Title: Achieving global biodiversity goals by 2050 requires urgent and integrated actions

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Introduction

Human impacts on the Earth's biosphere are driving the global biodiversity crisis. Three quarters of terrestrial ecosystems have been significantly altered, a quarter of assessed plant and animal species are threatened with extinction, and genetic diversity is declining in wild and domesticated species (1,2). This biodiversity crisis is driving declines in nature's contributions to people (NCP; 1,2). Governments are preparing to agree on a set of actions intended to halt the loss of biodiversity and put it on a path to recovery by 2050 (also known as "bending the curve"; 2,3). We provide evidence that the proposed actions can bend the curve for biodiversity, but only if these actions are implemented urgently and in an integrated manner.

These actions are laid out in the first draft of the post-2020 global biodiversity framework (GBF; CBD/WG2020/3/3) currently under negotiation. The final version of the GBF is to be adopted at the upcoming 15th Conference of the Parties of the UN Convention on Biological Diversity (CBD). The GBF contains twenty-one "2030 Action Targets" that are intended to put global action on track to meet the 2050 goal of reversing biodiversity loss. The targets are divided into three broad groups: reducing threats by acting on direct drivers, sustainable use and benefit-sharing to meet people's needs, and tools and means of implementation which mostly act on indirect drivers (see SM for a summary of the GBF).

Ever since the negotiation process formally started in late 2018, it was recognised that the biodiversity crisis cannot be stopped without transformative change. This involves deep, systemic changes in society such as rapid shifts to sustainable production and consumption especially in food systems, greatly increased financial and human resources for conservation and restoration, deep cuts in subsidies that are harmful for biodiversity and broader involvement of stakeholders including Indigenous Peoples and Local Communities (IPLCs; 1,2). This need for transformative change is reflected in the most recent draft of the GBF.

There has nonetheless been considerable debate among governments, stakeholders and scientists about the best way to structure and communicate the objectives of the GBF. Some proposals have focused on a single, "apex" goal for biodiversity, that would for instance put the emphasis on bringing extinctions to near zero (4), restoring ecosystem integrity (5), or achieving no net loss of natural ecosystems (6). Other approaches, focusing on individual actions, have also gained momentum, such as the intergovernmental High Ambition Coalition for Nature and

People[1] which aims to protect 30% of the planet by 2030. In contrast, others have insisted on the need to reflect the complexity of biodiversity, and to have objectives addressing ecosystem, species, and genetic diversity as well as NCP (7). Proposed objectives such as "bending the curve for biodiversity" and "nature positive" outcomes (2,3, www.naturepositive.org) reflect this complexity, and have helped shift the discourse from focusing on slowing biodiversity loss to an objective of net gain in biodiversity.

To better navigate the complexity of the GBF, several Parties to the CBD and stakeholders are seeking clarification of how the 2030 Action Targets are connected to the 2050 Goals, and how to track progress (see CBD/WG2020/3/6 for a summary of the state of negotiations). In this context, we provide a synthesis on how actions across the twenty-one targets can contribute to achieving Goal A (Integrity of biodiversity and ecosystems) of the GBF. Further details of this synthesis can be found in an information document that was prepared for the CBD (8).

A systemic approach across all targets is essential

Our synthesis focuses on targets 1-10, which act on direct drivers of biodiversity loss, either simply, e.g. targets 6, 7 and 8 on invasive alien species, pollution and climate change, respectively, or with greater complexity, e.g. targets 5 and 9 on direct exploitation, and targets 1, 2, 3 and 10 on land and sea use change (this last group of ecosystem-based targets also addresses direct drivers). Linking targets to drivers enables the proportional contribution of the direct drivers of biodiversity loss (1) to serve as estimates of the relative contributions of actions under each target, and of the targets to milestone achievement (Fig. 1A, S2).

Our analysis shows that no single target acting on direct drivers makes more than a 10-15% contribution to achievement of any one biodiversity outcome of the GBF (Fig. 1B). There is no one-to-one linkage from any action target to a given milestone or goal. Instead, “many-to-many” relationships exist among them. This finding reinforces and extends repeated calls from the scientific community to address the GBF in an integrated way (7), and for actors to treat the targets, milestones and goals of the GBF as an indivisible whole.

[1] www.hacfornatureandpeople.org also known as 30X30 and currently includes 82 participating countries and the European Commission.

Case studies provide additional evidence that slowing and reversing biodiversity loss often requires multiple concerted actions on direct and indirect drivers, and that the relative contributions of actions is highly context dependent (1). Multiple concerted actions were required to avoid extinctions of bird and mammal species over the last two decades (9), and to restore population sizes of a wide range of bird, fish and mammal species (8). At the ecosystem level, concerted action on multiple drivers is needed to prevent the collapse of coral reefs and slow the degradation of Amazon forests (8). There are cases where biodiversity loss has been slowed and reversed based on actions focusing on a single driver, but when setting global scale targets for action, no subset of the targets in the GBF can adequately address most contexts.

