Received: 2 May 2025 | Revised: 2 October 2025 | Accepted: 9 November 2025

DOI: 10.1111/csp2.70214

PERSPECTIVE

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access
WILEY

A framework for monitoring ecosystem restoration at landscape scale

Nancy Ockendon[1] | **Philippa R. Gullett**[2] | **Mark H. Hancock**[2] | **David Noble**[3] | **Taylor Shaw**[1] | **David H. L. Thomas**[1]

[1]Endangered Landscapes & Seascapes Programme, Cambridge Conservation Initiative, Cambridge, UK

[2]SPB Centre for Conservation Science, Inverness, and Caingorms Connect, Aviemore, UK

[3]British Trust for Ornithology, Thetford, UK

Correspondence
Nancy Ockendon, Endangered Landscapes & Seascapes Programme, Cambridge Conservation Initiative, The David Attenborough Building, Cambridge, CB2 3QZ, UK.
Email: no200@cam.ac.uk

Funding information
Arcadia Fund

Abstract

Successful large-scale ecosystem restoration projects are central to achieving ambitious global and regional restoration targets, but evidence on outcomes is scarce. We developed a novel framework for monitoring landscape and seascape restoration, refined through learnings from 14 large-scale restoration projects in Europe over 6 years. The framework captures changes at two timescales: short-term indicators assess progress towards project management or funding period outcomes while long-term indicators measure progress towards the ultimate vision for restored landscapes. It encompasses natural capital, ecosystem service, and socioeconomic dimensions, but allows projects flexibility to select context-specific indicators. We provide recommendations on the framework's application and illustrate its use in a large-scale restoration project in Scotland. The framework encouraged projects to select new indicators, particularly of social outcomes, widening their understanding. Other learnings highlighted misalignment between ecosystem restoration timescales and funding cycles, the need for flexibility, and the value of focusing on a few well-chosen indicators.

KEYWORDS

ecosystem services, evaluation, indicators, large-scale, long-term, natural capital, rewilding, socioeconomic

1 | INTRODUCTION

Given the scale of the intertwined biodiversity and climate crises, urgent action is needed to reverse declines in biodiversity and natural processes and restore ecosystems to benefit nature and people (IPBES, 2024). The importance of ecosystem restoration is enshrined in global and regional conventions, including the Kunming-Montreal Global Biodiversity Framework's target to restore 30% of degraded ecosystems by 2030 (CBD, 2022) and the EU Nature Restoration Law's legally binding targets to restore 20% of degraded ecosystems by 2030 and all by 2050 (European Parliament, 2023). The period 2025–2030 is therefore critical to scaling up the quantity and quality of restoration globally to meet these ambitious goals.

Extensive landscape- and seascape-scale approaches, across hundreds to thousands of square kilometers, will be vital for restoring ecosystems at a scale commensurate with the challenge (Murcia et al., 2016). Restoration at large scales also enables the recovery of natural processes, including ecological connectivity, hydrological dynamics, and trophic interactions, necessary for the functioning of self-sustaining ecosystems. Such functioning ecosystems are also likely to be more resilient, requiring less intervention and thus proving more cost-effective at delivering sustainable, long-term benefits to people (Ren & Coffman, 2023).

However, despite significant interest in restoring ecosystems at scale, evidence describing the outcomes is scarce (Bernhardt et al., 2005; Mirzabaev & Wuepper, 2023; Rey-Benayas et al., 2009; Wortley et al., 2013). Effective and rigorous monitoring is a cornerstone for building this evidence base and demonstrating restoration as a solution that can benefit biodiversity, climate, and people (Caruana et al., 2024). As well as evidencing the benefits of restoration to policy makers and other stakeholders, well-designed monitoring fulfills other purposes. It ensures restoration projects are on track, allowing outcomes of funded activities to be reported to donors. It can enhance the effectiveness of future restoration via adaptive management (Hutto & Belote, 2013; Larson et al., 2013) and contribute to the wider evidence base leading to improved practice across the restoration sector (Sutherland, 2022).

However, there are challenges to monitoring change across large scales. Landscapes are typically complex, containing mosaics of habitats, diverse threats, numerous landowners, and other stakeholders, and may be subject to multiple restoration activities, managed by different organizations, on different timescales (Hart et al., 2023). Landscape restoration often requires interventions extending beyond the environmental and ecological to the social and economic. It is important that changes in these dimensions are understood and measured. In addition, the long periods often needed to realize the full benefits of restoration rarely align with funding cycles (Hodge & Adams, 2016; Reis et al., 2024; Rey-Benayas et al., 2009). This complicates the task of identifying monitoring priorities and resourcing monitoring over the necessary timescales.

Various frameworks and indicator lists have been developed to assess the impacts of restoration and/or rewilding (e.g., FAO & WRI, 2019; Landscale, 2021; Perino et al., 2019; Torres et al., 2018). Some use qualitative expert-based metrics, which are relatively simple to apply but lack the detail needed to effectively compare outcomes or quantify benefits from restoration (Torres et al., 2018). Both Perino et al. (2019) and Torres et al. (2018) produced frameworks specifically targeted towards rewilding and the restoration of natural processes. However, these approaches focus solely on ecological effects, despite the important benefits of landscape restoration for people (Aronson et al., 2020; Elias et al., 2022; Martin & Lyons, 2018). Others are based around specific taxa or habitats (Cook et al., 2024; NOAA, 2024) or may be complex to apply or require a reference ecosystem (Gann et al., 2019). Although a few post hoc assessments of the effects of restoration or rewilding have been published (Segar et al., 2022), few practical examples have shown how frameworks have been applied in real-world project management (Suding, 2011).

The Endangered Landscapes & Seascapes Programme (ELSP) has been supporting ecosystem restoration projects focused on the recovery of natural processes across Europe since 2018. Projects are large, ranging from 300 to 12,000 km^2, and cover a huge range of geographies and habitats, including grasslands, wetlands, forests, rivers, and coastal and marine habitats (Figure 1 and Table S1). They employ a wide variety of ecological restoration approaches, from reintroducing keystone species and restoring natural hydrology to tree planting and passive restoration. All also work with local communities to increase the sustainable societal benefits provided by restored landscapes. The programme is committed to ensuring that projects have a sound scientific basis (Al-Fulaij et al., 2025; Parks et al., 2022) and include robust monitoring plans to build understanding and demonstrate outcomes of large-scale ecosystem restoration.

At its inception, the programme developed a bespoke monitoring framework that aimed to provide a flexible yet structured approach to selecting and designing indicators to measure progress across different dimensions of landscape recovery. The framework provides a common structure for monitoring, applicable across all habitats in marine, terrestrial, and freshwater ecosystems. Over the last 6 years, 14 landscape and seascape restoration projects have applied the framework (Figure 1), which has co-evolved in response to their experiences. Although some were already undertaking restoration actions and monitoring, the introduction of the framework led to much more varied and ambitious sets of indicators. Here we present the Landscape Restoration Monitoring Framework and reflect on learnings gained from the experiences of these diverse projects.

2 | THE MONITORING FRAMEWORK

The Landscape Restoration Monitoring Framework (hereafter, the Monitoring Framework) aims to support projects to select indicators meeting the range of purposes outlined above. This requires consideration of the different timescales and dimensions of the landscape over which changes due to restoration need to be assessed and reported. These considerations are reflected in two main considerations of the framework described below.

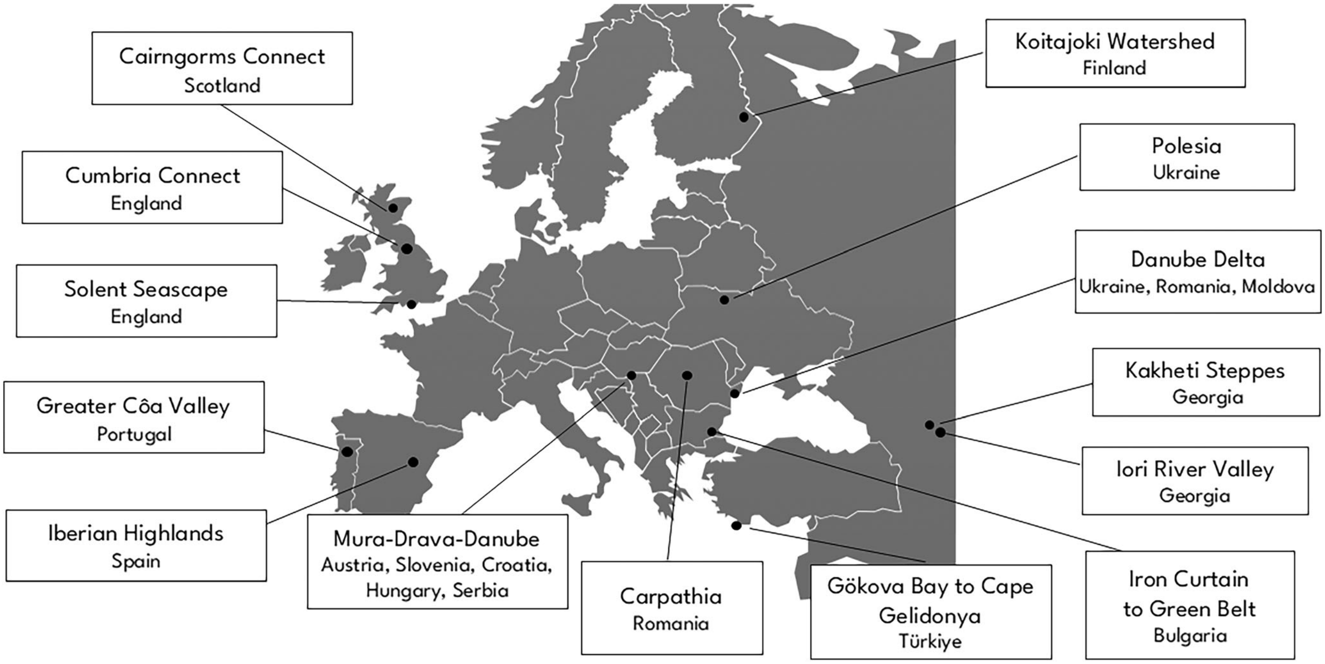

FIGURE 1 The 14 European landscape and seascape restoration projects, funded by the Endangered Landscapes & Seascapes Programme from 2019 to 2024, that have all applied the Landscape Restoration Monitoring Framework.

