THE INCREASING IMPORTANCE OF MONITORING WILDLIFE RESPONSES TO HABITAT MANAGEMENT

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Tests of habitat restoration could be valuable in helping to reverse the decline of the Nightingale.
Edmund Fellowes/BTOImages

The authors argue for a more strategic approach to monitoring the consequences of conservation actions and for greater sharing of the results.

Habitat loss and habitat degradation are fundamental causes of wildlife impoverishment in Britain in recent decades. The large-scale creation, restoration and management of habitat have become a crucially important focus of conservation, with a rationale for action now provided by Lawton *et al.* (2010). A strategic landscape-scale approach is vital in working towards the recovery of nature, and this is recognised in the Government's 2011 Natural Environment White Paper. In our crowded island, where the pressures on land are exceedingly high and the resources available to conservation very limited, it is a huge challenge to establish the types of habitat networks essential for maintaining and expanding the populations of many species. Nonetheless, remarkable work is being carried out across the conservation movement. This magazine has highlighted achievements in creating or restoring large sites or landscapes, including Lakenheath Fen (Sills & Hirons 2011), Thorne and Hatfield Moors (Lunn *et al.* 2011), The Great Fen (Bowley 2013) and Wallasea (Ausden *et al.* 2015). A recent article on the Meres and Mosses (Jones 2015) illustrates the reality of implementing Lawton's four primary principles of creating landscapes with *more, bigger, better* and *joined* habitat (Lawton *et al.* 2010). There is no simple blueprint; each landscape needs to be considered individually in terms of the needs of key species and the opportunities that exist for habitat creation or restoration.

Given the constraints on land availability for conservation, it is increasingly important that those areas under conservation management are subject to the most effective interventions to achieve the greatest effect (Baker & Fuller 2013). The most certain way to ensure survival of populations of localised species and ones with specialised habitat needs is to increase the area of high-quality habitat (Hodgson *et al.* 2009, 2011). This must take account of the critical needs of these species in terms of features such as soil type, water chemistry, preferred foodplants, microtopography and vegetation microstructures. In contrast, many interventions focus on very generalised prescriptions for managing vegetation that do not necessarily create the diversity of structures required by many of the species, especially invertebrates, that should be

Box 1 *WildSurveys*: an online system for recording wildlife responses to conservation interventions within Wildlife Trust Living Landscape schemes and reserves

This new internet-based monitoring concept has been developed by the British Trust for Ornithology and The Wildlife Trusts as a means of tracking responses of selected wildlife taxa to habitat creation and restoration within Living Landscape schemes and Wildlife Trust reserves. It provides a flexible data-capture system that can be adapted to many different habitat contexts, types of intervention and species groups. The system is being trialled within The Wildlife Trusts. The development of suites of related case studies, focusing on similar habitat interventions, will be encouraged in order to maximise the gain in knowledge about wildlife responses. In the long term, it has the potential to provide a framework for addressing specific questions about management interventions and habitat creation at landscape scales if sufficient case studies can be maintained for selected species groups.

WildSurveys strongly encourages the use of structured designs with controls wherever possible and relevant. The emphasis is on monitoring changes in numbers of individuals over time at carefully selected locations, using simple field protocols specific to the target taxa.

Although any species groups could be monitored through *WildSurveys*, several priority species groups of invertebrates and vertebrates have been identified; it is hoped that higher plants would be recorded at all selected locations. Recommended field methodology is based so far as possible on established practice in order to allow integration with national recording schemes.

The system allows the definition of exact study-site boundaries and the selection of sample locations within these. Data can be gathered and recorded in several different ways, so that the scale of data-recording is appropriate for the species group, the habitat type and the question being addressed about the intervention. Counts can be made at sample points, along sample transects or for whole plots as appropriate for the species group and location. The nature of the intervention, broad habitat types and vegetation structure are all recorded within the system. Vegetation structure is recorded at the sampling locations by means of a novel and rapid approach in which observed structure is visually matched to diagrammatic structures.

characteristic of those environments (Dolman *et al*. 2011, 2012). Hence, we use the term 'habitat quality' in the context of the resources on which species depend, rather than in the sense of some broad notion of vegetation condition.