Transformative change is needed to “bend the curve” for biodiversity

Scenarios provide a means of quantitatively evaluating how different sets of actions on direct and indirect drivers could contribute to achieving the biodiversity goals and milestones of the GBF. We have distilled three types of scenarios for 2030 and 2050 that are directly pertinent to the GBF based on a synthesis of several recent global sustainability scenarios studies (Table 1, S3). Achieving ambitious targets for expanding protected areas, species management plans, and ecosystem restoration as well as halting the conversion of existing natural ecosystems is projected to slow future biodiversity loss (Table 1, "Conservation and Restoration"). Reducing biodiversity loss further is hampered in part by insufficient progress on restoring biodiversity, ecosystem function and connectivity in working lands that occupy approximately 40% of the global land surface. There are, however, concerns that these targets may only be partially achieved, since current trends show that protected areas are under-resourced, progress in establishing ecologically representative protected areas has been slow, and restoration efforts using good ecological practices have been increasing but not at the rate and scale needed (2,10). Without substantially greater efforts on these actions, focusing on large increases in the extent of protected areas is likely to have limited effect on the trends in biodiversity loss observed over the last decade (Table 1, "Continued Trends + 30% PA" scenario type). The degradation of biodiversity can be halted by 2030 and recovery towards 2050 initiated, but only when indirect drivers of biodiversity loss are addressed (Table 1, "Transformative Change", see SM for projections to 2050). These scenarios of transformative change all rely heavily on rapid transitions to sustainable production and consumption especially in food systems, and even greater progress can be made by meeting a broad range of Sustainable Development Goals (S3). Limiting climate change to 1.5°C is essential for achieving ambitious biodiversity goals in all scenarios.

Act now and sustain actions due to time lags

There are significant time lags between the impacts of drivers and the magnitude of biodiversity change. For example, we know past and ongoing habitat loss and fragmentation will contribute to the future erosion of population genetic diversity, and species' extinctions (commonly referred to as "extinction debts"). Lags are also contributing to current deterioration in the functioning of terrestrial and marine ecosystems (8). Lags frequently span decades, so the sooner we mitigate the impacts of drivers, the shorter the duration of loss and the lower the cumulative loss of biodiversity and ecosystem processes in the coming decades.

Recovery from large-scale disturbances — such as collapse of fisheries due to overfishing, logging, or the restoration of ecosystems after land degradation or deforestation — also involves time lags. Recovery lags can range from years to several decades, and in some cases much longer. Biodiversity is also lost during recovery, and these recovery 'debts' can amount to 46–51% for abundance, and 27–33% for species diversity (11). Active restoration can result in faster or more complete ecosystem recovery and thus curtail recovery debts and shorten time lags. These lags are particularly critical for people and communities whose livelihood and well-being directly depends on the many benefits ecosystems provide.

The lag time to desired biodiversity outcomes should calibrate the ambition and timing of action on targets. Milestones for 2030 can be framed as intermediate objectives that account for delays in biodiversity recovery on the pathway to achieving the 2050 goals (see illustrative timeframes for target and milestone implementation in Fig. 1A). Resources invested now will enable achievement of biodiversity outcomes framed by the GBF in the medium (5-10 years) and longer (10-30 years) terms (Fig. 1A)

International collaboration and multiscale approach

Biodiversity loss arises from multiple drivers, acting across multiple spatial scales. The forces arising from a globalized economy mean that biodiversity loss due to direct drivers in one location may be caused by indirect drivers, such as the demand for agricultural goods, operating far away. International collaboration should be strengthened and focused on how to share efforts adequately and equitably i) to mitigate the drivers of biodiversity loss, ii) to protect, conserve and restore biodiversity, and iii) to account for differences in national capacities and access to means of implementation. Apportioning responsibilities will vary by case; almost a third of the global mitigation efforts required to alleviate the extinction risk of terrestrial mammals, birds and amphibians has been found to lie with just five countries (12). By contrast, wide-ranging benefits of collaborative efforts across countries at regional scales have been shown for other cases (8). When extrapolating to the global scale, it is clear that local realities and priorities, as well as the capacity to implement actions are varied, and require effective, transformative approaches to share the effort involved to achieve global ambitions (13). An enhanced dialogue between national agendas and global priorities and needs will be necessary, supported by responsibility and transparency mechanisms under development for the GBF, including more regular review of and enhanced collaboration around implementation (14).

A monitoring framework and review mechanisms to achieve outcomes

Current biodiversity indicators in the GBF monitoring framework allow detection of trends for some dimensions of biodiversity (i.e ecosystem extent, species habitats, species extinction risk). Indicators to assess trends in drivers are not currently included, but will be essential to demonstrate that action on drivers is resulting in biodiversity recovery.

The monitoring framework of the GBF can be strengthened in three ways: 1) the addition of a detection and attribution system to establish where and to what extent drivers are causing biodiversity change, to account for shifted baselines, and to show that the necessary reduction in drivers is being achieved, 2) adding a national and global scale data integration and disaggregation mechanism to assessing progress on driver and biodiversity change made by different countries, alone and in aggregate, and 3) a set of leading indicators (15) which guide proactive planning and action on drivers of biodiversity loss. In combination, these capacities will allow the monitoring framework to go beyond tracking progress to supporting adaptive policy and action.

Current biodiversity monitoring capacity is unequally distributed across the globe, resulting in biases in our understanding of biodiversity change across taxa, ecosystems, and biomes (8). An assessment of the resources needed to build an adequate global biodiversity observation system is needed. Investment in monitoring will: 1) sustain and enhance current global biodiversity information infrastructures, 2) develop local and national capacities to collect new data, make it openly accessible, and 3) implement workflows that rapidly deliver the biodiversity information needed to calculate and track indicators. This investment will allow stakeholders to produce and use appropriate biodiversity indicators, thereby improving the equity in monitoring capacities among parties and effectively supporting action on drivers across all regions. This capacity is essential if we are to ensure responsibility and transparency during the implementation of the GBF (14).

