Towards a Multidimensional Biodiversity Index for national application

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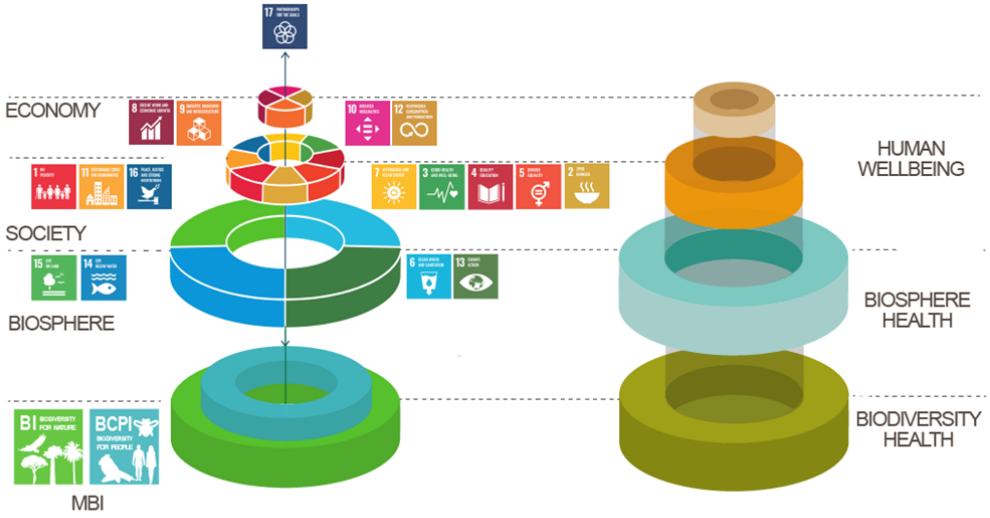
Preface: The lack of urgent action and progress to reverse biodiversity loss is partly due to the complex nature of biodiversity as a feature of our planet, and subsequently the often-confusing variety of narratives that policy makers receive on why biodiversity matters. This complexity makes it difficult to derive a clear link between biodiversity loss and associated risks to our societies in their attainment of the SDGs. Addressing this challenge calls for a more pluralistic and multidimensional perspective on biodiversity to reassess what we value, facilitate mainstreaming and support decision making. We propose a Multidimensional Biodiversity Index as a 'biodiversity lens' for multifaceted policy decisions on sustainability, where biodiversity is valued for its own sake and in relation to human wellbeing.

Biodiversity and human development are intrinsically linked (Box 1)[1–6]; people rely on biodiversity and its derived contributions to wellbeing in different ways, while development often negatively impacts biodiversity directly, and indirectly via the promotion of a narrow set of values in society towards living nature[7]. Effective policy interventions for biodiversity conservation and management ought to be inextricably linked to any socio-economic development agenda, so that biodiversity-related risks are no longer undervalued in policy- and decision-making. Without such a coupled approach, different types of biodiversity knowledge cannot meaningfully inform decisions aiming to achieve dual goals on enhancing ecological integrity and improving human wellbeing.
In a world where damaged ecosystems already negatively impact 3.2 billion people[8], one million animal and plant species are threatened with extinction[1], and where the global human population is already exposed to global disease outbreaks[9] and is currently in a pandemic era[10], we need ways to

assess and monitor the 'health' of biodiversity. We therefore propose a Multidimensional Biodiversity Index (MBI) that can be used and adapted by national policy makers as way to measure key values underpinning nature–human relationships, and how the dramatic loss of biodiversity brings serious risks to societies and economies.

START BOX 1----------

Box 1. The role of biodiversity health in underpinning human wellbeing and sustainable development (Modified from[11]). Biodiversity loss can undermine the achievement of all the Sustainable Development Goals (SDGs)[3]. Healthy economies depend on a healthy biosphere, which in turn relies on healthy and resilient biodiversity. Healthy ecosystems function better and deliver benefits to people. Hence, opportunities for human prosperity and sustainable development rely on the future and health of biodiversity. A coupled MBI metric that considers biodiversity and people as part of a healthy system could contribute to mainstreaming and integrating biodiversity considerations in national socio-economic development strategies and action plans.



END BOX 1----------

Biodiversity is defined by the Convention on Biological Diversity (CBD) at genetic, species and ecosystem levels, and complexity arises at all three levels of community organisation. Discussions on the need to address biodiversity as a multidimensional construct are long standing in the scientific community[7], but the development of synthetic measures for biodiversity is considered a difficult and controversial issue. In response, metrics and indicators continue to proliferate in attempts to capture different facets of, and values derived from, biodiversity. However, despite widespread recognition of the importance of multidimensionality, it is rarely applied in decision making.

Current biodiversity policy is mostly informed by multiple unidimensional indicators covering different facets of biodiversity[7,12–16]. Many of these can help assess the cumulative impacts on biodiversity outcomes of responses taken across countries to identify whether national commitments and implementation are contributing towards global biodiversity targets. This is particularly important within the context of the CBD and its reporting mechanisms. However, those indicators do not relate to human values about biodiversity and are difficult to apply at the scales where policy decisions need to be designed and implemented – typically from national to local. Hence, there is still a need for better integration, better representativeness and more multidimensional assessments of biodiversity. Without this, it is difficult for decision makers, including elected representatives within national and subnational governments and technical and policy advisers in natural resource-based departments, to make effective use of the extensive data collection and analysis achieved by the scientific community to inform sustainable development.

In our experience, there is a demand from policy makers at national levels for more pluralistic perspectives on (and thus measures of) biodiversity and to synthesise different types of biodiversity knowledge to make it more actionable. A multidimensional measure for biodiversity should reflect contextual socio-ecological trends and scenarios and unpack key facets of the concept of biodiversity including the values underpinning human wellbeing[7,17].

