Monitor Social-Ecological Systems to Achieve Global Goals for Biodiversity and Nature's Contributions to People

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Author biographies

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The adoption of the Kunming-Montreal Global Biodiversity Framework (GBF) has opened a critical window of opportunity for ecosystem conservation and restoration to respond to the biodiversity and climate crises. The GBF has sparked worldwide interest in biodiversity monitoring to track outcomes and guide action from local to global scales (Gonzalez and Londoño 2022). However, the GBF separates monitoring progress towards outcomes for biodiversity in the targets of Goal A from monitoring outcomes for nature's contributions to people (NCP) in the targets of Goal B. Separate monitoring for these two goals is a problem because the biodiversity and ecosystem services (ES; or NCP) outcomes that are the joint focus of the GBF arise from people-nature interactions in complex social-ecological systems. Isolated monitoring for these two goals perpetuates the disconnections between biodiversity conservation and human well-being (Mace 2014, Isbell et al. 2017). This disconnect can be addressed through the establishment of integrated ES Observation Networks (ESONs) that weave data and information needed to assess outcomes for the GBF's targets for biodiversity, ecosystems, and human well-being.

Challenges in ES monitoring

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) framework (Díaz et al. 2015) highlighted the linkages between biodiversity, ecosystems, and people in social-ecological systems, and established a conceptual framework comprising all these. While some components of this framework are consistently addressed in monitoring (including biodiversity, provisioning ES, some aspects of human health and economic well-being, and many anthropogenic drivers of change), others are much less frequently considered or entirely omitted (such as most regulating and cultural ES, and especially the linkages between various components, Fig. 1).

