UK Parliament POST

POSTNOTE

POSTnote 678 October 2022

The Habitat Restoration Target

Changes in land use and management have destroyed, degraded, and fragmented habitats.[1–3] This has driven the majority of declines in wildlife over the last century in England (PN 617, PB 42).[4] Restoring habitats will deliver nature recovery.[5] This POSTnote focuses on restoration of terrestrial habitats for the new 'wider habitats target' in England.

Overview

- A habitat provides all the environmental conditions to enable a species to persist.[6]
- Agricultural intensity, built development and infrastructure, pollution, invasive species, unsustainable extraction, and climate change can degrade habitats. Ecological restoration can promote their recovery.
- Defra has consulted on the 'wider habitats' target to 'create or restore 500,000 hectares of wildlife rich habitat' outside of protected sites in England by 2042.
- Barriers to delivering targets include: the funding of management and monitoring, land ownership and access issues, and capacity/skills gaps.
- Emerging monitoring technologies for habitats and species can be used to monitor success and identify when further intervention might be needed.

Background

Land use change is the main driver of declines in the extent size, and quality of habitats resulting in global losses of biodiversity (the variety of ecosystems and species and the interactions between them, PN 617).[1,2] Loss of habitats has impacts on humans, for example by reducing carbon storage (PN 651) or wellbeing.[7–9] The United Nations recognised the urgency to restore degraded ecosystems and declared 2021–2030 as the Decade on Ecosystem Restoration.[10,11] Internationally, governments have published restoration plans,[12] including proposals for legally binding targets for the EU.[13]

Ecological restoration can prioritise outcomes at the level of ecosystems, habitats or species (Box 1). UK environmental policy focuses on habitat and species outcomes.[14–16] Restoration methods can range from minimal human interventions that encourage natural regeneration of habitats like rewilding approaches (PN 537),[17–19] to more intensive interventions,[20] such as seeding or planting vegetation.[21,22] Once drivers of degradation have been addressed, methods have been developed for restoring most habitat types found in England such as grasslands,[23] saltmarshes,[24] and heathlands (PB 48).[25] However, projects achieve varied levels of success. This results from differences in site-specific contexts such as levels of degradation, project timelines and goals, restoration methods, and funding.[5,26–28]

The UK's devolved nations are setting out various approaches to nature recovery in plans and strategies.[16,29–32] The UK Government has commitments related to habitats including: protecting 30% of UK land and sea for nature by 2030;[33] establishing a Nature Recovery Network (NRN) in England; and, restoring 75% of protected sites (by area) to favourable condition by 2042, many of which are set out in its 25 Year Environment Plan (25YEP).[16,34] Under the Environment Act 2021,[15] which introduces a post-EU membership framework for environmental governance, the UK Government is required to set legally binding targets for nature recovery in England to help achieve key objectives for nature. Defra has since consulted on a suite of targets. These include a 'long-term wider habitats' target to create or restore 500,000 hectares (ha) of wildlife rich habitat outside protected sites by 2042 (3.8% of England's land area).[35] This supports the key target to halt the decline in species abundance (the number of individuals per species) by 2030.[35] This POSTnote (alongside PB 48) focuses on restoration of terrestrial habitats for the wider habitats target in England and the challenges involved. Terrestrial habitats are usually described as including freshwater and coastal habitat types.

The Parliamentary Office of Science and Technology, Westminster, London SW1A 0AA
02072192840 post@parliament.uk parliament.uk/post @POST_UK

Box 1: Glossary

- Defra define **habitat creation** as 'establishing a wildlife-rich habitat where it is currently not present'.[35]
- The CBD define an **ecosystem** as a 'dynamic complex of species and their non-living environment, interacting as a functional unit'.[36,37] The IUCN Global Ecosystem Typology classifies ecosystems on their functions and features for nature conservation and research purposes.[38]
- There are many definitions of 'habitat',[6] but the EU Habitats Directive defines **habitats** as 'terrestrial or aquatic areas distinguished by geographic, abiotic (non-living) and biotic (living) features, whether entirely natural or semi-natural'.[39,40] Habitats are classified into **habitat types** with shared characteristics (see PB 48).
- **Recovery** has been defined as the rate and process of an ecosystem returning to a pre-disturbance state.[41] It is also used to broadly refer to an improvement in environmental condition towards a projects target state.
- **Resilience** has many definitions, but can be described as an ecosystem's ability to recover from disturbance.[42,43]
- **Restoration** is the process of promoting ecosystem recovery from a degraded state.[44]

Identifying where and what to restore

In 2010, the Lawton review made recommendations to improve England's wildlife,[45] including restoration activities to increase the area of high-quality habitats and create connections between them (PN 652).[45] Natural England research suggests core areas for wildlife of at least 5,000 ha per area are required.[46] In response, restoration projects are being set up across England (such as the landscape-scale restoration case study in Box 2).[47–49] Defra intend that priority areas for restoration are informed by mapping of the NRN and local nature recovery strategies (PN 652), due by 2024. Restoration activities will also take place outside of priority areas.

