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Integrated Biodiversity Monitoring Across Spatial Scales

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Summary

This report contains guidance and recommendations for anyone who is interested in monitoring biodiversity at local and regional scale. This might include conservation charities, local environmental record centres, conservation agencies, councils and local authorities, businesses, community groups and individuals. Throughout the text we present many examples of monitoring biodiversity through citizen science, but the recommendations are applicable to professional surveys as well as citizen science approaches.

The aim of this report is to present some recommendations on the key decisions involved in setting up a biodiversity monitoring programme at regional/local scale that integrates with existing monitoring efforts and national monitoring schemes.

In section 2 we introduce the importance of biodiversity monitoring across spatial scales, the unique challenges of local/regional scale monitoring and why thinking about data integration is important when establishing new monitoring initiatives.

In section 3 we provide a review of common sampling methodologies for biodiversity monitoring. A more comprehensive review of existing monitoring schemes and the sampling methods used is provided in the supplementary resource ‘Monitoring portfolio attributes’.

Section 4 introduces a four-step guide to choosing the most appropriate sampling methodology for answering different types of ecological questions. Finally, in section 5 we include a worked example of the decision guide using a real-world case study.

Contents

1 Why do we monitor biodiversity

Monitoring biodiversity is critical for achieving conservation goals. Effectively tracking the status and trends of biodiversity allows early indication of species declines, identifies the need for management interventions and allows assessments of the effectiveness of conservation measures (Lindenmayer *et al.* 2012). The data generated through biodiversity monitoring programmes underpin various metrics, which are key tools used in policy, conservation planning and for the prioritisation of resources by decision-makers. For example, data generated through national monitoring schemes flow into biodiversity assessments such as the State of Nature report (Hayhow *et al.* 2019) or policy indicators such as the UK Biodiversity Indicators (UKBI).

1.1 Monitoring of local and regional scales

The UK has a long history of monitoring biodiversity through volunteer-based recording, with national monitoring programmes such as the UK Butterfly Monitoring Scheme and the Breeding Bird Survey producing long-term time series of quality data for wildlife populations. Although datasets like these present an invaluable resource for monitoring biodiversity at the national scale, there are gaps in the taxonomic, spatial, and temporal coverage and they lack sufficient detail to describe changes at local scales.

Recently, there has been a shift in the delivery of national scale policy towards regional and local action, for example the Local Nature Recovery Strategies in England and the Local Biodiversity Partnerships in Scotland. This policy driver has increased the need for local and regional scale assessments of biodiversity status, and to report on the impact of local interventions. Enhancing local monitoring can lead to directed conservation action and other environmental and societal benefits. For instance, the project Water in a Dry Landscape (part of the Chilterns Conservation Board's National Lottery Heritage funded Landscape Partnership Scheme, Chalk Cherries and Chairs – should/can I add this link to the 'cherries and chairs'? initiated a series of local volunteer-based surveys of all streams within a focal region in the Chilterns Area of Outstanding Natural Beauty in Buckinghamshire. The results of these surveys have been used to identify important sites for more focussed ecological surveys to assess habitat quality, wildlife populations, and identify opportunities for habitat enhancement and restoration.

Many regional groups and organisations are seeking to establish population baselines and to track the state of local biodiversity within sites and across landscapes. Monitoring biodiversity at local and regional scales presents some unique challenges. Over the long-term, constraints on resources (e.g. funding, staff, volunteer time or interest, etc.) can hamper progress to meet these ambitions. Likewise, variation in data collection methods across organisations, monitoring sites and species presents challenges for selecting, interpreting and using data which is relevant at the local scale. Though data from national monitoring schemes may be available for the area of interest, it is often not possible to re-analyse national scale datasets at smaller scales because a regional or local subset of the data is usually not large and/or representative enough. Therefore, new data collection efforts are often needed in order to assess biodiversity, and the impacts of various interventions, at differing spatial scales.