In an ideal world, all conservation interventions would be underpinned by a comprehensive management plan. This would incorporate not just the definition of objectives and the management actions intended to achieve those objectives, but also appropriate monitoring to determine whether satisfactory outcomes had been achieved (Ausden 2007). This would allow adaptive management whereby the plan is subject to review and then, if necessary, modified on the basis of clear evidence derived from the monitoring. In reality, the vast majority of conservation interventions are not systematically monitored. This often comes down to cost – understandably, resources are usually prioritised for purchase and management. In addition, apparently well-established techniques are frequently believed to deliver strong benefits for wildlife and it is thought that testing such assumptions is unnecessary. This is a worrying situation for several reasons. First, not all widely applied interventions have, in fact, been thoroughly assessed in terms of what they actually deliver, as pointed out by Denton (2013) in the case of grazing on heathland. Second, many interventions are aimed at one or a few species and the rest of the fauna and flora may be unknown. Third, funders and the public increasingly need assurance that conservation techniques really are successful. It is equally important to know when things work and when they do not, or when they have beneficial but completely unforeseen outcomes. Fourth, the environment is changing in many ways and it cannot be assumed that the established conservation techniques will be successful in the future. For example, many insects are thermally constrained in their choice of habitat, and climate warming may cause them to adopt new microhabitats (Davies *et al*. 2006). Future conservation management will need to consider how best to provide the optimum microclimates for these species (Suggitt *et al*. 2014).

If effective ecological networks are to be created, there is a need to improve understanding of how wildlife responds to the creation and restoration of all types of 'conservation habitat'. Robust monitoring can greatly help conservation decision-making by identifying which types of conservation intervention are likely to produce the best future outcomes for wildlife and over what timescale they are likely to materialise. This information

has huge potential value for understanding which conservation approaches will work best for different taxa and habitat types in the future. In Britain we are fortunate in having national monitoring programmes and atlases that allow us to track the general status of many taxa (Maclean 2010; Preston *et al*. 2012). These schemes generate invaluable data, but very few are designed to inform us about the performance of specific conservation interventions. We argue that the conservation movement needs to become far more strategic in monitoring the consequences of its actions and sharing the results of monitoring.

Some of the most exciting conservation schemes are being undertaken at very large spatial scales. For example, the Living Landscapes initiative of The Wildlife Trusts embraces more than 100 schemes throughout Britain. Individual schemes vary greatly in size – The Great Fen, in Cambridgeshire, is some 3,500ha, whereas Pumlumon, in west-central Wales, is 40,000ha. Monitoring of wildlife in any detail across an entire Living Landscape scheme would be impossible in most cases. We suggest that opportunities should be taken to establish long-term monitoring schemes in sample areas, including nature reserves, where a major effort is being made to create and improve habitat. The emphasis would be mainly on assessing whether habitat of high wildlife quality is being established. The quality of the evidence will be maximised by adopting structured, but straightforward, study designs, some of which we explore in this article. A recently developed online system has the potential to act as a basis for capturing such data and for sharing the resulting information (Box 1).

The diversity of conservation interventions

Habitat-based conservation schemes are conducted in many types of landscapes differing greatly in habitats and wildlife. For example, some Living Landscape schemes aim to improve the general 'landscape quality' for wildlife across a defined area. Others have a vision of establishing an expanse of wildlife-rich habitat in a previously wildlife-poor environment (e.g. The Great Fen). Most schemes, however, probably focus on selected tracts of countryside which have high, or potentially high, wildlife value with the intention of enhancing their capacity to support sustainable wildlife populations. The emphasis could be either on meeting the requirements of particular species or on providing diverse habitat structures at micro and macro scales that will support a wide range of species. Given this diversity, it is essential that monitoring approaches are appropriate for local aims and circumstances. Just as there is no single best way of doing conservation, there is no single best way to monitor.

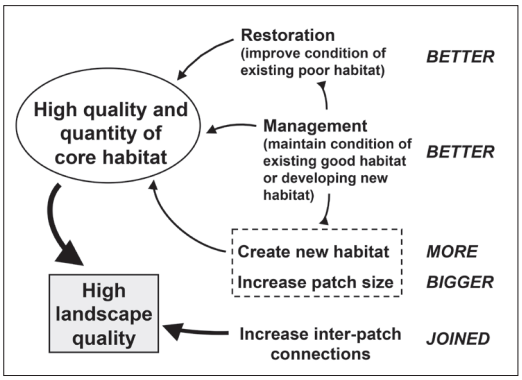

Figure 1 Relationships between major interventions likely to be used for increasing the quality of landscapes for wildlife (with reference to the Lawton Review headline conclusions: Lawton *et al*. 2010). The emphasis is on actions affecting the quality and quantity of core patches of semi-natural habitat and increasing the connections between them. Particular emphasis is given to the importance of establishing and maintaining core habitat, because this provides the critical resources that much wildlife, especially specialist species, requires.

