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A global biodiversity observing system to unite monitoring and guide action

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The rate and extent of global biodiversity change is surpassing our ability to measure, monitor and forecast trends. We propose an interconnected worldwide system of observation networks – a global biodiversity observing system (GBiOS) – to coordinate monitoring worldwide and inform action to reach international biodiversity targets.

The Kunming-Montreal Global Biodiversity Framework (KM-GBF) provides a vision for living in harmony with nature that will have lasting benefits for humanity[1]. Attaining this vision will require ambitious and rapid action to address the drivers of biodiversity loss and improve conservation action to avoid the great social and economic costs of ecosystem degradation[2]. This will require understanding where, why and how fast biodiversity is changing – something we have limited knowledge of today for much of the planet.

An essential part of the KM-GBF is its monitoring framework (as outlined in COP decision 15/5), which includes a set of indicators that will be used by nations to monitor and report their progress toward the framework's targets and goals. The indicators track actions and policies that implement the framework (such as the establishment of protected areas) and those that reduce the drivers of biodiversity loss (for example, pollution abatement). The indicators rely on monitoring to measure the outcomes for nature and people over time (for example, measures of ecosystem-service provisioning) and the risks of losing the benefits that we get from nature. Aggregation of the indicators at the national level can provide insight into progress at regional and global levels.

Disparities among nations in the access and use of biodiversity observations and knowledge[3] means that the global community is not adequately equipped to meet the information requirements of the monitoring framework: to monitor the drivers of biodiversity loss and track species and ecosystem recovery and restoration, as well as assess the risks of losing the many benefits that we get from nature.

To address this gap, we – as members of the Group on Earth Observations Biodiversity Observation Network (GEO BON) and its partner institutions – propose the establishment of a global biodiversity observing system (GBiOS) to initially interlink existing capacities and organizations to monitor how, where and why biodiversity is changing[4,5], and to progressively grow to guide the action needed to realize the targets and goals of the KM-GBF[2].

Biodiversity observations at the science–policy interface

To achieve the goals of the KM-GBF, we have identified four key components to bridge science and policy: (1) biodiversity observations guided by policy needs; (2) observations coordinated to form monitoring programmes designed to rapidly detect change and attribute causes for biodiversity change[6]; (3) observations that inform models to project biodiversity change and the loss of ecological and evolutionary resilience[7]; and (4) frequent assessments derived from monitoring to provide policy options to guide action[8]. Currently, the international biodiversity science–policy interface lacks all four of these components, and so the delivery of policy-relevant knowledge about biodiversity change is slow relative to the timeline set out by the KM-GBF.

The weather forecasting and climate assessment communities have had all these components that provision scientific knowledge to policy action for several decades. This includes daily weather

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forecasting, the Intergovernmental Panel on Climate Change (IPCC) created by the World Meteorological Organization (WMO) for scientific climate assessments, and the Global Observing System (GOS) to organize the international and interagency long-term strategies for operational collection of climate-relevant observations at multiple scales.

In 2012, the nations of the world established the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) — a mechanism to strengthen the foundations of knowledge for policy setting through scientific assessments[8]. However, a system such as a GBiOS to complement IPBES, as GOS does for the IPCC, does not exist.

Emulating the Global Climate Observing System

We see a GBiOS as resembling the model of the WMO's Integrated Global Observation System (WIGOS), which integrates observations made by the national climate networks of the GOS, and the Global Climate Observing System (GCOS), which maintains definitions of essential climate variables that are required to systematically assess the status and trends of global climate. These systems were established to support the United Nations Framework Convention on Climate Change (UNFCCC)'s Paris Climate Agreement; they are a remarkable example of international collaboration and enable billions of observations to be made and exchanged every day. The WIGOS is not a single, centrally managed observing system. Rather, it is a composite and federated 'system of systems' that is linked via a set of climate-relevant observing, data-management and distribution systems and information services.