1.2 The need for integration

The plethora of biodiversity data generated through national monitoring programmes and regional projects provides a readily available, but fragmented evidence base (Turner *et al.* 2023). This presents challenges for using existing data to answer questions outside of their primary context, particularly when there are conspicuous spatial, temporal or taxonomic gaps within as well as across datasets. In recent years, however, advances in modern statistics have widened the reach of existing biodiversity monitoring efforts and increased the re-use of data through integration. Data integration is a contemporary approach to tackle data quality issues whereby multiple datasets merge into a single model whilst separately accounting for the way in which the data were generated (Fletcher *et al.* 2019; Isaac *et al.* 2020; Miller *et al.* 2019; Zipkin *et al.* 2021). This approach makes efficient use of available data and can outperform single-dataset models in terms of precision of estimates and spatial coverage (Bowler *et al.* 2019; Isaac *et al.* 2020). Data integration can therefore bring together existing data generated from local projects and that of national monitoring schemes into a single analytical framework. Likewise, there is the opportunity to add new data through regional and local monitoring. This is likely to enhance our ability to track the status and trends of wildlife populations, and thereby inform progress towards achieving policy objectives. When we design new monitoring activities within a data integration framework, we can often reduce the survey effort required in terms of, for example, the number of sites that need to be monitored (Mancini *et al.* 2022). This is because the new monitoring data will become part of a bigger integrated dataset, thus achieving more statistical power, temporal and spatial coverage. However, new monitoring initiatives need to be designed in a way that facilitates this integration, both within a region but also across spatial scales, to strengthen the biodiversity monitoring effort at the UK scale.

2 How do we monitor biodiversity?

Biodiversity monitoring is three-dimensional. It encompasses: (1) the collection of biological data (e.g. occurrence or abundance indices) by either networks of volunteer recorders or through professional surveys at appropriate geographic and temporal scales; (2) the analysis of spatial and/or temporal facets of biodiversity indices, and; (3) production of informative outputs usable at decision-making and policy levels (Schmeller *et al.* 2017). An effective biodiversity monitoring programme will successfully deliver in each of these dimensions to meet the aims of the pre-defined purpose of monitoring. In the first, it will engage an appropriately skilled and abundant network of recorders that utilise suitable data collection methods to generate usable, informative data. Second, it will implement tried-and-tested techniques for data management and establish a robust analytical framework for deriving trends and assessing the drivers of observed changes. Lastly, it will have dynamic policies for targeted dissemination of the results and data re-use.

There are six stages to establishing such a biodiversity monitoring programme (Schmeller *et al.* 2017):

1. Identify monitoring questions and aims, including the temporal and spatial extent of interest.
2. Identify the key ecological components, functions and processes to effectively monitor, and what data are required to answer the monitoring questions.
3. Identify the most suitable monitoring methods.
4. Carry out monitoring activities.
5. Data management.
6. Data analysis and interpretation.

In this report we focus on stages 2 and 3 and provide recommendations that increase the potential for integration across datasets and spatial scales. Our aim is to provide general guidance to making decisions when designing biodiversity monitoring initiatives. For this reason, we do not provide detailed guidance on the best survey method for a specific species or taxonomic group. For more details and examples of different methodologies applied to monitor different taxa, please consult the supplementary resource 'Monitoring portfolio attributes'

2.1 Sampling Methodologies

In this section we review different sampling methodologies, categorising them into four broad classes: mass participation, unstructured, semi-structured and systematic recording. Monitoring projects in each of these classes can focus on a single population, a species, a taxonomic group, or all biodiversity within a focal area.

2.1.1 Mass participation recording

Anyone has the potential to take part in biological recording, regardless of background, experience or skill set. A now popular method used in citizen/community science is participation by the general public (Pocock *et al.* 2015a). Whilst each project may vary to some degree, they most typically operate with the objective of engaging many people in biological recording. This approach can be effective for generating large quantities of data, particularly when species are relatively simple to detect and identify (Pearce-Higgins *et al.* 2018). Whereas most recording activities rely on the recorder being proficient in species identification and survey method, mass participation recording initiatives do not. The rise in technological innovation (e.g. iNaturalist, Record Pool) in recent years (August *et al.* 2015;

Pocock *et al.* 2017) has meant that recorders can now capture observations and metadata in-situ (e.g. geotagged photographs). Mass participation recording now frequently implements post-hoc species identification verification. Where available, species experts check accompanying photographs submitted by the recorder to verify records. Where observations can be verified, their constituent data can be collated into wider biodiversity datasets (Pocock *et al.* 2015b). Mass participation recording projects generally produce multi-species datasets that can potentially run over long timeframes. For example, the RSPB Big Garden Birdwatch is a single event that happens once a year every year since 1979. The scheme encourages anyone to submit sightings of birds that they observe in their garden. In recent years, the taxonomic remit of the scheme has expanded to capture data on other wildlife observed in participants' gardens during the year. Mass participation recording initiatives can be very useful when no other data are available and to gather basic information on how many and which species are present, which can then inform more targeted monitoring.