Approaches for restoring habitats

The majority of habitats in the UK are regarded as semi-natural, which means that they support complex communities of native species but have been modified by human activities for thousands of years.[50–52] They are classified into types with shared characteristics and are the main focus of restoration activities (PB 48).[53] There are many drivers of habitat degradation, including: intensive agriculture, development, pollution, non-native invasive species, unsustainable extraction and climate change. Each causes different types and levels of degradation. For example, converting a semi-natural grassland to arable farmland would result in a loss of that habitat type.[54] Invasive non-native plant species (PN 439) can outcompete native plants for space, light and nutrients, degrading that habitat.[55,56] Restoration practitioners first assess the current condition, the causes of degradation and whether they can be stopped, reversed or reduced at the site (PB 48). However, this is not always possible at the site scale. The UK Government are also setting targets to reduce some of these pressures in England, such as reducing water pollution.[57]

The next steps involve identifying the key components of the habitat that are essential for its character or that support key ecological processes. Species that are critical for the functioning of the habitat may need to be reintroduced through planting or releasing animals.[58–60] There is evidence on how to restore many habitat types found in England (PB 48) but projects can

Box 2: Case study, the Wendling Beck Partnership

Five major nature recovery programmes have been funded across England,[47] including the Wendling Beck Partnership project along the river Wensum in Norfolk. The river is a chalk stream, a rare habitat of which 85% are located in the UK.[61] The key part of the partnership, the Wendling Beck Environment project (WBEP), covers ~809 ha and is a collaboration between four farmer landowners, Norfolk Council and Norfolk Wildlife Trust, with support from a range of NGOs and Anglian Water.[62] It will be funded via combined public and private finance for the provision of benefits like flood management, carbon storage and habitat banks (Box 3). So far, 89 ha of parkland, lowland meadow, lowland fen, native woodland, and heathland habitats have been delivered. WBEP will share lessons learned with landowners covering around 10,000 ha in the river catchment.[63]

vary in their levels of success.[5] The time taken to restore different parts of habitats to reach high levels of ecological complexity and biodiversity value can vary from a few years to centuries (PB 48).[64] There is limited understanding on restoring the more complex aspects of habitats, such as soil communities (PN 601),[65] but the evidence base is developing (PB 48).[66] It is unlikely that a habitat will return to a level that matches its original state.[67] Approaches that are more intensive and complex may speed up recovery times but may be more expensive compared to natural regeneration.[68] Achieving restoration and creation targets is more challenging on heavily degraded land and where that habitat is no longer present.[27] Ongoing projects are informing best practice for heavily degraded sites by conducting research on the costs and impacts of methods used in habitat creation, for example on farmland.[69,70] Defra has indicated that ~40% of their target might eventually be met by habitat creation.[71]

Challenges for habitat restoration

Habitat restoration has been previously required under legislation such as the Habitats Regulations.[14,72,73] Some progress has been made on 25 YEP targets, but some restoration targets have been challenging.[74,75] For example, the UK Government reported falling short of its target to restore 4,700 ha of peatland between 2020 to 2021 by 1,100 ha;[75] and many protected sites are in a declining or degraded condition.[76] Meeting future targets will depend upon overcoming a number of barriers summarised below.

Financing restoration

The Green Finance Institute has reported that in England there is at least a £21-53bn shortfall in public and private sector funding to deliver all the Government's nature recovery targets over the next ten years.[77] For commitments to protect and restore biodiversity such as habitats, this gap is estimated at £9bn.[77] Defra estimate the cost of their wider habitats target as £1.13bn to 2100, with the benefits estimated at £7.85bn.[57] Projects already often have to combine funding from different sources (PN 636),[78] which in future, may include:

- **Environmental Land Management schemes** (ELMs) (PB 42).[79] There are three complementary schemes: Sustainable Farming Incentive (SFI), Local Nature Recovery (LNR) and Landscape Recovery (LR). Alongside food production, ELMs will deliver a range of environmental objectives. SFI and LR have launched and LNR remains in a pilot phase.[80,81] ELMs has the potential to create 300,000 ha of habitat by 2042.[82]

What restoration activities farmers and landowners will be paid for will remain under consideration until ELMs is fully developed around 2024-25.

- **Payments for ecosystems services** (PES). These are payments for benefits arising from the restoration of ecosystems, such as sequestering carbon under the Woodland Code.[83,84] These can be traded through formal markets or negotiated via bespoke agreements (PN 661). If PES schemes only maximise one benefit, such as carbon sequestration, and do not manage trade-offs with other benefits, there could be negative impacts on biodiversity.[85]
- **Biodiversity Net Gain (BNG)** will be mandated from November 2023 in England, requiring all Town and Country Planning Act 1990 developments to deliver a minimum 10% increase in biodiversity from that present beforehand (PN 369, PB 34).[15,86] Some local planning authorities (LPAs) may choose to raise it to 20% to deliver more nature recovery.[87] When habitats themselves cannot be restored on-site then units can be purchased directly from a landowner who will deliver the units offsite or from a 'habitat bank' (Box 3). The number of 'biodiversity units' required to compensate for the loss of the area of habitat types in their current condition is calculated using Natural England and Defra's BNG metric.[88] This could generate £100-300 million per year,[89,90] with Defra estimating that BNG could contribute 1,551 ha of habitat towards the habitats target annually (29,469 ha by 2042).[57]
- **Other funding for restoration:** grants (such as the Nature for Climate Fund),[91] charitable donations, and income related to restoration activities.

