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Effective Biodiversity Indicators

The UK is committed to targets under international biodiversity agreements to value, conserve and restore the variety of life on earth (biodiversity). Progress towards targets is tracked using indicators, which are designed to summarise complex monitoring data. This POSTnote reviews indicator use and development in the context of the post-2020 Convention on Biological Diversity (CBD) Global Biodiversity Framework.

Overview

- Links between biodiversity loss and drivers of change are complex; indicators are used to describe and communicate trends in aspects of biodiversity, and can be used to aid policy decisions.
- The types, varieties and numbers of indicators can be a source of confusion, but they can help to identify important location-specific trends in biodiversity.
- The difficulty of setting appropriate baselines for reference, the ambiguity of biodiversity targets and the differing sensitivity of indicators to change over time create challenges for assessing progress towards biodiversity targets.
- The quantity and quality of representative data available for indicator development is a key limitation. Researchers suggest greater clarity about global biodiversity targets would aid the selection of indicators.

Background

The UK is committed to multiple international biodiversity goals and targets, such as those set out by the Convention on Biological Diversity (CBD) and the Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic. Biodiversity is rapidly declining (PN 617, PN 627), and most of the Aichi Targets set out in the CBD's Strategic Plan for Biodiversity 2011–2020 have not been met, either globally or in the UK.[1–3] The 15th meeting of the Conference of the Parties (COP15) to the CBD in 2021 will agree the new 10-year post-2020 Global Biodiversity Framework objectives. Global, regional, national and local biodiversity indicators will be used to measure and communicate progress towards the new targets.

Complexity of biodiversity

Biodiversity is critical for human health and well-being and can contribute to mitigating and adapting to climate change (PN 617).[1,4,5] It refers not only to the diversity of the biological components of a system (genes, species, ecosystems), but also more broadly to the interactions between species, structures of biological networks, and the overall functioning or resilience of ecosystems.[6] These broader concepts are often hard to understand, define and measure. This complexity can be measured in various ways but no single metric can adequately describe biodiversity as a whole.[7–10] Indicators are composed of one or more measures that summarise complex data into simple, standardised and communicable figures.[11] Individual indicators (such as forest area as a proportion of total land area, or estimates of bird population; PB 41) may be used to monitor specific aspects of biodiversity, whereas multiple indicators can be used to assess its overall state.[12,13]

The development and use of biodiversity indicators are challenging, but they can provide a basis for communicating progress towards targets and can also be used to evaluate policies underpinning conservation measures.[14] UK environmental policy is devolved and there are some different approaches to monitoring and reporting indicators across the four nations (Box 1). The Joint Nature Conservation Committee (JNCC) and Defra collaborate to publish the UK's indicators annually.[14] This POSTnote describes the challenges surrounding the effective use of biodiversity indicators. These challenges are interlinked and include the types, varieties and number of indicators used; challenges of assessing progress towards targets; and data availability. Possible future indicator developments and advances in monitoring are also outlined.

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Different suites of indicators

Many indicators have been developed for use at different scales (global, regional, national or local) and for reporting against various policy frameworks. The variety of different suites of indicators (outlined in PB 41) can cause confusion as the specific indicators used by each country do not have to be the same.[15] However, each country is required to measure against the same focal areas, which are based on the targets in international agreements.[16] As part of the CBD's post-2020 framework, the UK will contribute data to the global and UK indicator suites. As well as the suite of UK indicators, each UK nation will develop their own suite of indicators to monitor against devolved biodiversity strategies and other policy frameworks (Box 1). The specific indicators used within the national suites vary in response to several factors, including:

- Data availability and resolution;
- The relevance of the indicators to the specific national policy frameworks;
- Differences in ecological conditions, physical processes or geological properties between nations; and
- Differences in culturally valued species or groups.[15]

Box 1: UK biodiversity policies and indicators

Each UK nation has its own suite of biodiversity policies, including England's 25 Year Environment Plan, the Environment (Wales) Act 2016, the Nature Conservation (Scotland) Act 2004, and the Wildlife and Natural Environment Act (Northern Ireland) 2011. Each nation also has its own suite of indicators to aid reporting of progress towards biodiversity targets and goals. Although the JNCC collects some marine and species data at the UK level, there are differences in methods of collecting data, monitoring and reporting of indicators at national levels:

- **England.** Defra annually publishes England biodiversity indicators, which account for the outcomes and priorities in the England Biodiversity Strategy to 2020.[17] The England indicators generally reflect the UK CBD indicators.
- **Wales.** The Nature Recovery Action Plan[18] outlines the Welsh Government's commitment to track change and trends by monitoring two indicators that have been developed under the Well-being of Future Generations (Wales) Act 2015: *Areas of healthy ecosystems in Wales* and *Status of biological diversity in Wales*.[19] The State of Natural Resources Report in Wales assesses the extent to which sustainable management of natural resources is being achieved in Wales, and provides evidence for the future development of indicators.[20]
- **Scotland.** NatureScot developed a suite of indicators with the Scottish Environment Protection Agency, Marine Scotland and Scottish Forestry to monitor progress against the aims of the Scottish Biodiversity Strategy.[21,22] The indicators are split into two groups; one measuring the state of biodiversity in Scotland and the other measuring the level of engagement of Scotland's people with biodiversity.[23] These are reported every 3 years in a report to the Scottish Parliament outlining progress against the Strategy.[24]
- **Northern Ireland.** The Department of Agriculture, Environment and Rural Affairs has developed indicators to monitor progress towards the Biodiversity Strategy for Northern Ireland to 2020.[25] They are part of a larger suite of environmental indicators that are reported yearly in the Environmental Statistics Report[26]

Separating data and monitoring across the UK nations helps to avoid masking potentially important national trends that would otherwise be lost if datasets were aggregated to a UK scale. However, if countries mostly use their own suites of indicators it becomes difficult to aggregate collective national progress towards CBD targets and risks duplication of effort. Outside of the official suites of UK indicators, others have been developed by academics, NGOs and government departments for varying purposes. For example, some may be used at local levels to estimate biodiversity losses and gains resulting from developments or land management change (such as the Defra Biodiversity Metric 2.0; PB 034).[27] Others have been developed to fill gaps in global, regional or national suites of indicators (such as indicators for the impacts of commodity trade).[28]

Appropriate number of indicators

The application of indicators may differ between ecological science and environmental policy, and the appropriate number required in any situation may also vary.[29] Having too few indicators in a suite risks missing important aspects of biodiversity change, whereas large numbers of indicators may make clear communication of progress towards targets difficult; reducing focus on the desired outcomes and conservation actions.[6,30] The average number of indicators used by CBD signatories increased from 49 to 84 between the Fifth and Sixth National Reports.[15] The 2020 suite of biodiversity indicators in the UK comprised 24 indicators, which are made up of a total of 52 measures, each assessed using a 'traffic light' system (with red highlighting a deterioration in the value of the indicator measure).[14] Many indicators have a single measure, but where data cannot be combined logically, the indicator will have multiple measures.[14] These indicators are selected from a much longer list based on several criteria, including the economics and logistics of production and monitoring, biological representativeness, sensitivity of the measures, and relevance to targets.[31,32] Ideally the state of a larger part of an ecological system should be inferable from an indicator, even if it represents a relatively small part of the system.[8,33] However, many indicators are limited in scope and lack the empirical evidence to provide wider information, although they may inform focused conservation efforts on the species or group of species they represent.[8,34]

Aggregating Indicators

An approach to reduce the number of indicators is to aggregate them to a small number of 'headline' or summary indicators.[35] Though useful for communication, this method may not provide adequate understanding of important changes in biodiversity.[36] This risk is mitigated if users are able to disaggregate indicators to finer scales in space or time, so they can be expressed at the scale of ecosystems or habitats as well as political boundaries, such as nations, regions or local councils.

Assessing progress towards targets

Beyond evaluating the many aspects of the state of biodiversity (Box 2), specific information is needed to effectively assess progress towards targets.[11,37] This can include information on the drivers of biodiversity loss as well as conservation efforts, so that the links between human activities, changes in biodiversity, policy and management can be better understood.[38,39] However, assessment of progress towards targets can be limited by the constraints below.

Frameworks for categorising indicators

Several frameworks have been developed to categorise biodiversity indicators, evaluate key knowledge gaps and identify priorities for further indicator development. For example, the widely used Driver-Pressure-State-Impact-Response (DPSIR) framework is used to describe social and environmental interactions.[40] It has been used as a communication tool for a wide range of environmental issues, including biodiversity in the aquatic environments of the EU.[40,41] However, definitions of the different parts of the framework vary across academic disciplines and nations, which can confound its use. The UK biodiversity indicator suite uses the Pressure-State-Benefits Response framework, based on advice to the CBD. Applying these frameworks requires a high level of certainty about links between the components; how a human activity or 'driving force' is linked to specific environmental 'pressure', and the changes caused in the 'state' of biodiversity.[42] There are many other examples of frameworks for categorising indicators,[8,31,40,43–45] such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Conceptual Framework (Box 3), which engages both developing and developed countries.[46]