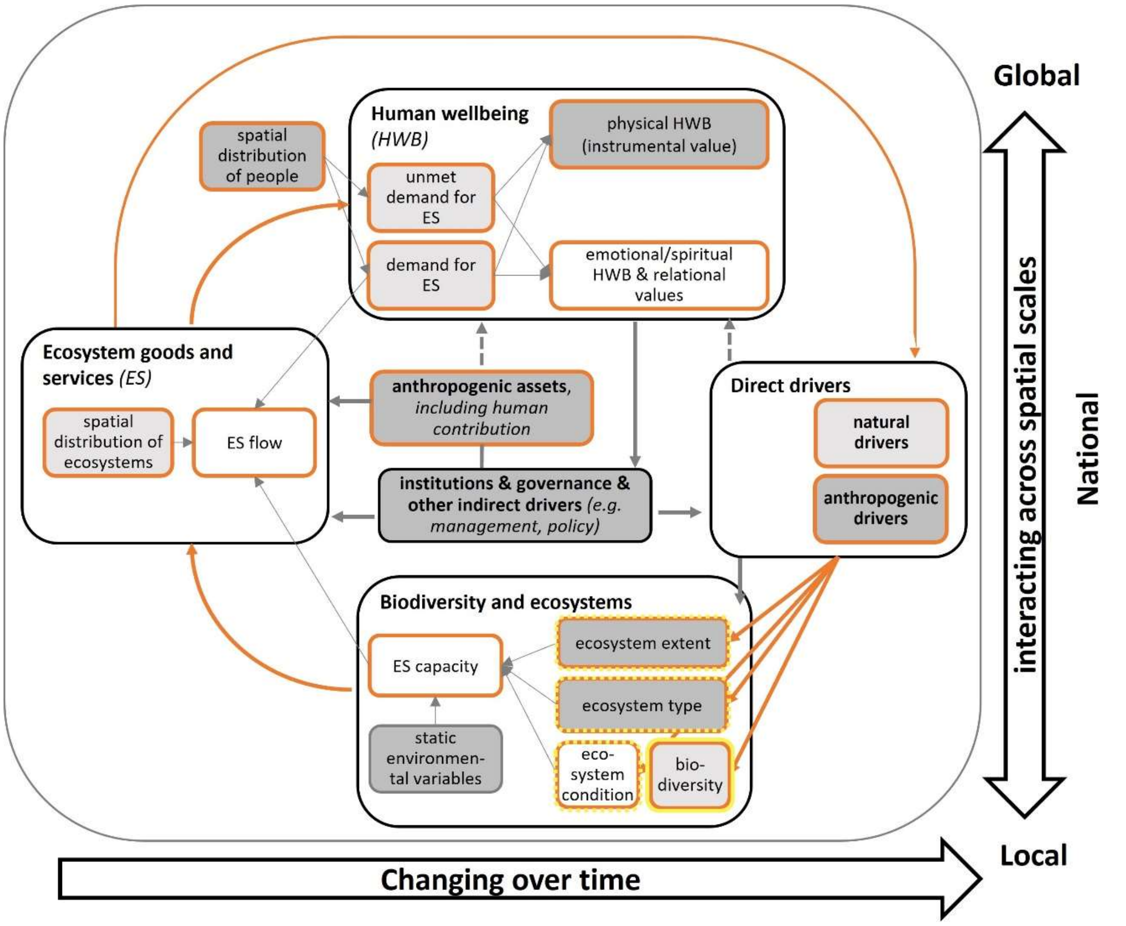

Figure 1. Components of an Ecosystem Service Observatory Network (ESON) mapped onto the IPBES conceptual framework (based on Diaz et al. 2015). Components that would be monitored in ESONs are outlined in orange. BON monitoring focus is outlined in yellow and yellow dashed for further components targeted. Where the original IPBES conceptual framework has six primary components (bold text), we have further broken some of these down into their component parts for more precision. Shades represent the amount of data potentially available, with darker shades of grey indicating greater data availability.

Despite its ambition to be a "whole-society approach", the GBF does not systematically consider the interconnections among components. For example, while the indicator for Goal B aims broadly at "services provided by ecosystems", other indicators address only a few ES at very few aspects/cascade levels, and assess only a very small set of regulating ecosystem functions. The adopted accounting approach focuses on ES *use* without reflecting on whether people's needs are met, or whether this happens in a sustainable way. Without monitoring whole systems, we do not have the information needed to mitigate and manage pressures and drivers (see example in Fig. S1) nor any of the ecosystem functions endangered by unsustainable or exploitative use (Bennett and

Reyers 2024, Falardeau and Bennett 2020). Here we describe three challenges for monitoring social-ecological systems and the gaps they come from, and suggest a way forward.

Challenge 1. *Monitoring for nature conservation is mostly centered around biodiversity, with little attention to how changes in biodiversity affect ES and people's well-being*. While there is agreement on the importance of interlinkages between biodiversity and ES, the way these linkages work are often not straightforward, hard to detect (Harrison et al. 2014), involve time-lags (creating an "ES debt", Isbell et al. 2015, 2017), or have a more general effect on ecosystem stability and resilience (cf. Insurance hypothesis; Loreau et al. 2003; resilience dynamics: Folke et al. 2004). Also, linking the observed changes in biodiversity and ES to drivers and pressures (causal attribution) requires the understanding of causal networks that relate change in variables to outcomes for people and nature (Gonzalez et al. 2023a, Mori et al. 2023). This is challenging because we often lack data linking drivers to biodiversity and ecosystem variables at the right scales, and both data and models come with considerable uncertainties (Gonzalez et al. 2023b).

Challenge 2. *Systematically designed monitoring variables for ES, like the Essential Ecosystem Services Variables (EESV), are much less developed than those for biodiversity* (Balvanera et al. 2022, Schwantes et al. 2024). The EESV framework, with its six classes of essential variables, each capturing key aspects of ES co-production, provides a structure for assessing ES that needs to be developed further (Balvanera et al. 2022). However, indicators for ES are nevertheless challenging to define, as they must encompass multiple aspects (e.g. demand for ES, use of ES, capacity of the ecosystem to supply ES; Haines-Young and Potschin 2010), which requires a combination of models and disparate data sources as well as different types of disciplinary knowledge (Firkowski et al. 2021, Schwantes et al. 2024).

Challenge 3. *Interactions in social-ecological systems are scale dependent but assessments often target a single spatial level*, e.g. the national Mapping and Assessments of Ecosystem Services (MAES) in Europe, or the National Biodiversity Strategies and Action Plans (NBASPs). The inclusion of social-ecological perspectives requires a multi-scale approach because the benefits of nature do not stay in one place and can move (Schröter et al. 2018) or be moved (Liu et al. 2013). Scale is a cross-cutting challenge that underpins questions of generalizability and transferability of knowledge across different geographical and administrative levels (Bennett et al. 2021). Therefore, there is no one monitoring blueprint that works for all, and place-based approaches are indispensable. Monitoring must be designed to assess how ES at different scales change and interact with other components of the social-ecological system.

