Cover photo: Oliver Barnett

Overarching Topic

Monitoring

David Parker & Oliver Barnett

Rebuilding nature

Good practice guidance for ecological restoration

CIEEM

This document is part of a series written by members of CIEEM's Ecological Restoration Special Interest Group. The series is prefaced by ten good practice principles for ecological restoration, set out in *Rebuilding nature: Good practice guidance for ecological restoration,* and includes five Overarching Topics that apply to any ecological restoration project in the terrestrial, freshwater and marine environments of the UK and Ireland:

- **Integrating Ecosystem Services into Ecological Restoration**
- **Project Planning and Implementation**
- **Physical Environment**
- **Large-Scale Nature Recovery and Restoration**
- **Monitoring**

Accompanying the five Overarching Topics are the habitat specific documents applicable to ecological restoration projects in terrestrial, freshwater and marine environments.

Monitoring – What is it and Why is it Important?

In summary, monitoring:

- is essential for learning and to improve best practice
- must be built into the project and budget from the outset
- must be simple, affordable, repeatable and founded on a good baseline survey
- should be tailored to the relevant habitat(s) / species
- results should be written up and disseminated

Purpose and definitions

Monitoring is the systematic process of collecting, analysing and using information to track a project's progress towards its objectives and to guide management decisions. Only through effective, robust monitoring can we demonstrate that the actions taken are achieving the desired results. Monitoring can be used to:

- demonstrate that a project has achieved, or is making progress toward achieving, its objectives and the desired outcomes
- develop a contemporary understanding of the effects of restoration actions to inform adaptive management or, potentially, to adapt project objectives
- build a body of data which, if published, informs the profession of the effectiveness of differing approaches towards restoration, whether through innovative or more standard practices.

Woodward & Hollar (2011) break down monitoring into three phases (though not all of these will be applicable in every scenario):

- **Implementation monitoring** – assessing whether management actions for ecological restoration have been conducted as planned
- **Effectiveness monitoring** – assessing whether the management activities are generating the desired habitat response
- **Validation monitoring** – assessing the efficacy of basic assumptions in terms of how prescribed management actions will affect biological outcomes.

These definitions are broadly comparable, but Woodward & Hollar's 'implementation monitoring' is useful, adding a (contract) compliance element to the monitoring process. This is similar to Inspection Test Plans (ITP) in construction projects, which are a way of checking that a task is implemented with proper supervision and sign-off before it is considered complete.

Monitoring Principles

Monitoring is a vital part of Principle 1 in CIEEM's Rebuilding nature – Good practice guidance for ecological restoration (CIEEM, 2024):

Principle 1. Set clear, measurable goals

> *"Identify the desired nature conservation outcome(s), evaluate the different mechanisms to achieve the desired outcome, select the best mechanism and then set clear, measurable goals to demonstrate whether the outcome(s) has been achieved. The desired outcome may be targeting a specific habitat type and condition, population size, species composition (including the presence of positive and negative indicators) or an establishment timescale informed by native reference ecosystems whilst considering environmental change."*

Any credible ecological restoration project will have clearly defined objectives (measurable goals). These can range from general to highly specific and can include ecological as well as social and other objectives. To determine whether a project is achieving or has achieved its objectives, it is vital to carry out monitoring.

The word monitoring can mean any type of measurement, including survey, census and research (Alexander, 2008). The word derives from the Latin, *monere*, which means 'to warn, to advise'. Project managers need a warning when things are going wrong and confirmation when things are proceeding satisfactorily. This means that project designers need to decide what characteristics they require for a specific feature; this is the objective which has been set. They must then make repeated measurements to ensure that the objective is being met or is on track to do so. This will also provide evidence needed to guide required interventions if things are not proceeding satisfactorily.

Recording, inspection or surveillance, without reference to the goals (objectives) of the project have little value, but focused surveillance is a key part of the monitoring process. One definition of surveillance (Alexander, 2008) is: "making **repeated standardised surveys** in order that change can be detected", meaning that surveillance is a vital tool to carry out monitoring.

Monitoring is important for many reasons, ranging from providing information on the success or otherwise of a project, to providing evidence that ongoing management needs to be changed (remedial action) in order to meet the project objectives. Monitoring may suggest a reassessment of whether the objectives remain achievable, perhaps given unforeseen changes encountered, and hence whether objectives should be changed or adapted. This 'adaptive management' will be considered later in this guidance.

