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PERSPECTIVE

Weaving for action: Transformative change in biodiversity monitoring

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Abstract

1. The Post-2020 Kunming-Montreal Biodiversity Framework aims to drive transformative change to halt biodiversity loss. To track progress toward its goals and targets, a dedicated monitoring framework has been established.
2. The current biodiversity monitoring framework relies on a set of indicators developed through a unidirectional process of data collection from local to global scales. As such, the current framework reinforces dominant views and established structures and practices, limiting its capacity to drive transformative change.
3. In this paper, we discuss the issues the current biodiversity monitoring framework is facing and propose strategies to facilitate, promote and accelerate transformative change.
4. We propose six strategies that enable transformative change in biodiversity monitoring by placing shared values at the core of knowledge infrastructure development. These infrastructures must leverage the potential of transformative biodiversity governance, diverse knowledge systems and emerging technologies; acknowledge the interdependence of biodiversity and society within socioecological systems; and operate across multiple scales to align with the spatiotemporal dynamics of these complex systems.

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KEYWORDS
biodiversity data, biodiversity monitoring, knowledge infrastructures, knowledge systems, pluralism, relational approach, spatiotemporal scales, values

We are standing at the crossroads—one that tests our ability not only to halt biodiversity loss but also to transform views, structures and practices to tackle the underlying causes and ensure just and long-lasting impacts. On the one hand, global efforts have not been able to reverse the ongoing crisis. On the other hand, there is potential for local experiences, combined with transformative change approaches, to address the underlying causes and ensure just, long-lasting impacts (O'Brien et al., 2024). To make the significant changes needed, we need a clear vision of the kinds of knowledge we need and the knowledge infrastructures that will support it. This article sets out such a vision and articulates how to develop better monitoring practices and data infrastructures for biodiversity.

According to the recently signed Kunming-Montreal Global Biodiversity Framework (KM-GBF), adopted by 196 countries during the 15th Conference of the Parties of the Convention on Biological Diversity (CBD) in Montreal, transformative change is essential if we are to halt biodiversity loss while safeguarding people's access to services and benefits from nature. This, in combination with the number of cases that have emerged from local communities and organizations that exemplify imagined visions, shifts in structures and context-based practices as ways to catalyse transformations, provides reliable pathways to halt biodiversity loss (O'Brien et al., 2024).

Transformative change is defined by the Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES) in its recent transformative change assessment as '*fundamental, system-wide shifts in views, structures and practices. Deliberate transformative change for a just and sustainable world shifts views, structures, and practices in ways that address the underlying causes of biodiversity loss and nature's decline*' (O'Brien et al., 2024, p. 12). In this context, all the instruments, policies and tools created under the KM-GBF should be developed to facilitate, promote and accelerate such transformative change for biodiversity, that is by considering indirect and direct drivers of biodiversity loss, the multiple values and benefits of biodiversity, the role of governance and pluralism and the diversity of knowledge systems. One of the actions proposed by the KM-GBF that is currently under development is a monitoring framework (decision 15/5) that includes several indicators of change selected by an Ad Hoc Technical Expert Group, for their relevance in tracking and reporting trends at national, regional and global levels (CBD, 2023). These indicators can be summarized in standardized measurements across various species categories, including occurrence and distribution, spatial changes in land status (e.g. deforestation, conservation), status of ecosystem services and status of practices (e.g. finances, waste, pollution) at the national level (CBD, 2023). In 2010, the Aichi Targets were set to halt biodiversity loss, but were unsuccessful: none of the targets were fully achieved, and only six of the 20 targets were partially achieved (IPBES, 2019; Maney et al., 2024). The task at hand is to pursue monitoring through the development of a framework that will not repeat the experience of the Aichi Targets, where monitoring was shown to be one of the factors contributing to limited success, and to ensure that such a framework is effective. Here, we delineate pivotal issues that biodiversity monitoring is facing and that require transformative change. We put forth that a better knowledge infrastructure that aligns biodiversity monitoring and action can be developed by pursuing six strategies. These strategies address ways of knowing (views), ways of organizing and governing (structures) and ways of doing (practices). Together, they bring critical elements to tackle the current crisis and catalyse transformative change.

1 | ISSUE #1. THE CONCEPT OF BIODIVERSITY AND THE BIASES OF ITS GLOBALIZATION

Since its creation in the 1980s, the concept of biodiversity has been conceived as global, an object that could be understood, researched and managed across countries and ecosystems worldwide. It emerged from the domain of conservation biology to problematize humanity's survival amid the loss of biological diversity. It was further normalized in the Global Biodiversity Strategy and during the Rio de Janeiro Earth Summit in 1992, where the CBD was signed (Núñez et al., 2003). The mainstreaming of the concept represented a shift in how humans and nature were perceived as connected, and shaped how biodiversity should be monitored, managed and conserved (Escobar, 1998).

In this context, the monitoring framework for biodiversity management and conservation required a specific type of knowledge that aligned with the views of the dominant system and the need for a global account of biodiversity, that is knowledge based on already set taxonomical, spatial and temporal scales that result in indicators of biodiversity that could be measured, mapped and compared across the world using standardized global maps and quantitative databases (Heywood & Watson, 1995). The main goals were to select/develop relevant indicators of change across scales and ecosystems, to collect sufficient data suitable for the indicators, and to do so within the timeframe of countries' policies, actions and commitments worldwide.