These three challenges highlight an important overarching issue: monitoring social ecological systems requires a much greater level of complexity. While challenging, approaching conservation more from a social-ecological perspective that includes people's needs and perspectives has repeatedly proven to be more successful (Reyes-García et al. 2019). The importance of understanding the complexity of social-ecological systems has been discussed for decades (e.g., the Millennium Ecosystem Assessment; MA 2003) and continues to be an important and challenging topic (Bourgeron et al. 2023). Making smart decisions about maintaining the benefits we obtain from nature into the future depends on a clear and accurate understanding of these complex systems. Assessments that embrace the complexity have been implemented in a variety of contexts (e.g. in the European Union; Maes et al. 2020, or in Canada; Bennett et al. 2021). However, a unified global approach that accounts for complex social-ecological systems has not yet been developed.

ES observation networks to fill the gaps

To address the gaps listed above, we call for the establishment of ES Observation Networks (ESONs; Fig. 2) alongside the ongoing implementation of national and regional Biodiversity Observation Networks (BONs; Navarro et al. 2017). Because social-ecological systems are complex, monitoring must be designed in a way that takes all their features into account. An ESON is a network of observation sites and groups at different geographical and administrative scales organized to carry out long-term integrated monitoring of social and ecological variables at multiple scales, thus addressing all three of the challenges that currently vex ES monitoring (Firkowski et al. 2021). Integrating ESONs with BONs will allow countries to jointly monitor ES and biodiversity to support the detection of change and of causal interlinkages (Gonzalez et al. 2023b).

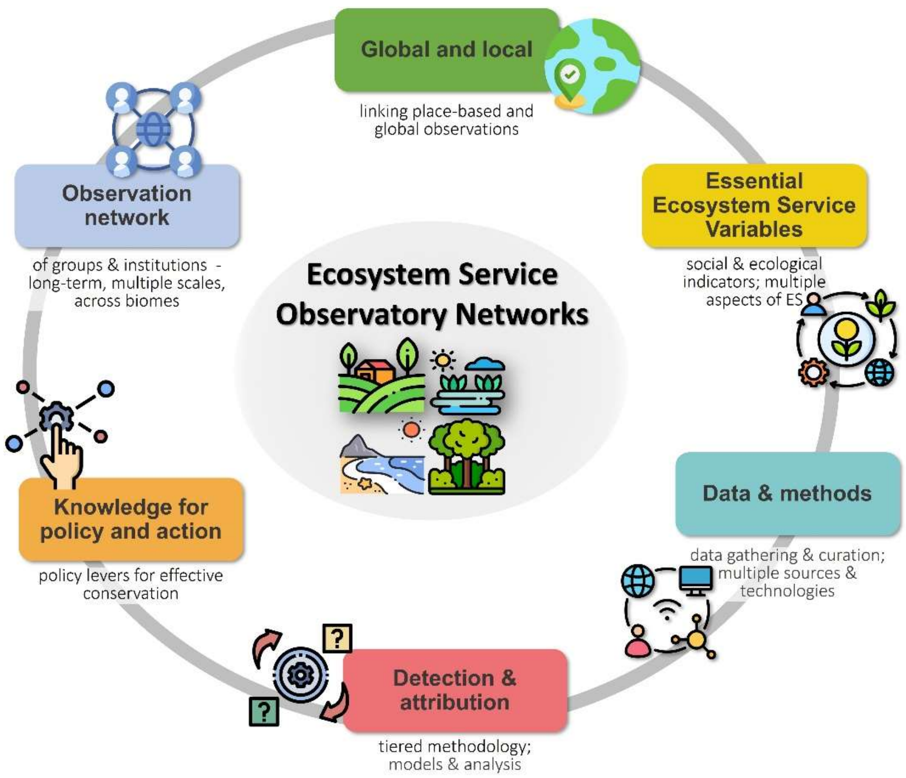

Figure 2. Features of the suggested Ecosystem Service Observatory Network.

ESONs meet the challenges of monitoring by enhancing the focus on ES and their linkages to biodiversity, and by bringing available knowledge together in a structured way. ESONs can combine multiple types of data e.g., national census data, field sampling, community-based monitoring and traditional ecological knowledge enabling local communities to contribute data and knowledge following FAIR and CARE principles (Wilkinson et al. 2016, Caroll et al. 2020). By addressing multiple scales of monitoring and management, and by strengthening the knowledge of indicators they will fill the gaps in current ES monitoring.