With most projects requiring ongoing management, monitoring is vital to inform management interventions. This may be in perpetuity, or for a legally defined period as with Biodiversity Net Gain (BNG) projects in England, which require a 30-year Habitat Management and Monitoring Plan (HMMP). It is much easier to produce an HMMP if design objectives are specific, and targets are measurable.

Projects that have a well-designed and effectively implemented monitoring framework are more transparent and find it easier to account for their actions and expenditure to funders, local communities and other stakeholders (Endangered Landscapes and Seascapes Programme, 2024).

Common Standards Monitoring for protected sites

Statutorily protected sites for nature conservation in the UK (including SSSIs, ASSIs, SPAs, SACs and Ramsar sites) have long had their own monitoring system: Common Standards Monitoring (CSM). CSM was developed to provide an agreed approach to the assessment of condition of statutory sites designated for nature conservation through UK legislation and international agreements. CSM monitors the features (species, habitats, geology) for which the sites are designated and protected, and is intended to offer a simple, quick, assessment of feature condition, supported by limited, more detailed monitoring.

CSM is managed by the JNCC on behalf of the UK Statutory Agencies (NatureScot, Natural England, Natural Resources Wales, and the (Northern Ireland) Department of Agriculture, Environment and Rural Affairs) (JNCC, 2019). In the Republic of Ireland, the National Parks & Wildlife Service (NPWS) has its own monitoring and assessment requirements, particularly for sites designated under the EU Habitats Directive.

The JNCC published a statement (JNCC, 2022) which summarises the agencies' current position on CSM. Its relevance to this guidance is that some ecological restoration projects will include statutory protected sites, and CSM principles and practice will need to be included in the monitoring plans which are developed for these. It is quite possible that an objective / outcome of a restoration project will be a SSSI feature, such as a heathland type or a rare species. On such sites there will be a need for close working between the project habitat management team and the relevant statutory agency.

How to Design a Monitoring Plan and How to Use the Results

Designing a monitoring plan

The fundamental importance of monitoring is to inform and focus positive management to achieve optimum results for your project. **Monitoring should always be part of the early thinking and design of a project,** and from this a monitoring plan will emerge. There are several important components and considerations which should be addressed within a monitoring plan, including:

- Ensure a comprehensive baseline data set is available to record the biodiversity and physical conditions of a site before project implementation;
- Determine the purpose of monitoring (i.e. establish 'why' it is to be done, referring to definitions above);
- Set clear project objectives to help determine how, what, where, how often, and for how long monitoring should be undertaken;
- Be clear about what information is actually required from monitoring to guide effective management to deliver project objectives;
- Establish clear and relevant success criteria, thresholds, triggers and targets against which effectiveness can be judged - prompting further actions where necessary;
- Identify what does *not* need monitoring to help focus resources on priority issues;
- Set out how monitoring data will be evaluated, recorded, stored and managed;
- Ensure the monitoring plan (and management plan and project objectives) has provision for review and modification in the light of experience or a change in circumstances;
- Be clear about who is responsible / accountable for completing the monitoring and, if remedial action or adaptive management are required to address the outcome of monitoring, who is responsible for this;
- Given that monitoring may be required for 30 years or more, ensure that succession procedures are in place to cover the passing on of responsibilities to a successor with suitable credentials and commitment.

It is essential that good baseline information is obtained about the site before the project commences. This will include site characteristics (such as slope, aspect and elevation), soil (physical, chemical and biological characteristics), biodiversity (habitats and species), habitat maps, site hydrology, etc. Baseline information needs to be aligned with the project objectives and goals, so that accurate change can be measured by the monitoring. Poor quality baseline data will make good quality monitoring difficult to deliver – a wasted opportunity for both learning and demonstrating success.

Setting project objectives with clear, measurable outcomes is the essential foundation for any habitat or ecological restoration project and development of a monitoring plan (see SMART objective setting in CIEEM's Project Planning and Implementation overarching guidance). Project objectives can be wide-ranging and not confined to ecological objectives. Social objectives, such as visitor numbers and local community support, can be important too and will require their own objectives (see Figure 1, below).

Figure 1a & 1b

Neston Reedbed, RSPB Dee Estuary, Wirral. Top, destroyed by fire 23 March 2022. Bottom, vegetation recovery by natural processes, but ditches dug to prevent public access to reduce fire risk, 14 January 2024. An example of adaptive management with ecological and social objectives being set for this restoration project.

