitat to substitute for any other *(47)* leads to exchanges of gains and losses between ecosystems whose differences mean that they are not truly substitutable. The timeline in the CBD goals suggests that (net) gains can be realized by 2030-2050. A large literature demonstrates limitations in our ability to re-create ecosystems, due to both long time lags in ecosystem recovery and restoration failure *(48-50)*. Also, expressing the goal as outcomes that should occur in the future, e.g. "by 2030", without a reference date could allow very heterogeneous application using whatever past or future dates that are the least constraining. This could permit e.g. a further decade of inaction and unmitigated loss of ecosystem area and integrity. These issues can be dealt with by setting a clear reference year (ideally 2020) and providing the NNL goal with a definition of ecosystems that captures unique assemblages that, if removed, could not be replaced by restoration in another area ("like-for-like" criterion). However, too-narrowly defined ecosystems covering too small areas – e.g., viewing every patch of a habitat mosaic as distinct–would jeopardize the implementation of the mechanism. A practical definition avoiding these two opposite risks could be "a clearly defined coherent geophysical environment and the assemblage of interacting organisms that persist there, which differs from adjacent/other ecosystems".

(c) Critical ecosystems require no loss. Some ecosystems are simply impossible to substitute because they are unique and/or evidence of their potential for restoration or replacement is lacking. These 'critical' ecosystems may already be rare (substantial habitat loss or intrinsically rare), contain particularly important or unique biotic assemblages, meet all three criteria such as oceanic islands *(51)*, or be so important for planetary function, that any further decline in their area or integrity will lead to either a collapse/extinction of the ecosystem itself or of the function it provides *(52, 53)*. We propose that the goal for these ecosystems should be no loss, rather than no net loss. To support this, an inventory and spatial database of no loss critical ecosystems should be developed at national and global levels.

(d) Ecosystem area and integrity are not mutually substitutable. Ecosystem integrity, currently defined to include functional, compositional, and structural/spatial components *(54, 55)*, is more elusive to monitor than ecosystem area, but no less crucial for the long-term continuity of ecosystem functioning *(56)*. Both area and integrity need to increase in order to achieve goals in other facets of biodiversity *(57)* and the stated ambition of the contribution of biological carbon sequestration to the Paris Climate Agreement *(32, 58)*. Therefore, area and integrity cannot be mutually substituted and should not be conflated in one integrated indicator to measure progress towards achieving ecosystem-related goals. Moreover, different actions are required in ecosystems that are predominantly "natural" compared to those that are predominantly "managed" (Box 1). A goal of net gain of both area and integrity should only apply to "natural" ecosystems because gain in their area will by definition have to come from "managed" ecosystems. The increase in area and integrity of "natural" ecosystems can be achieved both through restoration of "managed" ecosystems back into a "natural" state (increases in area first and then, over a longer time frame, also integrity) and by the restoration of degraded "natural" ecosystems to a higher level of integrity (but no increase in area). A substantial increase in overall "natural" ecosystem area and integrity could reduce the global extinction debt *(59)* in terrestrial systems by up to 70% *(60)*, and removing human pressures on 20% of marine ecosystem area could achieve 90% of the maximum potential biodiversity benefits *(61)*. Current evidence indicates that substantial recovery (i.e. 50-90%) of marine life is possible by 2050, if appropriate pressure alleviation and recovery measures are implemented *(62)*. The increase in overall "natural" ecosystem area and integrity will also buffer against loss of ecological interactions that can be crucial to maintain ecosystem functions, given that these interactions may go extinct well before species go extinct *(63, 64)*. Delaying this increase in area and integrity means that more of these species and their interactions will go extinct. The stated ambition of the contribution to the Paris Climate Agreement also requires substantial increases in "natural" ecosystem area. In the face of increasing competition for land resources, a 20% increase in "natural" ecosystem area, though feasible, requires transformative change in consumption patterns and agricultural management *(60, 65, 66)*.