The framework was developed by reference to a wide range of existing monitoring frameworks (e.g., Hughes et al., 2011), particularly including that developed for England's Nature Improvement Areas (Collingwood Environmental Planning Limited, 2014), and consultation with a range of researchers and practitioners working on large-scale ecosystem restoration. Since its initial release in 2018, the framework has been revised based on learnings from the landscape restoration projects that have applied it.

Note that, for simplicity, we refer to ‘landscapes’ rather than ‘landscapes and seascapes’, but the Monitoring Framework is equally applicable to terrestrial (including freshwater) and marine projects.

2.1 | Short- and long-term indicators

Landscape restoration is complex; it involves a wide range of approaches and the resultant changes in ecosystems and communities often take decades (Hodge & Adams, 2016; Reis et al., 2024). However, project design, implementation, and reporting usually work on shorter time scales, with restoration grants and project management cycles commonly lasting only 2–5 years.

Therefore, the Monitoring Framework comprises two types of indicators, allowing change to be assessed across both these timeframes (Figure 2 and Table 1). *Short-term indicators* are designed to show progress towards desired project outcomes for a management or funding cycle and therefore should respond to restoration activities within 5 years. *Long-term indicators* are designed to measure progress towards the ultimate vision for a recovered landscape and may show slower rates of change, potentially across successive funding cycles. This separation was introduced in response to the experiences of ELSP projects, that many of the most important changes are not seen within a funding cycle, and monitoring focused only on this period is likely to miss many of the most significant effects of restoration (Dombrovski et al., 2022; Isbell et al., 2019). While this distinction requires clarity and realism about expected rates of change in target variables, the selection of both short-term and long-term indicators enables projects to demonstrate change over both project-management timescales and longer, more ecologically and socially meaningful ones (Section 3).

2.2 | Multiple dimensions of landscapes

Given that the potential to provide multiple benefits to nature and people is a key driver for restoring ecosystems, it is critical that monitoring schemes detect and document a wide range of outcomes (Jellinek et al., 2019). It is particularly important that indicators extend beyond ecological outcomes to capture changes in ecosystem services and the social and economic dimensions of a landscape (Martin & Lyons, 2018). Socio-economic benefits are a key

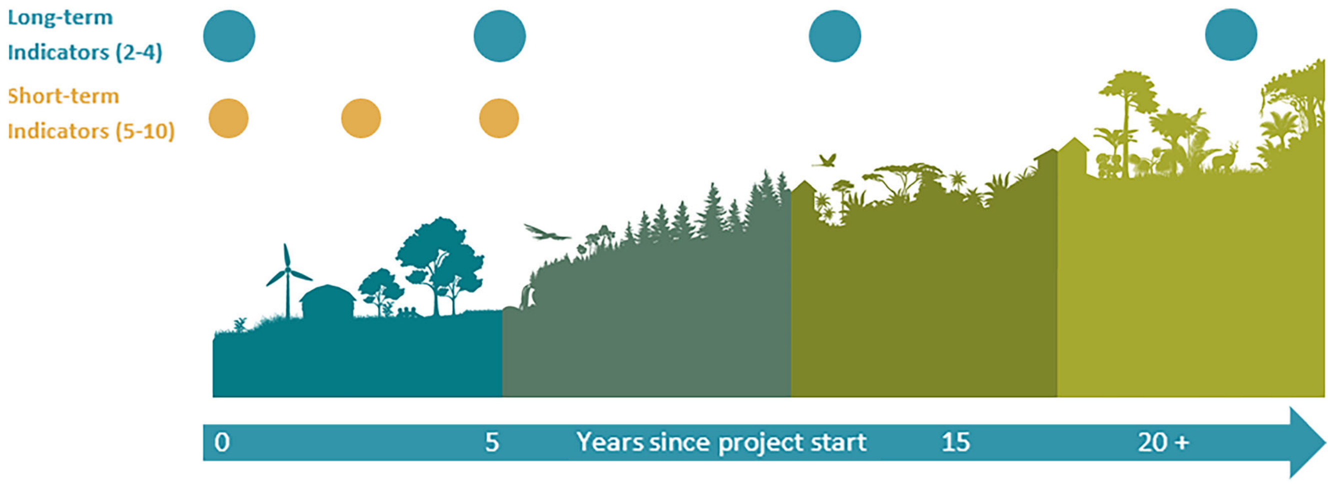

FIGURE 2 The approximate likely frequency and intensity of data collection for long-term and short-term indicators in the Landscape Restoration Monitoring Framework. Each circle represents a data collection event, with the exact number and frequency of events depending on the type of indicator and its expected rate of change. Circle size represents the relative likely effort and resources required. Numbers in brackets show the recommended number of indicators of each type. The graphic of restoration progress is adapted from SER's Restorative Continuum (https://www.ser.org/page/SERStandards). Further details of short-term and long-term indicators are provided in Table 1.

TABLE 1 Two types of indicators for measuring progress of landscape restoration projects over two time scales.

Type of indicator	Purpose	Spatial scope	Temporal scope	Data collection frequency	Example indicators (with associated restoration action)
Short-term Indicators	Measure progress towards outcomes expected to be achieved within a funding or project management period. Focus on outcomes of restoration actions, rather than the actions themselves.	May apply at site or landscape level.	Expected to show change within 2–5 years.	Baseline data, describing pre-restoration status, collected before restoration activities get underway. Data also collected towards the end of the funding/management period, to measure change over this period. Interim data collection (e.g., annually) may be appropriate for some indicators.	Ground water level (peatland restoration) Number of livestock killed by wild carnivores (activities to promote human-wildlife coexistence) Number of projects' recommendations included in a protected area management plan (protected area advocacy)
Long-term Indicators	Measure progress towards medium- or long-term vision for the landscape. Focus on outcomes of restoration actions, rather than the actions themselves.	Measure changes at landscape scale.	Change may be slow and may take decades to be seen.	Baseline data, describing the pre-restoration status, collected before restoration activities get underway. Appropriate intervals for follow-up monitoring are identified based on existing evidence of rates of change and year-to-year variation (e.g., scientific literature, expert opinion).	Change in flood resilience (peatland restoration) Population of predators such as wolves (human-wildlife coexistence) Fisher incomes based on enhanced fish productivity (protected area advocacy)

