Habitats

Heathlands

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Rebuilding nature
Good practice guidance for ecological restoration

CIEEM

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

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

Accompanying the five Overarching Topics are the habitat specific documents applicable to ecological restoration projects.

Habitat Description

Heathland, also referred to as dwarf shrub heath, is defined as vegetation that has a greater than 25% cover of plant species from the heath family (ericoids), dwarf gorse *Ulex minor* or western gorse *Ulex gallii* (UKHab Ltd., 2023; Fossitt, 2000). Heathlands occur on well-drained or poorly-drained, nutrient-poor, acid soils in both the lowlands and uplands, often found in a mosaic of habitats with gorse *Ulex europaeus* scrub, acid grassland, mire, bracken *Pteridium aquilinum*, and bare ground. Lichens are an important component in some heaths. Three main heathland habitat types are classified in the UK: lowland heath, upland heath and montane heath (**Table 1**), with distinct dry and wet heath communities both in the lowlands and uplands. In Ireland four categories are recognised: dry siliceous heath, dry calcareous heath, wet heath and montane heath (**Table 2**).

In lowland Britain and Ireland, dry heath is found on well-drained sandy and gravelly mineral soils. Dry heath can occur in chalk or limestone areas, or on stabilised sand dunes, where leaching of well-drained soils results in an acidic layer at the surface. In such situations, plants typical of acid soils can occur alongside calcareous species. Wet heath occurs on moist or waterlogged soils with a shallow layer of peat. Upland heathland, also called moorland, occurs above 300 m in altitude, is subject to high rainfall, and can have free-draining or peaty soils. For the purpose of this guidance, heathland does not include bogs, which are defined as wetlands that occur on deep peat (>30 cm) with species characteristic of peat-building, i.e. bog-mosses *Sphagnum* spp., present (see Habitat Section - Bogs). Montane heaths encompass dwarf herb communities in the montane zone, above the natural treeline, often above 600 m in altitude.

Figure 1.

Cattle grazing lowland heath, Purbeck, Dorset.

Photo credit: Phil Putwain

Characteristic species of heathland in the UK and Ireland are heather *Calluna vulgaris* (hereafter termed *Calluna*), bell heather *Erica cinerea*, cross-leaved heath *E. tetralix*, dwarf gorse, western gorse, bilberry *Vaccinium myrtillus*, crowberry *Empetrum nigrum* and bearberry *Arctostaphylos uva-ursi*. Dorset heath *Erica ciliaris* and Cornish heath *E. vagans* occur in the South West of Britain and Ireland, and Irish heath *E. erigena,* Mackay's heath *E. mackaiana* and St Dabeoc's heath *Daboecia cantabrica* are found in the West of Ireland.

Heathland can form a mosaic with acid grassland where grazing or disturbance is significant, and bare ground can be an important feature adding to habitat diversity. Lichens and bryophytes are often an element of heathland communities and can be very abundant. A range of invertebrates, reptiles, birds and mammals are adapted to the habitat and depend on it. Heathland is a dynamic community subject to continual change as heather species mature and regenerate, and colonisation of tree saplings, gorse and bracken can result in succession to scrub and woodland if not managed. Except in the case of montane or coastal heaths in very exposed environments, it is reliant on disturbance for its existence. It is widely acknowledged that much of the lowland heaths originated through prehistoric clearance of woodlands, and the habitat has been kept open through continued exploitation, e.g. cutting trees, gorse and heather turves for fuel or wood products, burning for game management, and livestock grazing. In some upland areas, browsing by wild deer helps naturally suppress tree growth.

Traditional heathlands were anthropogenic open landscapes with few trees and relatively homogenous dwarf shrub vegetation that existed as an arrested succession, a resource intensively exploited by humans, although sometimes resulting from an extreme climatic exposure.

Table 1: UK heathland habitat classification and vegetation communities (from UKHab Ltd, 2023)

UKHab Level 3 habitat type	UKHab Level 4 habitat type	UKHab Level 5 habitat type	Corresponding NVC communities
h1 Dwarf shrub heath	h1a Lowland heathland	h1a5 Dry heaths; lowland (H4030)	H1, H2, H8, H9 (dry heath) H3, H4 (transition to damper heaths) H7, H11 (maritime and dune heath)
		h1a6 Dry coastal heaths with Cornish heath (H4040)	H4c, H6
		h1a7 Wet heathland with cross-leaved heath; lowland (H4010)	H5, M15, M16
		h1a8 Wet heathland with Dorset heath and cross-leaved heath (H4020)	H3, H4c
	h1b Upland heathland	h1b5 Dry heaths; upland (H4030)	H10, H12, H13, H14, H16, H20, H21
		h1b6 Wet heathland with cross-leaved heath; upland (H4010)	M15
	h1c Mountain heaths and willow scrub	h1c5 Alpine and subalpine heaths (H4060)	H13, H14, H15, H17, H19, H20, H22 (montane heaths) (also H10, H12, H16, H18, H21)

Table 2: Ireland heathland habitat classification and vegetation communities (from Perrin, 2024)

Irish Habitat Classification category	Irish Habitat Classification habitat type	Corresponding IVC communities
HE Heath	HE1 Dry calcareous heaths	HE1A
	HE2 Dry siliceous heaths	HE2A, HE2B, HE2C, HE2D, HE2E
	HE3 Montane heaths	HE3A, HE3B, HE3C, HE3D, HE3E, HE3F, HE3G
	HE4/BG2 Wet heaths	HE4A, HE4B, HE4C, HE4D, HE4E, HE4F

Context

Distribution

Lowland heathland is distributed throughout lowland Britain and Ireland wherever suitable soils occur. At higher altitudes (above 300 m), upland heathland is found from Cornwall and Dartmoor to Wales, the Peak District, the Pennines, North York Moors, Lake District, Northumberland, Lowland Scotland, Highland Scotland and Northern Ireland. In the Republic of Ireland, upland heathland occurs on the mountains of Donegal, Mayo, Wicklow and Kerry as well as other locations.