A Financing Nature Recovery UK report, informed by 300 experts in the business, farming, and environmental sectors, identified measures to increase nature recovery investment.[92] They included updating tax and land valuations of restored land, establishing accreditation schemes for environmental benefits, implementing outcome-based monitoring and developing a BNG project and credit registry system.[92]

Capacity and skills

The Environmental Audit Committee (EAC) reported that a shortage of skilled ecologists and environmental land managers employed in the field is a significant barrier to the delivery of the Government's long term environmental targets.[93,94] A Defra commissioned report stated that only 5% of the 192 Local Planning Authorities that responded had the ecological skills and capacity needed,[95] following historic losses of this capacity.[96] The National Audit Office reported that funding cuts and restructuring at Natural England has resulted in fluctuations of staff numbers and their ability to monitor the recovery of protected sites.[97] There are also studies and reviews suggesting trusted, good quality advice improves land manager participation in and quality of engagement with agri-environment schemes, including habitat restoration.[98–102] For example, Defra-commissioned research into provision of government agri-environmental advice found 'high levels of agreement that scheme advice leads to beneficial outcomes', which was linked to 'high overall and individual schemes levels of appreciation among farmers'.[103] Other research has found a link between high quality advice and optimal environmental outcomes.[104,105,106] The House of Lords Science and Technology Select Committee recommended that the Government establish a training programme to increase ecological skills capacity.[111]

Box 3: Habitat banks
Habitat banks are areas of land where habitats are restored or created. They are established by landowners, LPAs, NGOs and private companies to deliver BNG units off-site. There are incentives within the BNG metric to set up habitat banks within priority areas identified in the LNRS, to deliver higher gains for biodiversity. Habitat banks will need to be registered in the BNG site register which is being developed by Natural England.[15,107] Voluntary legally binding conservation covenants could be set up to link landowners with 'responsible bodies', which will be designated by the Secretary of State.[108] Either through a covenant or planning obligation, units are legally secured for a minimum of 30 years. Some existing providers, like the Environment Bank,[109] monitor the ecology and physical characteristics of their habitat banks annually. While management and monitoring plans will be submitted to the register, there is no standard for monitoring or an accreditation scheme for projects to ensure a level playing field between providers.[110]

Accessing priority land

Defra stated that restoring habitats in rural areas is needed to deliver nature recovery targets.[35] However, this may be in competition with other land uses including food and timber production; development of infrastructure; renewable energy production or carbon storage (PB 42). State acquisition of land was proposed by experts advising Defra on the measures needed to achieve the wider habitats target,[35] but this approach is largely opposed by rural landowners.[112] The NFU suggested that meeting the targets could impact food production.[113] If this leads to increased food imports without other policy protections in place, it could lead to nature loss in more biodiverse habitats in the tropics.[114,115] Defra have committed to publish a land use framework in 2023 to manage these trade-offs,[116] but land uses are not yet considered in the national spatial planning system.

Monitoring restoration progress

Monitoring is essential to understand how successful restoration activities have been at achieving targets at the site and national scale.[117] An accurate assessment of the ecological condition of the area before restoration begins is needed to identify best approaches and monitor restoration progress.[59] Projects often determine goals and target states to guide restoration activities, such as establishing diverse vegetation.[118,119] Often recovery in the condition or quality of habitats is tracked by identifying biodiversity increases, the increasing similarity of the site to high-quality intact reference habitats or indicators that show the recovery of natural processes.[117] No single metric can be used to measure the condition of a habitat. Multiple measures (such as the number of species present, soil pH, age or height of trees) may need to be recorded. These are referred to as proxies or indicators and can provide information on the state of a single habitat component or the conditions of the whole habitat or ecosystem (PN 644). Projects may conduct additional monitoring to track the impacts of restoration activities on a particular species, whether a habitat is naturally functioning, and outputs of natural processes, such as carbon storage levels (PN 668). An investigation into a wetland restoration monitoring project reported that monitoring and evaluating restoration is complex, expensive and requires a range of expertise.[120]

Setting baselines, targets and goals

The Society for Ecological Restoration sets global restoration practice recommendations. It states that targets should be informed by native reference habitat sites, while allowing for adaptation to ongoing environmental change.[44] At the site and landscape-scale, information on native reference habitat sites may be obtained from historical archives,[121,122] or from contemporary habitat sites in favourable condition. However, for some habitats the pre-disturbance reference condition may be unknown due to a lack of data prior to their degradation. Differences in geography, geology and historic uses can also make it challenging to identify suitable contemporary comparisons for some habitats. Some commentators argue that in a UK context, expert judgement could be appropriate for determining targets for restoration when pre-disturbance conditions are unknown.[123] In practice, project targets are based on a combination of ecological, social, and financial factors. A review of 25 large scale UK and EU-based restoration case studies conducted by NatureScot found the targets and goals of restoration projects are highly variable and often change over time to meet the expectations of funders.[78] As project scale goals and targets are so varied, assessing success in delivering nature restoration at the country scale is complex.