Photo credit: David Parker

The historic and cultural environment are often inseparable from the natural environment, and project objectives need to take this into account. Projects with ecosystem services objectives such as carbon capture and storage, flood alleviation, water quality, and soil health are increasingly common, so monitoring prescriptions should accommodate these objectives too (see CIEEM's Integrating Ecosystem Services into Ecological Restoration overarching guidance for more information).

Monitoring can be expensive and required over long periods of time, so aim to obtain the most information for the least expenditure of resources. An example of this is the use of indicator species (both positive and negative) to monitor the development of a newly created species-rich grassland, rather than recording many standard quadrats. This can also be necessary to fit with the technical and practical abilities of those who will be carrying out the monitoring. Objectives can be quite straightforward, such as creating suitable conditions for a target species of bird to nest, with the objective being the bird nesting at all, or setting a target number of nesting pairs. A good example of this is the creation of suitable burrows for nesting Manx Shearwater *Puffinus puffinus* on Bardsey Island / Ynys Enlli, Wales (Figure 2).

Figure 2

Nesting Manx Shearwater *Puffinus puffinus* removed for ringing from a newly created burrow in a restored drystone wall on Bardsey Island / Ynys Enlli, 12 September 2006. (Current good practice is to wear gloves during the handling of wild birds.)

Photo credit: David Parker

The effectiveness of monitoring can be enhanced if it is built into the project as it is being developed. Too often in the past, monitoring has been added at the end of project development, usually appearing as the last chapter or even as an appendix.

Aim to include monitoring throughout project development by repeatedly asking, "how are we going to know whether a project objective(s) has been delivered?".

Early thinking can help projects to deliver more, and monitoring is then in place to show how the project is progressing, or to help set the project back on the right track to achieve the target objectives. Results can provide evidence of the need for adaptive management, leading to changes to project objectives and management over time. Without the monitoring evidence, any such changes could be misjudged and could well lead to poor outcomes.

Setting indicators

In 2000, English Nature, now Natural England, published their *Habitat Restoration Monitoring Handbook* (Mitchley *et al*., 2000). This handbook used the term 'attributes' for indicators and provides a useful definition of what an attribute / indicator is:

> *"Attributes are measurable qualities or properties of the target habitat, including permanent or transitory qualities, both positive and negative, which are associated with the successful development of the restoration site".*

The term 'indicator' is used here, and the following are examples of the types of indicators which will feature in the full range of ecological restoration projects. These have been adapted from those set out in the Endangered Landscapes and Seascapes Programme.

Ecosystem indicators (examples)

Abiotic – changes in physical or chemical attributes of the project site:

- Water quality: nutrients, sediment load;
- Hydrology: surface and groundwater levels, water flow, discharge rates;
- Soils: nutrients (e.g. plant-available phosphorus levels for grasslands and wetlands), soil water balance, soil microbial community, pollutants (e.g. heavy metals, organic phytotoxins).

Habitats – changes in the type, amount, or quality of habitat:

- Type: presence of vegetation type set in the project objectives (use of key species); a direction of travel may be better, e.g. towards wetter or more species-rich grassland;
- Area: area of vegetation type, heterogeneity of types;
- Quality: area in good quality as defined by physical condition.

Species – changes in the distribution, abundance or diversity of species or communities:

- Target species: presence and / or abundance, rate of recruitment;
- Species-richness: change in species diversity;
- Unwanted species: presence of species of concern, including invasive non-native species.

Ecological function – changes in ecological function, including connectivity and resilience:

- Habitat connectivity: physical or functional;
- Resilience: habitat heterogeneity, habitat stability or planned change.

Ecosystem Services indicators (examples)

Provisioning – changes in the yield of products from ecosystems:

- Yield of natural materials: for example wood or hay;
- Food production: products from grazing animals.

Regulating – changes in the level of human benefit arising from regulation of ecosystem processes, including:

- Soil organic carbon: sequestration or changes to soil carbon levels;
- Above-ground carbon: increase in woody vegetation or organic-rich silt in marine environments;
- Water quality: changes in pollutants, changes in nutrients;
- Flood risk: water storage capacities and slowing of water flows, reductions in hydrograph peaks downstream.

Cultural – changes in the non-material benefits that people gain from ecosystems:

- Visitors: visitor numbers, visitor satisfaction.

Societal indicators (examples)

Wellbeing – changes in physical or mental health:

- Mental health: direct measures of wellbeing;
- Engagement: volunteering opportunities taken up which are related directly to the project.

Economic – changes in the economic status of stakeholders:

- Local economy: creation of nature-based jobs and new businesses;
- Livelihoods: income arising from the project site (e.g. sustainable harvesting).