A GBiOS would provide a similar service for biodiversity by connecting existing data repositories and networks for observations of biodiversity and its drivers. National biodiversity observation networks (BONs) (Box 1) will be key units that make up a GBiOS, just as national weather agencies and climate observing networks are key units in the WIGOS. As with WIGOS, a GBiOS would ensure that biodiversity observations — along with data on drivers of biodiversity change — are updated frequently and available in standardized, interoperable, accurate and representative forms. The system would abide by FAIR (findable, accessible, interoperable and reusable) and CARE (collective benefit, authority to control, responsibility and ethics) data principles[9], and ensure that Indigenous peoples and local communities can exercise free, prior informed consent for data access.

Five critical issues that a GBiOS can address

A GBiOS can address five critical issues to support the monitoring framework and actions needed to meet the targets of the KM-GBF (as also discussed by the Expert Workshop on the Monitoring Framework for the Post-2020 Global Biodiversity Framework):

1. Gaps, biases, and standards in biodiversity data. A GBiOS would focus on addressing the gaps in the taxonomic and geographical coverage of biodiversity monitoring, both by mobilizing existing data and by creating consistent approaches for monitoring going forward. Data repositories such as the Global Biodiversity Information Facility (GBIF) and the Ocean Biodiversity Information System (OBIS) and databases such as BioTime[10] and PREDICTS[11] are the basis for progress but are not representative in their taxonomic and geographical coverage of the Earth's biodiversity (Supplementary Fig. 1). For example, occurrence records in GBIF and the OBIS cover less than 7% of the world's surface at 5-km resolution, and less than 1% for most taxa at higher resolutions and remain insufficient for informing about species status and trends[12] (Supplementary Fig. 1). These major data gaps were

highlighted in the appendix 4 of the Summary for Policymakers of the IPBES Global Assessment of Biodiversity and Ecosystem Services. A GBiOS would contribute to these databases and services by formally linking them to monitoring worldwide.

2. Information for indicators. A GBiOS would provide data and information needed to assess progress towards KM-GBF's goal A and goal B on halting extinctions and sustainably managing biodiversity and ecosystem benefits, respectively. Biodiversity observations compiled by a GBiOS can be used to estimate essential biodiversity variables (EBVs)[13,14] and essential ecosystem service variables (EESV)[15]. These essential variables underpin many of the indicators for goals A and B and many of the associated targets (for example, targets 2, 3, 4, 6, 11, 12, 19.2 and 20). The common use of EBVs and EESVs enables a harmonization of datasets collected by different governmental and nongovernmental organizations across a BON so that they can be compared and combined for different purposes, including the calculation of indicators, models of biodiversity change and assessment tools such as ecosystem accounts under the UN System of Environmental Economic Accounting (UN SEEA).