Linking biodiversity loss to drivers and pressures

Biodiversity is affected by different natural and human drivers, such as changes in land use, climate change, invasive species, overexploitation and pollution.[47] Linking biodiversity indicators to these drivers enables users to evaluate policy options and management strategies.[15,30,34] Direct links between pressures and biodiversity may be unclear as the relationships can be complex and non-linear;[6] and the impact of activities on biodiversity are not directly measured. Impacts may occur over varying time scales, can be intermittent or permanent, and their magnitude will be location-specific.[48,49] There may also be a spatial mismatch between a driver and indicator. For example, if an indicator for a migratory species is declining, it may be due to multiple complex and interacting causes that may be occurring along the migratory route or elsewhere. Surveillance indicators are those not linked to a specific pressure, but they may still contribute by increasing the knowledge base for management decisions, especially when combined with other datasets.[6,52] For example, indicators of the distributional range of species can help to interpret variations in population abundance.[52]

Box 2: Essential Biodiversity Variables (EBVs)

The Group on Earth Observations Biodiversity Observation Network (a partner organisation to the CBD) have proposed a set of Essential Biodiversity Variables (EBVs) – key components to effectively evaluate the state of biodiversity.[50,51] There are six EBV classes, which group a total of 20 possible EBVs into key biodiversity themes:

- **Genetic composition.** The spatial and temporal variation in a species' genetic composition.
- **Species populations.** The spatial and temporal variation in the distribution and abundance of species populations.
- **Species traits.** Within-species variation in characteristics such as body shape, size, seasonal activities and responses to the environment.
- **Community composition.** The abundance and diversity of organisms making up an ecosystem.
- **Ecosystem functioning.** Performance of ecosystems resulting from the collective activities of their organisms.
- **Ecosystem structure.** The spatial arrangement of groups of organisms comprising the ecosystem.

Setting appropriate baselines

It can be difficult to identify suitable baseline conditions against which changes in ecosystem conditions can be measured.[30,53] Setting baselines at the start of a data time-series may result in unambitious targets, as biodiversity loss may have occurred before monitoring began.[6,54] For example, most UK biodiversity data do not pre-date the 1970s, when conditions were likely to already be degraded compared to the natural state.[14,55] Historical baselines can be set when human impacts were negligible or absent. Or reference conditions from locations where human pressures are low or absent can be used as a benchmark.[56,57] However, such data may not be easily transferable and applicable to different contexts.[53] Areas that remain unimpacted by humans are increasingly scarce, which risks benchmarks shifting towards a more degraded state.[6,56] Unimpacted reference states are particularly difficult to find for mobile species that move between impacted and unimpacted areas.[53,58]

Baselines can be predicted using modelling given knowledge of human pressures and their biodiversity impacts.[39,59] This approach reduces the risk of under- or over-valuing reference states depending on conditions at the time and location of sampling for historical or reference benchmarks.[59] However, a detailed understanding of links between human pressures and the state of biodiversity are required for models to be effective.

Time lags and indicators

Some biodiversity indicators respond more quickly to pressures than others, and there is often a time lag between the change in a driver and when this is reflected in the indicator.[43,60] Indicators therefore need to be sufficiently sensitive to changes across space and time to be relevant to decision-making, ideally being able to detect a change in state before it is too late to correct the causes.[30,61] An indicator's time lag depends on a number of factors, including the type of data that feeds into the

Box 3. IPBES Framework for categorising indicators

IPBES has created a Conceptual Framework to categorise indicators,[44] consisting of

- **Nature.** The diversity of living organisms and their interactions among themselves and with their environment.
- **Nature's benefit to people.** The benefits that humanity obtains from nature; ecosystem goods and services.
- **Institutions, governance and other indirect drivers.** The ways in which people and societies organise themselves and their interactions with nature.
- **Direct drivers.** The changes, both natural and human-caused that affect nature directly.
- **Good quality of life.** The achievement of a fulfilled human life.

indicator, the strength and type of pressure, the timescale over which it changes, and the generation times of the species or group of species of interest. For example, indicators measuring the population size of short-lived species (such as plankton) will respond more quickly than one measuring that of long-lived species (such as large fish or marine birds and mammals).[62,63] These time lags make it difficult to predict tipping points (where conditions cross a threshold that causes an abrupt shift between different ecosystem states), the understanding of which remains limited.[30,64]

Indicators of the state of biodiversity should also ideally respond promptly to both degradation and improvement, although most focus on degradation.[30] However, indicators may not show signs of change until significant loss has already occurred, making it difficult to turn monitoring into timely policy action. It can often be difficult to improve a degraded system, and reductions in pressures may not be reflected immediately by indicators. For example, despite continuing improvements in the water quality of UK river systems, only partial ecological recovery has been recorded.[65–67] This could be due to other pressures on the system, changes in the biological community that resist change towards an improved state, and/or the inability of less mobile organisms to recolonise the improved areas.[68,69] These lags make it difficult to recognise improvements from policy and legislation, and progress towards biodiversity targets.