We recognise two major challenges in developing a workable multidimensional measure for biodiversity. Firstly, biodiversity is an emergent and dynamic property of ecosystems, with different functions and scales to consider, and its parts are interdependent. Secondly, given the different ways biodiversity may be conceptualized as living nature and the diversity of its values, it is challenging to include within a single measure the often-conflicting goals of biodiversity conservation and human

developmental aspirations[7]. Here, we discuss these challenges and outline a way towards conceptualising and ultimately operationalising a policy-focused MBI that incorporates both ecological and human-centred pluralistic perspectives on biodiversity for use by national governments.

Learning from other sectors

Our analyses of how different sectors have tackled the challenge of assessing complex societal issues such as human development[18], poverty[19], modern slavery[20], global rights[21] or corruption[22] suggest that, despite their limitations and criticisms, multidimensional indices are effective tools for policy analyses, advocacy and social awareness[23].

In the economic realm, despite its well-known limitations[24,25], Gross Domestic Product (GDP) continues to be the *de facto* policy goal for policy leaders and the 'thermometer' used to measure and monitor a nation's overall economic health and prosperity. It is well understood that if we run down the stock of produced and human assets, we will reduce the economy's productive capabilities. Likewise, relentless human pressures on biodiversity as a natural asset, undermining its stability, resilience and ability to support human development and wellbeing aspirations, can have catastrophic effects on society of equal or greater magnitude to any economic crash. Nevertheless, there is yet no analogue for biodiversity that could meaningfully influence national policy alongside macroeconomic indicators.

Governments are increasingly recognising that the various transitions and transformations to achieve the SDGs are all connected[26]. In addition, many economists are also calling for a paradigm shift in the way that economic progress is measured, arguing that economies must be designed to thrive and balance, not necessarily to grow[6,27–30]. As the Dasgupta Review points out, one could think of ecosystems as productive assets, and biodiversity as one descriptive feature of these assets. Of course, this should not preclude understanding biodiversity from a more pluralistic perspective[7]. But the point is that as policy making is most often determined by economic imperatives, policy interventions must also acknowledge that biodiversity plays a key role in the functioning of economies that they themselves try to protect and foster. One way to see the critical role of biodiversity to the economy is by noting its role in reducing uncertainty as regards the material contributions nature offers to people and on which economies largely depend upon, such stability for food security [6,31]. The variability of species and the genetic variation within those species enables ecosystems to respond to

104 change, acting as a form of natural insurance[32] or as a diverse portfolio that spreads risk, especially in
105 the context of increased risks due to climate change[33].
106 [244]Economists increasingly emphasise the need for a transition towards a mindset that considers both
107 the social and ecological conditions underpinning collective human wellbeing and economic
108 prosperity[6,25], which brings lessons to the biodiversity community to learn from as for the potential to
109 follow similar approaches.
110 Another successful index widely used to inform and coordinate multisectoral efforts on designing and
111 implementing development strategies, and as a platform for public debates on policy priorities, is the
112 Human Development Index (HDI). Whether or not HDI and GDP are flawed, discussions around these
113 metrics have leveraged strong political action and societal advocacy, reshaping our understanding of
114 sustainable development and economic prosperity.
115 In our view, a multidimensional index on 'biodiversity health' can contribute to: providing a coherent
116 national-level framework to monitor state and progress on safeguarding biodiversity that matter to
117 people; linking biodiversity conservation and management to different dimensions of human wellbeing
118 and thus to the idea of sustainable development as outlined in the 2030 Agenda for Sustainable
119 Development; and providing countries with a national condition indicator for the state of biodiversity
120 and its derived contributions to its citizens, which is important to both current and future uses of living
121 nature and for citizens to be able to demand, monitor and help enforce ambitious biodiversity
122 conservation decisions.
123 We expect that annually/biannually calculated changes in biodiversity health would guide
124 policymakers in priority setting and policy formulation on biodiversity conservation. This, together with
125 the analyses of associations between changes in other societal indices, could help to derive more
126 comprehensive conclusions on progress and trends towards sustainable development (Box 2). An
127 index on biodiversity and its contributions to people can also help track progress towards broader
128 societal visions such as 'Living in harmony with nature'[34], 'Ecological civilization'[35] or 'One Health'[36]
129 that capture the idea that 'biodiversity health' interacts with human wellbeing.
130 **The policy opportunity**
131 On current trajectories, the environmental dimension of the SDGs will not be achieved by 2030[2], with
132 further negative impacts across all other SDGs[1,37,38]. Also, the failure to meet the targets of the
133 Strategic Plan for Biodiversity 2011-2020[1] has created an urgent need for national governments and

civil society to raise ambition and forge a new transformative global plan for biodiversity[39]. The current policy momentum represents a crucial opportunity to rethink and challenge how we conceptualize, measure and monitor 'biodiversity health'. This provides a significant double policy opportunity for an MBI aligned to the implementation of the post-2020 global biodiversity framework (GBF) and the SDGs.

START BOX 2----------

Box 2. A 'biodiversity lens' for multifaceted policy decisions on sustainability.

To steer the global economy towards sustainable development, the performance of national economies should be assessed using a pluralistic, not unidimensional, approach. This requires national governments to monitor changes in different 'lenses' of sustainability (economic sustainability, environmental sustainability and social sustainability), not just movements in GDP. GDP promotes short-sightedness as it measures the economic metabolism of nations only proxied by short-term income[40]. Hence, misusing GDP growth as a policy goal is distorting decisions about real societal progress[25,28]. The dominance of single economic indices such as GPD has normalised the concept of economic growth at the cost of any consideration of reduction in natural capital and indeed social capital. In the absence of any compensating ecologically and socially focused metric, perverse consequences of reliance on GDP will continue. Adopting an MBI, together with other metrics measuring performance on different societal objectives, could act as a counterweight to these consequences and help to mainstream biodiversity risks into the socio-economic policy agendas. A biodiversity health calculus added to nations' macroeconomic metrics would make policy makers value living nature's essential role in the wealth of nations and the importance of its health in underpinning economic development. A MBI calculus might measure, among other things, the status of a nation's living resources including the variety and functioning of its ecosystems, the health of its flora and fauna, the sustainability of its agriculture, the resiliency of its food security, and the security of the cultural values its people derive from biodiversity, which are all necessary as a foundation of not only environmental, but also social and economic sustainability and future human wellbeing.