Conservation interventions are frequently targeted at 'desirable' species. These may be locally or nationally scarce, or ones that are especially distinctive of particular habitat types. Extra attention may be given to species that are poor dispersers, because only mobile species will reach new habitat quickly. In all cases, the provision of sufficient high-quality habitat containing the key resources is crucial, but for poor dispersers habitat connectivity becomes increasingly critical. Where there is a strong focus on one or more desirable species, it is obviously vital to understand the basic ecology in order to develop a sound management plan. Several general approaches to intervention can be recognised:

- Increasing structural and functional connectivity to improve movement of organisms between existing habitat patches, establish sustainable metapopulations and facilitate colonisation of potential habitat.
- Creating new habitat patches and extending the

Box 2 Intervention terms

Habitat patch: An area of semi-natural habitat, of any size, forming a unit for some intervention and usually perceived to be distinct from its surroundings in its habitat characteristics.

Core habitat: Habitat patches considered to be of high quality for wildlife. Patches of core habitat will typically be semi-natural and include, but not be confined to, all protected areas and County Wildlife Sites. Not all core habitat is long-established. New habitat and restoration habitat (see below) could, and should, become core habitat in time; in the case of early successional species, this could occur quite rapidly. Core habitat may change as a consequence of succession but nonetheless retain high wildlife importance, albeit for different species.

Restoration habitat: Habitat patches which have fallen into a low-quality state for wildlife and where restoration aims to return them to high quality and to add them to the pool of core habitat. This definition can include patches undergoing restoration and ones that have been apparently restored. Restoration does not necessarily imply the strict re-creation of some former state or condition. Restoration interventions will often be similar to those employed in ongoing habitat management.

New habitat: Entirely new habitat patches which are intended to support viable populations of some species, possibly as part of a wider network of sites. These may be extensions to existing core habitat or entirely separate. Unlike restoration habitat, new habitat involves a fundamental change in land cover, creating wildlife habitat where it did not previously exist, e.g. on former agricultural or industrial land. New habitat and restoration habitat have entirely different starting conditions; this is likely to have significant implications for the trajectory and speed of change in wildlife. The intensity and timing of management interventions are also likely to differ.

Managed habitat: Habitat management is crucial to maintaining habitat quality for target taxa in many contexts. Different management treatments may be employed within the same habitat types, either to benefit different taxa or because responses are uncertain. Management can be subtly different from restoration. Management may have been continuing over a long period with the aim of maintaining habitat suitability, frequently for early successional species, whereas restoration implies a period of neglect followed by intervention aimed at restoring some desired condition.

Connecting habitat: Habitat features within ecological networks that provide 'stepping stones' or that physically link habitat patches in ways that are assumed to facilitate movement of plants and animals through landscapes. The creation of new habitat is usually involved, but restoration may be relevant, for example where particular vegetation structures have been lost as a result of succession. What constitutes biologically meaningful 'connecting habitat' can be difficult to determine, because species differ so greatly in their dispersal ability and in the habitats that facilitate their movement. In reality, connectivity has functional meaning only in the context of the needs and behaviour of the focal species.

Habitat gradients: Frequently, habitat patches may contain various forms of gradient from one condition to another. There may be a transition from dry to wet conditions, from grassland to woodland, from grass to heather, and so on. In the context of wildlife-monitoring, gradients are important. Much wildlife interest may reside at the interface between distinctly different vegetation types. Consequently, these transition zones may need to be explicitly accounted for in monitoring designs. The existence of a habitat gradient can provide opportunities to assess how a species responds to interventions when these are implemented across a range of conditions.

Matrix habitat: The rest of the landscape/region not covered by the previous six categories. It is, therefore, broadly that part of the landscape where there is no particular focus on wildlife conservation within semi-natural habitat patches. Agri-environment measures, however, may occur within the matrix.

area of existing habitat patches. The expectation is that colonisation of new habitat by 'desirable' species will be more rapid when it is located adjacent to existing high-quality habitat.

- Restoring habitat quality through management interventions. 'Restoring' does not necessarily mean reverting to some previous state or condition; a new habitat structure or management system that has wildlife value could be introduced.
- Novel landscape-scale management to create new kinds of plant and animal assemblages. Where habitat patches are sufficiently large, or interconnected, 'natural processes' may form a major element of the conservation approach. It is most likely that this would involve extensive grazing. Outcomes may be entirely 'open-ended' (i.e. no expectation of a particular outcome) or the works be directed at the creation of desired habitat structures. They may allow for the development of shifting mosaics of vegetation which maintain early- and mid-successional habitats in perpetuity.

Relationships between the main types of interventions and approaches to landscape-scale conservation are illustrated in Fig. 1 (page 177). Various ways of testing wildlife responses to these interventions are possible. Given the variation in

objectives and contexts of landscape-scale conservation, a terminology for interventions is helpful (see Box 2). In practice, however, the distinctions are not always clear-cut and there will be grey areas. When does 'created habitat' cease to be thought of as 'new' habitat? When does deteriorating core habitat become potential restoration habitat? When does restoration habitat achieve core-habitat status?