2.1.2 Unstructured biological recording

There is expansive diversity in biological recording activities in the UK. Much of the recording portfolio is opportunistic: there is no formal structure imposed for recording observational processes. Rather, recorders of any skill-level or expertise document observations however, whenever, and wherever they choose for any given purpose (Isaac *et al.* 2014; Pocock *et al.* 2015). Nowadays, the widespread establishment of local environmental record centres and wildlife data e-infrastructures (e.g. the National Biodiversity Network Atlas) means that datasets generated through various forms of opportunistic sampling can be stored and distributed across shared platforms, rendering them potentially usable outside of their intended contexts (Turner *et al.* 2023). However, data collation in this way produces heterogeneous, 'unstructured' datasets: a compilation of records including some generated through casual observation and some generated through intensive search effort (including Atlas projects; Pocock *et al.* 2015b), generally with little means of discerning the observational processes that generated them. Whilst more convenient for the participants, these datasets can present considerable logistical and analytical challenges for biodiversity data end-users (e.g. researchers, land managers, decision-makers).

2.1.3 Semi-structured recording initiatives

Semi-structured recording initiatives can operate either with or without a standardised protocol, and without a formal sampling design. Participants in the scheme have some degree of choice in how data is generated, imposing some implicit observer-bias on the final dataset. However, semi-structured initiatives also enable some information about observational processes to be recorded (e.g. Mammal Mapper, Pollinator Monitoring Scheme Flower-Insect Timed Counts, NightWatch). Standardised effort metrics can therefore be drawn out of datasets, allowing quantitative comparisons in space and time. These initiatives require more engagement by observers and utilise specific data recording tools to document additional observational processes. They can therefore provide a useful means of generating information on the abundance and distribution of taxa, particularly for species with limited systematic recording initiatives.

2.1.4 Systematic monitoring

In systematic monitoring schemes, recorders collect data according to standardised repeated protocols and sampling designs developed by scientists and statisticians. This makes observations highly comparable in space and time, allowing the data to be used for inferring changes in the demography, abundance, and behaviour of species (Pearce-Higgins *et al.* 2018). The monitoring programme can implement either a stratified or self-selection (convenience) sampling design. In the former, the locations of monitoring activities are determined via random selection (e.g. the National Plant Monitoring Programme), which is beneficial for most statistical frameworks and improves the ability of schemes to meet their primary objectives (Pescott *et al.* 2015). In the latter option for sampling design, the recorders (usually volunteers) select the location of sampling (e.g. the UK Butterfly Monitoring Scheme). This reflects a trade-off between generating enough data of sufficient quality for analysis whilst ensuring recorders remain engaged with the monitoring programme (Pearce-Higgins *et al.* 2018). In both cases, recorders make repeat visits to the same monitoring locations within and between years which generates some of the highest quality of data available. Datasets generated through schemes of this nature can be used to produce annual national species trends which are usable in scientific research and national indicator frameworks. However, schemes of this nature require considerable time-input from recorders and programme coordinators alike, and typically have higher running costs than the other forms of sampling methods.

3 The decision guide

There are multiple decisions that need to be made when designing a monitoring programme that can be integrated with ongoing monitoring efforts. These decisions include whether to use professional surveys, volunteer citizen scientists, which data collection protocol to use and the number and location of sites to monitor. All these questions need to consider local/regional objectives, the national context, as well as the resources available. We have produced a decision guide that will take the user through a step-by-step procedure towards setting up local and regional scale monitoring (Figure 1; see also the supplementary resource 'Decision guide report form').