The MBI would provide governments with a 'biodiversity lens', that can monitor progress and identify changes, synergies and trade-offs between 'lenses' required to achieve different societal objectives, including environmental sustainability. Examples of indices that offer different lenses on environmental sustainability include the Ocean Health Index[41], the Environmental Performance

Index[42], the Ecological Footprint[43], the Sustainable Development Goals Index and dashboard[44], the Strong Environmental Sustainability Index[45], the Global Green Growth Index[46] or the Agrobiodiversity Index[47].

A MBI that encompasses in its final score measures both of biodiversity and of its contributions to people can account for the diversity of values underpinning nature-human relationships[17]. Temporal assessments of relationships between different sustainability lenses explored as potential synergies, can help governments to monitor policies and inform decisions on long-term national sustainable development paths through, for example, biodiversity-extended benefits/costs ratios. This could also inform target-setting at national and sub-national scales to help meet international policy goals. An example of complementary use of different 'lenses' on sustainability is the combined criteria of the Multidimensional Poverty Index (MPI) and unidimensional income-based poverty measures to reprogram conditional cash transfer (CCT) programs[48].

It is possible to argue that, while near-universal uptake of GDP as a measure of national economic progress has driven a number of perverse consequences in the dash for growth, the adoption of any index, including the MBI, might lead to perverse policy decisions. For the MBI, the well-known long time lags between policy implementation and conservation outcomes [49] suggest that long time frames required for investment to lead to upturns in 'biodiversity health', compared with those shorter time frames for investment in creating upturns for economic growth, might result in abandonment of investment due to political short-termism just at a point when benefits might be about to accrue. Nevertheless, we still need to help governments take necessary steps to preserve biodiversity as a foundation for sustainable development. Maintaining a better grasp of biodiversity health through pluralistic assessments such as the MBI could represent a solid step forward.

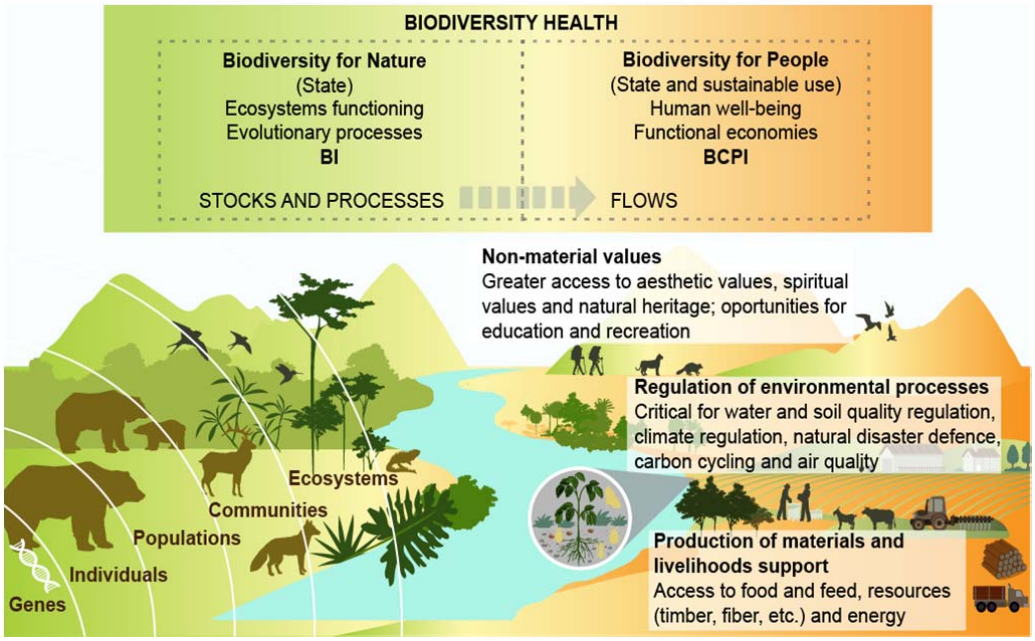
END BOX 2----------

Conceptualisation of biodiversity health

We define biodiversity health as the state of biodiversity at the genetic, species and ecosystem levels, which enables the maintenance of biological processes such as production[50] required to underpin fully functioning ecosystems and the continued flows of associated contributions to human wellbeing and human development. This definition encompasses both an ecological perspective that considers biodiversity as part of living nature from the 'supplier' side (i.e., ecological processes), and a social