In continental Europe, suitable soil and climate conditions for heathland occur from southern Scandinavia to Portugal, including northern Germany, the Netherlands, Belgium, Brittany and northern Spain. Montane heathlands are also found in central Europe.

Losses

There is thought to have been 30,000 km^2 of heathland in northwestern Europe in the 19th Century. Only 4,000 km^2 survives today, a loss of 86%. The extent of lowland heathland has significantly reduced in the recent past. In the UK, only 16% of the area of lowland heathland present in 1800 remained in 2002 (English Nature, 2002); and heather cover has declined in c. 90% of upland heathland sites in Britain and Ireland in the last 200 years (Stevenson & Thompson, 1993).

Threats

Whereas in the past heathland habitats were either too valuable as a resource, too poor for agricultural use, or just too remote to human settlement to be overexploited, changes in land use and the expansion of settlements have put pressure on heathlands. This process started in the early medieval period and was exacerbated with the Enclosures Acts during which open common land was fenced and converted to agriculture. This has continued through further exploitation during the world wars of the 20th Century, intensification of agriculture, expansion of housing developments, large-scale forestry planting, and natural ecological succession to scrub and woodland caused by neglect and mismanagement. Lowland heathland is threatened by loss of extent, fragmentation and degradation. The habitat is not resilient to threats and is highly vulnerable to loss of distinctiveness and therefore ecological value. Maritime heaths are threatened by erosion. Dune heath is particularly vulnerable to disturbance that causes intermixing of calcareous sands with the thin, upper layer of acid sand. Other threats include bracken invasion, rising sea levels, and increased nutrient availability.

Current land uses/management

In the UK, much heathland is present on former common land with open public access, although large areas, especially in the uplands, are privately-owned estates. Substantial areas of heathland are also within the ownership of The Crown Estate, Ministry of Defence, National Trust, RSPB and local authorities. In Ireland, much heathland is on state-owned lands. It is therefore a very important resource as a natural and accessible open space.

The Biodiversity Net Gain (BNG) process may influence land use change within England and could result in pressures from habitat creation and management on semi-natural habitats. The process could risk undesirable targeting of habitats such as tree planting on heathland. Conversely, there may be a demand in the creation of heathland biodiversity units, which should be targeted in the most favourable locations, ideally supported by local nature recovery strategies.

Importance

Table 3 summarises the importance factors for heathland habitats. These include biodiversity, historical and cultural significance, amenity and recreational use, agriculture and game management, and ecosystem services.

Table 3: Summary of importance factors for heathland habitats

Topic	Importance	Threats
Biodiversity	Heathlands have a significant number of plants, animals and fungi that are rare or restricted in distribution and rely on the habitat. Examples include Cornish heath, Dorset heath, Irish heath, dwarf gorse, yellow centaury *Cicendia filiformis,* marsh gentian *Gentiana pneumonanthe*, nightjar *Caprimulgus europaeus,* Dartford warbler *Sylvia undata*, black grouse *Lyrurus tetrix*, red-backed shrike Lanius *collurio*, woodlark *Lullula arborea*, silver-studded blue *Plebejus argus*, tiger beetles *Cicindela* spp., smooth snake *Coronella austriaca* and sand lizard *Lacerta agilis*, among others.	Loss and fragmentation due to development, degradation and loss of biodiversity through atmospheric input of nutrients, lack of management or incorrect management, invasion by trees, shrubs or bracken, and erosion caused by trampling, motorcycles and horse riding. Unmanaged wildfire.
Historical and cultural significance	Lowland heathland, with the exception of some coastal heath, has developed and been sustained by human exploitation. The cultural association of lowland heathland with human use goes back thousands of years and is extremely important in a historical context.	Loss of heathland extent, damage or degradation to archaeological sites, historical features such as barrows, banks and ditches as well as artifacts. Reduction in landscape value due to loss and fragmentation of semi-natural 'wilderness'.
Amenity and recreation	Lowland and upland heathland are important for local communities providing recreational access to open countryside and enjoyment of wildlife. Those within National Parks attract national and international tourists. Much heathland is present on former common land with open public access. Heathland is found in areas managed for sports, such as golf courses or horse racecourses, which are mostly privately-owned and managed.	Recreational over-use including motorcycle scrambling, horse-riding, dog walking, mountain biking, paintball, etc. which disrupts the wildlife (birds in particular) and causes erosion. Noise and dust from vehicle use. Excessive use caused by local population pressure damaging the amenity value. There may be loss of heathland due to expansion of golf courses, etc.
Agriculture and horticulture	Historically, much heath was common land where livestock was grazing, trees and gorse were cut for firewood, peat was cut for burning, and bracken harvested for use as animal bedding or mulch, or for creating potash. Rabbits have been important for maintaining open heathland, particularly in East Anglia.	Change in agricultural practices means that heathland is now rarely grazed for commercial farming in the lowlands. Conversely, overgrazing is a threat to upland heath. Taking of firewood, bracken and other resources has ceased due to conservation priorities, lack of markets, and risk of overexploitation.
Game management	Large areas of upland heathland are important in a commercial sense for the management of game birds, particularly red grouse. Therefore, they are managed as open space with little development. In Scotland, red deer (*Cervus elaphus*) have a significant role in maintaining open heathland.	Mismanagement can cause degradation of heathland habitat. 'Single use' objectives could result in loss of biodiversity.
Military use	Where heathland is used for military training, typically the land is managed as a mosaic of open heath, woodland and scrub, retaining much diversity. These areas often have a long continuity of management.	Overuse can result in erosion and degradation. Some wetter areas may be drained. Military activities could cause fires. Certain areas such as firing ranges have exclusion zones where management is restricted.
Carbon sequestration and Climate Change	Heathland soils (particularly peaty podzols) contribute substantially to carbon sequestration (Anderson, 2024).	Loss of extent. Damage to soils and erosion. Controlled burning and wildfires. Changes in hydrological conditions, increased fire risk and frequent droughts. Coastal and dune heathlands threat of rising sea levels.
Water supply	Heathland habitat forms part of a very important landscape, particularly in the uplands, where rainfall is captured and filters through to aquifers, springs and streams, which are valuable water sources.	Acidification and nitrification. Loss of heathland extent, fragmentation and disruption to hydrological processes through construction and development in the uplands.
Water retention and flood prevention	As part of upland and lowland landscapes along with bogs and mires, heathland habitats receive rainfall and slow the release into rivers preventing flood events.	Loss of extent, fragmentation, and mismanagement of watercourses.