Finally, monitoring must become a motor for transformative change. The involvement of individuals and local communities in biodiversity monitoring leads to greater knowledge, a greater sense of responsibility and greater engagement in conservation actions. New policies and programs are needed to engage local stakeholders, including Indigenous Peoples and Local Communities and traditional knowledge holders, to monitor biodiversity change, and to promote understanding from diverse knowledge systems.

Conclusions

Top level science-policy documents increasingly call for transformative change (1,2). Our findings establish that halting and reversing biodiversity loss by 2050 requires integrated and ambitious action across all targets of the global biodiversity framework. We emphasize the importance of actions on indirect drivers including massive reductions in harmful agricultural and fishing subsidies, deep reductions in overconsumption, and assuring participation and leadership at local levels by indigenous and local communities.

It is essential to treat the targets, milestones and goals of the GBF as an indivisible whole, rather than focus on its individual elements. Holistic messages like “bending-the-curve for biodiversity” and “nature positive” align with the scope and variety of actions required to meet the CBD vision of “living in harmony with Nature”. The knowledge we have in hand points to an integrated set of actions that could plausibly bend the curve for biodiversity by 2050, but only if these actions are implemented promptly.

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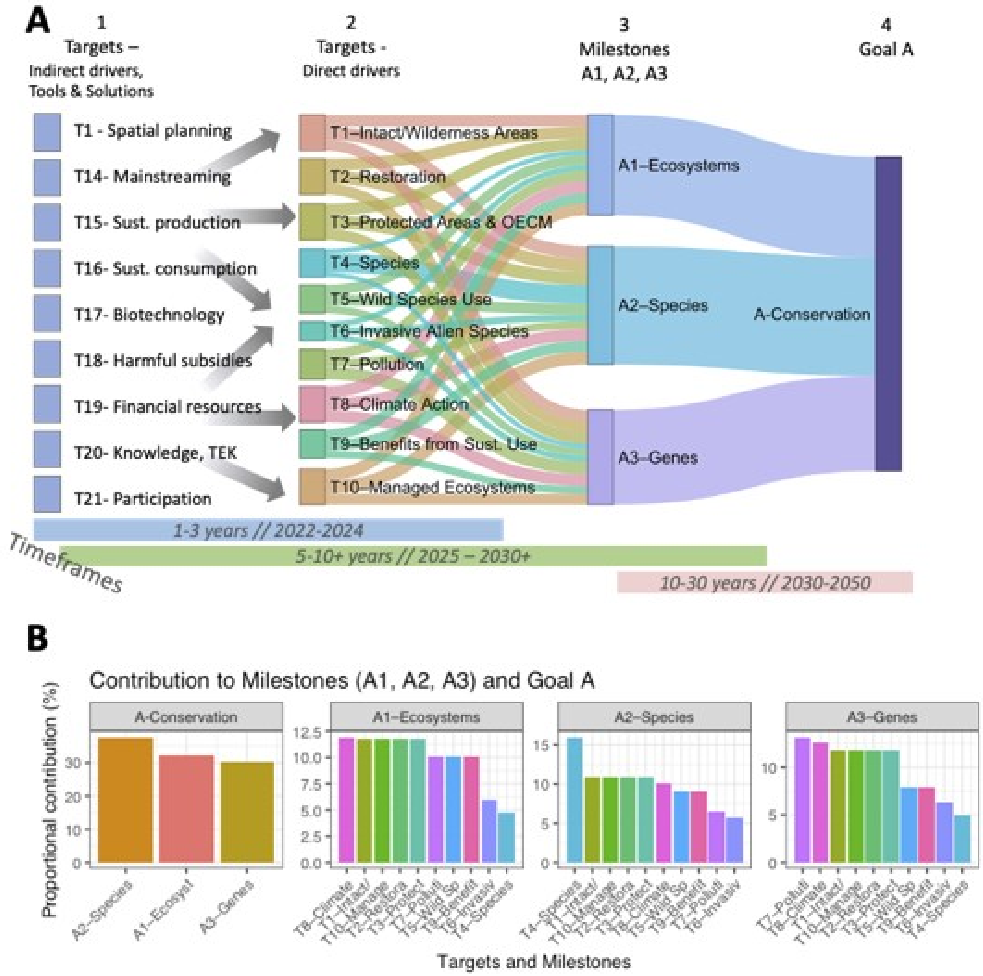

Figure 1. *Proportionate contribution of Targets to achievement of Milestones A1, A2 and A3 and Goal A in the first draft of the Global Biodiversity Framework. A) the width of lines from Targets 1-10 to Milestones A1, A2 and A3 was estimated from direct driver contributions to biodiversity loss (IPBES 2019), see S1 for details. Milestones under goals B and C on sustainable use and equity of benefit sharing were not included as comparable quantification of the contributions of targets to their achievement are not available. Targets related to indirect drivers and tools and solutions in the GBF are shown as prerequisites for implementation of Targets 1-10, but specific relationships and proportionate contributions are not possible to quantify. Note that two aspects of Target 1 are split in this illustration, separating spatial planning (indirect driver: institutions) and retaining intact and wilderness areas (direct driver: land/sea use change). Timeframes needed to invest in and deliver positive results for each set of targets, milestones and Goal A are shown below (see main text on time lags). B) the proportionate contribution of Targets 1-10 to Milestones*

A1, A2 and A3, and of these milestones to Goal A. The sum of proportions in each subfigure adds to 100%.