193 perspective which reflects the 'recipient' side (and which include instrumental values following
194 economic reasons) but also other ones, including relational values[17,51,52] (Figure 1).
195 From an ecological perspective biodiversity health is a property of a stable and resilient Earth system
196 (biodiversity for nature). The variety of species in the system, their interactions and the genetic
197 variation within those species enable ecosystems to respond to change, support complementary
198 ecosystem functions thereby increasing ecosystem stability, and result in positive effects on outputs
199 derived from Earth system processes such as productivity[50].
200 From an ecological perspective, supporting biodiversity health means preserving biodiversity for its
201 own sake (intrinsic value) but also as elements (stocks and processes) that underpin the stability,
202 productivity and resilience of ecosystems, preventing ecosystem collapse (insurance value), and that
203 directly and indirectly contribute to people's wellbeing. Key facets of biodiversity health include
204 functional diversity, ecological integrity (i.e., connectivity, intactness and resilience) and the
205 evolutionary processes of biodiversity. Ecologically centred biodiversity health should be assessed
206 using fundamental attributes (such as richness, abundance and phylogenetic diversity) at the genes,
207 species and ecosystems levels (Figure 1).
208 From a social perspective, biodiversity health means a state in which the provision of the positive
209 contributions that humans derive from biodiversity, is maintained through sustainable use and direct
210 protection. These positive contributions are the conduit between biodiversity and human development
211 and influence the attainment of 'social sustainability' in terms of the diversity of values of nature's
212 contributions to people[17]. Assessments of biodiversity health under this perspective require examining
213 biodiversity from a human-centred pluralistic perspective to define the values people hold and derive
214 from living nature, how and to what extent societies wish to transform the various assets, including
215 biodiversity as natural asset, in ways that can maintain the support for economies and thus people's
216 developmental aspirations across socio-cultural contexts[7].
217 **Figure 1. Conceptualisation of 'biodiversity health'.** We define biodiversity health under 1) an
218 ecological perspective (i.e., biodiversity has intrinsic value as well as insurance value against Earth
219 system collapse) and 2) a social perspective (i.e., biodiversity is a condition to maintain the wide
220 spectrum of values and benefits on which human wellbeing and economies rely). The grading in the
221 colours highlight how biodiversity underpins human development and functional economies. The MBI
222 metric provides an assessment of biodiversity health as a function of the state of biodiversity

(visualised as stocks and processes) and the state and sustainable use of its contributions to people (visualised as flows and human-nature relations).



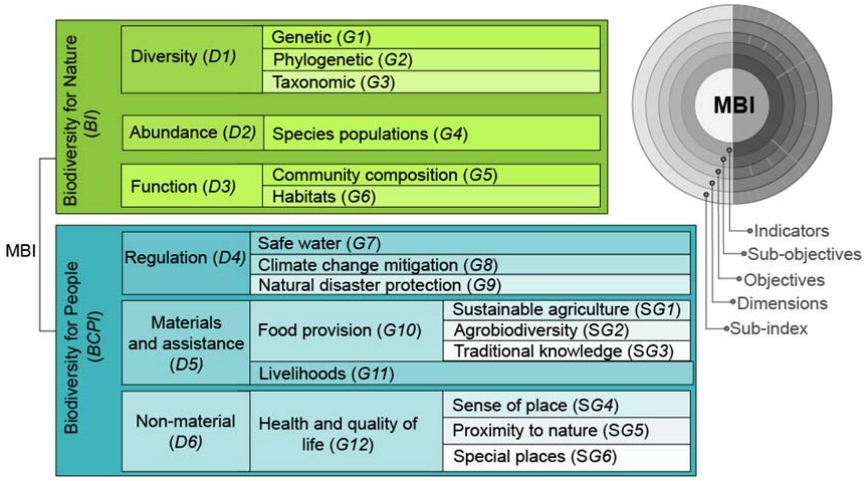
An integrated framework for Nature and People

We propose the MBI as a synthetic/summary measure of the achievement, at the national level, of key public 'biodiversity health objectives' building on both ecological and socio-economic data. In order to inform a 'core' MBI framework, we mapped the explicitly biodiversity-linked SDGs and targets, with the goals and targets proposed in the zero-order draft of the monitoring framework of the post-2020 GBF[23,39]. Arguably, a 'core' MBI structure could potentially allow for undertaking regional or supranational assessments of biodiversity health and therefore for interoperability among countries. It should therefore be comprised of indicators and metrics that are relevant to the post-2020 GBF and the environmental SDGs (See Supplementary Material).

We outline a core framework (Figure 2) that considers multiple indicators structured in four analytical and aggregation levels: 1) two sub-indices (Biodiversity State sub-index (BI), and Biodiversity Contributions to People sub-index (BCPI)), 2) a set of relevant dimensions under each sub-index representing fundamental facets of biodiversity as part of living nature and general categories of the contributions that biodiversity provides to people[53], 3) a set of public biodiversity health objectives, and sub-objectives where relevant, under each dimension, and 4) policy-relevant metrics, indicators

or proxies under each objective measuring performance as distance to a desired state or reference point.

Figure 2. Proposed 'core' MBI framework and nested structure of the metric. Each sub-index score is derived from a wide range of indicators and metrics. Indicators/metrics in the outer layer could be arranged around public biodiversity health objectives (and sub-objectives), given the diversity of values about living nature, and those around specific biodiversity dimensions. Dimensions combine to indicate the current status for each of the biodiversity health objectives.



Biodiversity State sub-index (BI). BI represents ecological integrity using three dimensions: diversity, abundance and function. These represent biodiversity at the three levels recognised by the CBD (i.e. genes, species and ecosystems[54]); summarise changes in conservation status[55]; and cover Essential Biodiversity Variables[56]. We suggest these dimensions are underpinned by, but not limited to, six biodiversity health objectives that we define as the conservation and recovery of 1) genetic diversity, 2) phylogenetic diversity, 3) taxonomic diversity, 4) species populations, 5) community composition and 6) habitats (terrestrial and freshwater) (Figure 2).

Indicators for the BI should represent the structure and function of ecosystems, the composition of biological communities, the diversity and traits of species, and genetic composition. Examples of global indicators that could be considered to include are indicators on trends in primary forest cover, species richness and phylogenetic diversity as well as, potentially, widely used global metrics[14,16].

Biodiversity Contributions to People sub-index (BCPI). BCPI measures the status and use of the realised benefits that people obtain from biodiversity. We use the concept of Nature's Contributions to People (NCPs)[17,53,57] as a pluralistic approach to recognizing the diversity of contributions that people

obtain from biodiversity. Hence, we propose three key dimensions for the BCPI as 1) regulation of environmental processes, 2) provision of materials and 3) supporting non-material, but nevertheless, key health and livelihood-related contributions to people's wellbeing. These in turn, reflect six public biodiversity health objectives and sub-objectives: 1) safe water, 2) climate change mitigation, 3) natural disaster protection, 4) food provision (with three sub-objectives on sustainable agriculture, maintenance of agrobiodiversity and traditional knowledge), 5) livelihoods (e.g., forestry and eco-tourism) and 6) health and quality of life (with three sub-objectives on sense of place, proximity to nature and protection of special places) (Figure 2).