More detailed guidance on setting indicators for monitoring objectives is provided in each specific habitat section in the Good Practice Guidance for Ecological Restoration. These should be read together with CIEEM's guidance on habitat and species survey techniques (CIEEM, 2021).

Examples of monitoring techniques

Specific types of monitoring may be required by grant schemes such as Environmental Land Management (ELM) Framework / Higher Tier (agri-environment) agreements, or habitat condition monitoring such as for BNG in England. Particular planning consents may require targeted monitoring which will be agreed with the relevant regulator. Some of the techniques and systems which can be used are:

Fixed point photography / photo-monitoring

Photo-monitoring is where a series of photographs are taken at fixed locations at regular intervals with the aim of visually showing change in vegetation condition. A simple methodology is set out in NSW Government (2015). This will only show broad-scale changes; fine-scale, quantitative assessments using this technique will not be possible. It can, however, be a powerful tool to use in public engagement with a project and can be carried out by volunteers.

Unmanned Aerial Vehicles (UAVs) (Drones)

The use of UAVs (drones) in vegetation / habitat mapping and the detection of environmental change is growing fast. There is a lot of information online, especially from companies offering their services, but there is a useful summary of the applicability of drones for use in restoration ecology in Robinson *et al.* (2022). The use of drones will be of the greatest use on large sites, such as river-restoration projects, and sites where access is difficult or dangerous, such as cliffs or extensive saltmarshes. Alongside ground-truthing, drone images should enable the monitoring of habitat type and condition. Drones mounted with multispectral cameras can be used to acquire data on plant health, such as stress induced by drought, poor nutrition or soil contamination. Drones can also be used to remotely count wildlife, such as breeding waterbird colonies or seal haul-outs, and this can be particularly useful in establishing baseline information before restoration interventions take place. Drones have considerable potential to revolutionise the science and practice of restoration at each stage of a restoration project and potentially reduce costs.

eDNA

The use of eDNA in environmental monitoring is a rapidly expanding field, mainly in water and soils, but also into airborne eDNA for monitoring terrestrial invertebrate communities. There is no space here to summarise all the available information and to speculate how far this technology may assist environmental monitoring in the future, but a useful summary is in Winding *et al.* (2019). It is already a standard technique for monitoring amphibia (e.g. Great Crested Newt *Triturus cristatus*) and freshwater and estuarine fish, particularly migratory salmonids. Soil eDNA is proving very useful for the identification of fungi, such as waxcaps and associated fungi of unimproved grasslands and coastal sand dunes. There is no doubt that eDNA will become an increasingly used technique in the monitoring of ecological restoration projects, particularly if its cost continues to fall.

Acoustic monitoring

Acoustic methods can now be employed for birds, invertebrates, amphibians, and a range of mammals. They can cover terrestrial, freshwater and marine habitats. This is a developing field and the range of activity is summarised in Browning *et al.* (2017).

AI-based remote sensing

AI-based remote sensing is revolutionising data collection and analysis by using algorithms to interpret satellite and aerial imagery. It enhances the ability to monitor environmental change, and map habitats and land use, potentially leading to improved decision-making and resource management.

This is a current work in progress and caution is needed, particularly with claims of accuracy where ground-truthing has not taken place. This section of the guidance will be updated as new information becomes available.

Data collection and analysis

In the design of a monitoring plan, it is important at the outset to decide how collected data are going to be analysed and which statistical (if any) techniques are to be employed, so that data can be collected and analysed effectively. The collection of digital data in a consistent format in large and / or long-term projects is key to enable data collected over a long time period to be compared. With very large projects where there is a great amount of data, and there may be several sites, it is good practice to use the digital data to create dashboards for ease of viewing, analysis and interpretation, so trends and issues can be identified more easily.

It can be helpful to tie monitoring protocols into existing national monitoring projects, such as Breeding Bird Survey (BBS, and I-BBS in Ireland), Wetland Bird Survey (WeBS), or UK Butterfly Monitoring Scheme. In these schemes, methods and data analyses have been developed and the monitoring data can also contribute to wider datasets.