Questions and issues that can be addressed by monitoring

Landscape ecology has established important principles concerning the interaction of species with habitat extent, spatial pattern and fragmentation (Southwood 1977; Lindenmayer & Fischer 2006; Lindenmayer *et al*. 2008). Much of the relevant research has been undertaken in North America or Australia, where the biological communities and, perhaps more importantly, the history and scale of landscape modification are very different from those in western Europe (Martin *et al*. 2012a, 2012b). It cannot be assumed that these findings always offer an optimum basis for developing habitat-based initiatives in Britain. At the simplest level, the existing principles are embodied in Fig. 1 and form the best basis that we have for action. There is, however, much scope for refining these for application in different cultural landscapes and socio-economic contexts. Furthermore, most of these principles have been developed by studying wildlife responses to habitat loss and fragmentation (i.e. existing spatial patterns of habitat), rather than responses to habitat creation and restoration. The latter is not a simple reversal of the former, because many processes and features of the environment will have irredeemably changed through a long history of human activity – for example, nutrient inputs, different assemblages of predators, the loss of former keystone species and the gain of new ones, possibly including some non-native species. Conservation is also operating in a situation in which many species are shifting their geographical range, and potentially their habitat use, in response to climate changes, rather than as a result of habitat interventions. Well-designed and conducted monitoring can help to distinguish these confounding factors and address many questions relevant to conservation in modern and future landscapes. To some extent the answers are likely to be specific to different contexts and taxa, but general principles may emerge that build on those which we already have.

Coppice under restoration in west Dorset. How quickly do species of young open woodland colonise woodland being brought back into a coppice rotation after a long period of neglect? Rob Fuller

Six generic questions about habitat creation and restoration are listed below. These and similar questions are frequently posed by conservationists; in addition, a profusion of specific questions could be asked with regard to how wildlife responds to different management treatments within core, restoration or new habitat. This list is not definitive; other types of question could be formulated, and regional priorities vary, as do the contexts in which the questions may apply.

1. How does wildlife in new habitat change over time and how does it come to compare with that in existing similar core habitat?
2. How does wildlife in restoration habitat compare with that in existing similar core habitat?
3. How does wildlife respond within restoration and new habitat when isolated from, or adjacent to, core habitat?
4. How does provision of connecting habitat between otherwise separate patches of core, restoration and new habitat affect wildlife?
5. Is close proximity of new or restored habitat adjacent to core habitat a better option for wildlife than provision of connecting features between core habitat patches?
6. How do habitat structure and composition within the matrix (the land between patches of conservation habitat) affect conservation success within core, restoration and new habitat (in the absence of provision of connecting habitat)?

As resources available for conservation are limited, decisions will frequently be needed about where to invest effort. One way to tackle this is to identify those opportunities that give the greatest information gains, for instance by answering several of the above questions. Questions 1 and 2 are relatively basic but critically important, especially when they are framed in the context of particular management approaches adopted in habitat creation or restoration. Questions 3 to 6 are somewhat more refined variants of the first two questions.

Some real-life examples of potential monitoring studies are given in Box 3 on page 182, together with the questions and general approaches that could be adopted.

Basic monitoring approaches and study designs

Decisions will usually be needed on how to maximise the quality and value of the information derived from monitoring for the resources that can be committed. Four points are of paramount importance.

1. The monitoring needs to be sustainable in terms of available resources and commitment. We advocate simple designs, rather than complex experiments. Resources will always limit what can be undertaken and, the more complicated the monitoring scheme, the less sustainable it is likely to be.
2. The data need to be gathered by using the same methods and intensity of sampling over time to ensure long-term comparability.
3. The treatment itself (i.e. the exact interventions) needs to be well documented and measures of habitat change recorded.
4. There is absolutely no point in embarking on monitoring if there is no chance that it will produce relevant and reliable information. The objectives need to be clear and the basic design must be appropriate. This requires consideration of controls, benchmarks, replicates, sample sizes and sampling frequency.

The inclusion of *control habitat* is often essential in order to determine whether the intervention is really making any difference to wildlife. It may be possible to strengthen the design further by gathering data before the intervention is made, allowing a 'before and after' comparison as well as a 'with and without intervention' comparison. *Benchmark or reference habitat* forms a complementary concept in representing a desirable state or condition that one may wish new or restored habitat to attain. Ideally, several examples (*replicates*) of the particular intervention of interest are needed in order to be reasonably sure that the observed response is constant and general. The countryside is hugely complex, and in practice these concepts can be difficult to apply, so they are discussed in more detail later in this article.