The basis for the development of the initial phases of the biodiversity monitoring framework was readily available national inventories, as nation-states had already been cataloguing nature on their lands and those colonized for decades. The focus of nation-states was around power and utilitarianism, with discoveries of potentially useful species that populated herbaria and natural history museums, and the development of biodiversity governance through the construction of national biodiversity knowledge infrastructures (Nout, 2022; Youatt, 2008). These knowledge infrastructures constitute the sociotechnical assemblage that currently supports and shapes the production of biodiversity knowledge (Beaulieu & Leonelli, 2021; Edwards, 2010). As these infrastructures developed, scientific endeavours to understand how, why and in what ways species coexist (synecology) and to assess the relevance of such interactions in the maintenance of communities and ecosystems also gained traction (Braun-Blanquet, 1964; Westhoff & Van Der Maarel, 1978). Relevés and long-term plots were set up in multiple landscapes, initially in Europe and rapidly

BRITISH ECOLOGICAL SOCIETY People and Nature

extended to the rest of the global North to survey the spatio-temporal arrangement and rearrangement of species in a specific system (Sperandii et al., 2022), in addition to the use of collections (Nadim, 2021). These initial surveys evolved and expanded and were modified to monitor other taxa as research institutions shifted toward measuring changes in species composition over time. The plots slowly expanded into other regions and ecosystems in the global South. This work became increasingly connected to policy and conservation efforts, with an important landmark in 1993, when the monitoring approach was presented by the Global Environment Facility and later published as part of the First Global Biodiversity Assessment by the United Nations Environment Program. It was then hailed as the accepted method for tracking biodiversity trends and informing priorities, conservation and management (Heywood & Watson, 1995).

By the 1990s, most of the data came from botanical and zoological collections and scientific fieldwork. And in the last decades, with the creation of the Global Biodiversity Information Facility (GBIF) in 1999 and the addition of community-based monitoring and citizen science (Groom et al., 2017), the quantity of biodiversity observations increased exponentially. Still, it remained limited to specific areas, with a total biodiversity data coverage of only 7% of the world (Hughes et al., 2021). Mirroring the unequal expansion of infrastructure, the data coming from the global North increased, since citizens in these areas more often had, and still have, the resources to add their observations to databases.

Inequities and structural exclusion of data from the global South also happened and continues to happen, caused by inequalities in terms of language, access, infrastructure, investment, species and ecosystem features and protocols and definitions of concepts like biodiversity or species (Christine & Thinyane, 2021; Skidmore et al., 2021; Turnhout & Purvis, 2020) The result is that even areas known to indigenous peoples and local communities for centuries are still deemed 'unexplored' to scientists, managers and policy-makers, since the knowledge does not match the requirements (e.g. Linnaean classification system, language) for databasing or even when it does match, the collections have not yet been included in the large data repositories (e.g. GBIF). The resulting map of biodiversity data reflects such biases in data collection, with clusters of data concentrated in the global North, close to cities, along maritime routes and coasts, and with especially large gaps for some non-charismatic groups, remote regions and the global South (Gorneau et al., 2023; Hughes et al., 2021).

In fact, not only are ecological processes spatial and temporally structured, but so are the factors that lead to biases across time and space. To reduce this effect, Geographic Information Systems (GIS), including remote sensing techniques, have been placed at the centre of biodiversity monitoring (CBD, 2023; Reddy, 2021), offering advantages but also limitations. On one hand, GIS, and particularly remote sensing, have become key to both as a direct measure of biodiversity or as a proxy of changes across space and time, for example, in the case of land-use change (Skidmore et al., 2021) and in the assessment of spatiotemporal biases as a measure of uncertainty (Rocchini et al., 2023). On the other hand, global satellite products have led to global biodiversity predictions that, while not requiring engagements with indigenous peoples and local communities, have the potential to shape biodiversity governance, even though they reflect geographical inequalities and therefore reinforce the underlying causes of biodiversity loss (Gabrys, 2016; Goldstein & Nost, 2022). That is the case of the variable spatial and temporal resolution across regions due to environmental factors (e.g. clouds, topography, ecosystem types), the costs of high-resolution sensors and data for their calibration, and the local infrastructure in terms of experts, institutions and instruments (Garzon-Lopez et al., 2024).

As a result, what started as an effort to understand biodiversity maintenance in the context of the local interactions and environmental properties, gradually—shaped by global agreements, institutional, technocratic and funding pressures and dominant views—became a race to collect highly formalized and decontextualized data that provides a coarse, uneven and biased global perspective of biodiversity. Furthermore, these limitations are to a large extent built into the knowledge infrastructures that support biodiversity monitoring, since they reproduce patterns of access and circulation, as well as hierarchies of language and classifications. This is in contradiction with multiple studies that have demonstrated the significance of the local context, including microclimates, ecological dynamics, social values and memories, among others, in explaining the distribution and persistence of biodiversity in a changing world (Beugnon et al., 2024; Carnicer et al., 2021). These findings, together with the recognition of the scale dependence of ecological processes (McGill, 2010), render these databases somewhat useful at global and national scales, where progress facilitates access to resources like international funding and collaborations tied to KM-GBF commitments, but largely inoperative at scales of socioecological dynamics, where the resolution of the indicators do not allow for such disaggregation (e.g. percentage of the country protected). The consequences of partial and abstracted views of biodiversity that claim to be global are an inability to both engage and act effectively at scales that are relevant to ecological, political, social and cultural aspects of communities and governance, and the reinforcement of simplifying assumptions like just more biodiversity or more hectares protected is better (Büscher, 2025). Evidence of this is in local communities that hold multigenerational knowledge about ecological dynamics and changes in biodiversity, yet are rendered useless as their knowledge systems do not comply with the views and structures of the current framework and, despite their vast knowledge, can only monitor and conserve after gaining a certificate from the dominant system. This has consequences in the range of local actions available to halt biodiversity loss, as presented in the Global Species Action Plan, where Indigenous Peoples and Local Communities are presented as stakeholders in the implementation, but not with shared power and supported as knowledge holders, which reinforces the disconnection between action, knowledge, capacity building (Target 20 and 21) and pluralism (Targets 14, 22 and 23) (IUCN, 2023).

What started as an endeavour to problematize our survival in the context of biodiversity loss and promote solutions to halt it has become an interoperability problem where biodiversity conservation is only possible if standardized and comparable data is collected, thereby excluding alternative types of knowledge (context-based, local, qualitative) despite their relevance to catalyse action at local scales.