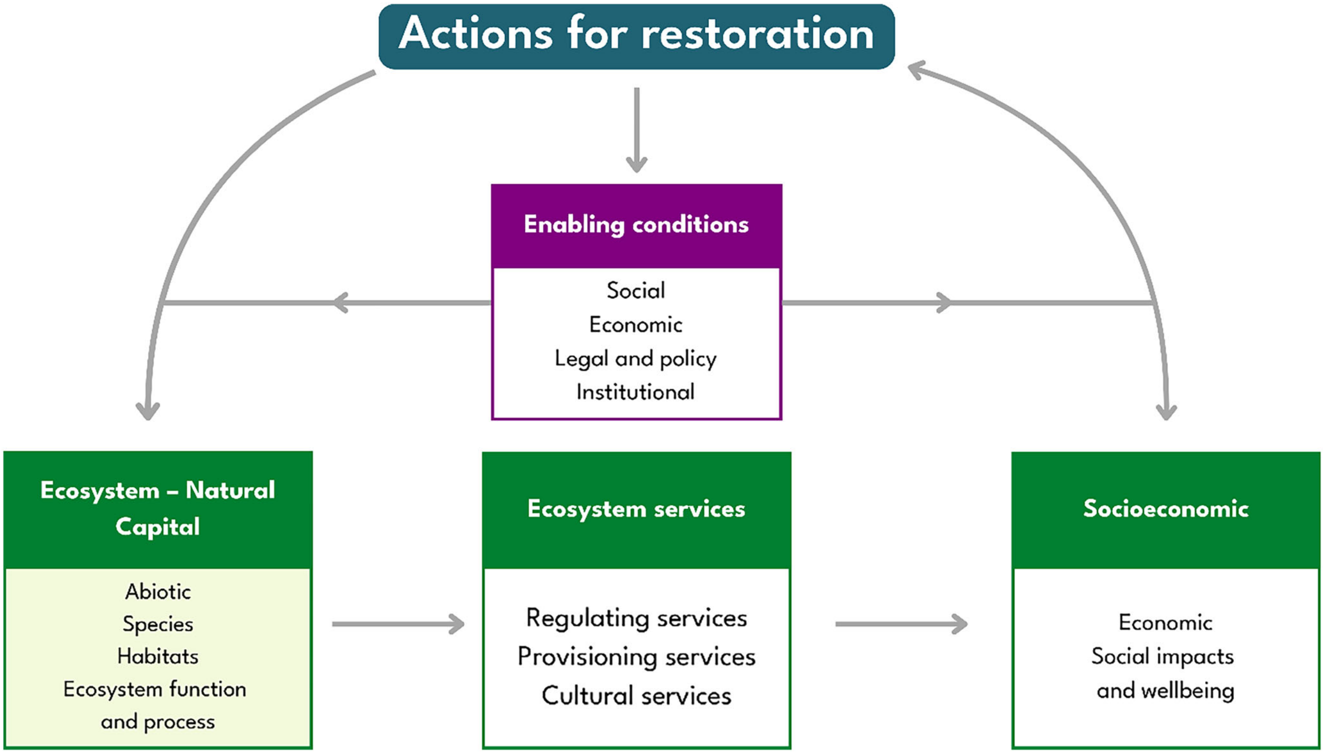

FIGURE 3 Themes of the Landscape Restoration Monitoring Framework, showing sub-themes within them. Actions taken by restoration projects may directly target the ultimate outcomes of restoration (green boxes) or may operate via improving enabling conditions (purple box), which then go on to facilitate enhancement in ecosystem (natural capital) or socioeconomic dimensions of landscapes. Restoration actions may be directly aimed at enhancing components of the ecosystem (species, habitats, function and processes, abiotic factors), with ecosystem services and then socioeconomic benefits to people flowing from the restored ecosystem. Actions may also be aimed at directly enhancing socioeconomic factors linked to ecosystem restoration; these socioeconomic benefits can then feedback via increased support for restoration actions. For example, a project may set up a volunteer programme for local communities to improve awareness of and connectedness with the landscape; this in turn may lead to increased support for the project, leading to greater action to restore ecosystems. Note that the first green box, representing ecosystems/natural capital indicators, is highlighted, as this is the primary focus of ecosystem restoration. Selecting short-term and long-term indicators from across all three ultimate outcome themes and multiple sub-themes ensures that the diversity of outcomes of landscape restoration is captured.

driver for mandating or incentivizing restoration in national or regional policies, but have tended to be neglected in past monitoring (Evju et al., 2020). The Monitoring Framework facilitates this by providing four themes and 12 sub-themes to consider during the selection of indicators (Figure 3). Restoration actions may directly target the ecosystem (for example, by habitat restoration) or socioeconomic factors (for example, by improving access to nature for local communities). Alternatively, they may act via intermediate outcomes or "enabling factors", which facilitate the delivery of ecosystem and socioeconomic outcomes (for example, campaigns to reduce damaging behavior such as illegal hunting or advocacy for policy change to support restoration). These enabling conditions have particular relevance to large-scale restoration because of the requirement for long-term institutional support, often across sectors and disciplines, as well as the need for societal buy-in, particularly from local communities. Enhancing institutional strength, project governance, and policy enablers is a critical but often under-monitored aspect of large-scale projects (Elias et al., 2025). By providing a specific theme, the framework encourages restorationists to collect data to measure and understand changes in the status of these fundamental enabling conditions. Short-term indicators may fall within any themes and sub-themes, including the "enabling" theme. Long-term indicators measure progress towards the ultimate ecological, ecosystem services, or socioeconomic outcomes of restoration (green boxes in Figure 3).

3 | HOW TO APPLY THE MONITORING FRAMEWORK

It is vital that monitoring, and the selection of indicators and approaches, is effectively integrated into the development of any landscape restoration project. Therefore, the framework is initially applied during the early stages of project planning. Projects are encouraged to regularly review their monitoring plans and indicators to ensure their scope and methods remain appropriate to any changes in outcomes, capacity, and timelines. Table 3 describes the real-world application of the Monitoring Framework to the selection and design of indicators in the Cairngorms Connect landscape in the Scottish Highlands.

When applying the Monitoring Framework, it is necessary to envision the future restored landscape and how this will differ from the existing situation, which typically includes degraded features and missing elements. Landscape restoration through natural processes is often open-ended and functioning ecosystems are usually dynamic; in addition, conditions, particularly climate, are likely to change, meaning ideas of a 'fixed' endpoint for restoration are rarely appropriate (Hughes et al., 2011, 2012). However, in order to evaluate a restoration project, clear ideas about the 'direction of travel' are needed, e.g., to create a more biodiverse landscape, with enhanced connectivity, more intact trophic chains, more dynamic natural processes, and more sustainable local economies.

By identifying the most important changes needed to achieve this vision of a fully restored landscape, a small number of long-term indicators can be selected to measure restoration progress (Table 1). During this selection, consideration of the themes and sub-themes in the green boxes of Figure 3 ensures that diverse landscape-scale responses are captured.

Grants for restoration, typically lasting 3–5 years, are steps on the path towards this landscape vision, through the delivery of a set of shorter-term project outcomes. Short-term indicators are used to assess progress towards these outcomes (Table 2). Again, reference to Figure 3 ensures that the full range of landscape-scale responses is captured by the suite of indicators selected. Some indicators, for example, abundance of reintroduced keystone species or the size of the nature-positive local economy, can serve as both short-term and long-term indicators.

Once an initial list of short-term and long-term indicators has been identified, these are refined to ensure:

- The overall suite of indicators is complementary and diverse, representing the range of goals of all project partners and the different dimensions of the vision for the restored landscape (Figure 3).
- The project has the skills, equipment and capacity to design, implement, analyze and write up the proposed indicators.
- It is feasible to sustain the planned monitoring, including data collection, processing and dissemination, over the time scales required.

TABLE 2 The short terms outcomes against which the Cairngorms Connect (CC) ELSP monitoring programme was established. These are steps towards the ultimate long-term CC vision, described as: Over the next 200 years, CC plans to restore native woodlands to their natural limits, including high-altitude montane woodland; to restore peatlands, wetlands and rivers; and to build support, understanding and societal benefits locally, nationally and internationally.

ELSP five-year outcome	Details
1. Woodland expansion	Woodlands are expanding to their natural limit: 800 ha of pinewood are established by natural regeneration and 1200 ha of pinewood are enhanced by planting 'missing' tree species. Woodland processes and their associated vertebrate and invertebrate communities are recovering, including restructuring of 1720 ha of former plantation pinewoods.
2. Peatlands restored	Peatland habitats and processes are restored across 1400 ha of blanket bog and 100 ha of bog woodland.
3. Hydrological processes restored	Natural hydrological processes are restored over 1000 ha of floodplain.
4. Local communities and partnership staff engaged & empowered	Local communities have increased awareness of the CC area's importance and values, and partnership staff and members of the public are increasingly empowered or engaged through meetings, volunteering and decision-making.
5. Livelihoods and wellbeing enhanced	A significant contribution is made towards the maintenance and enhancement of the livelihoods and/or wellbeing of local people

Below we discuss some important considerations when selecting and designing indicators, based on our experiences.

3.1 | Participatory planning

It is vital to involve relevant stakeholders in the process of developing indicators. Working at landscape scale

TABLE 3 Characteristics of the long-term (LT) and short-term (ST) indicators selected by Cairngorms Connect (CC) landscape restoration partnership.

Indicator; Outcome[a]	Theme; sub-theme	Question(s) addressed	Methods	Spatial scale	Monitoring frequency	How data will be used	Adaptations or learning points
Area of new native woodland (LT & ST) 1. Woodland expansion	Ecosystem; Habitat	What is the extent of natural recolonisation of woodland in response to restoration management (especially landscape-scale deer control)? Are some areas or tree species colonizing better than others?	Field surveys	Surveys carried out across the woodland expansion zone (~10,000 ha) with a target frequency of 1 plot / ha (reduced in some areas for practical reasons)	Every 5–10 years (depending on practical considerations). Baseline surveys existed prior to ELSP period; repeat surveys were carried out as close to the end of ELSP period as possible, with estimates of woodland expansion rates linearly scaled to provide area estimates over ELSP period.	Adaptive management, e.g., do we need to supplement natural regeneration with planting for some tree species or in some areas? Engagement with land managers, including beyond CC, to collaborate over best practice guidance. Scientific publication to share results with wider conservation community.	Originally, remote sensing methods using satellite data were planned to complement field surveys, with the aim of enabling cost-effective long-term landscape-scale monitoring; however a pilot study showed satellite images offered insufficient accuracy to measure area of young woodland with current methods. High-resolution LiDAR data collected for a separate project are now being trialed for this purpose.
Diversity, species richness and abundance of moths, birds & ericaceous shrubs (LT) 1. Woodland expansion	Ecosystem; Species	What is the rate and magnitude of the response of species to restoration management, especially landscape-scale reduction in browsing by deer? How do responses differ across three broad trophic groups? What might a restored species assemblage look like and how	As species responses are expected to be slow, two approaches used: (a) Chronosequence[b] monitoring at a set of sites at different stages of forest restoration, to understand species' responses to habitat recovery. (b) Longitudinal monitoring, to measure change through time across the full range of altitudes within CC area. At both sites, species were surveyed using the same well-established methods. Moths were surveyed monthly from	(a) Chronosequence monitoring: 36200 × 200 m^2 sites surveyed, randomly selected (stratified by altitude) throughout the CC area to give a representative sample across a full range of forest restoration stages (from 1 to 48 years since restoration began). Additionally, randomly selected control sites (stratified by	(a) Each chronosequence site surveyed once during the 5-year ELSP period; ambition to resurvey ~20 years later. (b) The longitudinal sites were monitored annually for the 5-year ELSP period during which restoration was ongoing; given considerable interannual fluctuations in moth numbers, this	To quantify the extent to which species are returning, as habitats are restored or as habitats transition to other types (e.g., open heathland to scattered woodland cover) and to identify whether other factors may be limiting their return, potentially requiring adaptive management such as planting of specific tree species. Scientific publication to share results with wider conservation community.	The number of sites monitored in the comparison areas was increased relative to original plans (16 sites), to enable more reliable comparison with CC area. This was decided after the first round of surveys had been completed, when the extent of variation in habitat type within the comparison areas became apparent. Additional Eastern Cairngorms sites were funded by the collaborating partner in that area, due to their