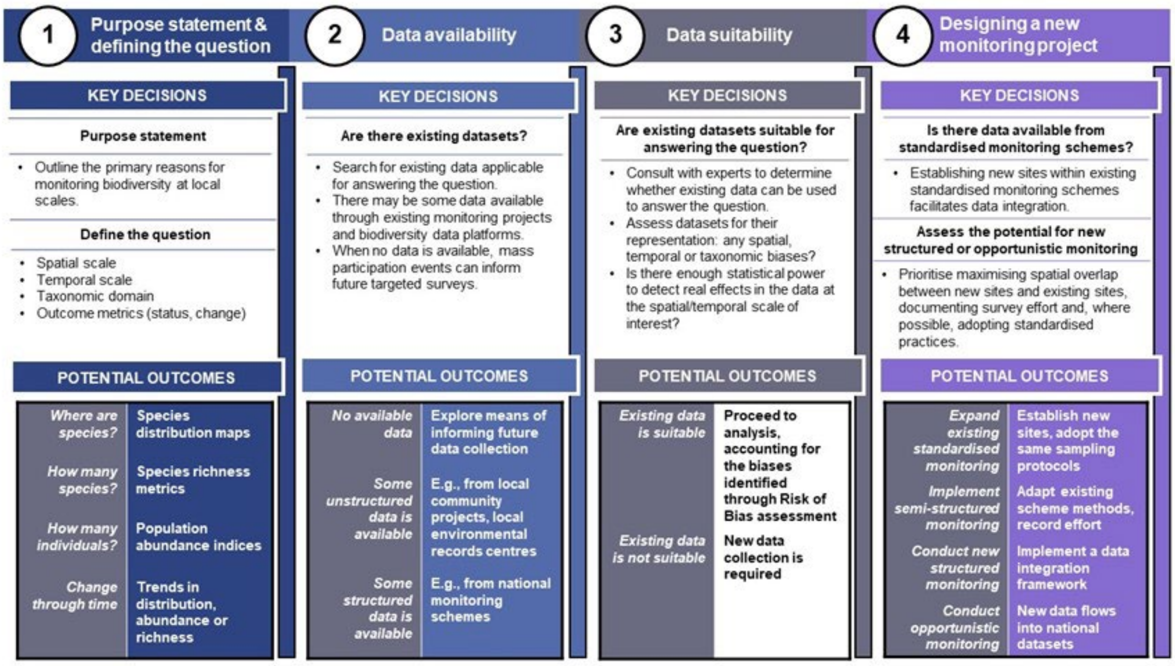

Figure 1. A framework conceptualising the key decisions and outcomes when designing a biodiversity monitoring programme that aims to produce datasets on local/regional scales and that can also integrate with national monitoring.

3.1 How to use the guide

In most cases this guide will not provide definite answers, but a set of recommendations ranging from gold standard to minimum viable options. The user will then decide based on the specific circumstances in which the monitoring takes place, including resources available.

If the user has multiple questions they would like to answer with the data, we recommend going through the following steps separately for each question and then compare the recommendations. When the guide leads to different outcomes for each question, the user should collect the data that allows them to answer the most information hungry question. This is because an information-rich dataset can always be degraded into a simpler one, but it is not usually possible to go the other way around. For example, if the user wants to answer the question "what is the distribution of species x" and how has its abundance changed over time, the guidance might provide a recommendation of collecting presence-only data to answer the first question and repeated count data following a standardised protocol for the second. In this case, the user should collect abundance data, as they can always degrade the counts to presence/absence data and thus estimate the species distribution, but they won't be able to obtain counts from presence-only data.

3.2 Step 1 – Define the question

In order to design monitoring activities that produce good quality data, the first step is to define the general purpose of monitoring, the questions that need to be answered with the data and what types of metrics are of interest. This includes defining details such as, which species, time period and geographical area will be the focus of the monitoring activities, whether the metric of interest is the distribution or abundance of the focal species and if the user is interested in quantifying the current status of this metric or its change through time.

3.3 Step 2 – Data availability

The second step is to gather all the data that is already available for the species, time, and area of interest. Two outcomes are possible: (1) No data is available for the taxonomic group, time period and/or area of interest; (2) Some data is available.

When no data is available it can be productive to organise some mass participation recording events, such as Bioblitz, in order to gather as much information as possible on what species are found and where. This rough data can be used to target future surveys.

The second outcome encompasses a range of situations. Unstructured data could be available from local community projects, local environmental record centres or national recording schemes. Alternatively, data from semi-structured or systematic surveys could be available from national monitoring schemes such as the UK Pollinator Monitoring Scheme or the Breeding Bird Survey. It is also possible that multiple datasets are available for the same taxonomic group, time period and geographic area with varying degrees of spatial, temporal and taxonomic overlap. In any of these cases, after collating all the datasets available, the next step is to assess the suitability of the available data to answer the question(s) defined in the previous step.

3.4 Step 3 – Data suitability

One important consideration in determining the suitability of available data is whether it has enough statistical power to detect an effect, assuming the effect exists. The effect could be a change through time or a statistically significant difference between two groups (e.g. a landscape with a conservation intervention vs a control). In other words, do I have enough data? This can be assessed through a statistical power analysis (Johnson *et al.* 2015), which will determine the optimal number of required sampling units needed in order to answer the question of interest.