2 | ISSUE #2. RELIANCE ON A GLOBAL TAXONOMIC CLASSIFICATION SYSTEM AS THE ONLY BASIS FOR BIODIVERSITY MONITORING AND CONSERVATION

Dominant systems for generating evidence about biodiversity, such as the Linnean scientific classification system, have arguably contributed to consolidating important insights. However, such systems limit the possibilities for implementing transformative change for biodiversity monitoring.

The Linnaean classification system, selected as the official system in 1993 and currently used in biodiversity monitoring, has been critical for studies exploring the taxonomic patterns in the distribution and maintenance of biodiversity. It has also guided the reconstruction of the evolutionary paths of diversification through time. But there are important critiques of the stability and usefulness of this system; it is difficult to categorize certain groups using the taxonomic approach (Laurin, 2010; van der Gulik et al., 2023), for example, in the classification and databasing of taxa like fungi (Hyde et al., 2024). Despite claims to being definitive, the system is also highly unstable, with continuous changes in the classification (changes in genus of up to 31% of the species of European reptiles and amphibians described between 1997 and 2010) (Vences et al., 2013), proposals of an alternative phylogenetic perspective (Sluys et al., 2004) and ongoing debates around the classification of microbial communities (Prinzi & Moore, 2023).

Parallel to this system, and across time, communities have classified the natural world in multiple ways, in relation to sociocultural forms, belief systems, functional uses, growth forms and their ecology (Chao, 2022). Each of these different knowledge systems, including the Linnaean classification, has implications for what we know and how we know it, and for how communities and societies interact and position themselves in relation to nature, and for how they organize their policies regarding nature and its conservation. For example, a brief exploration of the names and classification of one common shrub species originally from the Andes reveals its diversity across knowledge systems and its implications for the conservation of this plant. Under Linnaean classification, the shrub was classified by Carl Linnaeus himself as *Datura*, and later reclassified and renamed *Burgmansia arborea*, *Burgmansia* to honour the Dutch scientist Justin Brugmans for his work studying the connections between chemistry and medicine, and *arborea* referring to the tree-like growth form of this shrub (Persoon, 1807). For local communities in Colombia, it is known as 'borrachero', which translates to 'the drunkard', in relation to its strong hallucinogenic effects. For the Muisca indigenous society, it was known as '*Tijiki*' or '*Tyhyquy*', referring to its spiritual and medicinal properties—only available to the traditional healer—and its connection to the power of words and the spiritual realms (Lorente Fernández, 2022). Each classification and name this plant has received reflects its relevance and historical legacy within each knowledge system and leads to varying levels of connection to nature, as well as degrees of people's access to certain meanings.

In the context of a biodiversity crisis and given the strengths and limitations of global naming systems such as the Linnean one, and the potential for connection and action of other systems, a more pluralistic approach that enables combinations and coexistence of systems is needed, as previous research has stressed (Jensen et al., 2020; Ludwig & El-Hani, 2025). For example, the field of ethnotaxonomy has documented many cases of knowledge/classification systems, both ancient and contemporary, that reveal connections to the ecological context in which species occur and constitute invaluable archives of biodiversity and conservation (Franco et al., 2015). In Ethiopia, the site of origin of Sorghum, communities can identify 44 varieties of the crop, with a classification as well as names that convey information about their characteristics in terms of ecology and uses (Mekbib, 2007), while Huastec Mayan communities in Mexico have a practical and minimalist classification that facilitates the understanding of sustainable farming practices (Heindorf et al., 2020). The list of such systems goes on, and it is as diverse as the many cultures and knowledge systems around the world.

Indigenous Peoples and Local Communities are mentioned multiple times as key stakeholders in the achievement of the KM-GBF, in targets on the sharing of benefits from traditional knowledge (Target 13), the full integration of biodiversity and its multiple values into policies and planning (Target 14), the need for previous consent to access knowledge, practices and innovations (Target 21), plus a dedicated target on participative decision-making (Target 22). However, their role is limited to consultation on decisions and implementation, or to monitoring social indicators (rights, traditional practices, sustainable use), and knowledge creation remains limited to scientific knowledge through initiatives such as the Global Taxonomy Initiative and the Biodiversity Indicators Partnership. The consequences are threefold: first, it reinforces the paradigm of a unitary taxonomic classification as the only way to understand, conserve and manage biodiversity. Second, it reproduces one of the underlying causes of biodiversity loss (O'Brien et al., 2024) by enacting power relations through the concentration of knowledge in few institutions that undermine the legitimacy of other knowledge systems and widening the disconnection between nature and humans through the reproduction of dualistic and dominion worldviews resulting in the erosion and loss of diverse knowledge systems (Goldman, 2020). Finally, it dismisses the transformative potential of the place-based, multigenerational and relational approaches to biodiversity change of Indigenous peoples and Local communities (Salmón, 2000). In this context, openness to multiple systems is a key strategy for more inclusive and pluriform biodiversity knowledge.

3 | ISSUE #3. PATTERNS, PROCESSES AND CHANGES IN BIODIVERSITY

Biodiversity data reflects and reinforces social inequities around the globe (Chapman et al., 2024). Researchers and decision makers recognize that such biases have a paramount effect on the exploration of socioecological patterns, the direct and indirect drivers of biodiversity loss, as well as in the implementation of policies and management strategies based on biodiversity data (Hortal et al., 2015; Nost & Goldstein, 2022; Raja et al., 2022; Rocchini et al., 2023; Troudet et al., 2017).