(Continues)

TABLE 3 (Continued)

Indicator; Outcome[a]	Theme; sub-theme	Question(s) addressed	Methods	Spatial scale	Monitoring frequency	How data will be used	Adaptations or learning points
		close are we to achieving this?	June–September by setting moth traps overnight and identifying all moths caught. Birds were surveyed using 5-minute point counts on two dates each summer. Vegetation diversity and structure was surveyed in quadrats once each summer.	altitude) monitored in two comparison areas with similar climate & geology but contrasting management regimes: 20 sites in SW Norway (low browsing rates) and 24 in Eastern Cairngorms (high browsing rates). (b) Longitudinal monitoring: four 200 × 200 m^2 sites at 300, 500, 700, 900 m a.s.l., spatially dispersed throughout the CC area. (Figure S1).	5-year period will act as a robust baseline for periodic repeat surveys throughout 200-year CC vision, roughly every 3 years.		interest in the results. Additional Norway sites were monitored largely through expert volunteers, resourced through the Partnership.
Abundance, biomass, species richness & diversity of deadwood beetles (ST & LT) 1. Woodland expansion	Ecosystem; Function	Is active deadwood creation successfully restoring ecosystem function to areas of former commercial pine monoculture plantation? How do beetle communities in managed plots compare to those in semi-natural woodlands?	Three types of pinewood monitored: (i) Managed: plantation-origin with deadwood creation (10 plots) (ii) control: plantation-origin without active deadwood creation (6 plots) (iii) semi-natural reference: non-plantation woodland without active deadwood creation (6 plots). At each plot, two methods used:	A total of 22 monitoring plots dispersed throughout approximately 20 km^2 of the CC forest landscape, with plots spaced at least 500 m apart.	All plots surveyed in baseline year. Subsequently, all plots surveyed 1 & 2 years after deadwood creation carried out, to assess short-term response. Ideally all plots will be resurveyed roughly 7, 10 and 15 years after baseline, to assess longer-term responses to widespread	Adaptive management, e.g., to increase the intensity of deadwood creation in some areas or to reintroduce some critical missing invertebrate species. Dissemination of results to government agency to help inform future forestry policy and national strategies. Following long-term monitoring, scientific publication to share results with wider conservation community.	It was originally intended to also monitor commercial plantations with & without active deadwood creation. However, it was not possible to secure long-term monitoring plots in commercial areas due to the complexity of legally binding long-term forest management plans; in addition, no active deadwood creation was planned for commercial areas due to public safety considerations in these areas, with the

TABLE 3 (Continued)

Indicator; Outcome[a]	Theme; sub-theme	Question(s) addressed	Methods	Spatial scale	Monitoring frequency	How data will be used	Adaptations or learning points
			(a) Deadwood survey conducted over a circular area of 30 m radius. (b) A flight interception trap, baited with ethanol, emptied monthly from May–September.		deadwood creation during that time.		approach instead being passive deadwood creation (i.e., leaving naturally arising deadwood in situ where possible).
Number, diversity and diet of predatory birds & mammals (ST & LT) 1. Woodland expansion	Ecosystem; function	Does habitat restoration and cessation of predator control within CC enable a more complex vertebrate food web to develop?	Several approaches used: (a) Diet of main avian predators (goshawk, golden eagle, white-tailed eagle) assessed via identification of prey items from nest clearances. Diet of main mammalian predators assessed via genetic analysis of feces collected from transects (fox, pine marten) and setts (badger). (b) Abundance of avian predators (focussing on goshawk, golden eagle, hen harrier) estimated via territory surveys; abundance of predatory mammals (fox, pine marten, badger) estimated via baited camera traps. (c) Population size of key prey species (field vole) estimated by field surveys; population of secondary prey (bank vole) estimated via baited live traps.	(a) Avian predator nests surveyed throughout CC area; fox & marten feces collected along around 100 km of fixed transects throughout CC area; badger setts surveyed at six sites spread throughout CC area. (b) 40 camera traps sited in suitable habitat throughout CC area, spaced at least 1 km apart. (c) Field voles surveyed at 28 sites in grassland and clearfell habitat throughout CC area; bank voles surveyed at 28 sites (3 traps per site) in *Vaccinium*-dominated forest habitat throughout CC area.	(a) Avian predator diet surveys took place in the 3 years preceding ELSP period; mammal diet surveys in spring & autumn of years 1 & 5 of ELSP period. (b) Abundance of main predators estimated annually throughout ELSP period; aspiration to continue this at least every 5 years for long-term monitoring (c) Abundance of main prey (voles) surveyed each spring and autumn throughout ELSP period; aspiration to continue this annually for long-term monitoring.	To provide evidence to land managers and policymakers of the benefits of restoration for ecosystem services, and improve understanding of how species interact with one another in restored and unrestored areas. Results will be shared with the wider community, to build understanding of the benefits of restoring a fuller suite of predators.	On one occasion early in the project, results from a survey were made public before all partners were ready, a situation which can easily arise in a project involving many different staff and organizations. Subsequently this led to more strategic and joined-up planning of how partnership results are communicated.

(Continues)

TABLE 3 (Continued)

Indicator; Outcome[a]	Theme; sub-theme	Question(s) addressed	Methods	Spatial scale	Monitoring frequency	How data will be used	Adaptations or learning points
Water discharge, flood risk and peatland habitat condition (LT & ST) 2. Peatlands restored	Ecosystem service; Regulating	Are innovative peatland restoration techniques in high-altitude eroded peatlands effective in reducing peak water flows and discharge, and restoring peatland habitat condition?	Two approaches used: (a) Weirs with automatic data loggers to measure water discharge rates from peatland. (b) Drone surveys combined with ground-truthing surveys to assess peatland condition and degree of erosion.	The monitored restoration area is ~1500 ha, spanning several catchments: (a) Water discharge is measured using a BACI design with 4 monitoring weirs, 2 at restoration sites and 2 at unrestored degraded control sites. (b) Drone surveys take place across 1500 ha of peatland restored during the ELSP period.	(a) Water discharge monitored continuously, for 5 years following restoration, as responses are slow. (b) Drone survey conducted before and immediately after restoration; ideally it will be repeated every 5 years until habitat is considered fully restored.	To provide evidence to land managers and policymakers of the potential carbon and wider benefits of peatland restoration. Adaptive management.	Before restoration began, it was decided to add a third approach to the monitoring design, to assess changes in water quality, to assess any potential negative impacts of restoration; this is not standard practice in peatland restoration and thus was not included in original plans.
Floodplain natural processes (ST) 3. Hydrological processes restored	Ecosystem service; Regulating	Does removal of embankments and re-meandering of rivers reduce occurrence of extreme highwater events downstream? Do these restoration actions improve habitat quality/ quantity for priority species (salmonid fish)?	Three approaches used: (a) Drone surveys to assess floodplain geomorphology. Time lapse cameras to monitor hydrology changes, including flood events, at the same sites. (b) Automatic data loggers to measure water depth. (c) Drone and walkover surveys to map the area and diversity of habitat, including breeding habitat for salmonids.	(a) Drone surveys of floodplains across two restoration areas of 56 ha and 105 ha, and one control area of 56 ha (b) Water depth measured at 14 points on the floodplain and rivers, providing before/after comparison data in habitats within and outside planned restoration areas. (c) Habitats mapped across two rivers undergoing restoration, and one control river not	(a) Floodplain surveys conducted before restoration and then annually until restoration actions complete. (b) Water depth monitored continuously (every 20 min) before, during and after restoration, until 1 year after restoration actions complete. (c) Area of salmonid habitat mapped within one year before and within one year after restoration actions complete.	To provide evidence of the effects (positive and/or negative) of floodplain restoration on ecosystem service provision and biodiversity. Results to be disseminated to local communities, councils, policymakers and the wider scientific community, via a journal article and/or conference presentation.	Creating an accurate digital terrain model of the rivers and floodplain from the original drone surveys proved more difficult than expected, given the very fine scale of detail required to identify geomorphological changes occurring in response to restoration work. However, a LiDAR survey of the entire landscape, completed in summer 2023 as part of a different project, is now being used to complement drone surveys and provide a more accurate model.