Having enough data is only one aspect of having a representative dataset. In order for the sample data to be representative, it should have the same characteristics of the population. Sampling bias may produce a non-representative dataset, which can lead to biased results and misleading conclusions. For example, the data can be biased in space, with some areas being sampled more than others because they are easier for recorders to access. Temporal biases are also very common, with the number of records increasing through time as biological recording has become more popular. These biases are particularly prevalent in unstructured data, which were not collected using a specified sampling design and where survey effort is uneven and often not recorded (Isaac & Pocock 2015). If significant bias is detected then the extent of inference may be restricted, for example to a portion of the total area of interest or time period, or to a certain environmental space (e.g. habitat type or climatic region). A risk of bias assessment can be conducted using tools available in the literature. For example, for analyses that aim to produce temporal trends in species distributions the qualitative risk of bias assessment tool ROBITT can be used (Boyd *et al.* 2022).

In cases where technical skills such as data science and statistics are not available, consultation with experts is recommended. Taxon experts, such as county recorders or recording scheme organisers, could provide qualitative assessments of data suitability and advise on rules-of-thumb that may be available to determine the optimal number of required sampling units needed without having to conduct a full power analysis. For example, the Breeding Bird Survey reports trends for species that have been reported in at least 40 sites (for UK level trends) or 30 sites (for country or regional trends).

If multiple datasets are available for the same taxonomic group (e.g. data from structured monitoring scheme and unstructured data), it may be possible to use all available data sources to produce trends (Isaac *et al.* 2020; Zipkin *et al.* 2021). Assessments (qualitative or quantitative) of statistical power and risk of bias should be conducted on each dataset separately and on the joint dataset as data integration can greatly increase statistical power, temporal and spatial coverage, as well as, to some extent, correct for some of the biases present in each dataset (Sadykova *et al.* 2023).

3.5 Step 4 – Designing new monitoring

After assessing the available data, the conclusion might be that the existing datasets are not adequate to answer the question defined in step 1 over the spatial and temporal scale desired. This could be because of a lack of statistical power, patchy spatial and/or temporal coverage or because of severe bias that cannot be accounted for in analysis. The next step is to design a new monitoring project. The general survey design and sampling method will depend on the question defined in step 1 (see Table 1 for specific recommendations for some common ecological questions). However, the aim is to produce a dataset that can be integrated with the existing ones to produce the metrics needed to answer the relevant question. The availability of existing data lowers the requirements for the new monitoring project but there are some considerations to keep in mind for successful data integration.

The gold standard option is to extend any standardised monitoring schemes that might be already active in the area of interest, by recruiting either professional surveyors or local volunteers. For example, if there are already a few sites monitored by one of the national monitoring schemes, the simplest option is to establish a few more sites to be surveyed using the same sampling protocol. The results of step 3 can be used to inform how many sites it is sufficient to monitor to achieve the desired statistical power and where to place them so that any gaps or biases can be minimised. The new data can be easily merged with the existing dataset and analysed together at the local/regional scale as well as contributing to the national scale dataset.

If extending those standardised monitoring schemes is not an option, for example because of a lack of resources, then reduced effort alternatives may be considered. For example, it may be possible to design a modified protocol that is less demanding for the recorder so that a larger number of volunteers can potentially be engaged. Alternatively, a semi-structured approach could be useful. For example, the same protocol could be applied but the recorders could have the freedom to decide when and where to survey.

As a minimum viable option, unstructured monitoring with some form of effort recording could be considered. Examples of effort recording include using complete lists (all species detected and identified are reported) or providing details of the sampling protocol used, such as time spent searching (e.g. start time and end time).

When data is collected using the same methodology, integration is very simple as the datasets can simply be merged. When data is collected using different sampling methods, an integrated model will be required to use all data sources to produce the desired output. In this case it is important for successful integration, that the spatial overlap between the datasets is maximised. Practically this means surveying as many of the sites for which data is already available as possible. If an unstructured or semi-structured approach is chosen this can be tricky, as the recorders will not be assigned specific sites to survey. In this case, tools that use adaptive sampling could be useful, nudging recorders towards specific areas. Alternatively, a small number of professional surveyors could be recruited to make sure some of this overlap is achieved.