Table 1. *Three types of scenarios with different levels of achievement of targets of the GBF (top part of table) and projected progress towards achieving the 2030 milestones for biodiversity (bottom part of table; see S3 for more details and projections to 2050). The "Continued Trends +30% Protected Areas" scenario type is based on observed progress on direct and indirect drivers of biodiversity loss over the recent past, with one exception which is a large increase in the extent of protected area coverage but with weak to moderate progress on other elements of this target. The "Conservation and Restoration" scenario type is based on ambitious actions focusing on traditional conservation actions and restoration, but assuming continued trends for other major direct and indirect drivers. The "Transformative Change" scenario type assumes high ambition and achievement of all of the supporting processes and means of implementation in the GBF as well as achievement of conservation and restoration targets. Note: *Managed ecosystem integrity is included here because it is a component of the 2050 Goal for biodiversity even though it is not part of the 2030 Milestones. **Progress towards genetic diversity milestones have high uncertainty because they are rarely addressed in scenarios and much less information on trends is available, especially in wild species.*

Progress on Milestones and Targets

None or Little	
Modest	
Good or very good	

		Scenario Type		
		Continued Trends +30% PA	**Conservation & Restoration**	**Transformative Change**
Targets (T)	**Target elements**	**Assumptions for scenario types**		
Protected areas (T3)	*Area (30%)*			
	Effective & Representative			
Spatial planning, restoration & species management (T1, 2, 4)	----			
Sustainable use, pollution, invasive species, implementation and mainstreaming	----			
Dimension of biodiversity	**Milestone elements**	**Progress towards 2030 biodiversity Milestones**		
Ecosystems	*Area (natural)*			
	Integrity (natural)			
	Connectedness			
	*Managed ecosystems**			
Species	*Extinction rate*		e.g., Birds, Mammals	
			e.g., Invertebrates	
	Theatened status			
	Abundance			
Genetic diversity**	*Wild*			
	Domesticated			

Supporting Material

Supplement S1 - Description of GBF goals, milestones, targets and background on process

Supplement S2 - Synthesis of global sustainability scenarios

References

Supplement S1: Description of GBF goals, milestones, targets and background on process

At COP 14 in Egypt, countries adopted a preparatory process for the development of the post-2020 Global Biodiversity Framework, and established an Open-Ended Working Group (OEWG), co-chaired by Francis Ogwal, Ghana and Basile van Havre, Canada. The preparatory process is participatory, aiming for comprehensive consultation with a broad range of stakeholders across regions and themes. The first OEWG meeting was held in Nairobi, 27-30 August 2019, at which the scope of the framework was discussed, and the co-chairs were requested to prepare the zero order draft (ZOD) of the framework. A schedule for consultations was also set out at this meeting.

The second OEWG meeting took place in Rome, 24 - 29 February 2020. Participants reviewed the ZOD, and commented on the proposed goals and targets. SBSTTA was requested to provide a technical and scientific review, and the co-chairs were tasked to prepare a first draft. This first draft is available as CBD/WG2020/3/3[2]. Due to the COVID pandemic, part I of the 3rd meeting of the OEWG was conducted virtually from 23 August to 3 September 2021, providing an opportunity for parties and stakeholders to exchange views, and to prepare for part II of OEWG-3, to take place in Geneva, March 2022.

<u>Elements of the post-2020 Global Biodiversity Framework</u>

2050 Vision

The vision of the framework is a world living in harmony with nature where: “By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.”

2030 Mission

The mission of the framework for the period up to 2030, towards the 2050 vision is: “To take urgent action across society to conserve and sustainably use biodiversity and ensure the fair and

[2] CBD 2021: First Draft of the post-2020 Global Biodiversity Framework. CBD/WG2020/3/3, issued 5 July 2021. https://www.cbd.int/doc/c/914a/eca3/24ad42235033f031badf61b1/wg2020-03-03-en.pdf

equitable sharing of benefits from the use of genetics resources, to put biodiversity on a path to recovery by 2030 for the benefit of planet and people."

2050 Goals and 2030 Milestones

The framework has four long-term goals for 2050 related to the 2050 Vision for Biodiversity. Each 2050 goal has a number of corresponding milestones to assess, in 2030, progress towards the 2050 goals. The four goals and their associated milestones are:

Goal A. The integrity of all ecosystems is enhanced, with an increase of at least 15 per cent in the area, connectivity and integrity of natural ecosystems, supporting healthy and resilient populations of all species, the rate of extinctions has been reduced at least tenfold, and the risk of species extinctions across all taxonomic and functional groups, is halved, and genetic diversity of wild and domesticated species is safeguarded, with at least 90 percent of genetic diversity within all species maintained.

Milestone A.1 - Net gain in the area, connectivity and integrity of natural systems of at least 5 percent.

Milestone A.2 - The increase in the extinction rate is halted or reversed, and the extinction risk is reduced by at least 10 per cent, with a decrease in the proportion of species that are threatened, and the abundance and distribution of populations of species is enhanced or at least maintained.

Milestone A.3 - Genetic diversity of wild and domesticated species is safeguarded, with an increase in the proportion of species that have at least 90 per cent of their genetic diversity maintained.

Goal B. Nature's contributions to people are valued, maintained or enhanced through conservation and sustainable use supporting the global development agenda for the benefit of all.

Milestone B.1 - Nature and its contributions to people are fully accounted and inform all relevant public and private decisions.