Risks from ambiguous biodiversity targets

Ambiguity and complexity in the wording of targets can make it difficult to develop effective indicators.[6,70] Many previous CBD targets (such as the Aichi Targets) are complex; containing up to seven different components, most of which lack a numeric or quantifiable threshold to be achieved.[70,71] Ambiguity of terms within targets can also make interpretation and subsequent conservation and monitoring responses less consistent, complicating assessments of progress towards global targets.[70,72] Targets set without regard for the wider state of biodiversity have the potential for unintended perverse consequences by tracking processes and actions rather than intended outcomes. For example, researchers suggest that the area-based target to protect 30% of land and sea by 2030 should not focus solely on the quantity, but also the quality of protected areas and the biodiversity in them.[73–75]

Data availability

Data availability limits the full and effective use of biodiversity indicators. It is accepted that indicators should ideally be based on clearly defined, accessible and verifiable data, collected using standardised methods with known accuracy and precision.[30] However, the complexity of biodiversity (as outlined in Box 2) means large amounts of data are needed to fully and accurately monitor changes. Obtaining data is limited by practicality, ease of collection, funding to sustain existing biodiversity datasets, affordability and ownership, which affect both the quantity and quality of data.

Quantity of data

To overcome the cost barrier to data collection, indicators are frequently developed from existing ecological datasets, but finding and accessing existing data can be challenging. Datasets also often have incomplete coverage across time, space, biodiversity themes and groups of species:[15]

- **Spatial coverage.** Cost can limit the quantity of data collected in developing countries, which contain some of the world's most diverse species and habitats.[6] Remote or inaccessible locations, such as in the marine environment, are often missed by monitoring programmes, resulting in the under-representation of some habitats or ecosystems.
- **Coverage of biodiversity themes.** Most available data are focused on monitoring changes in abundance, distribution and population trends in specific species or groups of species. Data are limited on some of the broader and more complex biodiversity themes, including genetic diversity, community composition, and diversity of ecological function and ecosystem services.
- **Species or groups of species.** In the UK, there tends to be more data on groups of species that have great cultural value and are relatively easy to identify or accessible to observe, such as birds, land plants, mammals and butterflies. There is an under-representation of groups that provide other types of benefits to humans, such as soil biodiversity, marine microbes, plankton, fungi and algae.[76–78]

Quality of data

The majority of terrestrial biodiversity data in the UK is collected by skilled volunteers.[77,79] Long-term, standardised citizen science monitoring programmes are used to report on population trends and status (PN 476), but are well-developed for only a limited number of species groups.[8,80–82] Opportunistic data, such as species observations collected outside of standardised monitoring schemes, have broader species coverage. In the State of Nature 2019 report, abundance data for 697 species were collected from established standardised monitoring schemes, while opportunistic data for 6,654 species were reported.[4] However, opportunistic data are less structured than those obtained through monitoring schemes, and the absence of standardised protocols presents challenges for assessing trends in the status of species.[77,82] Effort put into opportunistic monitoring varies over space and time, which can either mask or be misinterpreted as real change.[77,83] The spatial resolution of data can often be either too coarse or locally-specific to influence decision-making. While these challenges exist for assessing species-specific trends, opportunistic data have been used successfully to understand broad changes in biodiversity when known biases are accounted for, such as the under-representation of some groups of species.[84–86]

The future of indicators

Researchers advocate greater clarity on the concepts and goals of the CBD's post-2020 global biodiversity targets to aid the definition and selection of indicators to assess progress,[15,87] and suggest that the new targets should be considered holistically, accounting for the linkages among aspects of biodiversity.[12,88] An equally integrated approach to monitoring would require current gaps in suites of indicators to be filled, though more high quality data are required to achieve this. Technologies such as drones, airborne laser scanning, satellite sensors, and acoustic and photographic recorders, combined with machine learning, are rapidly emerging and advancing, which could complement existing monitoring programmes (PN 628).[89–92]

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