Table 1: Options for sampling methods and survey design for common monitoring questions.

	Where are species	**How many species**	**Species abundance**	**How has species distribution / abundance / richness changed through time?**	**How has species distribution / abundance / richness changed in response to environment / intervention?**
Sampling method	• Atlas-type project. • Focused recording. • Potentially mass participation projects (e.g. bioblitz). • Aggregated records from local environmental record centres. • Existing species databases within Local Natural History Groups.	• Mass participation projects (e.g. bioblitz). • Aggregated records from local environmental record centres. • Existing species databases within Local Natural History Groups.	**Gold standard** Systematic recording; consistent detection methods/equipment.	**Gold standard** Systematic recording; consistent detection methods/equipment.	**Gold standard** Systematic recording; consistent detection methods/equipment.
			Intermediate Reduced effort or semi-structured recording.	**Intermediate** Reduced effort or semi-structured recording.	**Intermediate** Reduced effort or semi-structured recording.
			Minimum viable option Unstructured monitoring with effort recording.	**Minimum viable option** Unstructured monitoring with complete lists and effort recording.	**Minimum viable option** Unstructured monitoring with effort recording.

<table>
<tr><th></th><th>Where are species</th><th>How many species</th><th>Species abundance</th><th>How has species distribution / abundance / richness changed through time?</th><th>How has species distribution / abundance / richness changed in response to environment / intervention?</th></tr>
<tr><td rowspan="2">Survey design</td><td rowspan="2">Defined geographic area of interest.
Site selection strategy, convenience sampling and recorder self-selection.
Naturalistic versus urbanised settings.
Repeats within the sampling season. Depends on detectability of species: average 2-4 visits per season on an ad-hoc basis.
Focus resources on surveying new sites rather than re-surveying existing sites.
Single-/two year sampling – data should be collected from a comparable time period (e.g. within the same year, same month) for the given context.
Species identification validation procedures in place.</td><td rowspan="2">Convenience sampling.
Site-based survey or defined geographic area of interest.
Repeat visits to the same sites at fixed intervals (within the same year) to record a range of species where detectability varies across the seasons.
Single-year sampling.
Species identification validation procedures in place.</td><td>Gold standard
Fully randomised or stratified sampling design.
Repeats within the sampling season.
Standardised effort.
Single-/two year sampling.</td><td>Gold standard
Fully randomised or stratified sampling design.
Repeats within the sampling season, at timed intervals.
Standardised effort.
Annual survey replication.
Sites resampled every year.</td><td>Gold standard
Before - After - Control - Intervention (BACI) design.
Spatial replicates at randomly chosen sites.
Repeats within the sampling season, at timed intervals.
Standardised effort.</td></tr>
<tr><td>Minimum viable option
Recorder self-selection of sites.
Measurable effort.</td><td>Minimum viable option
Recorder self-selection of sites.
Repeats within the sampling season, at ad hoc intervals.
Measurable effort.
Regular (e.g. every other year) survey replication.
Most sites resampled regularly.</td><td>Minimum viable option
Before – After.
Control – Intervention.
Spatial replicates at sites chosen by the recorder.
Repeats within the sampling season, at ad hoc intervals.
Measurable effort.</td></tr>
</table>

	Where are species	How many species	Species abundance	How has species distribution / abundance / richness changed through time?	How has species distribution / abundance / richness changed in response to environment / intervention?
Surveyor information	• Professional surveyors. • General public, community scientists, experienced ecologists.	• Professional surveyors. • General public, community scientists, experienced ecologists.	• Professional surveyors. • Community scientists trained in survey methodology and species identification.	• Professional surveyors. • Community scientists trained in survey methodology and species identification.	• Professional surveyors. • Community scientists trained in survey methodology and species identification.
Outputs	• Species distribution maps.	• Species richness metrics and maps.	• Local population abundance estimates.	• Trends in distribution / abundance / richness through time.	• Effect of intervention on distribution / abundance / richness.

4 A worked example of the decision guide

The National Trust (NT) is a charity and major land-owning organisation working across England, Wales, and Northern Ireland. The NT protects and cares for places so people and nature can thrive. One of the organisation's strategic objectives is to protect and restore nature on NT sites for environmental and societal benefits. They are currently working on a future strategy for monitoring biodiversity across their sites and understanding the impact of their interventions.