Milestone B.2 - The long-term sustainability of all categories of nature's contributions to people is ensured, with those currently in decline restored, contributing to each of the relevant Sustainable Development Goals.

Goal C. The benefits from the utilization of genetic resources are shared fairly and equitably, with a substantial increase in both monetary and non-monetary benefits shared, including for the conservation and sustainable use of biodiversity.

Milestone C.1 - The share of monetary benefits received by providers, including holders of traditional knowledge, has increased.

Milestone C.2 - Non-monetary benefits, such as the participation of providers, including holders of traditional knowledge, in research and development, has increased.

Goal D. The gap between available financial and other means of implementation, and those necessary to achieve the 2050 Vision, is closed.

Milestone D.1 - Adequate financial resources to implement the framework are available and deployed, progressively closing the financing gap up to at least US $700 billion per year by 2030.

Milestone D.2 - Adequate other means, including capacity-building and development, technical and scientific cooperation and technology transfer to implement the framework to 2030 are available and deployed.

Milestone D.3 - Adequate financial and other resources for the period 2030 to 2040 are planned or committed by 2030.

2030 Action Targets

The framework has 21 action-oriented targets for urgent action over the decade to 2030. The actions set out in each target need to be initiated immediately and completed by 2030. Together, the results will enable achievement of the 2030 milestones and of the outcome-oriented goals for 2050. Actions to reach these targets should be implemented consistently and in harmony with the

Convention on Biological Diversity and its Protocols and other relevant international obligations, taking into account national socioeconomic conditions.

1. Reducing threats to biodiversity

Target 1. Ensure that all land and sea areas globally are under integrated biodiversity-inclusive spatial planning addressing land- and sea-use change, retaining existing intact and wilderness areas.

Target 2. Ensure that at least 20 percent of degraded freshwater, marine and terrestrial ecosystems are under restoration, ensuring connectivity among them and focusing on priority ecosystems.

Target 3. Ensure that at least 30 per cent globally of land areas and of sea areas, especially areas of particular importance for biodiversity and its contributions to people, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 4. Ensure active management actions to enable the recovery and conservation of species and the genetic diversity of wild and domesticated species, including through ex-situ conservation, and effectively manage human-wildlife interactions to avoid or reduce human-wildlife conflict.

Target 5. Ensure that the harvesting, trade and use of wild species is sustainable, legal, and safe for human health.

Target 6. Manage pathways for the introduction of invasive alien species, preventing, or reducing their rate of introduction and establishment by at least 50 per cent, and control or eradicate invasive alien species to eliminate or reduce their impacts, focusing on priority species and priority sites.

Target 7. Reduce pollution from all sources to levels that are not harmful to biodiversity and ecosystem functions and human health, including by reducing nutrients lost to the environment by at least half, and pesticides by at least two thirds and eliminating the discharge of plastic waste.

Target 8. Minimize the impact of climate change on biodiversity, contribute to mitigation and adaptation through ecosystem-based approaches, contributing at least 10 $GtCO_2e$ per year to global mitigation efforts, and ensure that all mitigation and adaptation efforts avoid negative impacts on biodiversity.

2. Meeting people's needs through sustainable use and benefit-sharing

Target 9. Ensure benefits, including nutrition, food security, medicines, and livelihoods for people especially for the most vulnerable through sustainable management of wild terrestrial, freshwater and marine species and protecting customary sustainable use by indigenous peoples and local communities.

Target 10. Ensure all areas under agriculture, aquaculture and forestry are managed sustainably, in particular through the conservation and sustainable use of biodiversity, increasing the productivity and resilience of these production systems.
Target 11. Maintain and enhance nature's contributions to regulation of air quality, quality and quantity of water, and protection from hazards and extreme events for all people.

Target 12. Increase the area of, access to, and benefits from green and blue spaces, for human health and well-being in urban areas and other densely populated areas.

Target 13. Implement measures at global level and in all countries to facilitate access to genetic resources and to ensure the fair and equitable sharing of benefits arising from the use of genetic resources, and as relevant, of associated traditional knowledge, including through mutually agreed terms and prior and informed consent.

3. Tools and solutions for implementation and mainstreaming

Target 14. Fully integrate biodiversity values into policies, regulations, planning, development processes, poverty reduction strategies, accounts, and assessments of environmental impacts at all levels of government and across all sectors of the economy, ensuring that all activities and financial flows are aligned with biodiversity values.

Target 15. All businesses (public and private, large, medium and small) assess and report on their dependencies and impacts on biodiversity, from local to global, and progressively reduce negative impacts, by at least half and increase positive impacts, reducing biodiversity-related risks to businesses and moving towards the full sustainability of extraction and production practices, sourcing and supply chains, and use and disposal.

Target 16. Ensure that people are encouraged and enabled to make responsible choices and have access to relevant information and alternatives, taking into account cultural preferences, to reduce by at least half the waste and, where relevant the overconsumption, of food and other materials.

Target 17. Establish, strengthen capacity for, and implement measures in all countries to prevent, manage or control potential adverse impacts of biotechnology on biodiversity and human health, reducing the risk of these impacts.

Target 18. Redirect, repurpose, reform or eliminate incentives harmful for biodiversity, in a just and equitable way, reducing them by at least US$ 500 billion per year, including all of the most harmful subsidies, and ensure that incentives, including public and private economic and regulatory incentives, are either positive or neutral for biodiversity.