3. Understand biodiversity change across scales. The actions needed to achieve the targets of the KM-GBF can be supported by monitoring the drivers for trend attribution and forecasting change over different scales[6]. Some drivers may be observed directly with biodiversity observations (such as invasive species occurrence and impact) but information about other drivers
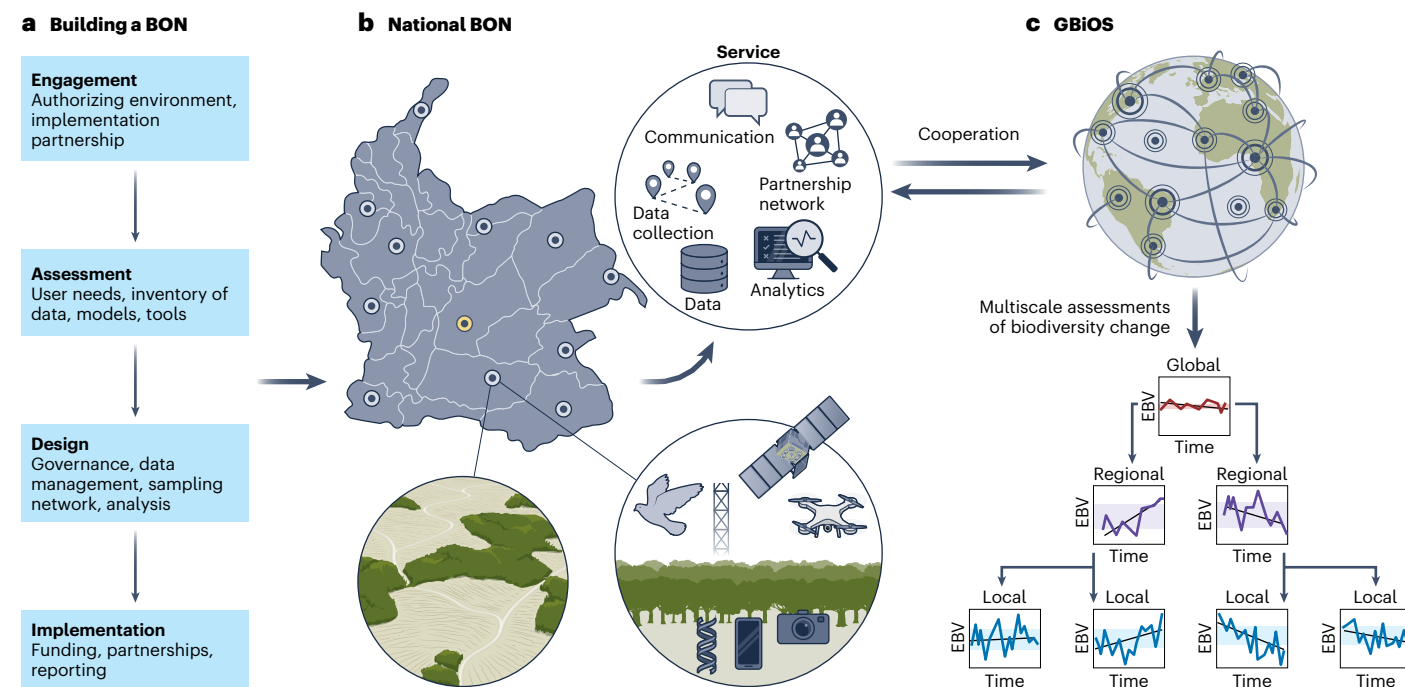
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Fig. 1 | A GBiOS as a global network of interconnected national and regional BONs to assess biodiversity trends worldwide. a, Countries without a national BON can establish and implement one following the multistep process identified by GEO BON[17]. **b**, Each national BON (Colombia is shown as an example) follows harmonized methods and coordinated activities for biodiversity observations, data curation and sharing, trend detection and attribution, modelling, and policy-decision support that forms a BON service. **c**, In the proposed GBiOS, national and regional BONs (circles) form an international network that shares technologies, data (for example, via a Global Open Science Cloud) and information about biodiversity trends (EBVs and EESVs) and ecological events, and in so doing enables the global community to make rapid multiscale assessments of progress towards international biodiversity targets and goals.

(such as climate, pollution and land use change) will require co-ordination with other observation networks to understand and project how drivers interact to cause biodiversity change.

4. Capacity and technologies. A GBiOS can be used to assess where data gaps exist and guide the strategic implementation of monitoring technologies for observation (for example, site-based observations and remote sensing), rapid classification, data assimilation for causal inference, and prediction to support action[6,7]. New data and monitoring standards that enable rapid updates of EBVs and EESVs would be available to national and subnational governments. This gap-filling process could support target 20 of the KM-GBF prompting strategic investment in capacity-building, regional biodiversity observing technologies, data collection and curation services, and international cooperation (south–south, north–south and triangular cooperation) to share tools and knowledge for areas that need them most.

5. Engagement across all sectors and knowledge systems. The task of building and maintaining a GBiOS is by design broadly collaborative, engaging national, subnational and local governments and Indigenous peoples and local communities, academic researchers, curators of biological collections, nongovernmental organizations, businesses and the financial sector. Broad engagement can foster the mainstreaming of biodiversity information into decisions across all sectors of society[16]. Each sector has specific needs for biodiversity observations so the design and implementation of a GBiOS should reflect the broad range of uses and decisions it will support and provide consistent and standardized time-series data with baselines and reference conditions across ecosystems.