Intervention Measures

This section focuses mainly on intervention measures for the restoration and habitat creation of lowland heath types as this is where the majority of damage and loss occurs. However, restoration creation and translocation techniques can be applied to heathland in both lowland and upland situations.

For this guidance, restoration has been defined as incorporating habitat creation, restoration and translocation[1]. The recognised definition of ecological restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (Gann *et al.*, 2019).

There is a suite of different habitat intervention measures that can be applied to heathlands, depending on the site location and the ecologist's desired target objectives of ecosystem structure and function, including creation, restoration/ enhancement and translocation. These are reviewed in the following sections.

Processes/Techniques

Restoration

When designing a scheme of restoration of heathland landscapes in Britain and Ireland there is a suite of wider historical, environmental, cultural and environmental factors that should be considered, assessed and built into the process of restoration (Chatters, 2021). The process should start with setting objectives and ensuring that appropriate monitoring is undertaken that measures progress towards the objectives (refer to Overarching Topic - Monitoring).
The following should form part of the process for determining objectives:

- Research into the history of heathland occupancy and use by local inhabitants in past centuries, archaeological evidence and mapping where heathland was converted to agricultural use, converted to plantation forestry or simply underwent ecological succession when local commoners abandoned the heath which was left neglected, ungrazed and not used as a resource for collecting gorse, bracken, turves or fuel wood (Dudley, 2008).

- On upland sites there may have been persistent historic overgrazing, by sheep in particular, that changed heathland into acid grassland.

- Studies of historic maps, aerial photographs and estate records. The National Character Area profiles for England (https://naturalcharacterareas.co.uk/) and the associated local-level landscape character information provide local and regional context.

- How the cultural landscape character and ecological networks have evolved suggesting where heathland restoration will contribute to the further development of ecological networks and more widely to Nature Networks which also encompass the delivery of Ecosystem Services benefits to people (Crick *et al*., 2020a, 2020b).

- In the long term, heathland restoration is a positive driver of carbon capture and sequestration (Anderson, 2024), even when trees are felled to make way for heathland (Stafford *et al*., 2021).

- Part of this process will be to prioritise and evaluate where and if degradation caused by past mismanagement or neglect can be reversed, where heathland fragments can be joined and where sites can be expanded in area and thus accommodate greater diversity of typical heathland species underpinned by variation in habitat structure and space for viable population sizes e.g. heathland spiders cited by Webb & Hopkins (1984). However, care must be taken when interpreting insect species richness data which can be greater on small fragments because the additional species comprise generalist and 'tourist' species, not typical heathland fauna.

1 https://cieem.net/wp-content/uploads/2024/01/Good-Practice-Principles-V4.pdf

- It is important to stress that if undisturbed soils have particular scientific (e.g. classic podzol) or archaeological value, restoration using minimal disturbance is the priority option or not undertaking heathland restoration on all or part of the particular site. Combinations of cutting, herbicide application or burning followed by grazing may provide options. Refer to Hawley *et al*. (2008) for a review of the issues.

When considering the objectives of restoration for a particular site an important determinant will be the flora and fauna that comprised the previous species assemblage or particular target species that are appropriate to the local area and are of specific conservation importance. This involves consideration of which functional groups form regional or local priorities for conservation (Dolman *et al.*, 2012). Particularly important functional groups include spiders, beetles, butterflies, moths, bees, wasps, reptiles, birds, mosses, lichens and fungi.

Restoration may be focused on safeguarding or expanding the population size of a particular priority species that has declined and is in danger of local extinction. For example, dry heathland creation at Butterfly Conservation's Prees Heath Reserve in Shropshire has substantially increased the population size of the last remaining colony of silver-studded blue *Plebejus argus* in England north of Birmingham (Davis *et al*., 2015). However, on southern lowland heath there can be a conflict between managed restoration using grazing cattle and the habitat requirements of certain reptiles including grass snake *Natrix natrix*, common lizard *Zootoca vivipara* and slow worm *Anguis fragilis*. All three species were more abundant on ungrazed areas in a comparative trial (Reading & Jofré, 2016). In contrast, habitat creation by the RSPB in Norfolk and Suffolk (Fairhurst *et al*., 2023) has focussed on population revival of birds such as woodlark *Lullula arborea*, Dartford warbler *Sylvia undata*, stonechat *Saxicola rubicola* and yellowhammer *Emberiza citrinella*. Similarly, heathland habitat creation in a mosaic with scrub and woodland at Rugeley Quarry near Cannock Chase has provided new habitat for 41 species of mining bees and wasps, woodlark and nightjar (Rugeley Quarry Case Study).

Scoping which restoration and management techniques will be appropriate to use will depend on many variables which will include:

- The short and long-term objectives of the restoration scheme and a risk assessment of the probable resilience and sustainability of the process.
- The physical scale of the project, from hundreds of square metres to thousands of hectares, and constraints caused by site elevation, difficult topography and restricted access for machinery and consensus among stakeholders.
- The availability of biological resources for habitat creation that are appropriate to the objectives, that also minimises carbon emissions during collection and transport.
- The physical, chemical and hydrological properties of soils and groundwater flows on potential restoration scheme sites.
- Consideration of the impact of the particular restoration or habitat creation measures on long-term carbon sequestration and storage in soils and mitigation against carbon emissions (Alonso *et al*., 2021).