Metrics for the BCPI should represent human-centred desirable outcomes derived from biodiversity, measured as the current state and the contributions of biodiversity to people. Of course, what may be considered 'desirable' is something that needs to be agreed upon in each nation, following "procedural ethics that is committed to openness, learning, and adaptation"[7]. Examples of indicators to consider include those based on metrics related to agricultural land under conservation agriculture, forest cover under sustainable management, population using safely managed drinking water supplies and metrics valuing the physical and psychological experience derived from living nature (such as areas with high outdoor recreation potential).

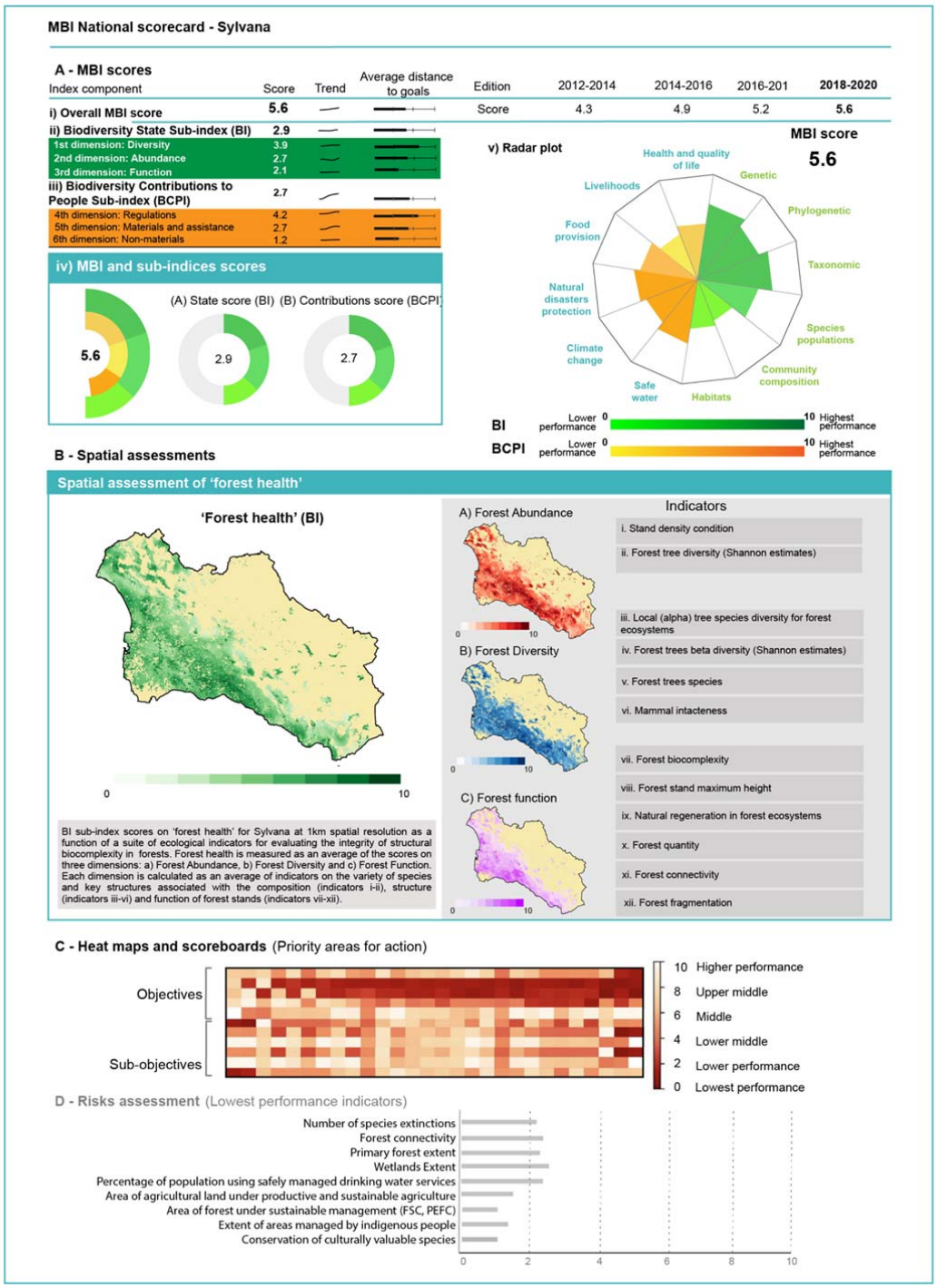
We suggest a scorecard-style framework to report/communicate the implementation of the MBI framework at national levels (Box 3). This would require the (re)definition of further biodiversity objectives and/or sub objectives under this core structure to account for context-specific biodiversity and contributions to people values. Hence, the MBI metric should be built up with indicators relevant at national scales.

START BOX 3----------

Box 3. The MBI as a biodiversity knowledge product for science-policy interfacing and data-driven biodiversity policy-making. The MBI is intended to support national governments with different information needs (from high-level policy makers to government officials and policy analysts) with meaningful messages on biodiversity state packaged into a 'blueprint' or knowledge product. MBI national scorecards can inform coordinated actions by different ministries and act as a monitoring and accountability tool within governments.