TABLE 3 (Continued)

Indicator; Outcome[a]	Theme; sub-theme	Question(s) addressed	Methods	Spatial scale	Monitoring frequency	How data will be used	Adaptations or learning points
				undergoing restoration			
Empowerment of staff across the partnership (ST) 4. Communities & staff empowered & engaged	Enabling; Institutional	How effectively are we building a strong, empowered partnership?	Staff survey sent via email, with questions addressing topics around how empowered staff feel to influence the direction and decision-making within CC.	All staff working within the CC area for one of the four core organizations of the partnership were surveyed.	Surveys carried out in Year 2 and Year 5 of ELSP period.	By managers across the partnership, to inform their strategy of how to adapt ways of working to maximize staff engagement and empowerment.	This indicator was significantly affected by the Covid-19 pandemic, which led to a major delay in baseline data collection. Original plans to include community councils and the wider public in this indicator had to be scaled back due to these delays and other challenges such as restrictions on face-to-face activities.
Perceptions of local communities towards restoration (ST & LT) 4. Communities & staff empowered & engaged	Enabling; Social	Is the outreach work of CC successfully increasing awareness of local people about landscape restoration and CC? Do local people feel engaged with CC?	Surveys of public attitudes towards restoration in general and CC specifically, including questions around knowledge and values, e.g., by showing photos of restored and unrestored sections of river and asking participants to score preferences.	Two groups surveyed: (a) Residents: all inhabited areas within or surrounding the CC landscape, by randomly selecting 1000 postcodes for door-to-door surveys (expecting a 10% response rate) (b) Visitors: Surveys carried out at key tourist hotspots throughout the CC area	Year 1, Year 3 and Year 5 of the ELSP period. Ambition to repeat this survey approximately 15 years after initial survey.	To inform the Partnership as to how successful their existing methods are in terms of increasing public awareness and engagement and identify opportunities for novel approaches.	Due to the Covid pandemic, the door-to-door survey had to be altered to a postal survey partway through the baseline data collection period. Subsequent surveys used a hybrid method of in-person and postal surveys, allowing results to be compared through time.

(Continues)

TABLE 3 (Continued)

Indicator; Outcome[a]	Theme; sub-theme	Question(s) addressed	Methods	Spatial scale	Monitoring frequency	How data will be used	Adaptations or learning points
Number of jobs created (ST & LT) 5. Livelihoods and wellbeing enhanced	Socio-economic; Economic	How does restoration benefit local communities economically?	Two approaches used: (a) Net change in number of jobs within the area that can be directly attributed to CC, calculated for each partnership organization. (b) Direct local economic spend by CC calculated from project budget transactions.	Data collected throughout CC landscape. Direct local economic spend calculated from goods and services purchased within 50 miles of CC area.	At start and end of ELSP period. Ambition to monitor this roughly every 10 years in the future.	To provide evidence to policymakers, site managers and general public of the economic benefits of landscape-scale habitat restoration.	Staff changes partway through the project led to a loss of the expertise required to develop and implement a robust economic indicator. It was therefore necessary to scale back original plans, which had included comprehensive surveys of local businesses to understand the value they ascribe to CC.

[a]For further details see Table 2 above.

[b]Chronosequence approaches use spatial variation in a factor as a proxy for variation in time (Foster & Tilman, 2000). Cairngorms Connect is using the spatial variation in restoration stage (i.e., time since restoration began in different areas) as a way of understanding during a short timeframe (5 years) how species are responding to management over a much longer timeframe.

often involves partnerships between organizations; it is critical to involve all partners in early conversations about what monitoring is needed and who will be responsible for design, data collection, analysis, and reporting (Sigouin et al., 2025). Moreover, engaging people who live, work, and spend time in a landscape in a participatory process, asking what aspects of the landscape are important to them and how these could be monitored, will make results more widely relevant and can help ensure long-term sustainability of monitoring programmes (Danielsen et al., 2021). Such co-development can also raise awareness of potential benefits and build local support for restoration (e.g., Villasenor et al., 2016). Undertaking these consultations at the start of the project will require extra time but will likely pay off in terms of the sustainability of monitoring and the utility of the results.

3.2 | Existing monitoring programmes

Another key planning stage is to scope any existing monitoring taking place within the landscape and decide whether this can be used or adapted to contribute to long-term or short-term indicators. Examples could include statutory water quality monitoring or national bird or butterfly volunteer surveys (Pocock et al., 2018). Such monitoring can have the advantages of providing a pre-restoration baseline, requiring less additional time and effort to collect, and being sustainable in the long term. Additionally, data from such monitoring schemes may cover areas outside the project landscape, potentially providing a long-term cost-effective counterfactual for any changes in the restoration landscape. However, despite these advantages, it is important that the existence of a prior dataset does not drive indicator selection, if more relevant or important metrics are available. Moreover, because national monitoring schemes are not specifically designed for the restoration project, the resolution and sampling design are often inadequate to detect landscape-scale changes and adaptations to the survey design or sampling strategy may be required.

3.3 | Number of indicators monitored

The first version of the Monitoring Framework included a requirement to monitor at least 10 outcome indicators per landscape, with projects selecting an average of 16 short-term and long-term indicators. Some projects then struggled to allocate the capacity necessary to effectively collect and report data for them all. It can be easy in the initial stages of a project to underestimate the time needed to collect, process, and analyze data and write up results. In response to shared learning with the projects, the requirement for a minimum number of indicators was removed from the framework. The emphasis is now on identifying a set of indicators that will provide evidence appropriate to the project's scope and context.

Another common experience was that, if early rounds of monitoring showed an indicator to be impractical, required more work than expected, or be insufficiently sensitive to measure expected change, flexibility was needed to allow projects to drop or amend indicators (e.g., see Table 3, Adaptations column).

3.4 | Attribution

In order to properly assess the effect of a project (i.e., changes which would not have happened if the project had not taken place), it is important to show a causal link between restoration activities and any subsequent changes in its target indicators. Collecting baseline data before restoration begins is vital, to allow a before-after comparison of metrics. Such before-after comparisons may be sufficient, particularly where it is reasonable to assume that background changes (not associated with restoration actions) are minimal, for example, over short time periods in stable ecosystems. However, identifying and monitoring a suitable control site, which is as similar to the project site as possible except for the absence of restoration, gives a before-after-control-impact design, maximizing the ability to detect change and ascribe it to project actions (Christie et al., 2019).

Monitoring of controls may be possible for some indicators and may be particularly important for indicators that are contentious or highly scrutinized. However, landscape restoration projects are large and complex and, in many cases, identifying and monitoring matched comparison sites is not practically possible. Quasi-experimental approaches, using naturally occurring spatial or temporal variation in interventions, may be useful. For example, a later-phased restoration site could be used as a 'time-shifted' control for a site that is already under restoration (e.g., Mackenzie & Keith, 2009). Remote sensing may be useful in assessing large-scale change at multiple locations (Ferraro & Hanauer, 2014; Schleicher et al., 2020) and national monitoring schemes may also have a role (Section 3.2) (e.g., Jellesmark et al., 2021).

3.5 | Methodologies

A variety of methodologies will be needed to monitor change across different themes and subthemes relevant to the vision and outcomes for a landscape (example in Table 3).

The defining characteristic of landscape restoration is that it aspires to affect change at large spatial scales. This has implications for the most appropriate data collection methodology. For some indicators (e.g., the diversity of organizations in a partnership, the area of healthy seagrass), the total number or area across the project landscape can be assessed. However, for many other indicators (e.g., forest structure, small mammal abundance, well-being of local people), it is necessary to design a sampling approach that accounts for the size of the landscape and its spatial heterogeneity, as well as the expected magnitude of changes in the indicator (Johnson et al., 2008). Statistical power analysis can be useful in estimating the approximate number of samples needed, although these are often also constrained by practical limitations such as unknown variances or difficulties in identifying desired effect sizes in outcome variables (Legg & Nagy, 2006).

Remote sensing technologies and analytical approaches that generate and process large datasets but require minimal fieldwork are highly relevant to landscape-scale monitoring (Stephenson, 2020). Satellite images are commonly used to assess changes in landcover over hundreds of square kilometers, and the resolution of images available is steadily improving, allowing increasingly detailed investigations of ecosystem structure and function (McKenna et al., 2023; Pettorelli & Schulte to Bühne, 2023). Acoustic and DNA metabarcoding techniques are increasingly employed to survey broad ranges of taxa with relatively low field effort, with machine learning providing much of the processing power (Stephenson, 2020). Although these advances provide exciting and informative new tools, some limitations remain (e.g., Abdelmajeed & Juszczak, 2024). For example, projects found that vegetation change was sometimes too subtle and complex to be effectively measured by remote sensing: in some contexts, such as wetland mosaics, it was challenging to produce an accurate landcover classification model to assess changes in heterogeneity and ecosystem function at appropriate scales. Other barriers occurred at the analysis stage, for example in terms of capacity to process, validate and meaningfully interpret data (Hahn et al., 2022). Hence, while these more cutting-edge approaches were often trialed by projects, there was also a core role for simpler, field-based approaches.

3.6 | Audiences

When selecting indicators, it is vital that projects understand the intended use and audience for the information generated. Authoritative science, communicated in a targeted and compelling way, can transform perceptions of restoration projects. Key uses of data highlighted by projects included: reporting to funders, informing future restoration actions via adaptive management, raising project profile and public engagement, contributing to national datasets and indicators, influencing policy support for restoration, and informing future funding bids. For example, a good understanding of the data needed to advocate for a new protected area or the design of an agri-environment scheme can ensure that the indicators selected meet these objectives. Sharing monitoring results with local communities can help foster evidence-based dialogues about how landscapes are changing, perhaps by measuring flood mitigation effects of river restoration or declines in human-wildlife conflict. Maximizing impact requires that results are made freely available, via open access publications and data repositories, to provide transparency and ensure learnings can be applied by others (Costello & Wieczorek, 2014).

One emerging use for data evidencing the results of restoration is to enable ecosystem services (primarily carbon) or biodiversity to be monetised via the sale of credits. Although many of these markets are still nascent, restoration projects may wish to collect data that are likely to meet future requirements and align with any existing standards. Currently, few standardized protocols exist for assessing the recovery of natural habitats, but this field is evolving rapidly; in the future, such methods and indicators could easily be integrated into the Monitoring Framework.