The quality of scoping will depend, in part, on a thorough understanding of the range of heathland NVC communities or the Irish Vegetation Classification (IVC) communities that occur in the wider local landscape and their current status, variation in local soils, location, size and shape, condition, fragmentation and past history of management of existing heathland. Restoration that successfully develops close similarity to the target heathland will be highly dependent on soil properties. The best probability of success is provided by a light sand-rich soil with a low concentration of extractable plant-available phosphorus (P <10-12 mg kg^{-1}) and exchangeable calcium (Ca <175 mg kg^{-1}), extractable potassium (<50 mg kg^{-1}) and low pH (<5.0 and ideally <4.5). Soil chemical properties vary considerably at differing heathland sites. The recommended values are based on data extracted from >10 published papers (e.g. Diaz *et al*., 2011; Clarke, 1997; Pywell *et al*., 2011; Marrs *et al*., 1998; Walker *et al*., 2004). Agricultural soils very rarely provide suitable starting soils and attempts to 'strip' nutrients by growing cereal or other crops for several (or many) years has usually failed to sufficiently reduce P and pH values. Natural loss of phosphorus on fallow sandy soils was <1% of total phosphorus per year and even less on clay soils (Clarke, 1997). It is recommended that unless there is a compelling reason, heathland restoration on agricultural soils is avoided. Soils under pine plantations, successional scrub and mixed secondary woodland and overgrazed upland acid grassland offer better prospects.

During the past 30 years in the UK, in response to continuing loss of lowland heathland, there has been an increasingly strong imperative to attempt restoration on areas of conifer plantation and mixed secondary woodland or agricultural land (grassland and arable) that were formerly heathland in the past, including back as far as the 19th century. In recent years a change in Forestry Commission England's policy towards recreating lowland heathland and other open habitats on existing plantations has underpinned many new restoration initiatives. Walker *et al*. (2004) reviewed evidence and concluded that targeting forestry plantations on former heathland gave the most practical, rapid and cost-effective outcomes. There was also focus on restoring lowland heathland on quarry sites following extraction of sand and gravel or kaolin (china clay) which often created heathland similar to the plant community originally present before quarrying commenced (Pywell *et al*., 1996; Symes and Day, 2003). A landscape scale example was the Tomorrow's Heathland Heritage project 'Putting back the Wild Heart of Cornwall' in which 788 ha of heathland was restored on china clay quarry waste in the St Austell district (pers. comm. Ian Davies, 2005). This project was successful because clay waste has a very low content of major nutrients (e.g. <3 mg kg^{-1} available phosphorus), low pH (3.5-4.0) and very low cation exchange capacity.

In UK upland areas the issues are different. Historical large-scale degradation of vegetation dominated by dwarf shrubs (mainly *Calluna*) was caused by loss of traditional management, overgrazing, afforestation, eutrophication, extensive accidental wildfires (or sometimes arson), and invasive species, including native species, such as bracken, and non-native species such as rhododendron *Rhododendron ponticum*. Habitat creation on bare ground after damage caused by wildfires has been a particular focus (Gilbert & Anderson, 1998), initiated following extensive damage on the North York Moors (Maltby *et al*., 1990) and in the Peak District National Park. Wildfires pose a significant threat to the delivery of ecosystem goods and services, such as erosion prevention, carbon retention, or provision of habitat for biodiversity (McMorrow *et al*., 2009). Increased risk of wildfire and the vulnerability of both upland and lowland heathlands is recognised in the UK Climate Change Risk Assessment (H.M. Government 2022). Glaves *et al*. (2020) provides useful context but does not provide an evaluation of solutions.

An initial impact of wildfire is the potential loss of the heathland seed bank and the risk that surface erosion will cause further depletion. Severe fires in which more than 100 mm of peat is destroyed will cause complete loss of the seed bank (Legg *et al*., 1992). It is well established that *Calluna* and bell heather often germinate satisfactorily after less severe fire, however a study of six upland sites in Northern Ireland (Kelly *et al*., 2016) demonstrated that wet heath species such as hare's-tail cottongrass *Eriophorum vaginatum*, crowberry and bog asphodel *Narthecium ossifragum* incurred a greatly reduced seed bank correlated with much lower abundance of these species in recovering vegetation. A secondary negative impact of severe fires is the development of crustose lichens and algae on the burnt surface that form a near continuous cover that will significantly reduce the germination of *Calluna* seeds. Rapid colonisation by bryophytes such as *Polytrichum* spp. and heath star moss *Campylopus introflexus* has a similar impact.

A combination of overgrazing, inappropriate burning regimes and atmospheric nitrogen deposition has caused extensive areas of previously *Calluna*-dominated upland moorland to become dominated by grasses, mainly purple moor-grass *Molinia caerulea* or mat-grass *Nardus stricta*. There is evidence from Scottish work that restoration of these degraded uplands can be achieved by disturbance made by tractor-mounted rotavator and trampling by cattle (creation of germination microsites) and addition of harvested seed of *Calluna* at a rate of 0.8 g m^{-2} (26,000 seeds per m^2) (Mitchell *et al*., 2008). In the Peak District, restoration of degraded *Molinia* moorland was achieved with a combination of burning, mowing or short-term heavy cattle grazing and burning and addition of brush-harvested *Calluna* seed at a rate of 4-6 g ha^{-1} (Smith & Bird, 2005). In comparison, Marrs *et al*. (2004) examined the outcome of *Molinia* control treatments at sites in the north Peak District and the Yorkshire Dales and failed to find consistent responses over a period of six years of monitoring. Similarly on sheep-grazed upland wet heath various techniques designed to enhance cover of *Calluna* using combinations of burning, cutting and herbicide treatment failed to reduce the abundance of Molinia (Ross *et al*., 2003).

There has also been considerable erosion and creation of bare ground as a result of recreational activity in the uplands. Over 45.2 million people visited upland national parks in England in 2017 and many of these will have been walking, mountain-biking or used off-road vehicles on tracks, or skied in areas of upland heathland. Bayfield and Aitken (1992) reviewed a range of restoration techniques that can be utilised for different types of repair. These included laying turves in prepared receptor sites, bare root direct planting of heathland plants or live mulching using a mixture of topsoil, bryophytes, vegetative plant fragments including rhizomes and sown nurse grasses. Some of this restoration has been undertaken in sub-alpine and montane heaths. Further guidance is provided by Gilbert and Anderson (1998, 'Montane and submontane habitats' chapter).