Large habitat-creation schemes present rather different monitoring challenges from those in which relatively small-scale interventions are spread more widely across the landscape. The former are 'landscapes in themselves' and the monitoring can be structured in such a way that replicates are internal to the initiative. Monitoring of smaller interventions, however, does not usually provide information about whether wildlife improvements are being realised at the wider landscape scale. 'Landscape' in this context does not, for example, have to mean an entire Living Landscape. It could be sensible to target monitoring on *focal areas* where there is an especially strong prospect of creating or restoring substantial amounts of wildlife-rich habitat. In the long term, conservation is more likely to have influence in the sphere of protecting and creating semi-natural habitat than it is in enhancing the quality of the agricultural and urbanised matrix. *Focal areas* may, therefore, be best located where quantities of semi-natural habitat are relatively high.

The emphasis here is on developing appropriate study designs, rather than on how to analyse the

Woodland glade at Swanton Novers NNR, Norfolk. Techniques for the creation of complex glade structures in woodland have been little studied.
Rob Fuller

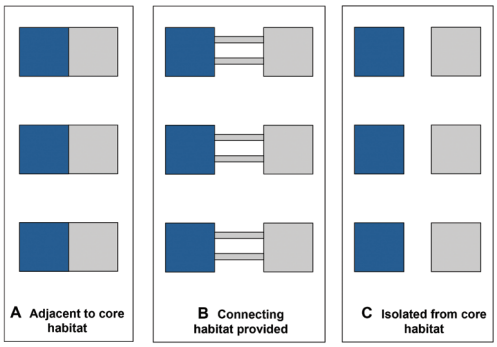

Figure 2 Three types of contrasts (A – C) for monitoring creation of new habitat, with three replicates in each case. Each block represents a site. Blue = core habitat; grey = new habitat. The core habitat provides a benchmark against which the effectiveness of the habitat creation can be assessed. If the goal of habitat creation is entirely open-ended, reference to core habitat is less important. Monitoring just A, B or C would be valuable, but it would be even better to monitor A & B or A & C as this would additionally give insights into the consequences of connectivity and isolation. Similar designs could be developed to account for the complexity of the matrix habitat. For instance, B could involve creating new habitat in a landscape with many existing potential connecting features.

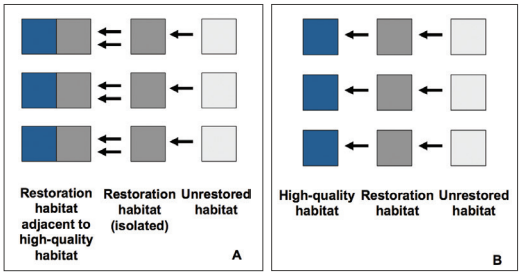

Figure 3 Simple contrasts of sites selected to monitor effects of habitat restoration. A is a study of the effects of restoring habitat in close proximity to existing high-quality (i.e. core) habitat. B examines wildlife trends in isolated sites. In each case three replicates are shown. The expected improvement and relative scale of improvement in wildlife is indicated by arrows. The core habitat provides a benchmark against which the effectiveness of the habitat restoration is assessed. The unrestored habitat provides a control for judging whether the restoration is making a difference to wildlife. The ideal would be to include both control and benchmark habitats. If a choice has to be made, however, it is probably best to invest effort in monitoring control habitat.

data that will accrue from the monitoring. Appropriate statistical analysis is important, but a monitoring study that is well designed at the outset will make the job of data analysis and interpretation far more straightforward. It is recommended, however, that some basic statistical advice is sought on the numbers of sample locations that may be appropriate when gathering data through point samples, either for species or for habitat.

Fixed-plot contrasts

It is suggested that, wherever possible, straightforward contrasts be adopted that allow the effect of a particular conservation intervention to be assessed. So far as possible, sites that are being compared should be similar in habitat type, soil type, elevation and surrounding-landscape composition and structure, but differ in the attribute of interest. This could involve contrasting wildlife responses under different restoration/management treatments, or one might compare treatment habitat with control or benchmark habitat. Contrasts are valid only if made between habitat patches or sites that have substantial features in common, though exact matching is rarely, if ever, possible in the real world.

Diagrammatic examples of site-selection designs for monitoring wildlife responses to creation of new habitat are shown in Fig. 2. These designs take into account the proximity of existing habitat and the creation of connecting habitat. Fig. 3, on the other hand, shows designs that focus on habitat restoration. In both instances, it would not be necessary to implement all the options shown to gather really worthwhile data. The taxa-specific sampling approaches would vary. In some cases this might involve taking many point samples within each habitat patch (this could be the case for surface-active or aquatic invertebrates and higher plants), whereas extensive transects or even whole-plot counts might be taken for other species groups (e.g. adult dragonflies, butterflies and birds). In practice, it would be necessary to adopt sampling that allowed for management or restoration that was implemented at different times in different locations.