The figure represents a hypothesised example for the fictional country of Sylvana of how an MBI framework could be operationalised as a national scorecard on biodiversity health. An index and sub-

293 indices scores aggregated at the national level (Figure A) might a) provide an easier-to-understand
294 message on progress over time and a general sense of whether a country is moving in the right
295 direction on biodiversity conservation given desired biodiversity-related socio-economic outcomes; b)
296 benchmark a country's performance against its aspirational or previous scores; c) facilitate
297 communication with citizens; and d) leverage advocacy by grasping the complex and
298 multidimensional nature of biodiversity and its contributions to people. Different visualisation options
299 allow assessments of the level of achievement on biodiversity health objectives; monitor progress
300 over time and distance to targets; and make comparisons across subnational regions. These scores
301 can reveal patterns which do not directly emerge by looking at the objectives separately.
302 Greater value to inform policy decisions derives from delving into the individual objectives scores,
303 which could involve dashboards or heatmap visualisations (Figure C) to identify areas of high versus
304 low performance, and risk assessments (Figure D) to identify strengths and weaknesses through the
305 scores and trends of indicators.
306 The framework could also be used to calculate spatially explicit scores relevant for a particular country
307 to inform the identification of critical areas with high 'potential' for prioritisation of actions. Figure B
308 represents a fictional example on an MBI sub-index on 'forest health' of the country Sylvana using a
309 suite of metrics associated with the abundance of species, diversity and function of forest stands as
310 indicators of forest biocomplexity. Forest biocomplexity is a necessary element for sustainable forest
311 management as the provision of forest ecosystem services and contributions requires natural forest
312 stands in good condition. Importantly, the MBI allow for areas to be assessed based on the pluralistic
313 values they provide (e.g., potential for biodiversity conservation but also to capture and store carbon,
314 protection of water sources, and recreational opportunities for the citizens of Sylvana).
315 MBI alone does not identify conservation priorities, neither it is prescriptive about the specific policies
316 and actions required in Sylvana. It identifies what 'health objectives', in principle, needs to be
317 prioritised to improve biodiversity state and achieve a sustainable use of its derived contributions to
318 people. Information derived from the MBI framework could be harnessed alongside data on for
319 example, cost-effectiveness of interventions, to inform conservation planning, policy decisions,
320 strategies and regional action plans to maximise the potential of return in the form of positive
321 biodiversity outcomes (increased MBI scores) and sustainable use of contributions for the people of
322 Sylvana.



END BOX 3----------

The need for cautious inference

Arguably, indices are easier to communicate to a wider audience and valued by policy makers (i.e., they are more straightforward to interpret than finding a common trend in many single indicators).

328 They are utilized globally to monitor compliance of international agreements, allocation of resources
329 and benchmarking[23]. Nevertheless, indices often lack transparency and are sensitive to the choice,
330 weighting and standardisation of its components[58,59], so they can produce perverse outcomes and
331 misleading policy messages (Box 2). We acknowledge that the challenges to develop a
332 multidimensional index for biodiversity health that captures essential (often context-specific) evolving
333 needs of humanity as related to human nature would necessarily remain[7], and what we propose here
334 it is only one approach that involves several assumptions and caveats.
335 Some of the elements within the MBI structure might not be measurable yet or there may be no
336 existing data for many countries. The MBI represents a model to aspire to as a unified framework to
337 assess biodiversity health that countries should aim for and work towards in order to better inform
338 decisions about current and future uses of and relations towards living nature[7].
339 Building on indicators proposed under the post-2020 GBF, and those already in use for the SDGs
340 would also ensure global policy alignment of the MBI to the post-2020 GBF and the environmental
341 dimension of the 2030 Agenda (SDG indicators have the added benefit of statistical scrutiny through
342 the UN Statistical Commission). This would improve the temporal and spatial comparability of the
343 index and ensure that there is a global and national commitment to continue to collect the data that
344 underpin it.
345 A further limitation in implementing the MBI may be difficulties in assessing biodiversity's contributions
346 to people. Nevertheless, the Intergovernmental Science-Policy Platform on Biodiversity and
347 Ecosystem Services (IPBES) approach on the inclusive evaluation of NCPs provides a solid
348 background to support countries in that direction.[17,53,57]. See Supplementary Material for a further
349 discussion on caveats and limitations.
350 We argue that implementing the framework at national and subnational levels is important for two
351 reasons. First, the MBI supports the understanding that the flows from biodiversity to people are
352 context-dependent, so solutions must be tailored to the social-ecological context-specific values and
353 problems related to biodiversity conservation and protection[60]. For example, rapidly growing
354 economies will face in the next decade the challenge of counterbalancing the ramping up of human
355 demand for biodiversity-related assets, processes and flows, which is not captured by macroeconomic
356 indicators such as GDP, with sustainable use to ensure future provision. This context-dependency of
357 the pluralistic perspectives on biodiversity may limit the feasibility and value of developing a 'global'

MBI. Nevertheless, it may be possible to develop regional or supranational approaches to allow for inter-country comparisons if these pluralistic perspectives can be commonly represented at those levels in a sufficiently agreed manner, noting that the social component of the index may be more likely to be contested across culturally different country contexts. Second, recognising the necessity of maintaining bespoke use of the derived flows of biodiversity to people is key to enhancing biodiversity governance.

Arguably, the implementation and success of the universal agenda for biodiversity (post-2020 GBF and SDGs) will require national sustainable development policies and establishment of voluntary national commitments and frameworks for monitoring progress made. In this respect, there is a possible analogy to make with climate change. The Paris Agreement marked a new generation of climate governance, with agreement on the 2^{o}C target providing added impetus to national action, monitoring and reporting. If an analogous success is to be achieved for biodiversity, incorporating elements of the climate model (i.e., a combination of top-down global targets and bottom-up nationally determined contributions (NDCs)) could reinvigorate biodiversity governance. Hence, voluntary biodiversity commitments by countries ('Nationally Determined Contributions for Biodiversity' (NDCBs)) that contribute towards internationally agreed targets might be a pathway for countries to raise their ambition and leverage a paradigm shift for biodiversity governance. The MBI could play a potential role for countries as a framework to analyse if the sum of voluntary commitments would be 'enough' to generate the global coordinated action necessary to achieve global biodiversity goals. Nevertheless, whilst in the climate sphere progress can be measured using a single parameter (i.e. emissions), the complexity of biodiversity, the lack of fungibility between its facets and components, and the divergent nature of the two main goals on safeguarding biodiversity (to preserve ecological integrity and to safeguard the multiple values of contributions to people from biodiversity[7]) make it necessary to use a multidimensional assessment of progress.