4 | CASE STUDY: APPLYING THE LANDSCAPE RESTORATION MONITORING FRAMEWORK IN THE CAIRNGORMS CONNECT LANDSCAPE

Cairngorms Connect (CC) is an ambitious landscape-scale partnership working to restore habitats and natural processes across 60,000 ha of the Scottish Highlands (Gullett et al., 2023). Through the restoration of forests, peatlands, and river catchments, it is enabling the recovery of natural capital, ecological processes, and ecosystem services while helping populations of rare and endangered species such as eagles, black grouse, beavers, and twinflower. CC also works to support a sustainable local economy and enhance opportunities for people to connect with nature.

Since forests, blanket bogs, and floodplains take time to recover from centuries of human impact (Rydgren et al., 2025; Summers, 2018), this is a long-term project with a 200-year vision. In 2018, the partnership received funding from the ELSP and applied the Monitoring Framework to select indicators for the CC landscape. Five long-term indicators were selected to measure progress towards the ultimate 200-year vision, and four short-term indicators were identified to measure changes towards the five outcomes that the project hoped to achieve during the 5-year ELSP funding period (Table 2). Of the nine indicators selected, four fall within the natural capital theme, two measure ecosystem services, two monitor social and institutional enabling factors, and one measures economic change; thus, the indicators span the themes of the Monitoring Framework (Table 3 and Figure S1).

5 | DISCUSSION: EXPERIENCES OF THE MONITORING FRAMEWORK

There is a clear need for more evidence measuring the ecological and social outcomes of large-scale ecosystem restoration and rewilding (Hart et al., 2023; Martin & Lyons, 2018; Ockendon et al., 2018; Rey-Benayas et al., 2009). The Landscape Restoration Monitoring Framework provides a flexible yet structured approach to designing monitoring programmes meeting this need and has already been applied by diverse land- and sea-scape projects across Europe to generate scientifically robust data (e.g., Kızılkaya et al., 2025). It has been shown to provide a consistent structure to indicator selection, setting expectations about the breadth and duration of data collection, but with projects retaining primacy in identifying indicators and methods for their specific context.

Two key requirements of the Monitoring Framework are (i) identification of indicators that measure change across two time scales; and (ii) consideration of changes in ecosystem service and socio-economic, as well as ecological, aspects of a landscape.

The separation of short- and long-term indicators was introduced in response to feedback from ELSP projects that many indicators important in demonstrating landscape change according to the considerations described here were unlikely to show significant change during a 5-year funding period (Dombrovski et al., 2022; Isbell et al., 2019). By supporting long-term indicators that may only show significant change after the grant period ends, the framework enables projects to start addressing the lack of evidence for landscape restoration effects over longer timeframes (Reis et al., 2024; Wortley et al., 2013). However, these indicators will only yield new evidence if data collection can be maintained beyond grant periods. Resourcing staff retention and consistent monitoring in the long term is an ongoing challenge, requiring collaboration between funders and a willingness to support pre-existing monitoring schemes. Participatory monitoring and citizen science, grounded in early discussions with local communities regarding how and what to monitor, have an important role in sustaining consistent field data collection beyond and across grant cycles (Gouraguine et al., 2019; McKinley et al., 2017).

As well as investing in long-term monitoring, our experience showed that there is significant value in monitoring indicators that respond relatively quickly to restoration, such as habitat diversity or some hydrological and physical metrics (Hughes et al., 2025). Indicators from the theme that measures change in enabling factors, such as reductions in threats, changes in attitudes among stakeholders, or policy changes that support restoration, can demonstrate that restoration actions are putting landscapes on a trajectory to recovery (e.g., Elias et al., 2025); these can be important stepping stones to ultimate restoration outcomes, and are therefore informative short-term indicators in these often complex projects. Results from indicators showing faster responses can also be important to inform communications describing the effects of restoration relatively early in a project. This can be invaluable to engage, inspire, and motivate stakeholders as work progresses, as well as providing practitioners with useful knowledge of early responses. By measuring restoration outcomes in both the short and long term, projects can produce a wider range of evidence, suiting various purposes and audiences (Adam et al., 2024).

The inclusion of indicators spanning ecosystem service and socioeconomic themes distinguishes our Monitoring Framework from other restoration and rewilding frameworks (Perino et al., 2019; Torres et al., 2018). A deepened understanding of perspectives, values, and concerns of local communities and other stakeholders is invaluable in project planning and design; it also provides the basis for evaluating how these factors change during a project (Danielsen et al., 2021; Sigouin et al., 2025). For many ELSP projects, the Framework provided an opportunity to extend monitoring beyond ecological metrics to include indicators of the benefits that people gain from restoration. Projects reported that the process of collecting these data strengthened their relationships with communities, enhancing their chances of long-term success. Furthermore, some social indicators, such as awareness of restoration and connectedness to nature, were among the quickest to show change. However, assessing economic change resulting from landscape restoration (e.g., the number of nature-positive businesses or local employment opportunities created) (Pendleton, 2010) has remained challenging. Making the economic case for ecosystem restoration is critical to advocacy with some audiences, such as local authorities, and there is a pressing need to develop practical methods to assess the economic costs and benefits associated with restoration (Iftekhar et al., 2017).

Enhanced ecosystem services from a restored landscape can be among the benefits most valued by local communities. However, projects found indicators in this theme of the Monitoring Framework the most complex to design and implement. In ecosystems where provisioning services (such as fish catch from marine or lake restoration, or timber from sustainable forestry) are valued, these proved relatively straightforward to monitor. However, regulating ecosystem services, often of central importance to a project, can be difficult to measure effectively (Hughes et al., 2016; Suding, 2011). For example, climate change mitigation benefits may accumulate slowly and non-linearly (Rydgren et al., 2020). Benefits associated with hydrological processes, such as flood mitigation or improved water quality, are complicated to measure as hydrological flows are highly dispersed across landscapes. Quantifying changes to services such as flood or fire mitigation depends on assessments of rare and unpredictable events with high levels of background dynamism, meaning that detailed modeling may be required (Harvey et al., 2024).

Monitoring schemes are commonly designed by restoration practitioners working for non-governmental organizations during project planning, often as part of a grant application. This has significant advantages, given practitioners' detailed knowledge of the landscape, its biodiversity, and people. Practitioners are typically committed to working in landscapes in the long term, enabling the continuity needed to monitor outcomes when change is slow. However, practitioners' capacity is often thinly spread, and their priority may be restoration delivery rather than data collection. Moreover, effective monitoring of large-scale restoration can be complicated, requiring ecological, social scientific, and technical expertise and specialist equipment, which may not exist within a single organization. To overcome this, many ELSP projects established collaborations with academic researchers, often local to their landscape, facilitating the use of more complex and time-consuming field and analytical methods. Academic research can also deepen understanding of processes and mechanisms, leading to improvements in restoration methods (Finger et al., 2023). As academics are particularly motivated to publish their findings in peer-reviewed journals, they also have an important role in quality controlling, publicly sharing, and archiving results from on-the-ground restoration (Hughes et al., 2011).

Our experiences also demonstrated the importance of flexibility during projects' planning and early implementation phases. Until a project's sampling sites and data collection methods are precisely specified, it may not be clear whether the approach proposed at the planning stage is feasible and appropriate. It is therefore important that during the first year(s) of a project, both practitioners and funders are open to changes in the selection of indicators and/or the approach used.

This relates to a wider point, that the time and effort dedicated to the planning stage of large-scale restoration projects rarely reflect the importance of this phase (Ockendon et al., 2025); projects have responded that ideally resources and time would be allocated to design and pilot monitoring methods before "real" baseline data collection gets underway. Such preliminary data collection would also allow more accurate power analyses, ensuring that sampling designs are likely to be informative and efficient (Christensen & Ringvall, 2013). A longer planning period would also enable deeper consultation and more participatory design of monitoring programmes. Given that landscape-scale transformation is likely to require monitoring over decades or even centuries, spending extra months at the start ensuring the most appropriate indicators are developed is likely to be worthwhile. At the other end of the funding cycle, even in a relatively generous 5-year grant, by the time projects have collected baseline data and implemented interventions, several years have often passed, leaving only a couple more years to detect any responses. Mechanisms that extend the time frame for monitoring (both before and after the 'main implementation grant period') would be welcomed by practitioners.

Over the last 6 years, the Landscape Restoration Monitoring Framework has been successfully adapted to a wide range of ecosystems and contexts to measure short- and long-term change resulting from landscape and seascape restoration. The breadth and ambition of the Monitoring Framework have raised projects' expectations about what can be monitored, how data are collected, and the value of the resulting information. Indicators from across the ELSP are starting to yield results informing many purposes, such as adaptive management, stakeholder engagement, policy advocacy, and future funding applications, helping to maximize the impact of these transformational projects.

AUTHOR CONTRIBUTIONS

David Thomas and David Noble conceived and produced the initial version of the Monitoring Framework. Nancy Ockendon, Taylor Shaw implemented the Framework across the ELSP and integrated the learnings. Philippa R. Gullett, Mark H. Hancock applied the framework to the Cairngorms Connect project. All authors contributed to the writing of the paper.