The Government intends to assess progress towards the habitats target through action-based assessment that will record whether an area of land is signed up to a restoration scheme such as ELMs.[35] This will not identify whether the restoration action was successful nor if long-term increases in habitat area are secured. Whether a loss in habitat area occurs will also not be monitored nationally, so overall gains or losses in habitats will not be measured. The Office for Environmental Protection (OEP) has criticised the target stating that this makes it 'weak from a nature recovery perspective'.[124] The OEP highlight that despite their importance, there is no target to improve habitat quality and connectivity between habitats (Box 4) as mentioned in the 25YEP.[16] This is due to a historic lack of data availability on habitat condition outside of protected sites. An outcome indicator (PN 644, PB 41), to monitor habitat quantity, quality and connectivity, is being developed. This may support monitoring the wider habitats target, but does not correspond directly to any targets being consulted on.[125]

Novel groups of species in habitats

Some researchers recommend that when there is no relevant habitat reference state to measure against, targets should instead focus on whether key ecological processes are re-established, and the complexity of habitats increased (PB 48). This should improve their resilience to environmental change (Box 1).[126,127] With climate change, habitats and the communities of species within them will be affected by changes in weather, such as increased rainfall, temperature and increasing frequency of extreme events. These could result in changes in species behaviour, such as migration patterns, as well as direct impacts on habitats (PN 679).[128] Restoring self-regulating natural processes is also a potential restoration target that is often used by rewilding projects (PN 537).[129]

However, this approach can be controversial due to unpredictable outcomes of restoration.[130,131] This is because the restored habitats may include new combinations of species that could include species non-native to the UK, and are referred to as novel ecosystems, communities or habitats.[137] While such changes have occurred historically, existing habitat type classifications commonly used in UK surveys are often fixed systems, with some exceptions (PB 48). If novel ecosystems were accepted, it would be difficult to assess their value ecologically and economically within existing environmental frameworks. Some researchers suggest this could lead to novel ecosystems lowering environmental standards and increasing the risk of new invasive non-native species becoming established (PN 673).[137,138] Others argue that novel ecosystems are inevitable and can support valued wildlife.[138–141]

Box 4: Restoring connectivity, B-lines for pollinators

In the UK, ~97% of wildflower-rich grassland has been lost over the last 100 years.[132] This has contributed to significant declines in insect numbers (PN 619), such as a 58.5% decrease in flying insects between 2004 and 2021.[133] Buglife has mapped a UK wide network of priority areas for wildflower habitat restoration and creation with an aim of increasing pollinator abundance.[134] Restoration along 'B-lines', creates stepping stones to connect existing wildflower rich habitat. To date over 2,500 ha has been restored or created within the network.[135] The West of England B-Line, a collaboration between Buglife and the Avon Wildlife Trust, has alone restored 140 ha of wildlife rich habitat with the assistance of 743 days of volunteer time.[136] However, the current funding landscape provides little support for training and coordination of large volunteer groups, which may be needed for the long-term monitoring of large-scale restoration projects.

Monitoring technology

Botanical and habitat surveys by expert ecologists are the most common approach to monitoring restoration outcomes. But a lot of UK biodiversity monitoring relies on skilled volunteers (PN 644)[142] with habitat monitoring systems developed to support them.[143] However, small or hard to identify species can be missed and these surveys are time consuming to conduct across large areas (PN 644, PB 41). Existing and new technologies that could assist with monitoring are:

- **Sampling environmental DNA**: Genetic material in environmental samples can be analysed to identify large numbers of species.[144] Environmental DNA has been used to monitor restoration projects,[145–147] including monitoring the recovery of groups of fungi and bacteria which are often omitted from traditional surveys.[148–150]
- **Acoustic monitoring**: Inexpensive remote sound recorders can monitor animals in a restored area, including at night or underwater.[151–153] Manual processing of acoustic data can be time consuming, but researchers are using machine learning to automate species identification.[154]
- **Remote sensing**: Satellite and drone derived data can be used to monitor vegetation cover, structure and ecosystem function of restored sites over large areas.[155–157]
- **Apps**: A range of apps have been developed to support land managers and NGOs in species identification, planning restoration and conducting ecological surveys.[158–161]
- **Artificial intelligence** is being used to inform decision making,[162] such as in trials to remotely track the spread of invasive species and diseased trees along train tracks, to indicate when management action is needed.[163]

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Rachael Holmes for researching this briefing, to NERC for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth.