Target 19. Increase financial resources from all sources to at least US$ 200 billion per year, including new, additional and effective financial resources, increasing by at least US$ 10 billion per year international financial flows to developing countries, leveraging private finance, and increasing domestic resource mobilization, taking into account national biodiversity finance planning, and strengthen capacity-building and technology transfer and scientific cooperation, to meet the needs for implementation, commensurate with the ambition of the goals and targets of the framework.

Target 20. Ensure that relevant knowledge, including the traditional knowledge, innovations and practices of indigenous peoples and local communities with their free, prior, and informed consent, guides decision-making for the effective management of biodiversity, enabling monitoring, and by promoting awareness, education and research.

Target 21. Ensure equitable and effective participation in decision-making related to biodiversity by indigenous peoples and local communities, and respect their rights over lands, territories and resources, as well as by women and girls, and youth.

Supplement S2 - Quantification of target-milestone interactions under Goal A

This section justifies the quantification of target - milestone interactions used in Fig. 1, also contained in CBD/SBSTTA/24/INF/31[3] (14 January 2022). The 21 action targets in the GBF correspond roughly to direct and indirect drivers and to nature's contributions to people as classified by IPBES (1), as well as tools and solutions for delivering the GBF. However this is a coarse mapping based on interpretation of the text of the targets and milestones, and the biological relationships that underpin them, contributing to the many-to-many relationships among the targets and to the outcomes. For example, Target 1 explicitly cites addressing land and sea use change and retaining intact ecosystems thus implying an ecosystem focus, but spatial planning also provides the framework for implementation and integration of all action targets together. Also, the IPBES assessment (1) assigned a greater impact of land and sea use change on species dimensions of biodiversity than on ecosystem dimensions (Tables S1 and S2), such that while Targets 1, 2 and 3 may relate most directly to land and sea use change as a driver, it impacts more on species (Milestone A.2) than ecosystem (Milestone A.1) outcomes.

The contribution of each target to the milestones of the GBF was derived using two sources of information: a) the attribution of direct drivers of biodiversity decline to components of biodiversity (fig. 2.2.22.A in IPBES 2019), and b) for those targets not covered by this (Targets 9 and 10), expert judgement. The approach used by IPBES (1, Section 2.2.6), was based on reviews of the scientific literature and on attribution by Indigenous Peoples and Local Communities (IPLCs) to assign weightings of drivers to components of biodiversity at a global level, among four world regions and major realms. This approach has limitations, and weightings may be quite different especially at smaller scales and specific systems.

The relative contribution of each direct driver to the decline in elements of biodiversity was estimated from Fig. 2.2.22.A in IPBES (1), the total attributed to 'other' causes of decline was assigned evenly across the direct drivers (assuming equal interactions across them; Table S1). These results were aggregated to the three components of biodiversity in milestones A1, A2 and A3 (Table S1). Table 3 documents application of the contributions of each driver to Targets 1-8, and assumptions made for Targets 9 and 10.

[3]Expert Input to the Post-2020 Global Biodiversity Framework: Transformative Actions on all Drivers of Biodiversity Loss are Urgently Required to Achieve the Global Goals by 2050 (https://www.cbd.int/doc/c/5735/c241/efeeac8d7685af2f38d75e4e/sbstta-24-inf-31-en.pdf)

Table S1. *Relative contribution of each direct driver to decline in dimensions of biodiversity, on a scale of zero to 10 (Source: IPBES (1), Section 2.2.6, fig 2.2.22.A). CC - climate change; Exp - direct exploitation of organisms; IAS - invasive alien species; LSUC - land and sea use change; Pol - Pollution.*

Component	Dimension	CC	Exp	IAS	LSUC	Pol	Other	Total
Genetic (A3)	**Genetic composition**	1.9	1.4	1.1	2.1	2.4	1.1	10
Species (A2)	**Species populations**	1.2	2.4	1.3	3.1	1.2	0.7	10
	Species traits	2.1	2.4	1.3	1.7	1.5	1.1	10
	Community composition	2.0	1.4	1.1	2.9	1.6	1.0	10
Ecosystem (A1)	**Ecosystem function**	1.9	1.7	1.3	2.4	1.6	1.1	10
	Ecosystem structure	1.5	2.1	0.8	2.1	2.3	1.1	10

Table S2. *Aggregate contributions for the three components of biodiversity in milestones A1 (ecosystems), A2 (species) and A3 (genetic), from Table S1.*

Component	CC	Exp	IAS	LSUC	Pol
Ecosystem (A1)	1.93	2.14	1.26	2.51	2.16
Species (A2)	1.96	2.27	1.42	2.73	1.62
Genetic (A3)	2.09	1.60	1.29	2.37	2.66
Overall weight	***5.98***	***6.01***	***3.96***	***7.62***	***6.43***

Table S3 *Weighting of Targets 1-10 in addressing Milestones A1, A2 and A3 in the global biodiversity framework. Values in the cells obtained from Table A1.2B.*

Target	Milestone			Comments
	A1	A2	A3	
T1 - Spatial planning, intact and wilderness areas	2.5	2.7	2.4	Spatial planning focuses on ecosystems/habitats, but is relevant to species as well. Overall magnitude assumed equal to LSUC (Targets 2 & 3)