ACKNOWLEDGMENTS

We are grateful to the 24 participants that took part in the ELSP monitoring workshop, held at Cairngorms Connect in October 2023. We thank Francine Hughes, Johnny Hughes, Charlie Burrell, Penny Green, Ivan de Klee, David Gibbons for useful conversations. Rob Fuller worked on the initial version of the monitoring framework. The ELSP (Nancy Ockendon, Taylor Shaw, and David Thomas) is managed by the Cambridge Conservation Initiative in partnership with Arcadia.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

No data are presented in this article.

ORCID

Nancy Ockendon https://orcid.org/0000-0001-5055-1079
Philippa R. Gullett https://orcid.org/0000-0001-7867-2315
Mark H. Hancock https://orcid.org/0000-0001-6437-7278

REFERENCES

Abdelmajeed, A. Y. A., & Juszczak, R. (2024). Challenges and limitations of remote sensing applications in northern peatlands: present and future prospects. *Remote Sensing*, *16*, 591.

Adam, M., Cooper, D. J., Jaunatre, R., Clément, J. C., & Gaucherand, S. (2024). Wetland restoration: can short-term success criteria predict long-term outcomes? *Restoration Ecology*, *32*, e14231.

Al-Fulaij, N., Abbott, P., Bowmer, A., Cope, D., de Zoeten, T., Foulks, G., Frick, W. F., Funk, S. M., Gibbs, D., Gupta, L., Heard, N., Holmes, B., Kowalska, A., Mickleburgh, S., Muir, M., Nuijten, R. J. M., Parks, D., Reid, H., Van Ryzin, P., … Ockendon, N. (2025). Approaches for integrating evidence of the effectiveness of actions in conservation funding to inspire more effective practice. *Ecological Solutions and Evidence*, *6*, e12404.

Aronson, J., Goodwin, N., Orlando, L., Eisenberg, C., & Cross, A. T. (2020). A world of possibilities: six restoration strategies to support the United Nation's Decade on Ecosystem Restoration. *Restoration Ecology*, *28*, 730–736.

Bernhardt, E. S., Palmer, M. A., Allan, J. D., Alexander, G., Barnas, K., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad-Shah, J., & Galat, D. (2005). Synthesizing US river restoration efforts. *Science*, *308*, 636–637.

Caruana, A., Muir, M., White, T. B., & Jones, J. P. (2024). Lessons lost: Lack of requirements for post-project evaluation and reporting is hindering evidence-based conservation. *Conservation Science and Practice*, *6*, e13260.

CBD. (2022). Kunming-Montreal global biodiversity framework. In Conference of the Parties to the Convention on Biological Diversity. Montreal, Canada: UN Environment Programme.

Christensen, P., & Ringvall, A. H. (2013). Using statistical power analysis as a tool when designing a monitoring program: experience from a large-scale Swedish landscape monitoring program. *Environmental Monitoring and Assessment*, *185*, 7279–7293.

Christie, A. P., Amano, T., Martin, P. A., Shackelford, G. E., Simmons, B. I., & Sutherland, W. J. (2019). Simple study designs in ecology produce inaccurate estimates of biodiversity responses. *Journal of Applied Ecology*, *56*, 2742–2754.

Collingwood Environmental Planning Limited. (2014). *Updated Monitoring and Evaluation Framework for Nature Improvement Areas*. Collingwood Environmental Planning Ltd.

Cook, P., Law, A., Pattison, Z., Wallis De Vries, M. F., & Willby, N. J. (2024). Invertebrate responses to rewilding: a monitoring framework for practitioners. *Restoration Ecology*, *32*, e14195.

Costello, M. J., & Wieczorek, J. (2014). Best practice for biodiversity data management and publication. *Biological Conservation*, *173*, 68–73.

Danielsen, F., Enghoff, M., Poulsen, M. K., Funder, M., Jensen, P. M., & Burgess, N. D. (2021). The concept, practice, application, and results of locally based monitoring of the environment. *Bioscience*, *71*, 484–502.

Dombrovski, V. C., Zhurauliou, D. V., & Ashton-Butt, A. (2022). Long-term effects of rewilding on species composition: 22 years of raptor monitoring in the Chernobyl Exclusion Zone. *Restoration Ecology*, *30*, e13633.

Elias, F., Djenontin, I. N., Kamoto, J. F., & Mansourian, S. (2025). Accelerating forest landscape restoration monitoring in Africa: informing tangible actions from a practical perspective. *Restoration Ecology*, *33*, e14366.

Elias, M., Kandel, M., Mansourian, S., Meinzen-Dick, R., Crossland, M., Joshi, D., Kariuki, J., Lee, L. C., McElwee, P., Sen, A., Sigman, E., Singh, R., Adamczyk, E. M., Addoah, T., Agaba, G., Alare, R. S., Anderson, W., Arulingam, I., Bellis, S. G., K. V., … Winowiecki, L. (2022). Ten people-centered rules for socially sustainable ecosystem restoration. *Restoration Ecology*, *30*, e13574.

European Parliament. (2023). Regulation of the European Parliament and of the council on nature restoration (12 07 2023).

Evju, M., Hagen, D., Kyrkjeeide, M. O., & Köhler, B. (2020). Learning from scientific literature: can indicators for measuring success be standardized in “on the ground” restoration? *Restoration Ecology*, *28*, 519–531.

FAO, & WRI. (2019). *The Road to Restoration: A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration*. World Resources Institute.

Ferraro, P. J., & Hanauer, M. M. (2014). Advances in measuring the environmental and social impacts of environmental programs. *Annual Review of Environment and Resources*, *39*, 495–517.

Finger, A., Rao, S., Cowie, N., MacDonell, T., Beck, A., & Denny, B. (2023). Conservation genetics of montane willow populations in Scotland—Limited natural recovery despite long-distance gene flow and high genetic diversity. *Environmental Research: Ecology*, *2*, 015001.

Foster, B. L., & Tilman, D. (2000). Dynamic and static views of succession: testing the descriptive power of the chronosequence approach. *Plant Ecology*, *146*, 1–10.

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverria, C., Gonzales, E. K., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. *Restoration Ecology*, *27*(S1), S1–S46.

Gouraguine, A., Moranta, J., Ruiz-Frau, A., Hinz, H., Reñones, O., Ferse, S. C., Jompa, J., & Smith, D. J. (2019). Citizen science in data and resource-limited areas: A tool to detect long-term ecosystem changes. *PLoS One*, *14*, e0210007.

Gullett, P. R., Leslie, C., Mason, R., Ratcliffe, P., Sargent, I., Beck, A., Cameron, T., Cowie, N. R., Hetherington, D., MacDonell, T., & Moat, T. (2023). Woodland expansion in the presence of deer: 30 years of evidence from the Cairngorms Connect landscape restoration partnership. *Journal of Applied Ecology*, *60*, 2298–2308.

Hahn, N. R., Bombaci, S. P., & Wittemyer, G. (2022). Identifying conservation technology needs, barriers, and opportunities. *Scientific Reports*, *12*, 4802.

Hart, E. E., Haigh, A., & Ciuti, S. (2023). A scoping review of the scientific evidence base for rewilding in Europe. *Biological Conservation*, *285*, 110243.

Harvey, G. L., Hartley, A. T., Henshaw, A. J., Khan, Z., Clarke, S. J., Sandom, C. J., England, J., King, S., & Venn, O. (2024). The role of rewilding in mitigating hydrological extremes: State of the evidence. *WIREs Water*, *11*, e1710.

Hodge, I., & Adams, W. M. (2016). Short-term projects versus adaptive governance: Conflicting demands in the management of ecological restoration. *Land*, *5*, 39.

Hughes, F. M., Adams, W. M., Butchart, S. H., Field, R. H., Peh, K. S. H., & Warrington, S. (2016). The challenges of integrating biodiversity and ecosystem services monitoring and evaluation at a landscape-scale wetland restoration project in the UK. *Ecology and Society*, *21*(3), 1.

Hughes, F. M., Adams, W. M., & Stroh, P. A. (2012). When is open-endedness desirable in restoration projects? *Restoration Ecology*, *20*, 291–295.

Hughes, F. M., Stroh, P. A., Adams, W. M., Kirby, K. J., Mountford, J. O., & Warrington, S. (2011). Monitoring and evaluating large-scale, ‘open-ended’ habitat creation projects: a journey rather than a destination. *Journal for Nature Conservation*, *19*, 245–253.

Hughes, R., Anderson, R., Cowie, N. R., Gullett, P. R., Hancock, M. H., Klein, D., Littlewood, N., Martin-Walker, A., Pravia, A., Stagg, P., & Smith, T. (2025). Hydrological and vegetation change during peatland restoration at ex-forested sites in a blanket bog ecosystem. *Journal of Applied Ecology*, *62*, 2357–2372.

Hutto, R. L., & Belote, R. T. (2013). Distinguishing four types of monitoring based on the questions they address. *Forest Ecology and Management*, *289*, 183–189.

Iftekhar, M. S., Polyakov, M., Ansell, D., Gibson, F., & Kay, G. M. (2017). How economics can further the success of ecological restoration. *Conservation Biology*, *31*, 261–268.

IPBES. (2024). In K. O'Brien, L. Garibaldi, A. Agrawal, et al. (Eds.), *Summary for Policymakers of the Thematic Assessment Report on the Underlying Causes of Biodiversity Loss and the Determinants of Transformative Change and Options for Achieving the 2050 Vision for Biodiversity of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat.

Isbell, F., Tilman, D., Reich, P. B., & Clark, A. T. (2019). Deficits of biodiversity and productivity linger a century after agricultural abandonment. *Nature Ecology & Evolution*, *3*, 1533–1538.