How to use the results

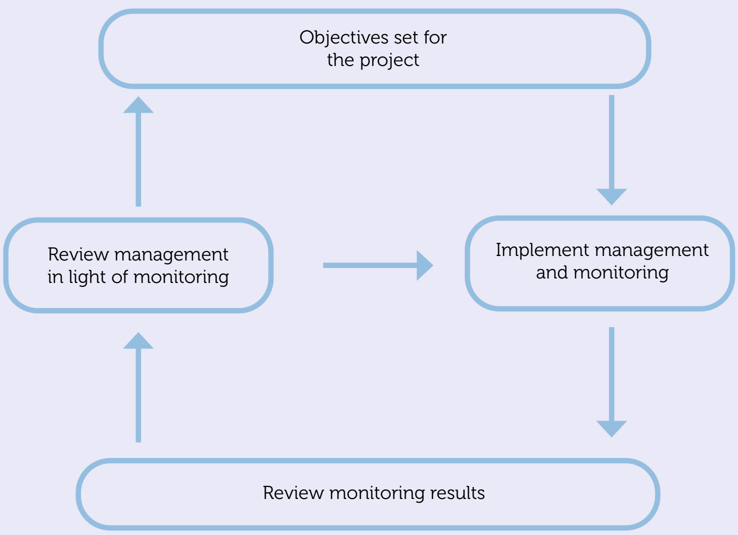
Once an ecological restoration project has been completed, the management plan is put into operation, monitoring commences, and results are produced. This will build on earlier baseline surveys before and after project implementation, but how are these results best used?

The management plan will have been designed to ensure that the objectives of the project are met. The timescales for this can vary enormously, depending on the nature of the project, but every good project will be striving for the longest period of management that it is possible to deliver.

The flowchart in Figure 3 indicates the process which should be adopted to make best use of monitoring information. The most important part of this process is the feedback loop. Monitoring data will reveal whether the management is on course to deliver the objectives which have been set. It is essential to have the resource capacity within a project to both collect and review the monitoring results. Only then will there be confidence to see that things are going well or that management changes (adaptive management) are required to deliver the project's objectives. This all seems very simple, but so often this feedback does not take place, and it is critical to the success of most ecological restoration projects.

Figure 3

The process to adopt to make best use of monitoring information.



It is inevitable that, despite following sound ecological design and implementation principles, the objectives of some projects will have to be revised given the results of monitoring, unpredicted ecological outcomes, or changes to on-site conditions. This should not be seen as a failure, but as an evolution of the project to deliver the maximum gains for biodiversity. If changes are made openly, based on good evidence and learning, these will be seen by all to be positive changes to the project. Changes could be difficult to make if habitat and species objectives are tied into project commitments and licensing, but sound monitoring and management evidence will make changes easier to negotiate (see CIEEM's Project Planning and Implementation overarching guidance).

Once there is a degree of confidence that project objectives are being met through effective management, a case can be made to reduce the frequency of monitoring or to change how monitoring is carried out. An example to illustrate this situation is a successful hay meadow creation, which has achieved its objective of certain target plant species (Figure 4). The focus now will be on maintaining the target species and recording new species entering the sward, both wanted and unwanted, and perhaps fauna too, such as butterflies. The presence of new species could require a change to the management of the grassland and will require a different monitoring approach. Monitoring could also reveal an unexpected or unintended colonisation by a rare or notable species (plant or butterfly for example). In these circumstances, monitoring might inform an adjustment to management so the species is retained in the long-term. In this case, not meeting a project objective, and adjusting monitoring accordingly, may reflect something very positive taking place on the site.

Figure 4

Hollybed Farm Meadows, Worcestershire Wildlife Trust, 7 June 2023. An example of successful hay meadow creation restoration project which has moved into a steady management phase which will now require a different monitoring approach.

Photo credit: David Parker

Monitoring and recording of ecosystem services are increasingly important: for example, permanent grasslands are an effective carbon store, and evidence is growing that they can also sequester carbon, so the monitoring of meadow soils should be considered. Of course, carbon storage and sequestration could have been set as a project objective at the outset.

Monitoring for biodiversity improvement

Monitoring is a key part of the Habitat Management and Monitoring Plan (HMMP) required for BNG projects in England, but the principles are applicable to comparable biodiversity improvement projects across the UK and Ireland. The Defra guidance on creating an HMMP (Defra, 2024) sets out what needs to be included, including:

- how you should plan to manage any off-site gains or significant on-site enhancements, taking into account any legal restrictions and requirements;
- when and how you should monitor habitats (this will vary for different types of habitat);
- when and how you should report monitoring results;
- when and how you should review management proposals; and,
- how you should change the way you manage the habitat, so that you achieve the target habitats or wider objectives.