T2 - Restoration	2.5	2.7	2.4	Restoration actions cross a full range across ecosystem, species and genetic actions, so equivalent to Targets 1 and 3.
T3 – Protected and conserved areas	2.5	2.7	2.4	From IPBES (1) direct driver quantification. Protection is equivalent to ecosystem actions and LSUC.
T4 - Species recovery	1.0	4.0	1.0	Target 4 focuses on direct species actions, not attributable to direct drivers, so heaviest weight is applied to species actions, with a minor component on genetic diversity and habitat actions.
T5 - Wild species use	2.1	2.3	1.6	From IPBES (1) direct driver quantification on direct exploitation of species.
T6 - Invasive alien species	1.3	1.4	1.3	From IPBES (1) direct driver quantification on invasive alien species.
T7 - Pollution	2.2	1.6	2.7	From IPBES (1) direct driver quantification on pollution.
T8 - Climate change	2.5	2.5	2.5	Increased from IPBES (1) direct driver quantification of climate change impacts, to be equivalent to largest driver, LSUC (Targets 1, 2, 3) and equal impact across dimensions.
T9 - Share benefits	2.1	2.3	1.6	Equivalent to Target 5, addresses benefit sharing from wild species use.
T10 - Use/extraction	2.5	2.7	2.4	Managed ecosystems - assume equivalent to Land/Sea Use Change (Targets 1, 2, 3).

Supplement S3 - Synthesis of global sustainability scenarios

This supplement consists of verbatim extracts from CBD/SBSTTA/24/INF/31[4] (14 January 2022).

"Scenarios on land for the period 2030-2050 show:

- Continued trends in direct and indirect drivers result in rapid degradation of all dimensions of biodiversity (although genetic diversity is rarely addressed).
- Strong conservation actions, including protected areas, can play a very important role in reducing biodiversity loss. However, protected areas with weak levels of protection, weak management or placement in areas of low biodiversity value are of little, or no, help in slowing biodiversity loss.
- Expansion of protected areas to 50% of land ("half Earth") may substantially increase the risk of food insecurity.
- Limiting global warming to 1.5°C or below is essential to meeting ambitious biodiversity goals, especially for 2050 and beyond.
- Conservation and restoration can slow biodiversity loss, but only transformative changes of underlying drivers such as unsustainable production and consumption can halt and reverse biodiversity loss over the long term.
- Limiting global warming to 1.5°C or below is essential to meeting ambitious biodiversity goals, especially for 2050 and beyond.
- Conservation and restoration can slow biodiversity loss, but only transformative changes of underlying drivers such as unsustainable production and consumption can halt and reverse biodiversity loss over the long term."

"Table S4 provides a qualitative synthesis of six very recent scenario studies that are relevant to setting ambition for the GBF goals, milestones and targets for terrestrial biodiversity (see also Appendix 1.3 of CBD/SBSTTA/24/INF/31 for a quantitative analysis of the land use impacts on species extinction risk). We compare four scenarios that have a basis in the relatively complex Shared Socio-economic Pathways developed in support of the IPCC. Three of these, (2-4), have made significant modifications to increase the representation of sustainability and explicitly add biodiversity conservation. Two of the scenarios (5,6) use statistical extrapolations of land use trends along with relatively simple assumptions about the land use implications of protected areas

[4] Expert Input to the Post-2020 Global Biodiversity Framework: Transformative Actions on all Drivers of Biodiversity Loss are Urgently Required to Achieve the Global Goals by 2050 (https://www.cbd.int/doc/c/5735/c241/efeeac8d7685af2f38d75e4e/sbstta-24-inf-31-en.pdf)

and food systems. These scenarios highlight the importance of i) well-implemented conservation and restoration and ii) transformations of agricultural production, sustainable diets and reducing food waste. Only two of the studies include climate change impacts on biodiversity (1,3) and both indicate that even low levels of climate change greatly increase the risks for biodiversity."

"In addition to these global sustainability scenarios, other scenarios, models and observations indicate that expansion of protected areas in the future could help slow biodiversity loss, but not halt it, and are only beneficial when properly placed and well-managed. Observations show that species abundance within protected areas has continued to decline, the placement and resourcing of the majority of protected areas has been poor, and more than half of recent protected areas have had significant increases in threats to biodiversity (7,8). Scenarios and models suggest that substantial increases in protected areas on land could be beneficial for biodiversity (Table S4), but most of these scenarios assume that protected areas in the future are well-managed, well-placed and properly resourced. Scenarios with non-optimal placement, or weak management indicate that increasing protected area coverage will be of little value and even counter-productive (7,9,10). Scenarios and models also suggest that expansion to 50% global coverage of land area could compete for land with agriculture and substantially increase the risk for food security, especially in sub-Saharan Africa (Table S4)."

"At regional scales, (2) and (5) also point to the regional diversity of what constitutes the most efficient combinations of actions on direct and indirect drivers, and spillovers across regions via trade. Direct actions to stop habitat loss in one region are ineffective if the harmful activities relocate to another region as many of these activities are tightly linked to international value chains (11). Direct actions to stop habitat loss are, thus, best complemented with action to replace these commodities by lower footprint alternatives to decrease the overall pressures, and thus decrease the risk of spillovers across regions. Sustainability scenarios and models for terrestrial systems at local scales show a combination of careful spatial planning, the introduction of sustainable or regenerative production practices and a decrease of overall pressure through the value chain."

"An important caveat concerning these scenarios is that they do not consider invasive alien species, pollution from fertilizers, pesticides and light (see Appendix 1.6 for discussion of future light impacts on species), bushmeat hunting, and many other factors that will increase human impacts on biodiversity. In addition, only two studies take into account climate change impacts on biodiversity."