References

1. Foley, J. A. *et al.* (2005). Global Consequences of Land Use. *Science*, Vol 309, 570–574.
2. Tilman, D. *et al.* (2017). Future threats to biodiversity and pathways to their prevention. *Nature*, Vol 546, 73–81.
3. Banks-Leite, C. *et al.* (2020). Countering the effects of habitat loss, fragmentation, and degradation through habitat restoration. *One Earth*, Vol 3, 672–676.
4. Hayhow, D. *et al.* (2019). State of Nature 2019. The State of Nature partnership.
5. Suding, K. N. (2011). Toward an Era of Restoration in Ecology: Successes, Failures, and Opportunities Ahead. *Annu. Rev. Ecol. Evol. Syst.*, Vol 42, 465–487.
6. Jung, M. *et al.* (2020). A global map of terrestrial habitat types. *Sci. Data*, Vol 7, 256. Nature Publishing Group.
7. Harrison, P. A. *et al.* (2014). Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosyst. Serv.*, Vol 9, 191–203.
8. Martin, L. *et al.* (2020). Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *J. Environ. Psychol.*, Vol 68, 101389.
9. Dobson, A. *et al.* (2006). Habitat Loss, Trophic Collapse, and the Decline of Ecosystem Services. *Ecology*, Vol 87, 1915–1924.
10. United Nations General Assembly (2019). Resolution: 73/284. United Nations Decade on Ecosystem Restoration (2021–2030).
11. United Nations (2022). UN Decade on Restoration. *UN Decade on Restoration*.
12. Sewell, A. *et al.* (2020). Goals and commitments for the restoration decade: A global overview of countries' restoration commitments under the Rio Conventions and other pledges. PBL Netherlands Environmental Assessment Agency.
13. Directorate-General for Environment (2022). *Proposal for a Nature Restoration Law*. European Commission.
14. The Conservation of Habitats and Species Regulations 2017 (S.I. 2008/301.). Queen's Printer of Acts of Parliament.
15. Environment Act 2021. Queen's Printer of Acts of Parliament.
16. Defra (2018). 25 Year Environment Plan. HM Government.
17. Perino, A. *et al.* (2019). Rewilding complex ecosystems. *Science*, Vol 364, eaav5570. American Association for the Advancement of Science.
18. Redhead, J. W. *et al.* (2014). The natural regeneration of calcareous grassland at a landscape scale: 150 years of plant community re-assembly on Salisbury Plain, UK. *Appl. Veg. Sci.*, Vol 17, 408–418.
19. Garbutt, A. *et al.* (2008). The natural regeneration of salt marsh on formerly reclaimed land. *Appl. Veg. Sci.*, Vol 11, 335–344.
20. Atkinson, J. *et al.* (2020). "Active" and "passive" ecological restoration strategies in meta-analysis. *Restor. Ecol.*, Vol 28, 1032–1035.
21. Fuentes-Montemayor, E. *et al.* (2022). The long-term development of temperate woodland creation sites: from tree saplings to mature woodlands. *For. Int. J. For. Res.*, Vol 95, 28–37.
22. Willoughby, I. H. *et al.* (2019). Direct seeding of birch, rowan and alder can be a viable technique for the restoration of upland native woodland in the UK. *For. Int. J. For. Res.*, Vol 92, 324–338.
23. Blakesley, D. *et al.* (2016). *Grassland Restoration and Management.* Pelagic Publishing Ltd.
24. Hudson, R. *et al.* (2021). Saltmarsh restoration handbook: UK and Ireland. Environment Agency.
25. Day, J. C. *et al.* (2003). *A Practical Guide to the Restoration and Management of Lowland Heathland.* The Royal Society for the Protection of Birds.
26. Cortina-Segarra, J. *et al.* (2021). Barriers to ecological restoration in Europe: expert perspectives. *Restor. Ecol.*, Vol 29, e13346.
27. Maron, M. *et al.* (2012). Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biol. Conserv.*, Vol 155, 141–148.
28. Watts, K. *et al.* (2020). Ecological time lags and the journey towards conservation success. *Nat. Ecol. Evol.*, Vol 4, 304–311. Nature Publishing Group.
29. The Department of Agriculture, Environment & Rural Affairs (DAERA) (2021). Environment Strategy Consultation.
30. NatureScot (2022). Scotland's Biodiversity Strategy 2022-2045. *NatureScot*.
31. Scottish Government (2020). Scottish biodiversity strategy post-2020: statement of intent.
32. Welsh Government (2020). Nature recovery action plan.
33. HM Government (2020). PM commits to protect 30% of UK land in boost for biodiversity. *GOV.UK*.
34. Defra (2022). Nature Recovery Network.
35. Defra (2022). Biodiversity Terrestrial and Freshwater Targets. 154. Department for Environment, Food and Rural Affairs.
36. The Biodiversity information system for Europe (2022). Ecosystems and their services.
37. United Nations (1992). Convention on Biological Diversity - Article 2. Secretariat of the Convention on Biological Diversity.
38. Global Ecosystem Typology.
39. European Environment Agency (2022). An introduction to habitats.
40. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *OJ L*.
41. Kelly, J. R. *et al.* (1990). Indicators of ecosystem recovery. *Environ. Manage.*, Vol 14, 527–545.
42. Dakos, V. *et al.* (2022). Ecological resilience: what to measure and how. *Environ. Res. Lett.*, Vol 17, 043003. IOP Publishing.
43. Chambers, J. C. *et al.* (2019). Operationalizing Ecological Resilience Concepts for Managing Species and Ecosystems at Risk. *Front. Ecol. Evol.*, Vol 7,
44. Gann, G. D. *et al.* (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restor. Ecol.*, Vol 27, S1–S46.
45. Lawton, J. *et al.* (2010). *Making Space for Nature: A review of England's Wildlife Sites and Ecological Network.* 119. Report to Defra.
46. Natural England (2020). Nature Networks Evidence Handbook - NERR081. Natural England.
47. Defra *et al.* (2022). Five landmark nature recovery projects launched to protect wildlife and improve public access to nature. *GOV.UK*.
48. RSPB (2022). Landscape Scale Conservation: Sites We're Working On.
49. Trust, W. (2022). Landscape-Scale Conservation. *Woodland Trust*.
50. Woodbridge, J. *et al.* (2014). The impact of the Neolithic agricultural transition in Britain: a comparison of pollen-based land-cover and archaeological 14C date-inferred population change. *J. Archaeol. Sci.*, Vol 51, 216–224.
51. Fyfe, R. M. *et al.* (2015). From forest to farmland: pollen-inferred land cover change across Europe using the pseudobiomization approach. *Glob. Change Biol.*, Vol 21, 1197–1212.
52. Roberts, N. *et al.* (2018). Europe's lost forests: a pollen-based synthesis for the last 11,000 years. *Sci. Rep.*, Vol 8, 716. Nature Publishing Group.