Jellesmark, S., Ausden, M., Blackburn, T. M., Gregory, R. D., Hoffmann, M., Massimino, D., McRae, L., & Visconti, P. (2021). A counterfactual approach to measure the impact of wet grassland conservation on U.K. breeding bird populations. *Conservation Biology*, *35*, 1575–1585.

Jellinek, S., Wilson, K. A., Hagger, V., Mumaw, L., Cooke, B., Guerrero, A. M., Erickson, T. E., Zamin, T., Waryszak, P., & Standish, R. J. (2019). Integrating diverse social and ecological motivations to achieve landscape restoration. *Journal of Applied Ecology*, *56*, 246–252.

Johnson, S. E., Mudrak, E. L., Beever, E. A., Sanders, S., & Waller, D. M. (2008). Comparing power among three sampling methods for monitoring forest vegetation. *Canadian Journal of Forest Research*, *38*, 143–156.

Kızılkaya, Z., Saydam, E., Walker, K., Tabak, T., Miran, B., Tüney, I., Olguner, M. T., Kok, F., Alan, V., Atay, B., Pennetti, S., Tosunoğlu, Z., Mulligan, B., & Güçlüsoy, H. (2025). Progress and challenges of multi-habitat marine restoration in the eastern Aegean Sea, Türkiye. *npj Ocean Sustainability*, *4*, 12.

Landscale. (2021). Assessment Framework: Assessment Guidelines Version 1.0. https://www.landscale.org/wp-content/uploads/2022/10/v1_framework_EN.pdf

Larson, A. J., Belote, R. T., Williamson, M. A., & Aplet, G. H. (2013). Making monitoring count: Project design for active adaptive management. *Journal of Forestry*, *111*, 348–356.

Legg, C. J., & Nagy, L. (2006). Why most conservation monitoring is, but need not be, a waste of time. *Journal of Environmental Management*, *78*, 194–199.

Mackenzie, B. D., & Keith, D. A. (2009). Adaptive management in practice: conservation of a threatened plant population. *Ecological Management & Restoration*, *10*, S129–S135.

Martin, D. M., & Lyons, J. E. (2018). Monitoring the social benefits of ecological restoration. *Restoration Ecology*, *26*, 1045–1050.

McKenna, P. B., Lechner, A. M., Hernandez Santin, L., Phinn, S., & Erskine, P. D. (2023). Measuring and monitoring restored ecosystems: can remote sensing be applied to the ecological recovery wheel to inform restoration success? *Restoration Ecology*, *31*, e13724.

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., Evans, D. M., French, R. A., Parrish, J. K., Phillips, T. B., Ryan, S. F., Shanley, L. A., Shirk, J. L., Stepenuck, K. F., Weltzin, J. F., Wiggins, A., Boyle, O. D., Briggs, R. D., Chapin, S. F., III, … Soukup, M. A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, *208*, 15–28.

Mirzabaev, A., & Wuepper, D. (2023). Economics of ecosystem restoration. *Annual Review of Resource Economics*, *15*, 329–350.

Murcia, C., Guariguata, M. R., Andrade, Á., Andrade, G. I., Aronson, J., Escobar, E. M., Etter, A., Moreno, F. H., Ramírez, W., & Montes, E. (2016). Challenges and prospects for scaling-up ecological restoration to meet international commitments: Colombia as a case study. *Conservation Letters*, *9*, 213–220.

National Oceanic and Atmospheric Administration (NOAA). (2024). NOAA Restoration Center Implementation Monitoring: guidance for proposing and conducting Tier 1 Monitoring. https://www.fisheries.noaa.gov/s3/2024-05/Grantee-Guidance-for-Tier-1-Monitoring.pdf

Ockendon, N., Shaw, T., Bautista, S., Bhattacharjee, A., Cortina-Segarra, J., Iordache, V., Ospina López, V., Thomas, D., Satyal, P., Van doninck, J., & Birk, S. (2025). Overcoming barriers and leveraging opportunities to scale up landscape-scale restoration in Europe. *Restoration Ecology*, *33*, e70075.

Ockendon, N., Thomas, D. H., Cortina, J., Adams, W. M., Aykroyd, T., Barov, B., Thomas, D. H. L., Boitani, L., Bonn, A., Branquinho, C., Brombacher, M., Burrell, C., Carver, S., Crick, H. Q. P., Duguy, B., Everett, S., Fokkens, B., Fuller, R. J., Gibbons, D. W., … Sutherland, W. J. (2018). One hundred priority questions for landscape restoration in Europe. *Biological Conservation*, *221*, 198–208.

Parks, D., Al-Fulaij, N., Brook, C., Butchart, S. H., Collomb, J. G., Cope, D., et al. (2022). Funding evidence-based conservation. *Conservation Biology*, *36*, e13991.

Pendleton, L. (2010). Measuring and Monitoring the Economic Effects of Habitat Restoration: a summary of a NOAA Blue Ribbon Panel. Nicholas Institute for Environmental Policy Solutions, Duke University, Durham, NC.

Perino, A., Pereira, H. M., Navarro, L. M., Fernández, N., Bullock, J. M., Ceaușu, S., Cortés-Avizanda, A., van Klink, R., Kuemmerle, T., Lomba, A., & Pe'er, G. (2019). Rewilding complex ecosystems. *Science*, *364*, 5570.

Pettorelli, N., & Schulte to Bühne, H. (2023). Current and future opportunities for satellite remote sensing to inform rewilding. *Remote Sensing in Ecology and Conservation*, *9*, 301–310.

Pocock, M. J., Chandler, M., Bonney, R., Thornhill, I., Albin, A., August, T., Bachman, S., Brown, P., Cunha, D., Grez, A., Jackson, C., Peters, M. A., Rabarijaon, N. R., Roy, H., Zaviezo, T., & Danielsen, F. (2018). A vision for global biodiversity monitoring with citizen science. *Advances in Ecological Research*, *59*, 169–223.

Reis, B. P., Branquinho, C., Török, K., Řehounková, K., Nunes, A., & Halassy, M. (2024). The added value of the long-term ecological research network to upscale restoration in Europe. *Journal of Environmental Management*, *366*, 121736.

Ren, J. W. F., & Coffman, G. C. (2023). Integrating the resilience concept into ecosystem restoration. *Restoration Ecology*, *31*, e13907.

Rey-Benayas, J. M., Newton, A. C., Diaz, A., & Bullock, J. M. (2009). Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. *Science*, *325*, 1121–1124.

Rydgren, K., Andersen, R., Halvorsen, R., Hancock, M. H., Hughes, R. D., Martin-Walker, A., Töpper, J. P., & Cowie, N. (2025). Restoration of formerly afforested blanket bog: estimating time for vegetation recovery. *Ecological Applications*, *35*(8), e70138.

Rydgren, K., Auestad, I., Halvorsen, R., Hamre, L. N., Jongejans, E., Töpper, J. P., & Sulavik, J. (2020). Assessing restoration success by predicting time to recovery: But by which metric? *Journal of Applied Ecology*, *57*, 390–401.

Schleicher, J., Eklund, J., D. Barnes, M., Geldmann, J., Oldekop, J. A., & Jones, J. P. G. (2020). Statistical matching for conservation science. *Conservation Biology*, *34*, 538–549.

Segar, J., Pereira, H. M., Filgueiras, R., Karamanlidis, A. A., Saavedra, D., & Fernández, N. (2022). Expert-based assessment of rewilding indicates progress at site-level, yet challenges for upscaling. *Ecography*, *2022*(4), e05836.

Sigouin, A., Porzecanski, A. L., Betley, E., Gazit, N., Lichtenthal, P., Cheng, S. H., Pacheco, P., & Mahajan, S. L. (2025). Enabling participatory monitoring and evaluation: Insights for conservation practitioners and organizations. *Conservation Science and Practice*, *7*, e70032.

Stephenson, P. J. (2020). Technological advances in biodiversity monitoring: Applicability, opportunities and challenges. *Current Opinion in Environmental Sustainability*, *45*, 36–41.
Suding, K. N. (2011). Toward an era of restoration in ecology: successes, failures, and opportunities ahead. *Annual Review of Ecology, Evolution, and Systematics*, *42*, 465–487.
Summers, R. W. (2018). *Abernethy forest. The history and ecology of an old Scottish pinewood*. RSPB.
Sutherland, W. (2022). *Transforming conservation: a practical guide to evidence and decision making* (p. 430). Open Book Publishers.
Torres, A., Fernández, N., Zu Ermgassen, S., Helmer, W., Revilla, E., Saavedra, D., Perino, A., Mimet, A., Rey-Benayas, J. M., Selva, N., & Schepers, F. (2018). Measuring rewilding progress. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*, 20170433.
Villasenor, E., Porter-Bolland, L., Escobar, F., Guariguata, M. R., & Moreno-Casasola, P. (2016). Characteristics of participatory monitoring projects and their relationship to decision-making in biological resource management: a review. *Biodiversity and Conservation*, *25*, 2001–2019.
Wortley, L., Hero, J. M., & Howes, M. (2013). Evaluating ecological restoration success: a review of the literature. *Restoration Ecology*, *21*, 537–554.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Ockendon, N., Gullett, P. R., Hancock, M. H., Noble, D., Shaw, T., & Thomas, D. H. L. (2025). A framework for monitoring ecosystem restoration at landscape scale. *Conservation Science and Practice*, e70214. https://doi.org/10.1111/csp2.70214