Work to implement several science-policy frameworks that requires updated estimates of ES status and trends can spur the development of methods for monitoring ES (Schwantes et al. 2024). At the global scale, the United Nations' System of Environmental Economic Accounting - Ecosystem Accounting (SEEA-EA) provides the best developed methods and theoretical backing (UN 2021), its application in ARIES for SEEA is a useful foundation (UN 2022), whereas in Europe work on the European Union's Mapping and Assessment of ES has advanced and streamlined methods (Vári et al. 2024). Drawing on these experiences in a modular and multi-tiered way enables ESONs to combine global and place-based approaches.

Galvanizing action

We call on the scientific community to develop a framework for jointly monitoring biodiversity and ES, and, critically, to focus on their interlinkages to guide appropriate monitoring practices and technologies for the actions and outcomes sought by the GBF. This should work with the recently launched IPBES methodological assessment on monitoring biodiversity and NCP, and contribute knowledge to the Conference of the Parties (COPs) and the supporting scientific and technical bodies. For implementation, collective action is needed: both civil and government organisations that have the capacity to establish and run ESONs will be essential for linking regional, national and international monitoring. ESONs will enable us to measure progress towards international goals and targets, and deliver key information needed to guide conservation worldwide.

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Supplementary Figure

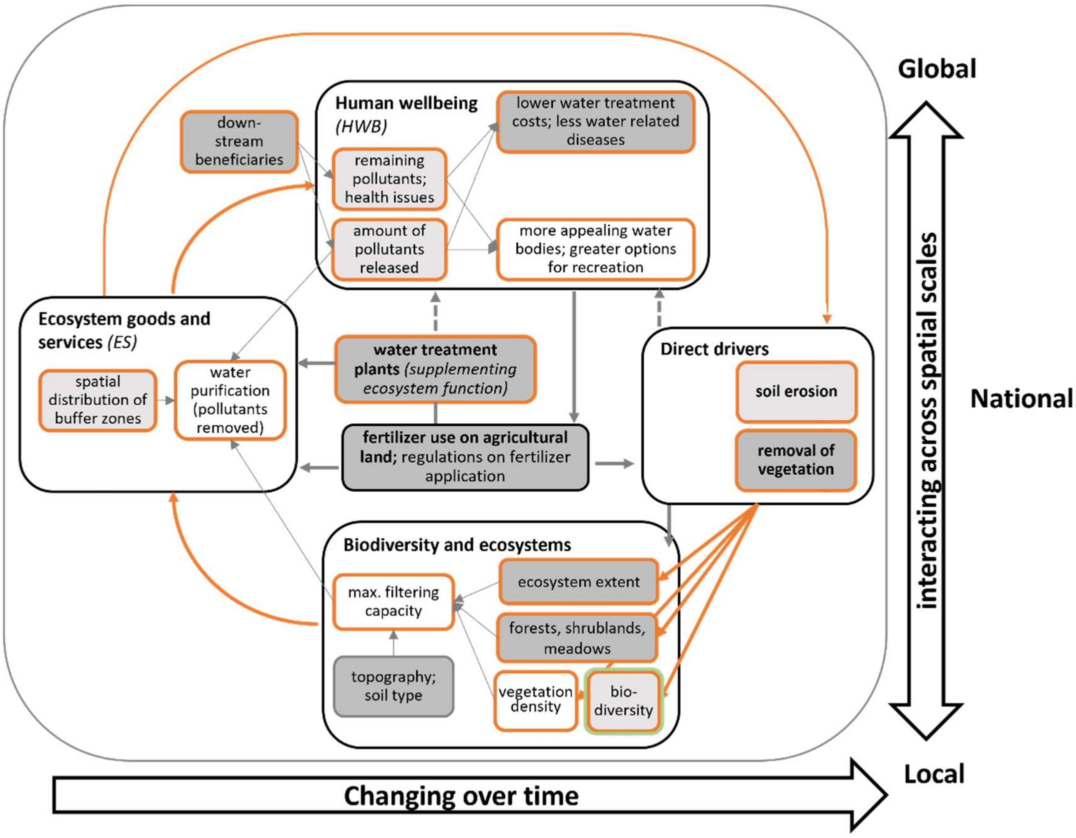

Figure S1. Ecosystem Service Observatory Network (ESON) components with a set of example indicators related to Goal B of the GBF, shown for one selected ecosystem service, "water purification", related to Target 7 ("reduce pollution"). ESON components outlined in orange, BON monitoring focus in yellow.