53. JNCC (2019). Terrestrial habitat classification schemes.
54. Petit, S. *et al.* (2006). Predicting the risk of losing parcels of semi-natural habitat to intensive agriculture. *Agric. Ecosyst. Environ.*, Vol 115, 277–280.
55. Martin, P. A. *et al.* (2020). Management of UK priority invasive alien plants: a systematic review protocol. *Environ. Evid.*, Vol 9, 1.
56. Langmaier, M. *et al.* (2020). A Systematic Review of the Impact of Invasive Alien Plants on Forest Regeneration in European Temperate Forests. *Front. Plant Sci.*, Vol 11,
57. Defra (2022). Environment Act targets: Summary of evidence and approach. Defra.
58. The Wildlife Trust for Lancashire, Manchester and North Merseyside (2022). Great Manchester Wetlands Species Reintroduction Project.
59. Holl, K. D. (2020). *Primer of ecological restoration.* Island Press.
60. Shaw, N. *et al.* (2020). Seed use in the field: delivering seeds for restoration success. *Restor. Ecol.*, Vol 28, S276–S285.
61. Environment Agency (2021). New strategy launched to protect chalk streams. *GOV.UK*.
62. (2022). Wendling Beck Environment Project.
63. Anderson, G. (2022). Personal Communication. WBEP.
64. Maskell, L. *et al.* (2014). Restoration of natural capital: review of evidence. 20. Final Report to the Natural Capital Committee.
65. De Deyn, G. B. *et al.* (2021). The role of soils in habitat creation, maintenance and restoration. *Philos. Trans. R. Soc. B Biol. Sci.*, Vol 376, 20200170.
66. RestREco Project (2022). Restoring Resilient Ecosystems.
67. Benayas, J. M. R. *et al.* (2009). Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis. *Science*, Vol 325, 1121–1124. American Association for the Advancement of Science.
68. Broughton, R. K. *et al.* (2021). Long-term woodland restoration on lowland farmland through passive rewilding. *PLOS ONE*, Vol 16, e0252466. Public Library of Science.
69. The Allerton Project (2022). Boosting biodiversity.
70. Robson, H. *et al.* (2022). Restoring lost farmland ponds. *WWT*.
71. Dijk, F. (2022). Personal Communication. Defra.
72. The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 (S.I. 2017/1012.). Queen's Printer of Acts of Parliament.
73. Defra (2021). Changes to the Habitats Regulations 2017. *GOV.UK*.
74. Defra (2022). 25 Year Environment Plan Annual Progress Report - April 2021 to March 2022. 63.
75. Defra (2021). Annual reports and accounts 2020-2021. Defra.
76. Starnes, T. *et al.* (2021). The extent and effectiveness of protected areas in the UK. *Glob. Ecol. Conserv.*, Vol 30, e01745.
77. GFI *et al.* (2021). The finance gap for UK nature.
78. Underwood, S. *et al.* Mainstreaming Large Scale Nature Restoration. NatureScot.
79. Rural Payments Agency *et al.* (2021). Environmental Land Management schemes: overview. *GOV.UK*.
80. Defra (2022). Sustainable Farming Incentive: full guidance. *GOV.UK*.
81. Defra *et al.* (2022). Projects of Landscape Recovery scheme announced. *GOV.UK*.
82. (2022). Environmental land management schemes: outcomes. *GOV.UK*.
83. Defra (2013). *Payments for ecosystem services: A best practice guide.* 85. Defra.
84. UK Woodland Carbon Code (2019). Home - UK Woodland Carbon Code.
85. Bullock, J. M. *et al.* (2011). Restoration of ecosystem services and biodiversity: conflicts and opportunities. *Trends Ecol. Evol.*, Vol 26, 541–549.
86. Defra (2022). Consultation on Biodiversity Net Gain Regulations and Implementation.
87. Lichfield District Council (2016). Biodiversity & development: supplementary planning document. Lichfield District Council.
88. Defra *et al.* (2021). Biodiversity metric: calculate the biodiversity net gain of a project or development. *GOV.UK*.
89. Trémolet, S. *et al.* (2021). Biodiversity net gain in England: Developing effective market mechanisms. The Nature Conservancy.
90. Dickie, I. *et al.* (2021). Biodiversity Net Gain: Market Analysis Study - NR0181. EFTEC.
91. Defra (2021). Nature for people, climate and wildlife. *GOV.UK*.
92. Young, D. *et al.* (2022). Financing Nature Recovery UK: Scaling Up High-Integrity Environmental Markets Across the UK.
93. House of Commons *et al.* (2021). Biodiversity in the UK: bloom or bust? 144. House of Commons.
94. House of Commons *et al.* (2021). Green Jobs. House of Commons.
95. Snell, L. *et al.* (2022). *Survey of Local Planning Authorities and their abiility to deliver biodiversity net gain in England: Do local planning authorities (LPAs) currently have the necessary expertise and capacity?* Association of Local Government Ecologists.
96. Oxford, M. (2013). Ecological capacity and competence in English planning authorities: What is needed to deliver statutory obligations fro biodiversity? Association of Local Government Ecologists.
97. Davies (2022). *Environmental compliance and enforcement.* 44. National Audit Office.
98. Ahnström, J. *et al.* (2009). Farmers and nature conservation: What is known about attitudes, context factors and actions affecting conservation? *Renew. Agric. Food Syst.*, Vol 24, 38–47. Cambridge University Press.
99. AIC (2013). The value of advice report. Agricultural Industries Confederation Ltd.
100. Ingram, J. (2008). Agronomist–farmer knowledge encounters: an analysis of knowledge exchange in the context of best management practices in England. *Agric. Hum. Values*, Vol 25, 405–418.
101. Rose, R. J. *et al.* (2000). Changes on the heathlands in Dorset, England, between 1987 and 1996. *Biol. Conserv.*, Vol 93, 117–125.
102. Vrain, E. *et al.* (2016). The roles of farm advisors in the uptake of measures for the mitigation of diffuse water pollution. *Land Use Policy*, Vol 54, 413–422.
103. Quadrant Consultants and BMG Research (2012). Provision of Advice to Farmers: A Survey of Scheme Effectiveness. Defra.
104. Smallshire, D. *et al.* (2004). Policy into practice: the development and delivery of agri-environment schemes and supporting advice in England. *Ibis*, Vol 146, 250–258.
105. Environment Agency (2014). Catchment Sensitive Farming Evaluation Report – Water Quality Phases 1 to 4 (2006-2018) - NE731. Natural England.
106. Christie, A. P. *et al.* (2022). A practical conservation tool to combine diverse types of evidence for transparent evidence-based decision-making. *Conserv. Sci. Pract.*, Vol 4, e579.
107. Hughes, M. (2021). Biodiversity Net Gain – more than just a number.
108. Defra (2019). Summary of responses and government response. *GOV.UK*.