The spatial and temporal dimensions have been recognized as critical factors driving ecological dynamics and our ability to detect and attribute changes in biodiversity (Dornelas et al., 2023; Garzon-Lopez et al., 2014; Gonzalez et al., 2023). In this context, the challenge is not only in identifying the spatiotemporal scale(s) at which the changes operate and can be traced, but also in the selection of data and tools that accurately reflect patterns across scales as well as the drivers (e.g. ecological and anthropogenic), at the scale(s) and socioecological context(s) in which actions take place (Wyborn & Evans, 2021). Approaches like citizen science have exponentially increased the number of biodiversity observations in global biodiversity databases such as the GBIF and the Ocean Biodiversity Information System (Mandeville et al., 2023). Still, this data has been recognized as reflecting and reinforcing inequalities in access to digital tools worldwide (Hughes et al., 2021). Other technologies reflect similar inequalities, like the use of remote sensing, put forward by GEOBON (Group of Earth Observations Biodiversity Observation Network) in the KM-GBF and artificial intelligence (AI) as a key source for the collection of continuous data across space and time. Inequities that are especially prominent for some of the indicators of change, including ecosystem extent, structure, composition and functioning (CBD, 2024; Skidmore et al., 2021).

Innovations like remote sensing and AI have significant potential to map, model and predict multiple dimensions of biodiversity across space and time, from satellite to drone and from RGB to hyperspectral imagery, by itself or in combination with AI-based classification of large extents at varying resolutions. Remote sensing, alone or in combination with AI, provides a wide range of possibilities to collect data with such detail that it can even detect early stress in the form of changes at the species level in its chemical structure/function (Lock et al., 2021; Pettorelli et al., 2014; Reddy, 2021). AI tools automate the analysis of data collected on the ground and via remote sensing, such as sound recordings or camera trap data (Kissling et al., 2024; Rasmussen et al., 2024). However, its accuracy and relevance largely depend on the availability of such tools globally, in the structure of the algorithms and in the accuracy of the field data collected and methods used to validate the remotely sensed estimates, to train AI models and to understand the dynamics they reflect across a heterogeneous spatiotemporal mosaic of social and ecological features (Cavender-Bares et al., 2022; Kochupillai, 2024). This leads to inequalities, as outcomes are biased by factors such as local research methods and contexts, the availability of technologies and local capacity for remote sensing use. These enabling conditions are shaped by socio-economic factors across countries, the colonial practices in research and publication and the lack of local stakeholder networks (Garzon-Lopez et al., 2024). Even more, some indicators can only be measured by specific institutions, like the International Union for the Conservation of Nature in the case of Red Lists, which puts enormous pressure on such institutions to provide timely data and reports, and limits action at places where other knowledge systems have already assessed status and needs. In addition, the resulting assessments/estimates of biodiversity are aggregated in national and global maps. These are then used to inform policies that fail to account for the heterogeneity of socioecological systems. Furthermore, they are not informative to conservation and management efforts at local scales, which ultimately results in mismatches between global goals, national policies and local actions (Turnhout et al., 2016; Wyborn & Evans, 2021).

To properly implement techniques such as remote sensing and AI, a rollout is insufficient, as it reproduces and reinforces entrenched hierarchies. These techniques are especially relevant for the KM-GBF given that most of the current targets rely on spatial tools to measure status and progress on the development of baselines (Target 1 and 20), progress in restoration, sustainable management and conservation (Targets 2, 3, 10 and 12) and assessments on ecosystem services (Targets 11 and 15). Therefore, their deployment must be critically considered for its impact on equity and inclusion, if they are to contribute to the kind of biodiversity monitoring we need.

4 | STRATEGIES TO HARNESS TRANSFORMATIVE CHANGE FOR BIODIVERSITY MONITORING

Biodiversity monitoring is key to understanding ecological dynamics and to reversing biodiversity loss. However, the form this monitoring takes is determinative of the kinds of actions that can be taken. In this context, biodiversity monitoring should foster conservation, not only at the global and national levels through policies and fund mobilization, but also at the local levels, where data are collected and where communities can be more effectively involved in biodiversity conservation. The KM-GBF provides us with a unique opportunity to rethink and reorganize the structures and paradigms underpinning biodiversity monitoring to ensure that all efforts promote transformative change and ultimately halt the biodiversity crisis. It does that by recognizing the key role of pluralism in the construction of liveable futures, the integrative and adaptive nature of the mechanisms and practices it fosters, and the resulting frameworks that can be implemented in the complex context of biodiversity, where actors work in different ways, in other contexts, with different outcomes and incentives. Previous attempts, including the Aichi targets, failed to address the underlying causes of biodiversity loss, identified in the recent IPBES assessment as disconnection from and domination over nature and people, concentration of power and wealth and prioritization of short-term individual and material gains (O'Brien et al., 2024). While it is true that the goal of the indicators of the KM-GBF is to measure achievement at national and global level and therefore have specific requirements, it is also true that ultimately the goal of the KM-GBF including the indicators is to halt biodiversity loss and, as such, the mechanisms and incentives should be aligned with that goal. In other words, it is essential to ensure that the underlying causes of biodiversity loss are addressed in the framework's creation and in the identification and selection of indicators. It is in this context that we propose six strategies: (1) The articulation of components and approaches around a set of shared values (All KM-GBF Goals); (2) The use of relations as the unit of analysis; (3) Plural spatial, temporal and relational approaches (Target 21 with targets 14, 22 and 23); (4) Citizen science and other forms of knowledge co-creation and circulation that are appropriate to local contexts (Target 2, 3 and 11); (5) Integration of these multidisciplinary approaches in a responsible knowledge infrastructure (All targets); (6) Transformative biodiversity governance that tackle power relations and harnesses the diversity in terms of values, knowledges and interactions (Targets 5, 9 and 14) (Figure 1).

4.1 | Strategy 1. Open space for transformative change through focus on shared values

An essential step in the transformative change process requires the close examination of one's values, relationships with nature, assumptions and paradigms. The recognition of how they shape the development of a biodiversity monitoring framework, how it materializes in interactions with diverse stakeholders, the definitions of what constitutes knowledge and the role it plays in shaping how and the power relations in who participates in the construction of structures and practices around it. In this context, inner transformation not only refers to unsustainable or extractive values in nature but also to the role of dominant systems that have and continue to reinforce inequalities and marginalization of values, forms of knowledge and alternative practices (Escobar, 1998; Turnhout, 2024). That is the case for environmental sciences. We have presented the three key issues that connect directly to the role of science in creating narratives about global patterns of biodiversity, organizing biodiversity in a classification system and structuring the basis of what counts as knowledge and evidence. This highlights the relevance of opening space for transformative change even before the start of the development of a KM-GBF. With this aim, we propose a strategy that places transformative change at the core of the framework development by setting shared values that make explicit the nature of the challenge, moving the focus away from tools and onto the aim of halting biodiversity loss, ensuring social and environmental justice. For this purpose, the set of shared values that best align with transformative change for biodiversity monitoring is Pluralism, Integration, Coverage, Equity and Relevance.