A roadmap for an operational MBI at national level

Developing a MBI is both a technical and a political process that demands both scientific input and political commitments to provide policy steer. We propose four steps as a roadmap to develop an operational MBI, based on short-, mid- and long-term actions (Figure 3).

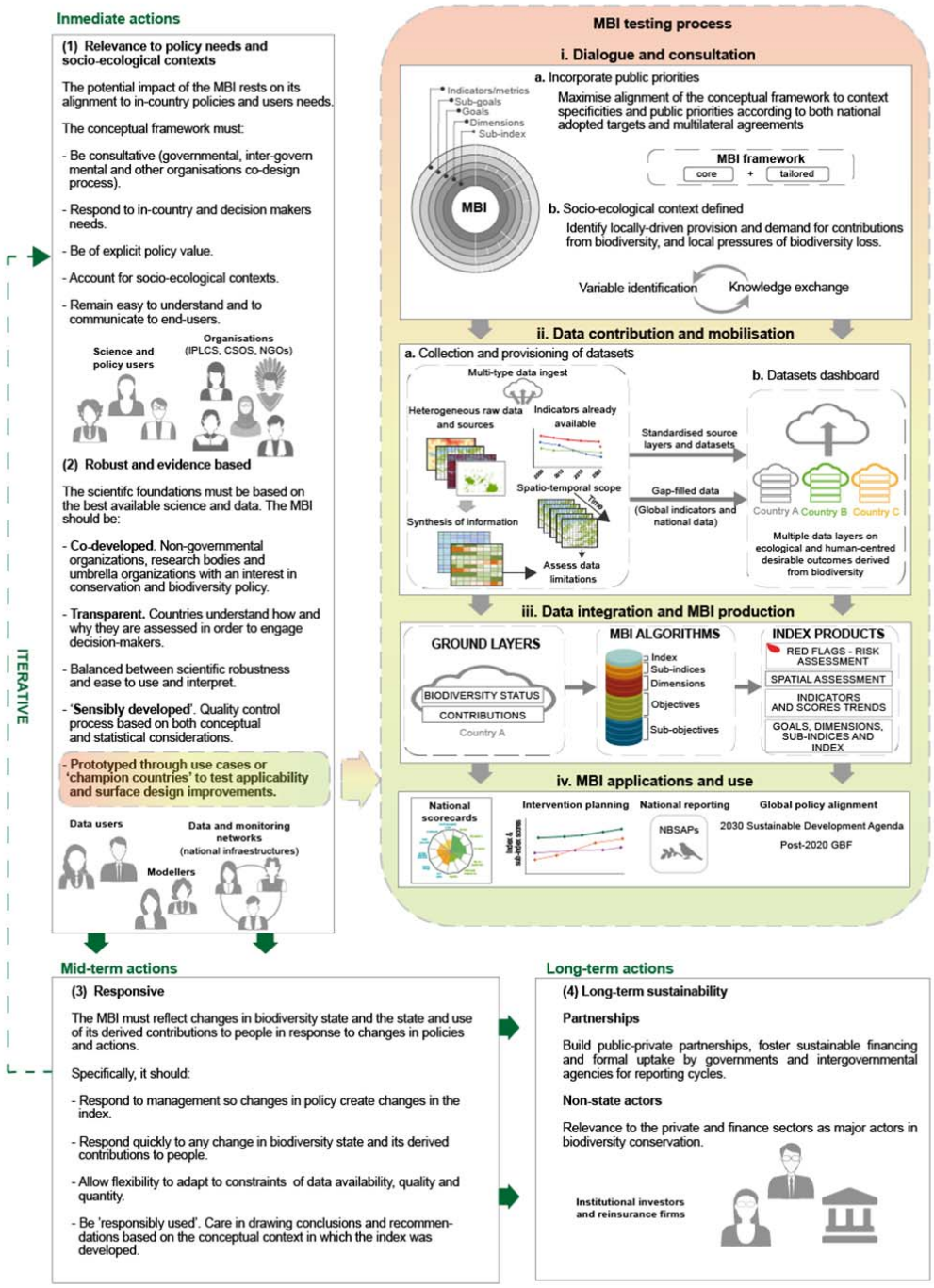
Short-term actions should focus on (1) implementing an inclusive co-production process with decision-makers, experts and relevant stakeholders, including Indigenous peoples and local communities (IPLCs) and (2) developing the knowledge foundations of the index in an open and transparent consultative manner to reflect the best available data and science. Hence, Figure 2 only represents a first approach as the final conceptual framework should be co-designed through a consultative process with experts and end-users to ensure that scalability and diverse perspectives and policy needs for biodiversity conservation are incorporated (i.e., countries are clear about their reasons and benefits of a national MBI). Scientific robustness requires inter-operability through existing networks and stakeholder engagement for data mobilisation and integration, also accounting for traditional ecological knowledge and values held by IPLCs. This includes testing the framework and piloting the index through the implementation of national case studies to foster accountability, policy acceptance, and surface design improvements. Figure 3 also illustrates a testing process coordinated by a network of experts working at different scales and governance levels, comprising i) dialogue and consultation to incorporate context specificities and public priorities, ii) data contribution and mobilisation including the identification of scientifically validated potential indicators to quantify objectives, iii) data integration and MBI production and, iv) MBI applications and policy use.

Mid-term actions (3) should focus on fostering an iterative process of monitoring and evaluation to implement improvements, and to ensure alignment to user needs and responsiveness to changes in management or policy.