In the Mourne Mountains of Northern Ireland at the Donard-Commendagh saddle, severe erosion of heath has been caused by foot traffic. In response the Mourne Ranger Team launched a recovery project to restore braided paths and erosion scars (https://www.nationaltrust.org.uk/visit/northern-ireland/the-mournes/starling-bank-peat-restoration-and-saddle-heath-recovery-project). The initial work involved removing stones and smoothing eroded areas. The restored area was stabilised with pegged-down coir rolls to create a stable rooting matrix. Seed of upland grass species and heather plugs were planted in a peat-aggregate mix. The restoration work commenced in early 2024 and it continues.

Creation

Scoping for heathland habitat creation is essentially the same as for restoration (refer to this under restoration sub-heading). There is a contrast in the drivers of heathland creation in the uplands in contrast to the lowlands. In the uplands, deliberate creation of new dwarf shrub communities was initiated in the 1970s when extensive moorland fires occurred on the North York Moors (Maltby *et al.*, 1990; Legg *et al.*, 1992) and Pennines including the Peak District National Park in particular. Re-creating heathland following severe damage caused by wildfires has been a recurrent requirement through ensuing decades. Natural erosion of surface peat has also created substantial areas of bare substrate where heathland creation has been undertaken, discussed by Gilbert & Anderson (1998).

Development in the uplands often generates damage to heathland, creating bare substrates where new heathland creation is a project requirement. These situations encompass construction of new road embankments, new wind farm developments and decommissioning old sites, opencast coal extraction, deep mined colliery spoil, hard rock quarries (including slate and associated historic quarry waste rock heaps) and construction of linear features such as pipelines. The Nature after Minerals website provides general restoration guidance for upland sites after mineral extraction (https://afterminerals.com/advisory-sheet/upland-heathland/).

Lowland heathland has often become degraded due to defence training, for example in Dorset, invasion by bracken, trees (silver birch *Betula pendula* and downy birch *B. pubescens*), pedunculate oak *Quercus robur* or sessile oak *Quercus petraea* and shrubs such as European gorse and broom *Cytisus scoparius.* The changes came about due to the cessation of traditional management many decades ago that allowed unconstrained ecological succession to proceed. Substantial intervention may be required to create new heathland habitat starting with areas cleared of existing vegetation. Removal of trees can be controversial with local communities, in particular on common land where commoners hold rights. Consultation with local communities is important to obtain local support for proposed works. Re-creation of heathland on areas of conifer afforestation which were planted many decades ago is another important focus.

Figure 2.

Invasion of European gorse on heathland in Wirral.

Photo credit: Phil Putwain.

Following cutting and removal of trees, the persistent residual seedbank will regenerate. It is known that *Calluna* seed will remain viable for 60 years and sometimes even longer (Pywell *et al.*, 2002).

Development also impacts lowland heath, for example extraction of sand, gravel and ball clay has created bare mineral substrates, often adjacent to existing heathland. Similarly, there are considerable areas of bare quartz sand and gravel waste generated by the china clay industry in Cornwall (Grigg *et al*., 1998). Ground disturbance caused by human recreational use (horses, uncontrolled dogs, motorbikes and off-road vehicles) also creates a requirement for new habitat creation (Underhill-Day, 2005). Pollution and nutrient enrichment can also be a consequence of nearby urban areas as occurs in Dorset. Wildfires are a significant cause of damage to lowland heath and restoration intervention may be required. There are also selected opportunities for creation of new heathland on existing agricultural land (grassland and arable) that may have been heathland decades or more than a century in the past. This can help to expand and/or join up patches of fragmented heathland as has been undertaken at Dunwich Forest and Minsmere RSPB reserve (Fairhurst *et al.*, 2023). Creating new heathland on former arable land will result in enhanced carbon capture in soils and also in vegetation (Alonso *et al*., 2021).

Heathland plant resources for creating heathland

At any particular site, available plant resources for heathland creation depends mainly on the proximity of heathland species assemblages in the desired target UKHab level 5 type and the desired NVC community (although this may encompass several possible NVC communities where the restoration objective provides for a less prescriptive outcome). The same argument holds for heathland communities in Ireland, namely HE1, HE2, HE3, HE4 and their respective sub-communities. Resources collected from donor sites for creating new heathland include: (a) brush-harvested seed and capsules; (b) vacuum-collected surface litter containing abundant seed; (c) shoots of dwarf shrubs bearing ripe seed within capsules collected using a forage harvester or custom cut and collect machine; (d) cutting longer shoots bearing capsules, harvesting and transporting loose shoots or as bales; and (e) nursery propagation of plug plants from seed or cuttings and collection and transfer of topsoil.

Biosecurity is a consideration when machine cut shoots, litter or soil are transferred from a separate donor site to a new receptor site (Mitchell, 2024). For example, *Phytophthora kernoviae* has spread through heathlands in Southern England (Drake & Jones, 2017) and infected bilberry causing dieback and death of shoots. Heather beetle *Lochmaea suturalis* is widespread on heather moorland and has been spreading in range and severity of damage to *Calluna* in the past two decades (Heather Trust, 2024). Similarly, heather beetles may cause significant damage in lowland heath. Thus, a biosecurity risk assessment should be a routine element of planning a habitat restoration project.

The following paragraphs describe the way in which heathland plant resources are used in creating and enhancing heathland. Refer to Flora Locale and English Nature (2003) and also Ecoscope (2000), Gilbert & Anderson (1998) and Symes & Day (2003) for additional guidance. The utilisation of these resources will be very similar on all types of bare substrates such as quarry spoil, soil after removal of existing trees or shrubs or agricultural grassland treated with herbicide and rotavated or on arable soils.