(e) **Location is crucial for success.** Conservation and restoration outcomes strongly depend on location *(18, 60, 61, 67, 68)*. If carefully targeted, small area gains can make large positive contributions to biodiversity outcomes*(69)*. If not carefully targeted, the benefit of gain in ecosystem area on species, genetic diversity, and NCP can be small. NNL can even lead to a loss in these components if sub-optimal locations are used for compensation *(43)*. Integrated planning is therefore necessary for prioritizing locations for conservation, restoration, and human use. Such planning should also be forward-looking and adaptive to future change across a range of scenarios. The conceptual figure below illustrates this concept: depending on whether the conservation locations have been chosen in an optimized manner or not, the same biodiversity outcome (e.g. reduction in extinction debt or genetic erosion, increase in the provision of regulating NCP) requires drastically different amounts of land (for empirical examples see *(60, 67)*).



Species extinctions –risks, roles and history

(f) **Shift the focus from threatened species to extinction risk and extinction rate.** Extinction risk is a measure of the likelihood that a species will go extinct. Threatened species are those species judged to be at high extinction risk today following a well-established international protocol *(70)*. A goal focused on the reduction of the proportion of threatened species is useful to prioritize conservation efforts in the short term (e.g. by 2030), but the longer-term goal should be to reduce extinction risk across all species. Extinction risk is a continuous measure from low to high; it is determined by species' susceptibility to extinction (related to species' life histories), their exposure to threats, and the effectiveness of conservation actions they receive *(71)* and is generally forward-looking, because it determines future extinction rates *(8)*. Reducing the percentage of species threatened with extinction does not necessarily mean avoiding or reducing the rate of extinctions. Reducing the rate of extinction is the key to avoid irreversible loss of species, taxonomic diversity and evolutionary history, and thus should be included explicitly in the goals.

(g) **Reduce extinction progressively by 2030 and 2050.** Scientific evidence suggests that the recent species extinction rate is at least tens to hundreds of times the background rate *(2, 72, 73)* and is likely to be increasing rapidly *(74)*. At the same time evidence shows that species extinctions would have been 2-4 times higher without conservation action in recent times which indicates that conservation action can reduce extinction rate *(75)*. Therefore, a plausible goal for extinction rates is to prevent their increase in the coming decade and to reduce them progressively through 2050, towards being as close as possible to background levels by 2050. Halting human-induced extinction completely by 2030 is likely not realistic because some extinctions that have been avoided to date have been simply delayed *(76-78)*, certain threats will continue to intensify (e.g. climate change and sea level rise) and the life histories of other species suggest that they are on a trajectory to extinction that will be slow or difficult to reverse *(8)*. Even in the most optimistic policy scenarios, the estimated extinction rate by 2030 is expected to stabilize to 2010 level, which is still above background rate of extinction *(79)*. However, where both the species at risk and the drivers of decline are known, extinctions can probably be avoided given sufficient political will and investment *(75)*. Given the unavoidable time lags affecting the conservation status of many currently threatened species *(80)*, we suggest that any 2030 goal or milestone be focused on stabilization (rather than reduction) in the proportion of threatened species. This may be still challenging according to scenarios exploring alternative socio-economic pathways for the 21st century and associated biodiversity trends *(81, 82)*. Halving the rate of decline may be more feasible, but requires strong conservation action and reduction of drivers of loss *(81, 82)*. A reduction of the extinction rate to 10 times higher than the natural background rate over the next 100 years has been considered an ambitious but achievable goal *(8)*. The 2050 goal could realistically include the reduction of species extinction risk, because even species with a slow life history and small capacity to recover can respond to conservation action in a time span of three decades *(83)*.