4.1 Step 1 – Purpose statement and defining the question

The main goal for monitoring biodiversity is:

"To assess the impact of interventions across multiple sites, using a standardised approach, and report on the impact of interventions at local, regional and national scales within the National Trust."

The monitoring will be conducted at multiple scales: single sites, multiple sites, regional/country level and for the whole NT. The monitoring will target a range of species, including priority and indicator species, to quantify both biodiversity status and changes over time. The time period of interest varies. At the whole NT level, there is a need to evaluate the impact of 10-year strategies, but individual programmes may be interested in changes at different temporal scales.

The overarching questions that the monitoring strategy needs to answer is:

"How has biodiversity (status, distribution and abundance) on the National Trust land changed in response to various site-based interventions over time?"

4.2 Step 2 – Data availability

Some species monitoring data is (or will soon become) available for NT, including:

1. Standardised data from national monitoring programmes that collect data on NT land, including Breeding Bird Survey (BBS), UK Butterfly Monitoring Scheme (UKBMS) and National Plant Monitoring Scheme (NPMS).
2. Standardised data from large NT programmes that collect monitoring data across multiple sites, particularly targeting birds, butterflies, plants, pollinators, and freshwater macroinvertebrates.
3. Standardised data from individual sites and smaller projects.
4. Unstructured data from national recording schemes and societies and to a lesser degree Local Environmental Records Centres. Some of this data flows into the Biological Records Centre's database through iRecord or the recording schemes and ultimately into the National Biodiversity Network Atlas.

This data landscape is therefore very heterogeneous with a mix of unstructured and systematic data collected for multiple purposes and using different sampling methods. Ideally, all the available data sources will be used to answer different questions about biodiversity at multiple scales and about the impact of different interventions. Integrating different datasets has the potential to: (1) increase the statistical power available to detect the effect of interest (e.g. impact of intervention and change in species distribution/ abundance over time); (2) increase the spatial and temporal coverage of the data, and; (3) mitigate some of the biases that might be present in each dataset (Sadykova *et al*. 2023).

4.3 Step 3 – Data suitability

The next step in the decision framework is to determine if these datasets are adequate to answer the above question. As a first assessment, the NT could seek advice from the monitoring schemes and/or taxon specialist. For example, in determining if the existing BBS data is suitable to monitor birds on NT land, the organisation could make use of the threshold of 40 squares for UK level and 30 squares for country or regional level trends.

The next step would be to assess whether there are biases in the data that might restrict the level of inference that can be derived. This could be achieved through a quantitative data exploration, for example using the R software package occAssess (Boyd *et al.* 2021) and the risk of bias assessment tool ROBITT (Boyd *et al.* 2022), or through expert consultation.

Because multiple data sources are available and may be integrated to answer the questions of interest, assessments of statistical power and risk of bias should be conducted on each dataset separately and on the joint dataset.

4.4 Step 4 – Designing a new data collection project

The results of these assessments will determine whether the existing data can be used to answer the question of interest or whether the existing data on its own is not adequate. In the case when biases and gaps have been identified in the available data, more monitoring may be necessary in order to produce robust outputs that are representative of the entire area and/or time period of interest. It is possible to use the results from the previous step to target monitoring activities so that integration is possible across the new and existing data and that new data collection efforts are optimised.

The gold standard option for designing a new data collection project that integrates with the national scale monitoring is to expand the existing standardised monitoring scheme. This means establishing new monitoring sites and applying the standard sampling methodology from the national monitoring schemes. This has already been implemented for butterflies, which are monitored on NT land mainly through the UK Butterfly Monitoring Scheme (UKBMS). To supplement the UKBMS and improve representation across the NT estate and wider-countryside species, a design-based network of randomly selected squares, the National Trust Farmland Butterfly Survey (NTFBS), was set up in 2016. New data collected in this way can simply be merged with existing data from the national monitoring schemes and analysed together, thus increasing the power available for the local, regional or whole NT analysis but also contributing to national scale trends and indicators.

5 Conclusions

In today's heterogeneous biodiversity data landscape, we don't just need "more" data, we need "better" data. Integrated models offer the opportunity to make the most of all available data sources, mitigating existing bias and reducing the need for new monitoring initiatives. Monitoring biodiversity is complex and resource intensive and a culture of data integration is necessary to achieve biodiversity targets when limited resources are available for monitoring activities. Designing local and regional scale monitoring projects with data integration in mind ensures that the data collected will not only produce impacts for local and regional conservation, but also contribute to achieving national and global biodiversity goals.

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