Biodiversity is conceived in multiple dimensions within environmental sciences and across indigenous peoples and local communities, policymakers and investors, from genetic composition to kin, including species classification, ecological networks, components of life and ecosystem functioning, as part of material flows and ecosystem services. This leads to mismatches in the priorities, strategies and policies around the conservation and management of biodiversity. This has been stressed multiple times in research (Dawson et al., 2023; Ellis et al., 2025; Isacs et al., 2022; Pascual et al., 2021; Salmón, 2000; Valera et al., 2016) to the extent that

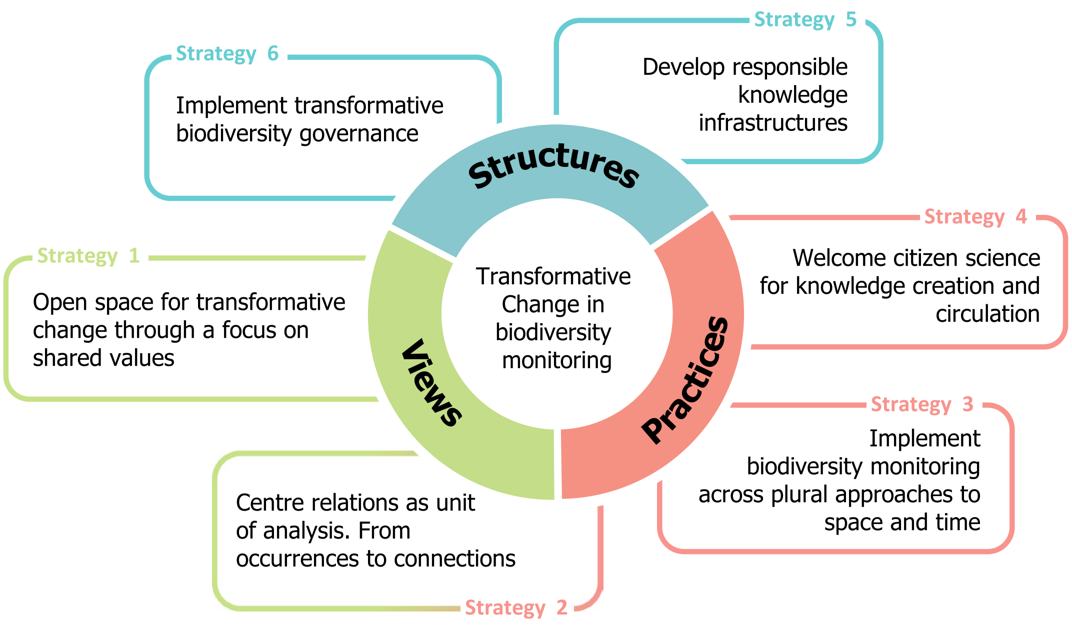

FIGURE 1 The six strategies presented to enable transformative change in biodiversity monitoring, along with the dimensions of transformative change (views, structures and practices) they address.

IPBES has produced an assessment dedicated to addressing the relevance of such diverse values and developed the concept of Nature's Contributions to People to bridge the myriad concepts and address the power relations among perspectives (IPBES, 2022; Pascual et al., 2023). Pluralism calls not only for the inclusion of other definitions of biodiversity, but also for deep reflection on how these different views lead to normative positions, and on how power relations shape which definitions are included and how that affects marginalized communities. In the context of biodiversity monitoring, pluralism ensures that all voices are included, guarantees fair monitoring frameworks that lead to action at multiple scales, and acknowledges and re-evaluates the role of diverse knowledge systems in biodiversity monitoring. This should support richer knowledge as well as the demonstrated role of indigenous peoples and local communities in the protection of biodiversity (Dawson et al., 2024; Reihana et al., 2023; Reyes-García et al., 2022). Integration recognizes connections across time, space and knowledge systems and calls for the inclusion of multiple social actors and other forms of evidence to address this connectivity in the development and application of a biodiversity monitoring framework. Coverage is critical for the development and maintenance of the biodiversity monitoring framework because it stresses the importance of the interplay between which biodiversity is monitored (context) and what evidence is needed to assess change and enact solutions, by shifting the goal from more data to better data and evidence, that is, reformulating social and ecological objectives, priorities and connections within and across spatial and temporal contexts. Equity is an essential value shared; it ensures that agency is enacted in the autonomy of indigenous peoples and local communities to what is shared and what is meaningful only at the community level, that power relations, intersectionality and historical legacies are addressed and tackled at each step of the process so that transformative biodiversity governance is enabled (Visseren-Hamakers et al., 2022). Relevance draws attention to the continuous consideration of not only the outputs but the process of producing them, asking questions like what dimension(s) of biodiversity loss are being assessed and where, what types of data and evidence are needed to understand the particular dimension, and who should be involved in the production of evidence and decision-making. These considerations ensure alignment between the knowledge produced and the goals and provide the framework with the capacity to be adaptive and open to diverse, creative and innovative pathways. That is the case of the relational approaches from indigenous peoples and local communities, already shown to protect biodiversity successfully (Dawson et al., 2024), promoting transformations in the biodiversity monitoring framework from extractivism to reciprocity and the redefining of what change in biodiversity is and how it is measured, moving from occurrences to relations (Salmón, 2000) with the advantage that the second promotes the protection of both components and their interactions. Relevance is also significant because it renders diverse onto-epistemologies applicable to monitoring and managing biodiversity and the indigenous peoples and local communities that nurture and understand them, are autonomous to apply them in the identification and co-creation of ways to monitor and manage changes in nature (Hokowhitu, 2016). These sets of shared values are not exclusive, as transformative biodiversity governance could lead to a collaborative, participatory selection of shared values in local contexts.