Natural England has provided comprehensive guidance and templates for producing an HMMP (Natural England, 2024), where the setting of objectives, targets, monitoring programmes, timescales and reporting are embedded within the plan. The reader is advised, if working on a BNG project, to follow the procedures and templates set out in this Natural England Guidance.

Constraints and Limitations

It is important to distinguish limitations from constraints:

- **Limitations** refer to inherent factors or conditions that restrict the scope or extent of an activity, assessment, or project. These are often due to gaps in data, resources, or capabilities. For example, limited survey data or time may affect the accuracy of ecological assessments and subsequent monitoring.
- **Constraints**, on the other hand, are external conditions or requirements that must be adhered to, such as legal, environmental, budgetary, or physical features and boundaries. These are typically non-negotiable and influence how a project is planned or executed, such as protected species regulations or the presence of protected habitats.

While **limitations** affect what can be achieved, **constraints** define the parameters within which the project must operate. Both must be acknowledged and managed to ensure successful outcomes.

The cost of monitoring and the need for it to continue long after the completion of project construction can be seen as a major constraint. However, if it cannot be demonstrated that an expensive project has been successful, then no assessment of value for money, cost-effectiveness or success can be made.

Monitoring must be an inherent part of the project and budgeted for accordingly. It is difficult to put a figure on the financial resource needed, but 10% of the total cost of the ecological restoration / habitat creation element of the project should be considered as a first step which can then be modified according to the scale of the project. Once the detailed design of the project has been completed, the required monitoring must be properly costed up by a suitably qualified and experienced person. This will allow for funding for the years following project completion, and financial mechanisms need to be constructed to provide this funding into the future. Usually this can be linked to the post-implementation management budget for the project where monitoring must be part of the management operation.

As we have seen above, monitoring results will inevitably guide future site management, and this integrated approach is essential for successful project outcomes. Projects should include contingency funding for potential remedial measures or adaptive management actions, should the monitoring show that the objectives are not being reached.

Case Studies

Case studies will appear in the appropriate habitat chapters of this guidance series. A virtual library of previous webinars on habitat creation / restoration / enhancement is being developed.

Biographies

David Parker

David is an independent consultant ecologist, now mostly working on a voluntary basis for environmental charities. His career has been in both the private sector, as an ecological consultant and, in the public sector, for statutory agencies, latterly as Chief Scientist for the Countryside Council for Wales. He is a founder member of CIEEM, was President 1998-2000, and continues to support CIEEM on committees and judging the annual Best Practice Awards. He has had a long interest in habitat creation and ecological restoration, recognising that this is essential if we are going to rebuild the natural environment that supports us all.

Oliver Barnett

Oliver is Director of Ecology at Mortimer Environmental and has worked in ecological consultancy since the early 2000s, having transferred from academia where he completed a PhD in population and community dynamics of meadow plant species. He has worked as Ecological Clerk of Works on several national infrastructure schemes, supporting the design, creation, monitoring and management of various habitat creation areas, including mosaic grasslands and broadleaved woodlands. Oliver is Co-Convenor of CIEEM's Ecological Restoration Special Interest Group and is keen to support development in our understanding of how to re-store and re-create important habitat types.

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UKHab is a national standard habitat classification system and mapping framework that underpins consistent, high-quality ecological assessment and monitoring across the UK. Developed by leading ecologists, UKHab is a comprehensive classification, incorporating all habitats of conservation value in the UK, which supports the effective monitoring of ecological restoration, Biodiversity Net Gain (BNG) and wider nature recovery. The system is used by consultants, local authorities, conservation organisations and developers to generate reliable, comparable data that inform evidence-based decisions.

By improving the quality and consistency of habitat creation and restoration targets, UKHab helps track progress towards restoring the UK's natural environment and achieving meaningful, measurable nature recovery. UKHab is managed by a not-for-profit organisation, independent of government and supported by leading scientists and habitat specialists. The unique management structure enables UKHab to deliver training, coaching and advice to government, NGO and commercial organisations wishing to collect and record habitat data.

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Other sources

Conservation Evidence, Department of Zoology, University of Cambridge https://www.conservationevidence.com/
There is a wealth of information here about a wide range of projects where interventions have taken place and their success or otherwise evaluated. Monitoring is an essential component in the assessment of success, and it may be possible for the reader to find projects which assist with the development of their own.

HS2 Learning Legacy: *The use of remote sensing to identify habitats at a large scale*
https://learninglegacy.hs2.org.uk/document/the-use-of-remote-sensing-to-identify-habitats-on-a-large-scale-linear-infrastructure-project/

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