Table S4. *Analysis of six global sustainability scenarios. The four studies at the top of the table are based on modifications of the Shared Socio-economic Pathways (SSP) scenarios developed in support of the Intergovernmental Panel on Climate Change (IPCC). Background color: continued trends = grey, conservation and restoration only = blue, transformative change = green. Arrows indicate the qualitative response of biodiversity for habitat area, biodiversity intactness and extinction risk (downward arrows indicate more species threatened with extinction). Short arrows indicate responses for "current" to 2030 (first arrow) and then 2030 to 2050 (second arrow). Long arrows indicate responses for "current" to 2050. Color and angle of arrow indicate direction of response compared to reference date which is 2010 or 2015 for the long arrows and first short arrow, 2030 for second short arrow: black = very negative ; red = negative; orange = negative but slower than current trend; yellow = stabilization; green = slight improvement; blue = substantial improvement. In the "Scenario assumptions" column: SE = socio-economic scenario; CC = climate change scenario and projected 2050 global warming.*

Study	Scenario name	Scenario assumptions	Protected Areas	Restoration	Food Systems	Climate impact	Habitat Area	Intactness	Extinction Risk	Comments
(1, 12) Biodiversity model = Multi-model	Continued trends	SE = SSP3 CC = RCP6.0 ≈ 3-4°C by 2100	None explicit	None explicit	Continued trends	no				
	Continued trends	SE = SSP3 CC = RCP6.0 ≈ 3-4°C by 2100	None explicit	None explicit	Continued trends	yes				
	Sustainability	SE = SSP1 CC = RCP 2.6 ≈ 2°C, stable	30%, reduced deforestation	Not explicit	Close yield gaps Sustainable consumption	no				Weaker land use constraints than other sustainability scenarios
	Sustainability	SE = SSP1 CC = RCP 2.6 ≈ 2°C, stable	30%, reduced deforestation	Not explicit	Close yield gaps Sustainable consumption	yes				idem
(2)	Continued trends	SE = SSP2 CC = NA	no further expansion beyond 2010	None explicit	Continued trends	no				
Biodiversity model = Multi-model	Conservation and restoration	SE = SSP2 CC = NA	40% by 2020 (KBAs & Wild. areas)	≈5 million km² by 2050 (≈ 4%)	Continued trends	no				Also includes land-use planning over all land
	+ Sustainable production & consumption	SE = SSP1 CC = NA	40% by 2020 (KBAs & Wild. areas)	≈10 million km² by 2050 (≈ 8%)	Close yield gaps; Healthy diet, -50% meat; -50% food waste	no				Also includes land-use planning over all land
(3)	Continued trends	SE = SSP2 CC ≈ 2,1°C rising	17% by 2020, no further expansion	None explicit	Continued trends	yes				
Biodiversity model = GLOBIO	Conservation = "Sharing the Planet Earth"	SE = SSP2 CC = 2,1°C rising	30% by 2050, focus ES	Rehabilitation	Continued trends	yes				
	Conservation ="Half Earth"	SE= SSP2 CC = 2,1°C rising	50% by 2050, focus BD	Ecological restoration	Continued trends	yes				Food security risk above SSP-2 baseline; highest food security risk
	Conservation = "Sharing the Planet" + Sustainability	SE = SSP2 CC = 1.6°C stable	30% by 2050, focus ES	Rehabilitation	Close yield gaps; Sustain diet, -50% animal products; -50% food waste	yes				Lowest food security risk Largest improvement regulating services

Study	Scenario name	Scenario assumptions	Protected Areas	Restoration	Food Systems	Climate impact	Habitat Area	Intactness	Extinction Risk	Comments
(4)	Continued trends	SE = SSP2 CC = NDC ≈ ??°C	None explicit	None explicit	Continued trends	no	↘↘	↘↘	—	Nat. habitat = primary and secondary vegetation?
Biodiversity model = BII	Sustainability + Climate mitigation	SE = SSP1 CC ≈ <1.5°C	Increase in forest protection	?	Close yield gaps Global equity	no	→→	→→	—	
	+ SDG package	+ try to meet all SDG objectives CC ≈ <1.5°C	Above + expansion to biodiversity hotspots	?	Close yield gaps Sustain. diets (EAT) Reduce food waste Global equity	no	↗↗	↗↗	—	Actions have strong synergies across multiple SDG goals. Lower food security risk
(6)	30% Strict Protected Area	SE = PA optimization CC - none	34% by 2030	19 million km²	Continued trends	no	→	—	↘	Arrows use 2015 baseline
Biodiversity model = habitat suitability	100% Spatial planning	SE = land use optimization CC - none	17% + Spatial planning	14.5 million km²	Continued trends	no	↗	—	↗	Lowest trade-off between biodiversity and food security
	30% Strict PA + spatial planning everywhere else	SE = both of above CC - none	34% by 2030	18 million km²	Continued trends	no	↗	—	↗	Highest food security risk
(5)	Continued trends	SE = Statistical extrapolation of land use trends	Continued trends	Continued trends	Continued trends	No	↘	—	↘	
Biodiversity model = habitat suitability	Spatial planning	SE = Global land use planning	Protect high priority areas	Not explicit	Continued trends	No	↘	—	↘	
	+ Sustainable production and consumption	SE = above + Sustainable agriculture and consumption	idem	Regrowth on abandonned land	Close yield gaps Sustain. diets Reduce food waste	No	↗	—	→	

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