In many circumstances it is by no means necessary to sample every year. The intervals between sampling, however, do need to be determined in

Box 3 Case studies: examples of monitoring wildlife responses to interventions in early successional habitats on Wildlife Trust reserves

Scrub-grass mosaic at Draycott Sleights, Somerset. Kiff Hancock

Mendips limestone grassland, Somerset

Draycott Sleights is a 65ha SSSI located on the southern scarp of the Mendip Hills, and is owned and managed by Somerset Wildlife Trust. The underlying geology of limestone and windblown loess, alongside historical management, has created complex mosaics of CG2, CG3 and MG5 grassland interspersed with scrub developing into secondary woodland. The site is important also for invertebrates, particularly butterflies (with 32 breeding species). Monitoring aims to assess the impacts of management to (i) restore degraded mesotrophic and scrubbed-over areas and (ii) maintain the botanical interest of high-quality calcareous grassland. Key questions are, first, how best to retain a dynamic habitat mosaic beneficial to the target species and, second, what the responses of grassland species are to scrub clearance, focusing on recovery times and impact of mulch depth on recovery. A variety of techniques is used, including point samples in grids or transects to identify changes in vegetation communities and to monitor recovery of grassland after scrub clearance.

Ash regeneration at Arger Fen & Spouse's Vale, Suffolk. Rob Fuller

Former arable farmland, Suffolk

This site consists of several formerly arable fields owned by Suffolk Wildlife Trust at its Arger Fen & Spouse's Vale reserve. One of the fields was taken out of production some 10 years ago and an area adjacent to an ancient wood was rapidly colonised by Ash *Fraxinus excelsior*, while mixed scrub is developing in other areas. The Ash has subsequently suffered heavily from ash dieback. The other fields were more recently arable and are not yet showing large-scale scrub development. The fields are being left to natural succession for the indefinite future. The long-term vision is for an extensively grazed mosaic of scrub and grassland, rather than dense woodland. Monitoring aims to assess how plant, bird and invertebrate communities gradually change as a result of the policy of non-intervention and light grazing by deer. An understanding of how wildlife responds to the developing vegetation mosaics will inform long-term vegetation management at this and other sites. In total, 96 plots (5m radius) are located throughout the dying Ash and the mixed scrub. Tree, shrub and ground vegetation cover will be estimated at each of these plots on an annual basis. The plots will also form sample units for plants and selected invertebrate groups. Birds will be counted at points along line transects running through all the habitat types.

Magnesian limestone grassland, South Yorkshire

The Yorkshire Wildlife Trust's Sprotbrough Flash reserve contains small areas of limestone grassland that are rich in plant species. This grassland type is localised along a thin belt running north–south between Nottinghamshire and Durham. The site is a former quarry that was landfill, with the original topsoil restored. Birch *Betula* woodland subsequently regenerated over part of the site, while other areas were kept free of trees by grazing. Over the past decade, Hebridean sheep have been used to graze within fenced plots on the open grassland and the woodland has been partially cleared, resulting in a species-rich diverse sward structure with low patchy scrub. Grazing may not be sustainable in the future owing to ongoing antisocial problems. The management question is whether the interest of the site can be maintained through periodic scrub management. Specifically, how do the ground flora and sward invertebrates change with increasing scrub development, and can 'tipping points' be identified beyond which scrub growth becomes detrimental to the conservation interest? Potentially, monitoring of plants and invertebrates following scrub removal could help to identify the optimal successional stages that provide the maximum conservation benefits and, in turn, these could inform adaptive management of the site.

Grassland at Sprotbrough Flash reserve, South Yorkshire. Rob Fuller

Chalk grassland, Kent

The Medway Smile Living Landscape contains several fine examples of unimproved calcareous grassland, such as those along the Wouldham to Detling Escarpment and Queendown Warren SSSIs. These sites are botanically rich and support many plant and invertebrate species of elevated conservation priority, such as Early Spider-orchid *Ophrys sphegodes* and Adonis Blue butterfly *Polyommatus bellargus*. The project run by the Kent Wildlife Trust aims both to restore and to create areas of species-rich grassland on calcareous soils, and to maintain the existing quality of established sites. Management is through grazing with cattle and sheep, restoration through scrub control, and creation on former agricultural land through reseeding and conservation grazing of former pasture. Monitoring aims to answer the questions of (i) whether restoration by scrub removal and creation by agricultural reversion produce species-rich grassland that can support key plant and invertebrate species, (ii) how rapidly changes in plant and invertebrate communities occur, and (iii) how restored and created habitats compare with established grassland. Plant communities, butterflies and ground beetles will be monitored by means of, respectively, 2×2m quadrats, line transects, and pitfall traps and direct searching, in replicates of core, restoration and new habitat, and of current and historical management. Established sites will be used as benchmarks against which changes are assessed.