Long-term actions (4) should focus on leveraging long-term sustainability of the tool by building partnerships and foster a formal uptake by governments, statistical commissions and/or intergovernmental agencies as potential custodians. Capacity building and support for policymakers in developing biodiversity policies that are grounded in multidimensional assessments of biodiversity is also a crucial component of this process, as is ensuring that the index is used for national biodiversity assessments in the context of relevant intergovernmental policy processes including the SDGs and the CBD. Finally, given the cross-cutting nature of biodiversity, it is important to ensure scalability, relevance and applicability to different sectors. By ensuring the framework is relevant to different sectors, the MBI could help to identify opportunities for non-state actors (including the private and finance sectors) and quantify the potential contribution towards enhancing biodiversity health of reducing threats derived from economic activities.

These four steps are designed to create four fundamental conditions for policy uptake and usage 1) the index is contextualised to national biodiversity policies and socio-ecological conditions; 2) it is based on robust science while respecting the perspectives from other knowledge systems, including indigenous and local knowledge around the world, 3) it is responsive to positive and negative changes and is 'responsibly used', and 4) it is relevant as a frame of reference for national biodiversity assessments.

Figure 3. Roadmap to operationalise a MBI framework on biodiversity health calling for immediate, mid- and long-term actions, key actors and workflows for the implementation and use of national MBIs.


Inmediate actions
(1) Relevance to policy needs and socio-ecological contexts
The potential impact of the MBI rests on its alignment to in-country policies and users needs.
The conceptual framework must:
- Be consultative (governmental, inter-govern mental and other organisations co-design process).
- Respond to in-country and decision makers needs.
- Be of explicit policy value.
- Account for socio-ecological contexts.
- Remain easy to understand and to communicate to end-users.
Science and policy users
Organisations (IPLCS, CSOS, NGOs)
(2) Robust and evidence based
The scientifc foundations must be based on the best available science and data. The MBI should be:
- Co-developed. Non-governmental organizations, research bodies and umbrella organizations with an interest in conservation and biodiversity policy.
- Transparent. Countries understand how and why they are assessed in order to engage decision-makers.
- Balanced between scientific robustness and ease to use and interpret.
- 'Sensibly developed'. Quality control process based on both conceptual and statistical considerations.
- Prototyped through use cases or 'champion countries' to test applicability and surface design improvements.
Data users
Modellers
Data and monitoring networks (national infraestructures)
ITERATIVE
MBI testing process
i. Dialogue and consultation
a. Incorporate public priorities
Indicators/metrics
Sub-goals
Goals
Dimensions
Sub-index
MBI
Maximise alignment of the conceptual framework to context specificities and public priorities according to both national adopted targets and multilateral agreements
MBI framework
core
+
tailored
b. Socio-ecological context defined
Identify locally-driven provision and demand for contributions from biodiversity, and local pressures of biodiversity loss.
Variable identification
Knowledge exchange
ii. Data contribution and mobilisation
a. Collection and provisioning of datasets
Multi-type data ingest
Heterogeneous raw data and sources
Indicators already available
Spatio-temporal scope
Time
Synthesis of information
Assess data limitations
Standardised source layers and datasets
Gap-filled data
(Global indicators and national data)
b. Datasets dashboard
Country A
Country B
Country C
Multiple data layers on ecological and human-centred desirable outcomes derived from biodiversity
iii. Data integration and MBI production
GROUND LAYERS
BIODIVERSITY STATUS
CONTRIBUTIONS
Country A
MBI ALGORITHMS
Index
Sub-indices
Dimensions
Objectives
Sub-objectives
INDEX PRODUCTS
RED FLAGS - RISK ASSESSMENT
SPATIAL ASSESSMENT
INDICATORS AND SCORES TRENDS
GOALS, DIMENSIONS, SUB-INDICES AND INDEX
iv. MBI applications and use
National scorecards
Intervention planning
Index & sub-index scores
National reporting
NBSAPs
Global policy alignment
2030 Sustainable Development Agenda
Post-2020 GBF
Mid-term actions
(3) Responsive
The MBI must reflect changes in biodiversity state and the state and use of its derived contributions to people in response to changes in policies and actions.
Specifically, it should:
- Respond to management so changes in policy create changes in the index.
- Respond quickly to any change in biodiversity state and its derived contributions to people.
- Allow flexibility to adapt to constraints of data availability, quality and quantity.
- Be 'responsibly used'. Care in drawing conclusions and recommen-dations based on the conceptual context in which the index was developed.
Long-term actions
(4) Long-term sustainability
Partnerships
Build public-private partnerships, foster sustainable financing and formal uptake by governments and intergovernmental agencies for reporting cycles.
Non-state actors
Relevance to the private and finance sectors as major actors in biodiversity conservation.
Institutional investors and reinsurance firms

Here, we have discussed the need for a shift in how we measure biodiversity and link it to the attainment of sustainable development through science-policy interfacing. Having measures that can grasp the pluralistic perspectives of biodiversity[7] can help to overcome the bias in public decision making, currently dominated by narrow considerations of economic growth to the exclusion of crucial ecosystem assets, biodiversity-led contributions and associated values. The MBI could help bridge the gap between evaluation and implementation of actions to leverage transformative change and influence potential radical shifts in flows of finance at national level. We hope that these ideas can shape an agenda for policy, science and practice to work together on this large undertaking, and that will inspire interdisciplinary efforts and bridge across knowledge systems in the pursue of collaborative spaces. This will be essential to forge a shared level of ambition and political intent to advance a common fundamental motivation - to stem loss and set biodiversity on the path to recovery ensuring human wellbeing in a new era of environmental and social sustainability.

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Author Contributions

CSN developed the original idea with conceptual inputs from all authors, but especially from MH and SH. CSN and NDB led the writing of the manuscript with input on drafts from all authors. CSN generated all figures and all authors approved the final version of the manuscript.

Competing Interests statement

The authors declare no competing interests.