4.2 | Strategy 2. Centre relations as units of analysis: From occurrences to connections

Using relations as a unit of analysis for biodiversity monitoring enables the combination and coexistence of diverse knowledge systems, including, but not limited to, the Linnaean classification. Human–nature relations are diverse, shaped by the values, knowledge systems and worldviews of local communities worldwide. In biodiversity monitoring, the relational approach is relevant to what is changing, how and why, as it connects to how humans understand biodiversity (West et al., 2024). Furthermore, relations have been crucial for understanding ecological networks (e.g. pollination, competition, symbiosis) and functional diversity (e.g. pollinators, herbivores, parasites), which are commonly studied in biodiversity research (Bascompte, 2009; Cadotte et al., 2011). Using relations as the unit of analysis has a number of advantages to connect monitoring to action: (1) it allows the explicit inclusion of the diverse types of human–nature relations (trees as part of ecological networks, as components of taxonomical and functional diversity, as kin, as spiritual beings, as resources, as culture, as forests), (2) It facilitates the assessment of the attribution of change in patterns as well as in relations that include underlying causes (relations shifting from care to domination and vice versa) and, (3) Relations are meaningful to local communities and have the potential to embrace their views and knowledge systems, rendering their knowledge readily useful for action. In this context, the aim is not to select a specific type of biodiversity or even share/recognize the views and values that a local community holds (Hokowhitu, 2016). Instead, it is to provide them with the autonomy to identify the diversity of relations with nature that constitute a nexus with other areas of well-being, as well as changes in biodiversity and that should be included in the co-creation of indicators for biodiversity monitoring (Figure 2).

4.3 | Strategy 3. Implement biodiversity monitoring across plural approaches to space and time

Social and ecological dynamics take place across time and space. Time and space are differently conceptualized across diverse worldviews. These diverse understandings of space and time shape how we view life, which connections are valued, and what is considered essential to sustain different forms of life and their well-being. However, in recent decades, biodiversity monitoring has been dominated by particular views of how time and space should be understood and which methods and tools should be deployed (length of life, distance,