Brush harvested seed and capsules

Various types of brush harvesting equipment have been used to collect seed capsules of *Calluna* and *Erica* species in the period October to late December when seed has ripened. Brush harvesters are normally towed by quad bikes or small tractors. Smaller amounts of seed of heathland grasses such as bristle bent *Agrostis curtisii*, wavy hair-grass *Avenella flexuosa* or purple moor-grass are often collected in addition to dwarf shrubs. Early collection helps to reduce the amount of unwanted *Molinia* seeds. The particular species of grass collected depends on the type of plant community being harvested. Usually however, vegetation derived from brush harvested seed is dominated by *Calluna* and smaller proportions of *Erica* species. Two passes of the harvester with the second being at 90° to the first may provide a greater capsule yield per unit area. The collected material can be spread thinly (<100 mm depth) in a covered airy place to dry, if damp when collected and then passed through a coarse sieve (20-25 mm mesh) followed by a finer sieve with c. 10 mm mesh size to successively remove woody fragments. Dry capsules can be bagged for storage in breathable jute or woven polypropylene bags. Fresh brush harvested seed contains a variable proportion of dormant seed. Exposure of seed directly to heather smoke, as if it had been heat treated in a wild or prescribed fire, or to smoke treated water breaks much of this dormancy.

Figure 3.

Brush harvester for collecting seed of heather and grasses.

Photo credit: Ian Davies

Estimating the quantity of brush-harvested material that will create an adequate population of dwarf shrubs and associated heathland plants is difficult because the ratio of seed to litter weight is variable depending on the abundance of capsules per unit area in a donor site. If there has been abundant flowering on the harvested area, a general rule of thumb is that harvested material can be spread on at least twice the harvested area. Greater precision can be achieved if 4-6 small random samples (2-3 g) are accurately weighed (if there is available laboratory access) and the total number of seed capsules and loose individual seeds are counted under 5x to 10x magnification. On lowland heath the average number of seeds per capsule for both *Calluna* and bell heather was 9-10 (Bullock & Clarke, 2000) although Putwain (pers. comm.) counted an average 7-8 seeds per capsule for *Calluna*. A sample of capsules has to be checked for the proportion of plump viable seeds compared with shrivelled non-viable seeds. The weight of harvested material to be spread per m^2 to achieve a recommended application of 5000 seeds m^{-2} (*Calluna*) or 2,500 seeds m^{-2} (*Erica*) is then calculated. Note that the weight of an individual seed of bell heather is at least twice that of *Calluna*.

A brush harvesting trial undertaken by Imerys plc using a defined 0.5 ha area on Hensbarrow Downs, Cornwall, yielded 13 kg of sieved capsules mixed with small twig and leaf fragments. The commercial purchase cost of this material was approximately £50/kg (Richard Scott pers. comm., 2022). Small sites (<200 m^2) can be sown by hand broadcasting after marking out compartments to aid accuracy. Brush-harvested material can be mixed with fine sawdust or fine dry sand (ratio 2:1, carrier/seed) as a carrier for large sites and broadcast using a tractor-mounted custom seed broadcaster or a fertiliser spreader, calibrated for rate of spread. On almost all lowland heathland sites companion grasses are not necessary and may even suppress establishment of dwarf shrubs (Gilbert & Anderson, 1998). On less exposed sites protection of

seedlings can be provided by using a light covering (250-350 g m^{-2}) of freshly harvested heather shoots (if available locally). If this is cut and spread in autumn/early winter, there will be the benefit of adding additional seed of dwarf shrubs.
On upland sites companion grasses should not be sown unless soil surface stabilisation is a necessary requirement on very exposed areas with moderate or steep gradients, due to rain splash, wind impacts and frost heaving or with very acid soils. The optimum approach is to sow a companion grass at a low target population density using wavy hair-grass or sheep's fescue *Festuca ovina*, with sowing rates in the range 0.5-1.2 g m^{-2}. On exposed sites these native species germinate, establish and grow too slowly to provide adequate initial protection and therefore Highland bent *Agrostis castellana*, should be sown (0.5-1.0 g m^{-2}) as a companion species in the seed mixture because it establishes and grows more rapidly and at the recommended sowing rate produces an upright canopy with sufficient space for heathland plants to become established. This species is non-native but does not persist more than 6-7 years.

Companion grass seed should be broadcast using either a battery powered handheld spreader for areas measured in hundreds of square metres or using a tractor mounted seed/fertiliser spreader for thousands of square metres, before firming the soil with a Cambridge roller. At low rates of application seed can be mixed with sawdust or fine sand at a ratio of 2:1 sand: seed to facilitate an even density of seed spread.

Heathland litter

Heathland litter consists of dispersed seed and capsules plus fallen leaves. The seed content is mainly *Calluna* and *Erica* species but may also contain seed of other heathland plants and thus is a preferred source for heathland creation in comparison with brush harvested seed. A disadvantage being that seeds of undesirable plants, such as rushes *Juncus* spp. and silver or downy birch, may also be present and could provide a management issue during the early establishment years. Ideally, where time allows, a greenhouse germination test (spread samples of known weight thinly over an acid compost/ sand mixture, keep moist with mist spray) will establish the content of seed likely to germinate over a period of weeks. Heathland litter contains few dormant seeds compared with freshly collected brush harvested seed. A variety of vacuum collectors (e.g. Billy Goat, Marclean Wheelie Vac) have been used to collect litter from donor areas or hand collection for small areas. On donor sites where breeding birds are present, collection should not take place between March and July. If reptiles are present, April-May and September should be avoided. Collection in October-November is optimal as it will include dispersed seed from the current year.

Once collected, heather litter can be spread as collected if hand broadcast or coarse sieved to remove twigs and woody fragments and mechanically spread at the receptor site on the same or next day. Alternatively, it can be spread out to dry and bagged for storage (as described for brush harvested seed) for spreading according to the work programme. Previous research (Environmental Advisory Unit, 1988) revealed that 100-200 g m^{-2} of heather litter would provide a minimum of 300-500 germinable seeds per m^2.