A federated network of BONs

Over the past decade, GEO BON has supported and endorsed the establishment of BONs that are designed to help national and subnational governments to monitor biodiversity (Fig. 1). As a growing international network of about 2,600 members who span 141 countries, GEO BON would convene the expertise needed to inform and support the establishment of a GBiOS. Further, GEO BON has been endorsed by Parties to the Convention on Biological Diversity — most recently through an invitation to support the operationalization of the monitoring framework of the KM-GBF (as described in CBD COP decision 15/5).

A GBiOS would assemble an intercommunicating system of BONs and other monitoring programmes[4]. In a first phase, a GBiOS could be established immediately as a globally coordinated network of BONs (Fig. 1); this first phase would develop a collective assessment of our current capacity to observe biodiversity and ecosystem trends, with the needs to improve it including human capacity and technologies for observations and data sharing and analysis[17].

BONs can be designed to support national biodiversity strategies and action plans to guide action by parties under the KM-GBF. BONs support long-term research sites and stations conducting observations from the ground, air, water or space[18,19]. BON development may involve investment in additional monitoring capacity at new and existing

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sites to reduce data gaps. The addition of new sites to the BON can reduce uncertainty in trend detection and improve understanding of biodiversity change locally and nationally, as well as contribute information for regional and global assessments. Other sites may be chosen to acquire the information to improve models for forecasts projecting future changes in biodiversity[7]. Research centres working with BONs will provide services for supporting the use and sharing of data, trend assessments, and predictive modelling to guide decisions for conservation and spatial planning.

Next steps

Several next steps are needed to establish the governance model, funding, the deployment of technologies and other resource needs, and investment in careers to support GBiOS activities in the long term.

Co-sponsorship and governance. A proposal for a governance model should be elaborated, along with identification of the partner organizations – from both the public and private sectors – that can co-sponsor a GBiOS. One option is to follow the solution taken by the GCOS, which is co-sponsored by several intergovernmental organizations: the WMO, the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization, the United Nations Environment Programme and the International Science Council.

Assessment of resource needs and added value. At this point, an assessment of the technical and financial investment is needed. This includes the necessary technologies and data infrastructure (including existing large repositories such as GBIF, OBIS and GenBank) needed to support long-term monitoring and make the data available in a secure manner; mechanisms for governance and financing; and the existing national and regional BON components that can be integrated to form the first phase of the GBiOS implementation. This assessment would include the knowledge and capacity needs, and the economic costs and benefits (return on investment) that may arise from an initial investment in a GBiOS, followed by alternative pathways for progressive development of its capacity by 2030 and beyond.

Funding a GBiOS for the long term. A long-term funding model could help to support nations with the establishment of their BONs, to conduct standardized biodiversity monitoring and publish data into national and international data repositories (for example, GBIF and OBIS) within weeks to months. An integrated system of observations for biodiversity will connect to observing systems for climate and other human drivers and pressures. One way to fund a GBiOS would be through a UN coalition fund, similar to the Systematic Observations Financing Facility (SOFF) for GCOS. Data from the GBiOS would support ecosystem accounts under the UN SEEA ecosystem accounting framework and guide investments to create local social and economic benefits for the global public good. Global data production and exchange could be an important measure of success, along with use by the private sector for financial disclosures and impact assessments. A SOFF for the GBiOS could contribute to strengthening societal adaptation and resilience across the globe, benefitting the most vulnerable peoples and countries.

A GBiOS would be a missing piece of the science–policy puzzle needed to support the realization of the KM-GBF, the Sustainable Development Goals and other multilateral environmental agreements and protocols. The global community is increasingly aware of the great benefits that society receives from biologically diverse and resilient ecosystems. A GBiOS could contribute to a representative and inclusive understanding of biodiversity change and thereby support effective implementation of policies that are designed to reverse biodiversity loss and achieve the global goals for nature in the coming decades.

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