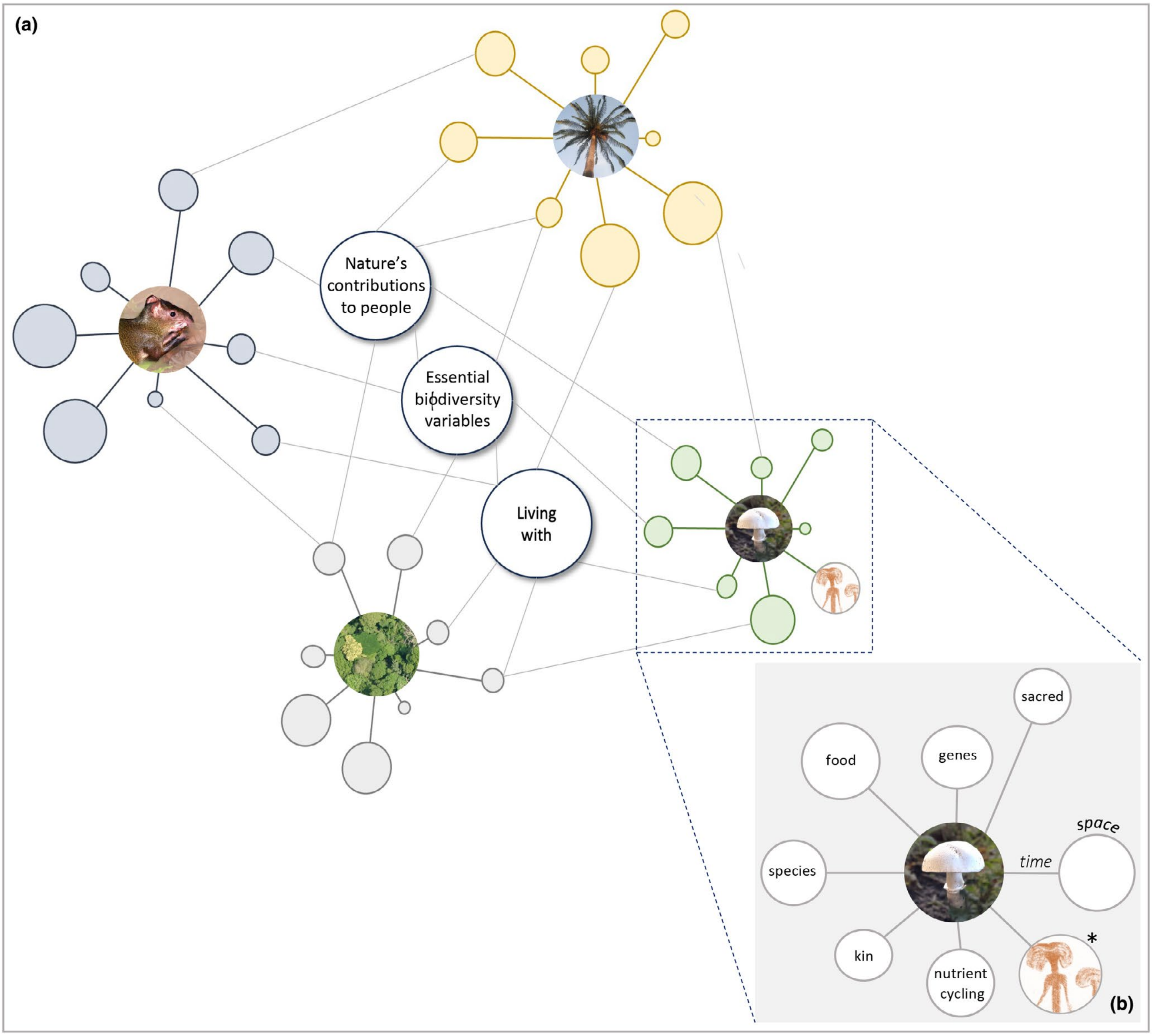

FIGURE 2 Representation of the use of relations as a unit of analysis. An entity (e.g. a mushroom, a rodent, a palm tree, a forest) has multiple identities depending on the varied worldviews. Therefore, each entity forms a cluster of relations that connect to other entities in various ways, depending on the actors involved, context and dimensions of biodiversity (Nature's contributions to people, Essential biodiversity variables, living with), creating a cluster of clusters (a). Additionally, in a plural context, time (the length of the connector) and space (the size of the circle) are also kept plural and vary across relations (b). This relational approach ensures that context-relevant dimensions of biodiversity can be foregrounded (species composition from the Essential Biodiversity Variables) and informed by the indirect connections it has to other clusters (food provision from nature's contributions to people) and that, (ii) situated knowledge readily connected to action at local contexts is included. *Image from Pettigrew, 2011, of a representation from the Sandawe and Bradshaw cultures.

scales). This dominance has profound implications for biodiversity maintenance and for understanding change and connections to humans. This approach limits the presence and recognition of other knowledges and related practices, since the current infrastructures are built within that dominant perspective to include specific measuring systems (spatiotemporal scales of fragmentation, conservation priorities or restoration efforts) (Beaulieu, 2026). This is the case of the shifting baseline syndrome and its implications for biodiversity conservation. The shifting baseline syndrome is a condition in which new generations evaluate current environments based on their own experience of past environments. This limits their ability to define change and, therefore, shapes the extent to which intervention is possible (Jones et al., 2020; Ureta et al., 2020). However, traditional indigenous knowledge is characterized by an adaptive, intergenerational, cumulative process of knowledge generation, with the potential to inform baselines (Jardine, 2019). In this context, a strategy that includes plural approaches to time and space would expand the role of interconnectedness and complexity to other worldviews and diversify the indicators and tools used to define and explore change in biodiversity.

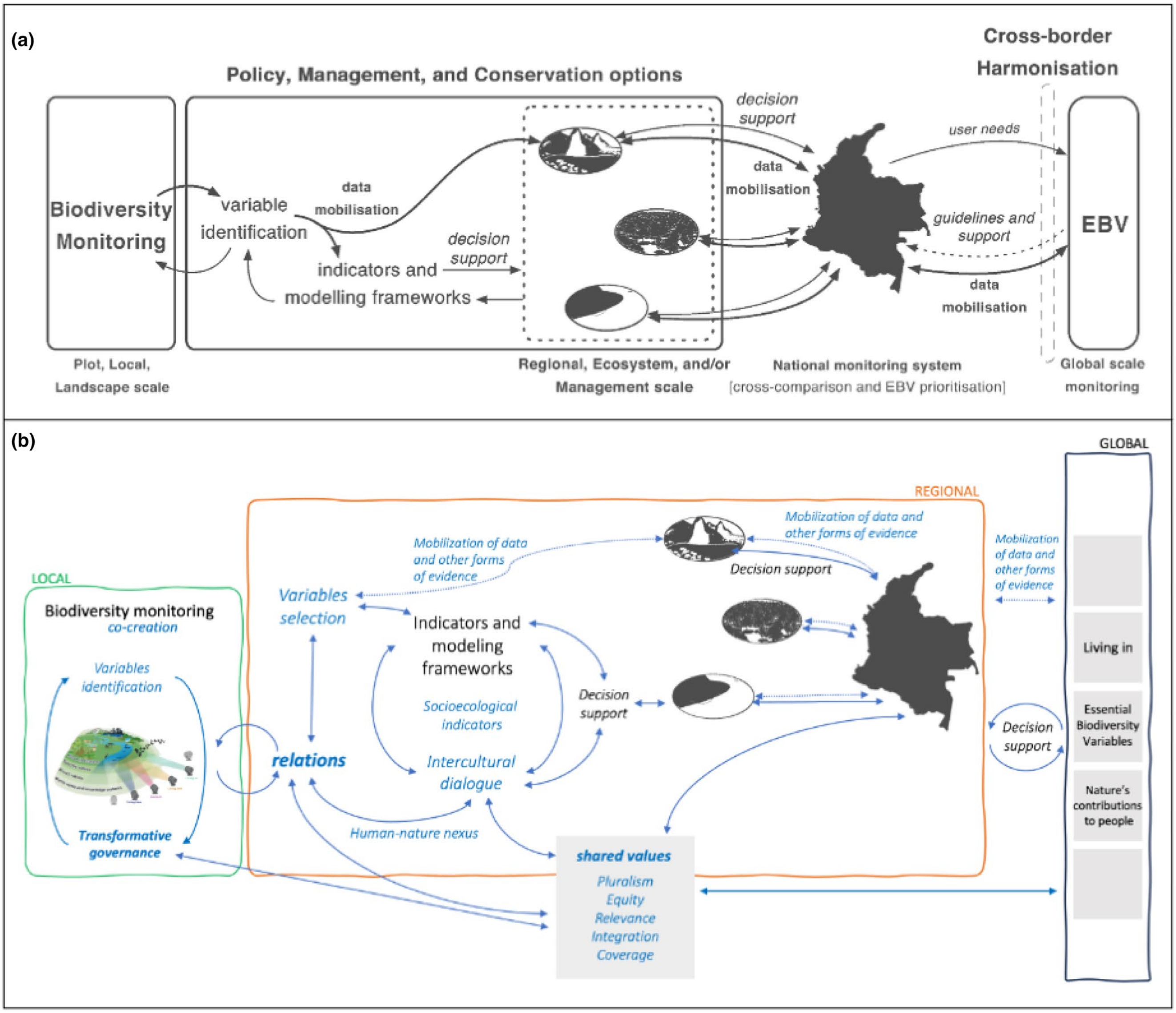

FIGURE 3 (a) Current cross-scale approach to biodiversity monitoring as published in Navarro et al. (2017). (b) Modified cross-scale approach to biodiversity monitoring to harness the six strategies proposed, including the features, namely transformative governance, relations, socioecological indicators and human–nature nexus, as well as the tools and mechanisms to enable the shared values across scales. Relations are included as the unit of analysis and presented using the Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES) values typology to represent the relational approach at the local levels, where variables are identified and cocreated. Relations, in combination with transformative governance and shared values, enable intercultural dialogue and allow for the exchange of data and other forms of evidence of changes in biodiversity. Arrows are bidirectional to enact agency and action within and across contexts. At global levels, multiple types of evidence can serve to assess various dimensions of biodiversity (e.g. Nature's contributions to people [NCP], Essential biodiversity variables [EBVs], values typology [living with]).