Cut and collect heather brash

Probably the most cost-effective means of establishing new heathland vegetation on bare substrates (>1ha) is to harvest shoots bearing mature capsules which have not shed seed from areas with prolific flowering in summer. Cutting to remove just the top 350 mm of shoots will enhance the ratio of capsules to vegetative shoots and younger heather provides a better seed yield than older material (pers. comm. Penny Anderson). The quantity of harvested material to spread per unit area is very difficult to estimate accurately because it is influenced by many variables including:

- The timing of harvesting, which should be from early October to end December (for *Calluna*), to maximise seed capture because winter gales cause much seed to be dispersed.
- Bell heather can be harvested from early/mid-September to end November because it flowers earlier than *Calluna*.
- The abundance of capsules (reflecting previous flowering) and the proportion of woody shoots and twigs in the harvested material (in part dependent on cutting height).
- The type of harvesting machinery utilised and whether double-chopped or baled.

Independent recommended application rates for lowland heath were c. 6,000 kg ha^{-1} (Gimingham, 1992; Pywell *et al.*, 1996) and 1,550 kg ha^{-1} (Davis *et al.*, 2015). At these application rates, at least twice and possibly 3-4 times the size of the donor area can be spread on a receptor site. It would be advisable to increase the rate of spread on exposed upland sites up to 10,000 kg ha^{-1} (Gimingham, 1992) using double-chopped harvested material, which is less likely to be dispersed by wind-blow than longer shoots. At lowland sites harvested shoots should be pressed lightly into the soil using tractor tyres, low ground pressure tracks, or a ridge roller, helping to create germination microsites. Generally, using harvested shoots is preferable to using brush-harvested seed because the shoots provide a protected microenvironment for germination (conserve moisture) and provide at least some protection from surface wind and water erosion. There may also be greater carryover of mycorrhizal hyphae.

Figure 4.

Harvesting heather cut and collect.

Photo credit: Phil Putwain.

Figure 5.

Spreading harvested material using a rear discharge muck spreader.

Photo credit: Phil Putwain.

Direct planting of nursery grown plug plants

This is an expensive and labour-intensive process but can be used to introduce species that fail to establish from seed or were not present in harvested seed or shoots used in creating new heathland. It can be the only feasible way to establish very rare or scarce species. Local origin seed or plant cuttings need to be collected and plug plants raised by a contracted specialist nursery that has appropriate propagating equipment. Volunteers with Non-Governmental Organisations (NGOs) may be able to assist with seed collection. Plug plants of a few species can be obtained commercially, although rarely of local origin. For example, the current cost (2025) per plug (for >100 per order) is: *Calluna* (£0.81), cross-leaved heath (£0.93), crowberry (£0.93), and harebell *Campanula rotundifolia* (£1.25). At Prees Heath Common Reserve, 25,000 plugs of bell heather were planted by volunteers because this species was not present in the harvested material spread as cut shoots and did not establish directly from sown seed collected at the reserve. Approximately 50% of plugs had survived after two years and subsequently spread laterally but slowly. A current (2025) quotation from a specialist nursery for bell heather plugs, including collecting and cleaning seed and producing 20,000 plugs, is £0.56 per plug (including VAT). In order to cut costs, it has been suggested that small clumps covering about 10% of the total area should be planted with the hope that dispersed seed will colonise the surrounding area (Ecoscope, 2000). Unfortunately, this will not necessarily happen, because there will be much less opportunity for seedling establishment as vegetation cover becomes denser over time. Sparsely colonised areas of soil are required for seedling establishment.

Creating heathland on bare substrates

Walker *et al*. (1997) reviewed attempted lowland heathland creation at 37 sites in England and found that those on former arable land had mainly failed, but 50% of those at former pine plantations had been successful. There are also selected opportunities for creation of new heathland on existing agricultural land (grassland and arable) that may have been heathland decades or more than a century in the past. Although challenging, careful consideration of location, soil type and techniques can help to expand and/or join up patches of fragmented heathland. Robust interventions have been utilised at some sites to achieve positive outcomes (Davis *et al.*, 2015). Successful creation of lowland heath on arable land and grassland necessitates a reversal of relatively high soil pH (from >7.0 to <5.0) and the residual nutrient availability that has accumulated through long-term production. Usually the concentration of extractable phosphorus, exchangeable calcium and soil pH are all too high (Clarke, 1997). The upper thresholds for potentially successful heathland creation are pH <5.0 preferably <4.5, extractable phosphorus < 10-12 mg kg^{-1} and exchangeable calcium <175 mg kg^{-1} (unit per kg of dry soil). Permanent grassland that historically had low inputs of fertilizer or none and was former heathland, often several or many decades previously, is the best starting point.

The options are soil profile inversion at sites where there are no archaeological features that could be damaged, stripping topsoil from grassland and removing it from the area or using herbicide (e.g. Roundup Proactive) to kill existing vegetation followed by cultivation. Soil inversion is feasible on light sandy soils using a forestry plough (Bovlund plough) that will bury 80%+ topsoil below 500 mm (Davis *et al*., 2015). This will bring infertile subsoil to the surface (chemical analysis is recommended to confirm this) to which elemental sulphur (S) in the form of Brimstone 90 pellets, can be incorporated to reduce soil pH within 4.0-4.5. The rate of incorporation of S on soils with a very high percentage of sand can be as low as 1.25 t ha^{-1} but on soils with a modestly higher content of silt and clay (sandy loam) a rate of 2-3 t ha^{-1} will be required to reduce soil pH to c. 4.0 (Owen & Marrs, 2000). Heathland seed, litter or harvested shoots with capsules can then be spread as described previously. Soil inversion is not effective on clay-rich soils. At Butterfly Conservation's Prees Heath Reserve, heathland creation on arable crop land using soil inversion was very successful creating >20 ha of new heathland that supports a large population (>50,000 adults in 2023) of the nationally rare silver-studded blue butterfly. Soil inversion will bury some organic carbon from the former topsoil at depth, where reduced biological activity can slow decomposition and potentially contribute to longer-term soil carbon storage. However, disturbing soil during inversion can also increase mineralisation of organic matter and lead to short-term carbon losses. The net effect is uncertain and site dependent.