(h) Not all extinctions have equal consequences. Not all species have the same impacts on ecosystem functioning and derived benefits to people *(84)*, or represent the same amount of accumulated evolutionary history *(85)*. Because of this, we propose that a goal on extinction rate incorporates functional and phylogenetic dimensions of biodiversity among the criteria for implementation, rather than being based on species numbers alone. Much remains unknown about the functional roles of every species, and even if we knew them in detail, a global policy instrument cannot directly identify species with important roles at the level of every local ecosystem. However, there is ample scientific evidence indicating that some ecological or functional groups of species have globally-relevant roles either because they intervene in regulating processes at the continental or larger scales, such as migratory animals *(86)*, or because they are locally important across a large number of ecosystems around the world, such as pollinators *(87)*, scavengers *(88)*, top predators *(89)*, and large-bodied mammals and trees *(90-92)*. Moreover, the life-history characteristics that make them functionally relevant are in many cases the same, or are tightly coupled with those that make them vulnerable to anthropogenic drivers *(93, 94)*. In addition, some ecological groups may also have high existence values based on complexity or evolutionary proximity to humans *(95)*. In terms of evolutionary history, some species like the reptile tuatara *(Sphenodon punctatus*) or the ginkgo tree (*Ginkgo biloba*), have no close relatives and have been evolving independently for many millions of years (over 260 million years in the case of the ginkgo, which is the only representative of its order). They represent unique, deep branches of the Tree of Life *(96)*. Losing an entire broad lineage (visualized as a "deep pruning" of a tree) means a loss of that lineage's characteristics and potential benefits forever *(97)*. In contrast, losing one of hundreds of similar species within a given lineage represents a smaller loss in terms of accumulated evolutionary history. We thus recommend that conservation interventions prioritize evolutionarily distinct species. A goal could address the potential future loss of evolutionary history by qualifying that the reduction in extinction rate should be well distributed across the Tree of Life, in other words it should avoid the entire loss of a branch (genus or family). To incorporate phylogenetic diversity into global goals, we recommend giving priority to avoiding the loss of species that do not have multiple close relatives. Close relatives are species that have descended from the same common ancestor within the timespan of the average species age (+/- 1 million years) for the lineage.

(i) The relevance of common species. While global extinctions have irreversible consequences for the Tree of Life, in most cases the ecological role of species depends on its existence in locally sufficient numbers. A population might not be on the brink of extinction, and yet its ecological role be extinct to all practical purposes if its abundance does not reach a certain threshold *(63)*. Declines in the abundance of common species, and species or groups of species with key ecological roles (see annotation **h**) even when they are still far from extinction, have been shown to have large effects on community assemblage *(64, 98)* ecosystem functioning *(99)* and NCP *(100, 101)*. A goal for the retention and recovery of local population abundance across the whole geographical extent addresses local biodiversity losses that are important for ecosystem functioning, within-species genetic diversity, species evolutionary potential and adaptive capacity. All these would not be addressed by focusing only on globally threatened species.

Furthermore, increases in the abundance of some species can be undesirable and/or costly (e.g. alien and invasive species *(102)*), or shift ecosystems into undesirable alternate states (e.g. proliferation of jellyfish in Namibian waters *(103)*). For these reasons, a goal for increases in total population abundance without qualifying to which species it applies could have unintended and undesirable consequences. By qualifying the goal with phylogenetic and functional considerations, such risks are avoided.

Genetic diversity – safeguarding evolution in an ever-changing world

(j) Why there should be a separate goal focused on genetic diversity. In a changing world, genetic diversity provides the variation that supports species survival and adaptation *(9)* and supports ecosystem stability and the provision of nature's contributions to people, including sustained food production *(104-107)*. This is especially true under increasing climate change, habitat fragmentation, and new pests and diseases, and there are numerous examples of catastrophic loss to societies and economies caused by over-reliance on narrow genetic stocks in agriculture, forestry, aquiculture and fisheries *(106, 107)*. Further, the population is the key unit at which evolution and adaptation take place, and genetic diversity within and among populations is the primary determinant for ensuring resilience and survival of the species. The capacity of populations in the wild and on farm to respond to environmental change and to be resilient depends on the breadth of the genetic diversity and traits contained within the populations that allows them to evolve and adapt to environmental and climatic changes. It can be argued that local abundance is a key factor in the maintenance of genetic diversity; therefore by conserving sufficient numbers of individuals one increases the likelihood of conserving genetic diversity. However, abundance does not always correlate well with genetic diversity. For example, a population of an endangered species might have gone through a strong bottleneck and its current population size may not reflect its current genetic diversity *(108)*. The population might be above a certain critical population size threshold, but may be "living on borrowed time" genetically, and require managed translocation and gene-flow to prevent it losing adaptive resilience. Linking population abundance and genetic diversity in a single goal statement would thus have the disadvantage of missing within-population genetic diversity, essential for continued adaptation to a changing environment. Monitoring genetic diversity within wild and domesticated species is thus crucial to achieve the 2050 Vision. The monitoring of this aspect is becoming increasingly affordable, a tendency that is likely to accelerate in the near future *(109, 110)*.