4.4 | Strategy 4. Welcome citizen science for knowledge creation and circulation

Enabling inclusive and equitable collaborations between stakeholders has the potential to catalyse transformative change and tackle systemic, structural, power-sharing and knowledge co-creation practices (O'Brien et al., 2024). It can also unlock the potential of the local to connect diverse knowledge to action. Examples of citizen science and other types of knowledge creation, such as community-led biodiversity monitoring or participatory monitoring, span multiple dimensions: (1) from completely digital and AI-supported systems to local storytelling-based techniques of monitoring, (2) from local to global efforts, (3) quantitative and qualitative data collection, and across levels of agency from non-humans and across demographic groups. Such diversity provides myriad possibilities to co-create tools and transform the practices of biodiversity monitoring, catalysing transformative change by connecting with parties as both agents of knowledge and agents of change.

4.5 | Strategy 5. Develop responsible knowledge infrastructures

Knowledge, scientific knowledge, and more recently, indigenous peoples' and local communities' knowledge (Forest Peoples Programme et al., 2020), is presented by the CBD as central to understanding, managing and preserving nature (CBD, 2021). This, together with a sense of urgency to develop the data-gathering process to monitor and halt biodiversity loss in the midst of the biodiversity crisis, requires careful and dedicated attention to the type of knowledge infrastructure that supports bending the curve of biodiversity loss. To ensure the production of diverse and inclusive knowledge outlined in the preceding strategies, we propose integrating transdisciplinary approaches into a responsible knowledge infrastructure (Beaulieu & Leonelli, 2021) as the fifth strategy. These knowledge infrastructures can then support transformative change in communities across levels of organization and provide biodiversity indicators and attribution of changes across socioecologically relevant spatiotemporal contexts. With the support of knowledge infrastructures that include diverse actors and evidence across plural knowledge, space and time dimensions, pluralism can ensure a participative and action-oriented framework for biodiversity monitoring and conservation (Isacs et al., 2022; Pascual et al., 2021; Salomon et al., 2023), one that foregrounds relational and intrinsic values, as well as instrumental ones and that fosters the connection and reciprocity in the human–nature nexus.

4.6 | Strategy 6. Implement transformative biodiversity governance

Social and environmental justice is only possible when the dimensions of equity, historical legacies and power dynamics are explicitly addressed in the development of participatory frameworks. These must furthermore consider stakeholders across scales, levels of involvement with non-humans and local communities, since they all have a direct stake. In addition, many are also knowledge holders in the co-creation of indicators of change. With this inclusive approach to governance, transformative change can benefit biodiversity.

Currently, biodiversity is governed through a network of policies, instruments and mechanisms within various frameworks and regimes across scales. These governance structures shape the relationships between biodiversity and other actors, influencing who can participate in its monitoring, conservation and management. In this way, biodiversity governance not only shapes how biodiversity is understood, but it also establishes monitoring standards, regulatory systems and the conditions for intervention and action across all levels (Paavola et al., 2009; Youatt, 2015). Currently, global objectives (CBD, KM-GBF) are not aligned with national policies (Biodiversity Strategies and Actions Plans—NBSAPs) and local actions, resulting in the deployment of a series of tools (maps, indicators, protocols, technologies) that neither align with the global needs nor with the local realities and exacerbate the underlying causes of biodiversity loss. Transformative biodiversity governance includes enabling processes that foster system restructuring, including examining values, interests and worldviews, as well as who should be involved in this process (Visseren-Hamakers et al., 2021). In this way, transformative biodiversity governance tackles the underlying causes of biodiversity loss across scales and opens space to embrace justice as a core element of a biodiversity monitoring framework.

5 | CONCLUSIONS

The strategies proposed, together with the recognition of current issues and the complex interdependence of climate, biodiversity and inequality, further highlight how transformative change presents a challenging yet unique opportunity to rethink and reshape current practices. Through systemic and structural changes, we address biodiversity loss by fostering agency, values and capacities for the benefit of both the local and the global (Figure 3).

The impact of embracing these strategies would be a shift from fragmented, top-down approaches to biodiversity monitoring toward inclusive, context-sensitive frameworks that recognize the value of diverse knowledge systems, relationships and governance structures. By embedding pluralism, equity and justice at the heart of biodiversity monitoring, these strategies create the conditions for meaningful, locally grounded action that aligns with global goals without erasing local realities. This transformative approach not only addresses the root causes of biodiversity loss but also strengthens the connections between people and nature, ultimately fostering more resilient and sustainable socioecological systems.

AUTHOR CONTRIBUTIONS

The manuscript is the product of discussions between all the authors. Carol X. Garzon-Lopez and Anne Beaulieu conceived the research idea. Duccio Rocchini, Camilo Castillo, Tahani Nadim, Duccio Rocchini, Koenraad Van Meerbeek, Laura M. Bellis, Esther Turnhout and Margaret Gold were involved in developing ideas and writing sections. Carol X. Garzon-Lopez led the writing of the manuscript. All authors contributed critically to the development of the sections, worked on the drafts and revisions based on reviewer feedback and gave final approval for publication.

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The authors declare no conflict of interest.

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