Recent scrub removal on chalk grassland near Detling, Kent. Rob Fuller

Grazing and turf-stripping on lowland heathland, West Sussex

The Sussex Wildlife Trust's Iping and Stedham Commons reserve (125ha) consists of large areas of heathland, Purple Moor-grass *Molinia caerulea* mire, birch–pine *Betula–Pinus* woodland and small areas of wet heath. Stedham has been 'pulse'-grazed for more than 10 years with cattle. Iping is currently not fenced and, because of the lack of grazing, is losing key species such as the reintroduced Field Cricket *Gryllus campestris*. Heath Tiger Beetles *Cicindela sylvatica* have been reintroduced on Iping on purpose-made 'scrapes' (the stripped turfs used to create more heathland on nearby golf courses). Invertebrate-monitoring has examined the effects of grazing in three areas similar in vegetation and aspect. These were: (i) grazed for 10 years; (ii) summer-grazed, with temporary electric fencing used; and (iii) a control plot with no livestock grazing. All invertebrates were recorded within a one-hour period by several observers, using a range of methods. Records were bulked over multiple visits from April to September. Comparisons between plots were made in terms of the guild composition of the invertebrate assemblages. On the scrapes, Heath Tiger Beetles and other invertebrates were counted by observers walking each scrape at a steady pace per unit area. These data were used to show which scrapes produced the most beetles and the greatest diversity of bare-ground invertebrates.

accordance with the speed with which vegetation and other habitat conditions change in relation to the habitat needs of the target organisms. The rapidity of successional change tends to be far greater in the early stages of habitat development than in later stages. The niches for many early successional species are available for only short periods, so that, if sampling intervals are too wide, these may be missed. It may be possible to adopt mixed sampling intervals, whereby either (i) certain taxa are monitored at shorter intervals than others or (ii) a small sample of sites is monitored at short intervals but a much larger sample is then monitored at longer intervals.

Rotational management, gradients and shifting mosaics

Conservation management frequently involves rotational cutting or mowing, this being the case in many habitat-restoration projects. The conservation interest may reside in the overall diversity created by the resulting vegetation gradients, or may be more focused on particular developmental stages (usually the earlier stages) or the transitions between patch types. Monitoring may be relevant when comparing different rotational treatments or simply in assessing whether ongoing management is providing suitable habitat for target species. It may be necessary to stratify the samples that are taken so that particular stages of vegetation development or transitions are sampled over periods of time.

Monitoring wildlife responses to rotational management or shifting mosaics does not necessarily involve the use of strict controls or reference plots, because the comparisons are essentially those made between the different stages of development. There may, however, be instances when controls would be desirable, especially when a comparison is needed

between managed and unmanaged treatments. Furthermore, one may wish to test responses to different kinds of management by matching samples under different treatments, where 'conventional' or 'traditional' treatments may be regarded as a control against which a 'novel' treatment is compared.

Replicates, controls and benchmarks in the real world

Conservation is frequently dealing with sites that are highly individual, distinctive and sometimes unique. This can make it difficult to find valid and suitable controls, benchmarks or replicates. It is worth bearing in mind that the real world operates by drawing on many kinds of information; not all monitoring has to reach the highest standards of a rigorous experiment. Even though the design might not match the requirements of a peer-reviewed paper in the scientific literature, results from very simple monitoring can be enormously informative.

Wherever possible, it is highly desirable to adopt replicates to measure the effects of specific habitat changes on wildlife; one needs to know whether observed changes are constant. Even two replicates are better than none. The adoption of replicates may, however, prove impractical in some instances. So, are replicates absolutely essential?

An alternative approach is to focus on monitoring case studies, i.e. single examples of habitat creation or restoration. Case studies are definitely worthwhile, especially if the types of contrast discussed above can be included within them. They can act as good-practice demonstration sites, especially where the benefits can be illustrated by using the data from monitoring. Even if no replication is possible at the time, a later case study, following the same interventions and using the same monitoring protocols, may provide an effective replicate some years after. It is strongly suggested that the value of case studies could be greatly increased by forming monitoring partnerships to establish sets of related case studies, each set addressing some intervention matter in common. For example, these partnerships could be among different Wildlife Trusts, with interventions spread across several Living Landscapes. Hence, the 'replicates' might be spread over a wide geographical area. If these case studies were designed and monitored in comparable ways, some of the benefits of replicates within a single scheme could be derived.