109. Environment Bank (2022). Biodiversity Net Gain (BNG) Credits.
110. Toovey, E. (2022). Personal Communication. Environment Bank.
111. Science and Technology Select Committee (2022). *Nature-based solutions: rhetoric or reality? - The potential contribution of nature-based solutions to net zero in the UK*. 82. House of Lords.
112. Country Land and Business Association (CLA) (2022). *Environmental targets consultation response*. 16. Countryside Landowners Association.
113. National Farmers Union (2022). Defra consultation on environmental targets Response of the National Farmers' Union of England & Wales. NFU.
114. Lim, F. K. S. *et al.* (2017). Perverse Market Outcomes from Biodiversity Conservation Interventions. *Conserv. Lett.*, Vol 10, 506–516.
115. Fuchs, R. *et al.* (2020). Europe's Green Deal offshores environmental damage to other nations. *Nature*, Vol 586, 671–673.
116. Defra (2022). Government food strategy.
117. Wortley, L. *et al.* (2013). Evaluating Ecological Restoration Success: A Review of the Literature. *Restor. Ecol.*, Vol 21,
118. Prach, K. *et al.* (2019). A primer on choosing goals and indicators to evaluate ecological restoration success. *Restor. Ecol.*, Vol 27, 917–923.
119. Rieger, J. *et al.* (2014). *Project planning and management for ecological restoration.* Island Press.
120. Hughes, F. *et al.* (2016). The challenges of integrating biodiversity and ecosystem services monitoring and evaluation at a landscape-scale wetland restoration project in the UK. *Ecol. Soc.*, Vol 21, The Resilience Alliance.
121. McCarroll, J. *et al.* (2016). Using palaeoecology to advise peatland conservation: An example from West Arkengarthdale, Yorkshire, UK. *J. Nat. Conserv.*, Vol 30, 90–102.
122. Egan, D. *et al.* (2005). *The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems*. Island Press.
123. CIEEM Ecological Restoration and Habitat Creation Special Interest Group (2022). Personal Communication.
124. Office for Environmental Protection (2022). OEP response to consultation on environmental targets. Office for Environmental Protection.
125. Defra (2022). Indicator: D1 - Quantity, quality and connectivity of habitats - Outcome indicator framework for the 25 Year Environment Plan.
126. Bullock, J. M. *et al.* (2022). Future restoration should enhance ecological complexity and emergent properties at multiple scales. *Ecography*, Vol 2022,
127. Moreno-Mateos, D. *et al.* (2020). The long-term restoration of ecosystem complexity. *Nat. Ecol. Evol.*, Vol 4, 676–685.
128. Harris, J. A. *et al.* (2006). Ecological Restoration and Global Climate Change. *Restor. Ecol.*, Vol 14, 170–176.
129. Carver, S. *et al.* (2021). Guiding principles for rewilding. *Conserv. Biol.*, Vol 35, 1882–1893.
130. Murcia, C. *et al.* (2014). A critique of the 'novel ecosystem' concept. *Trends Ecol. Evol.*, Vol 29, 548–553.
131. Hobbs, R. J. *et al.* (2014). Novel ecosystems: concept or inconvenient reality? A response to Murcia et al. *Trends Ecol. Evol.*, Vol 29, 645–646. Elsevier.
132. Plantlife (2018). Action now for species-rich grasslands. Plantlife.
133. Ball, L. *et al.* (2022). Bugs Matter Citizen Science Survey 2021. Buglife, Kent Wildlife Trust.
134. Buglife (2022). B-lines: Insect superhighways. Buglife.
135. Robbins, J. (2022). Personal Communication. Buglife.
136. West of England B-Lines - Buglife projects. *Buglife*.
137. Hobbs, R. J. *et al.* (2009). Novel ecosystems: implications for conservation and restoration. *Trends Ecol. Evol.*, Vol 24, 599–605.
138. Miller, J. R. *et al.* (2016). What's wrong with novel ecosystems, really? *Restor. Ecol.*, Vol 24, 577–582.