(k) In protecting genetic diversity, both wild and domestic species need to be addressed explicitly. The evolutionary process is the engine perpetually producing new "solutions" to environmental challenges from which people benefit in many ways, most prominently through useful organisms *(111)*. The raw material for this engine is genetic variation at the intraspecific level, i.e., within and among populations of the same species. This is true not only for wild species, but also for domesticated ones. Goals related to genetic diversity should therefore specify that they are applied to wild as well as domesticated species, as their dynamics are very different, and ecosystem integrity and provision of

NCP depend on both. The genetic diversity of wild species supports species survival and adaptation, facilitating the achievement of goals related to ecosystems and species. Genetic variation across the gene-pool of domesticated species (including crops and livestock and also their wild relatives) is necessary to sustain food and nutrition security and production systems by providing genetic materials to cope with pests, diseases and climate change, and meet future market demands *(19, 112, 113)*. Over-reliance on narrow genetic stock from a few lineages in agriculture, forestry and fisheries reduce future food security and have already resulted in dramatic declines in NCP *(106, 107, 114)*. Much of this domesticated species genetic diversity persists on farms and in "natural" landscapes in the regions of origin, where it often lacks formal protection and is thus vulnerable to erosion and even extinction *(19, 115, 116)*. For example, populations of wild sheep and goats in Iran lack the diversity found in domestic gene-pools due to population contraction, fragmentation and overhunting, imperiling their future role as providers of new genetic variation for their domestic counterparts *(117)*. With regard to crop genetic diversity on farm, the replacement of locally distributed and traditionally diverse landraces by modern varieties is considered a major cause for genetic erosion *(118)*; for example, in the North Shewa zone of Ethiopia a loss of 65% of landraces of barley was reported between 1994 and 2010 *(119)*. This in situ genetic diversity is only partially safeguarded in ex situ conservation repositories, such as gene banks including community seed banks maintained by local communities *(120, 121)*. Furthermore, in ex situ repositories, organisms are not subject to the same selective forces as in the field, and therefore they lose adaptability to environmental change *(34, 112, 122)*.

(l) **The genetic diversity within wild species of all plants, animals and microbial groups and domesticated species matters, not just the percentage of species that is targeted**. For crop species, conserving at least 70% of the genetic diversity of a crop is a reasonable goal to achieve for most crop species in a relatively small sample, provided that a scientifically sound sampling strategy is applied *(123-125)*. It is also most probable that for major crops more than 90% may already have been conserved in gene banks, although we do not have concrete scientific evidence for this. Very few crop species are sufficiently safeguarded in repositories (ex situ) and in the wild (in situ), and there is inadequate genetic diversity preserved in repositories for most species *(34, 126-128)*. For livestock species and breeds, there is much less diversity that is adequately conserved due to the lack of ex situ repositories. It is very important that the genetic diversity be conserved within wild and on-farm populations of livestock and crops to allow the process of natural selection and evolution to continue *(129, 130)*. It also needs to be backed up in ex situ repositories *(34, 131)* in order to halt human-induced loss of genetic diversity (i.e. genetic erosion). For wild species, it is important that all species are covered (limiting the targeting to 90% of wild species, for example, would mean that the goal could be achieved while ignoring the genetic diversity in up to 10% of all species). Special mention should be made of oceanic islands, which host large numbers of endemic species with unique genetic heritages, meaning that even a single population loss could lead to significant genetic erosion *(132)*.