Studies of wet-grassland management have determined the conditions that benefit breeding waders such as Lapwing and Redshank. Howard Stockdale/BTOImages

The concepts of controls and benchmarks are clearly closely linked and complementary, the former effectively looking backwards (how far have we travelled?), the latter forwards (how much farther do we have to go?). It is often questionable whether both are needed, and careful consideration should be given on a case-by-case basis. The wider value of controls and benchmarks is context-dependent and depends on the nature of the intervention. Conservationists may feel that neither a control nor a benchmark is justifiable, because both of these merely waste resources and areas of land that could be directed towards priority conservation action on the ground. An argument can sometimes be made that it is self-evident whether or not habitat creation has succeeded – have lots of 'interesting species' colonised or not? This viewpoint is understandable where there is a wholesale transformation of the landscape from one that is demonstrably poor in wildlife, for example where arable farmland is converted to wetland. In such cases, a simple benchmarking process might involve identifying the target species and then establishing systematic monitoring to track whether these species (as well as other 'interesting species') do colonise and, if so, on what scale. Even in such extreme cases, controls are not entirely without value; quantitative evidence that large-scale habitat transformation makes a big difference for wildlife is valuable in policy and educational terms.

In situations of new habitat creation, there may be value in rapidly shifting the emphasis from control to benchmark. In the early stages of habitat creation, one may wish to know how quickly the wildlife in the new habitat is diverging from the starting habitat and which species are benefiting. Very soon, however, the interest may switch to knowing whether the plants and animals are converging on a desired target state. At this point, the monitoring of the starting habitat may cease and effort be redirected on to benchmark habitat. In situations where habitat creation is given the freedom to develop in an open-ended way without any target end point, monitoring of the new habitat without reference to a benchmark would be entirely reasonable. In such cases, it would be interesting to assess how the wildlife compared with that of managed or long-established core habitat at a similar successional stage, although this may be best undertaken as a one-off exercise rather than as part of an ongoing monitoring programme.

In general, benchmark habitat may be more useful than controls in monitoring wildlife responses to habitat creation if the starting point is almost devoid of wildlife, such as arable farmland. When monitoring habitat restoration and management, however, it is often best to choose controls rather than benchmarks. Scientifically, the use of clearly defined controls is best practice because it can produce the most convincing evidence of the effects of an intervention. In the absence of controls, one cannot be sure that changes in wildlife are attributable to the treatment or intervention rather than to some other factor, e.g. changing climate, predator pressure or pollution. In the worst case, monitoring without controls may lead to false conclusions being drawn regarding the effects of conservation interventions. Benchmark habitat may itself be subject to substantial conservation intervention, resulting in 'shifting goalposts'. Furthermore, valid control habitat (poor quality, unmanaged, etc.) is generally easier to find than valid benchmark habitat. There are, in any case, other ways of establishing benchmarks or references than through the monitoring of core habitat. For example, target species may be identified that are known to be present in nearby core habitat and that have the necessary dispersal ability to colonise. The use of atlas data and other biological records can be helpful in setting targets against which outcomes can be measured. The fundamental message is that serious attention should always be given to the rigorous sampling of controls wherever possible.

Final thoughts

The exchange of information to improve the effectiveness of conservation will be increasingly important in the future. Evidence-based conservation is not a new concept; it has been strongly advocated for years (Sutherland *et al.* 2004). A growing repository of information is available at www.conservationevidence.com. This website offers '…a free authoritative information resource designed to support decisions about how to maintain and restore global biodiversity.' Evidence is periodically summarised from the established scientific literature on what conservation actions work (e.g. Sutherland *et al.* 2015), and new original observations are published in its online journal *Conservation Evidence*. Findings from the types of monitoring studies advocated in this article would make valuable contributions to the growing body of evidence – there are many gaps in knowledge, and the environment is constantly changing. In developing the concepts behind *WildSurveys*, we discovered that some practitioners seem to be unaware of the *Conservation Evidence* resource, suggesting that communication between conservation practitioners and ecologists could improve further. While much monitoring activity is happening on conservation land throughout Britain, very little of this is coordinated, or in any sense strategic, so that lessons are rarely extended beyond the site in question. Moreover, some of this monitoring is not designed in ways that can generate robust evidence. Establishing several series of case studies focusing on similar habitat interventions would be a huge step forward.

There are no 'off the shelf' monitoring solutions, because the real world is complex, irregular and messy. The development of habitat-creation initiatives and habitat networks is an ongoing process which creates challenges for monitoring in that opportunities may gradually develop and change over time. It is hoped that the thoughts presented here may help in decisions on how best to tailor monitoring to local needs, while recognising that there is much to be gained from adopting common

Redgrave and Lopham Fen NNR, Suffolk. An example of large-scale wetland-habitat restoration, undertaken in the 1990s by Suffolk Wildlife Trust, which has created a mosaic of reedswamp, sedge fen, lagoons, wet scrub and woodland. Rob Fuller

approaches to information exchange on shared problems and opportunities.

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