139. Perring, M. P. *et al.* (2013). Incorporating novelty and novel ecosystems into restoration planning and practice in the 21st century. *Ecol. Process.*, Vol 2, 18.
140. Perring, M. *et al.* (2013). Novel Urban Ecosystems and Ecosystem Services. in *Novel ecosystems: intervening in the new world order*. 310–325. John Wiley & Sons, Ltd.
141. Backstrom, A. C. *et al.* (2018). Grappling with the social dimensions of novel ecosystems. *Front. Ecol. Environ.*, Vol 16, 109–117.
142. Burns, F. *et al.* (2018). An assessment of the state of nature in the United Kingdom: A review of findings, methods and impact. *Ecol. Indic.*, Vol 94, 226–236.
143. Crick, H. Q. P. (1992). A bird-habitat coding system for use in Britain and Ireland incorporating aspects of land-management and human activity. *Bird Study*, Vol 39, 1–12. Taylor & Francis.
144. Ruppert, K. M. *et al.* (2019). Past, present, and future perspectives of environmental DNA (eDNA) metabarcoding: A systematic review in methods, monitoring, and applications of global eDNA. *Glob. Ecol. Conserv.*, Vol 17, e00547.
145. Fernandes, K. *et al.* (2018). DNA metabarcoding—a new approach to fauna monitoring in mine site restoration. *Restor. Ecol.*, Vol 26, 1098–1107.
146. Breed, M. *et al.* (2019). The potential of genomics for restoring ecosystems and biodiversity. *Nat. Rev. Genet.*, Vol 20,
147. van der Heyde, M. *et al.* (2021). Scat DNA provides important data for effective monitoring of mammal and bird biodiversity. *Biodivers. Conserv.*, Vol 30, 3585–3602.
148. Gellie, N. J. C. *et al.* (2017). Revegetation rewilds the soil bacterial microbiome of an old field. *Mol. Ecol.*, Vol 26, 2895–2904.
149. Yan, D. *et al.* (2018). High-throughput eDNA monitoring of fungi to track functional recovery in ecological restoration. *Biol. Conserv.*, Vol 217, 113–120.
150. Liddicoat, C. *et al.* (2022). Next generation restoration metrics: Using soil eDNA bacterial community data to measure trajectories towards rehabilitation targets. *J. Environ. Manage.*, Vol 310, 114748.
151. Borker, A. *et al.* (2019). Do soundscape indices predict landscape scale restoration outcomes? A comparative study of restored seabird island soundscapes. *Restor. Ecol.*, Vol 28,
152. Lamont, T. A. C. *et al.* (2022). The sound of recovery: Coral reef restoration success is detectable in the soundscape. *J. Appl. Ecol.*, Vol 59, 742–756.
153. Greenhalgh, J. A. *et al.* (2021). Ecoacoustics as a novel tool for assessing pond restoration success: Results of a pilot study. *Aquat. Conserv. Mar. Freshw. Ecosyst.*, Vol 31, 2017–2028.
154. The Endangered Landscapes Programme (2022). Acoustic Monitoring.
155. Pettorelli, N. *et al.* (2018). Satellite remote sensing of ecosystem functions: opportunities, challenges and way forward. Remote sensing in ecology and conservation, vol 4 (2), p 71-93
156. Schulte to Bühne, H. *et al.* (2022). Monitoring rewilding from space: The Knepp estate as a case study. *J. Environ. Manage.*, Vol 312, 114867.
157. McKenna, P. B. *et al.* (2022). Measuring and monitoring restored ecosystems: Can remote sensing be applied to the ecological recovery wheel to inform restoration success? *Restor. Ecol.*, Vol n/a, e13724.
158. UKCEH (2020). E-Surveyor.

159. eCountability Ltd (2022). Introducing the UKHab Survey App.
160. Achieving Sustainable Agricultural Systems (ASSIST) (2020). E-Planner.
161. PlantSnap (2022). Plant Identifier App.
162. Li, V. O. K. *et al.* (2021). AI for Social Good: AI and Big Data Approaches for Environmental Decision-Making. *Environ. Sci. Policy*, Vol 125, 241–246.
163. UKCEH (2022). AI holds key to improving biodiversity by Britain's railway tracks | UK Centre for Ecology & Hydrology.