(m) **Estimating precise quantitative targets for maintaining genetic diversity may be difficult, but current knowledge suggests a minimum of 90% by 2050**. There are thousands of wild species that support nature and society have economic uses (e.g. timber, food, medicine, fish and invertebrate protein that sustains many economically disadvantaged and rural communities) *(133)*; are valued as national, cultural or religious symbols; or have distinct, particularly important roles in ecosystems (see annotation **g**). Maintaining their genetic diversity is critical for these species for their survival and continued contribution to people. Though there are knowledge gaps in molecular genetic diversity data for certain taxa and for geographic regions, progress in assessing genetic diversity has been made over the past four decades *(110, 134-136)*. Further, due to continually decreasing costs of genomic analysis, better data stewardship, and technical advances *(109, 134, 137)*, such that more affordable, frequent genetic monitoring can support ambitious goals on genetic erosion.

(n) The problem with maintaining genetic diversity "on average" across species (e.g. in the Zero Draft of the post-2020 Global Biodiversity Framework *(5)*). First, given that not 50% of the species are threatened, rare or relict species, the connotation "on average" allows in principle to ignore all these species, while it is crucial for the long-term survival of these species that their genetic diversity is maintained–and it is for those species that it is most difficult to achieve. Second, maintenance of genetic diversity is especially a challenge in populations of large, slow-growing organisms with long generation times and with small population sizes *(79, 138)*. The population size of many small organisms (microbes, invertebrates) tend to be high and loss of genetic diversity may not be an imminent risk, or difficult to quantify. Thus "on average" is not ambitious enough and would seriously undermine ecosystem stability (e.g. large organisms often have a strong cascading impact on ecosystems), raise extinction rates of many species that are currently struggling to cope with human drivers, and jeopardize the capacity of agroecosystems to sustain food production, leading to food insecurity. Current evidence shows that genetic diversity is already being eroded globally as a result of land use change, direct harvest, disease, and extreme events, even for species that are not formally classified as threatened *(137, 139-142)*. One recent study documented 6% global loss of genetic diversity over the past 100 years, and 28% loss for island species *(142)*. On this basis, minimizing genetic losses to less than 25% or even better, 10% of genetic diversity may not only be essential for species and ecosystem function, but also represent meaningful goals to attain. Furthermore, while certain genetic parameters (such as expected heterozygosity) decline relatively slowly with respect to loss in population size, others (especially allelic diversity) decline very rapidly, potentially risking the loss of the "option value" of rare alleles, which may be of beneficial selective value in the future *(143)*.

Nature's contributions to people – the key link between nature and human quality of life

(o) Address nature's contributions to people (NCP) directly and do not conflate them with quality of life. NCP underpin almost every dimension of a good quality of life *(84)*, but they need to be addressed separately. For example, food provision is at the basis of food and nutritional security, regulation of water quality and quantity is at the basis of water security, and the provision of physical and psychological experiences by green spaces and the provision of genetic resources by wild organisms contribute to human health. However, a good quality of life depends not only on nature-based elements, but also on a number of anthropogenic assets *(101, 144)*. For example, the regulation of water quality and distribution provided by some ecosystems are important for the access to safe drinking water *(145, 146)*, but access to safe drinking water also depends on adequate sanitation systems and distribution networks *(147)*. Most of these anthropogenic assets are beyond the objectives and mandate of the CBD; so are many of the components of a good quality of life. Therefore, we suggest that the goal is formulated in terms of NCP, with a mention of their key role underpinning a good quality of life. In addition, as different NCP depend on different aspects of nature, with some being synergistic but some others showing strong tradeoffs, such as between some material and regulating NCP *(145, 146)*, it is important to specify which NCP are to be aimed for.

(p) Both "natural" and "managed" ecosystems provide important NCP. Nature's capacity to deliver vital contributions to people now and into the future is reliant on the area and integrity of both "natural" and "managed" ecosystems and their constituent species and within-species genetic diversity *(33, 145)*. This means that a NCP-related goal needs to refer to species, ecosystems and genetic diversity. We also point to the fact that essential to the achievement of such outcome is the sustainable management of biodiversity, which we recommend to mention explicitly in the targets derived from this goal, without being the main focus. "Natural" ecosystems are critical for preserving essential contributions from nature to people. It is estimated that maintaining 50-85% of high-integrity forests *(148)* as well as the ecosystems with the highest carbon density (e.g., Amazon, Boreal forests) *(149, 150)* is required to ensure climate regulation through biological carbon sequestration, and to achieving the land-based mitigation targets under the Paris Agreement. Nature-based solutions ("solutions inspired and supported by nature" *(151)* implemented in both "natural" and "managed" ecosystems) can support up to 37% of climate mitigation action required by the Paris Agreement *(58, 152)*. The preservation of the integrity of marine ecosystems contributes to achieve climate change mitigation and food provision *(61, 153, 154)*. The integrity of "managed" ecosystems is crucial to deliver NCP, but with different nuances from "natural" ecosystems. In "managed" ecosystems, integrity is enhanced through the increase in crop and breed diversity, associated wild diversity (e.g. pollinators, natural enemies of pests, soil biota) in embedded native habitats *(21)*. Restoration of native habitats within "managed" systems to a minimum of 10-20% at fine scales (1 km^2) has been proposed as a threshold to support their integrity and maximize synergies for people and nature *(21, 155, 156)*. Regulating the harvest of wild species to sustainable levels is also critical, since 34% of marine exploited species are considered overexploited *(157)* and approximately 15,000 species of the medicinal plant species worldwide are endangered *(158)*.

(q) Ensuring all people benefit: inter- and intragenerational equity- and recognizing the contributions of Indigenous peoples and local communities. The number of people who can benefit from nature depends not only on nature's ability to provide NCP across geographical ranges where people live, but also on societies' ability to manage demand and distribution of NCP. The 2050 Vision of "Living in harmony with nature" will be compromised unless goals related to reducing societies' demands from NCP and distributing them in a fair way are also achieved. The growing demand for many of the material goods provided by nature, including food, energy, timber, and other materials, is related to the decline of nature’s capacity to provide beneficial regulation of environmental processes —such as modulating water quality, sequestering carbon, or building healthy soils *(2)*. Therefore, not reducing societies demand for some material NCP will increase tradeoffs with other facets of nature. Inter- and intragenerational equity are important for ensuring good quality of life for all people. Intergenerational equity recognizes that the effects of measures taken today might only be perceived by future generations, and as such is inextricably linked with sustainability. Intragenerational equity recognizes that additional support could be needed by marginalized and vulnerable groups and stress the importance of recognizing the rights to nature, including for many Indigenous peoples and local communities, who more directly depend on the use of nature and whose livelihoods and quality of life are disproportionately impacted by biodiversity loss *(159, 160)*. Numerous Indigenous peoples and local communities have played an important role as guardians and stewards of genetic, species, and ecosystem diversity *(29, 161, 162)*, sometimes facing violence for their actions in defense of nature *(163)*. Their past and present contributions to maintaining nature should be fairly and equitably compensated and the right to continue access to NCP that underpin their livelihood should be ensured. The uneven distribution of NCP across regions leads to numerous NCP being traded across large distances, resulting in telecoupling *(164)* and reinforcing inequity. We suggest that the mechanisms considered by the CBD to achieve goals for nature and its contributions to people are designed in a way that (a) they do not have perverse effects for people whose livelihoods directly depend on nature, such as limiting the sustainable access to nature by local populations; (b) they expand the sharing of benefits across people and generations beyond tangible resources derived from commercial use and include all NCP; and (c) they recognize Indigenous peoples and local communities rights, abilities (e.g. knowledge and skills), engagement in environmental governance, and respect their voice regarding sharing of NCP derived from their lands.

Supplementary Materials for

Set ambitious goals for biodiversity and sustainability

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