Figure 6.

Bovlund plough used for soil inversion.

Photo credit Richard Scott.

Figure 7.

Silver-studded blue butterfly.

Photo credit: Stephen Lewis.

Figure 8.

Ridged potato crop on Prees Heath, 1960s.

Photo credit: Unknown owner deceased.

Figure 9.

Prees Heath Common Reserve in 2022, 15 years after initial soil inversion.

Photo credit: Phil Putwain.

Stripping topsoil to a depth of 100-150 mm will usually remove significant amounts of soil phosphorus unless its concentration does not decrease with depth in the soil profile. This method is only suitable for small areas because the financial cost and carbon emissions are not sustainable. Stripped soil could be used to create bee/beetle banks near to site boundaries or suitable corner areas. Following soil stripping, soil pH may remain high. Soil testing will determine whether incorporation of S will be necessary. On semi-improved grassland, following treatment of existing vegetation using Roundup, a suitable substrate can be prepared. This can be done using a rotavator or power harrow to break up clods, followed by consolidation using a ring roller. Following this seed can be introduced using any of the methods described in the preceding paragraphs.

A slightly different approach may be required for heathland habitat creation on mineral extraction sites including sand and gravel, ball clay, china clay (kaolin), slate and hard rock quarries producing acid wastes. Raw mineral materials contain negligible organic matter and very low concentrations of major nutrients. Cation exchange capacity of substrates is very low so that nutrient inputs in rainfall and dust are rapidly leached out. This can be remedied by adding a thin (<25 mm) layer of subsoil and slightly incorporating into the mineral substrate using a chain harrow. Restoration of heathland on china clay wastes utilised water treatment sludge for this purpose (Davies pers. comm., 2001) which enhanced the establishment of *Calluna*. At some exposed china clay sites annual Westerwolds ryegrass was sown to provide initial surface stabilisation thus protecting germinating and establishing *Calluna* seedlings. This site supports a rich flora of lichens and bryophytes after 18 years (**Figure 10**). At other china clay sites initial successful establishment of heathland flora after 5-10 years was not sustained due to lack of adequate grazing management or cutting management (**Figure 11**). (Davies pers. comm., 2024).

Figure 10.

Established heathland at Park Lake, Bodmin Moor (2025) on china clay waste after spreading of brush harvested seed and sowing annual Westerwolds ryegrass (2007).

Photo credit: Phil Putwain.

Figure 11.

Part of the restored area at Caerloggas Downs after 20 years, dominated by dense western gorse due to lack of grazing (cutting was not possible due to surface granite cobbles).

Photo credit: Phil Putwain.

Managing created heathland in the early years of ecosystem development

Creating heathland that is not properly managed in subsequent years is a waste of resources. Responsive management is crucial for long-term sustainable outcomes. A risk-assessed management plan should be a component of initial planning of a heathland restoration project.

In the two or three years after the initial restoration has been undertaken there are often two main management issues:

- Control of non-heathland annual, biennial and perennial plants (weeds).
- Grazing by rabbits, sheep, ponies or deer.

Low densities of ruderals, e.g. rosebay willowherb *Chamerion angustifolium* and common ragwort *Jacobaea vulgaris*, and perennials such as creeping thistle *Cirsium arvense* or bramble *Rubus fruticosus* agg. can be controlled by spot treatment using a herbicide glove delivering Roundup impregnated gel. This form of non-mechanical weed control has the least environmental impact. Dense infestations are treated using a tractor mounted weed wiper. It is most efficient to hand pull birch (*Betula* spp.) seedlings in late summer/early autumn each year (using a tree popper), until the canopy of dwarf shrubs is sufficient to suppress birch seedling establishment.

On upland sites, fencing to exclude sheep, ponies and deer is essential and should be retained for 3, 4 or 5 years depending on grazing pressure. On lowland sites, rabbit grazing can significantly retard the early establishment of dwarf shrubs and the development of other heathland plants. It may be necessary to install rabbit proof fencing when rabbit grazing is very damaging and retain it for 4-5 years. Although rabbit grazing might appear to be a problem during the early establishment and growth stage of heathland development, after several years the impact usually becomes much less and grazing and disturbance caused by rabbits can be beneficial (White & Gilbert, 2003; pers. comm., Stephen Lewis, 2018) maintaining open patches of habitat for invertebrates and reptiles such as lizards, adder and smooth snake. During ecological succession in the decade following initial habitat creation, it will be important to maintain structural diversity in the vegetation and this includes safeguarding wet habitats (e.g. for rove beetles and craneflies), providing areas of bare ground for beetles, and mining bees and wasps, and creating a mosaic of dwarf shrubs of varying age and thus diversity of height and structure (Buglife, 2019).

Using management techniques to create habitat and restore heathland

Degradation and loss of heathland can arise from extreme impacts such as wildfire or progressive impacts such as excessive grazing pressure, the cessation of traditional historical management practices resulting in succession to grassland, bracken, gorse scrub and secondary woodland or deliberate conversion to plantation forestry and agriculture. Management in response to these impacts is now comprehensively documented (e.g. Symes & Day, 2003) and forms the basis of many current Nature Based Solutions for heathland restoration within a landscape scale patchwork of different ecosystems, including in large urban conurbations (e.g. Hardman, 2024). There is overlap between routine management to maintain heathland in good condition and restoration after severe degradation in which intervention may be required to create new heathland habitat, but which utilises some of the same management techniques described by Symes & Day (2003). Usually, the distinction between restoration and routine management is reasonably clear. An important aspect of long-term after-management is the impact of nitrogen deposition because for both upland and lowland heathland in many regions of the UK there is exceedance of critical loads for heathland ecosystems (Hall *et al*., 2015, Zappla *et al*., 2020). This causes the reduced occurrence of many plant and lichen species and drives changes in ecosystem function. Management techniques described below mitigate the negative impact of nitrogen accumulation by removing a proportion from the ecosystem.

Management techniques that have commonly been used as part of a restoration process are litter removal from under-managed heather, grazing, cutting, removal of turves and creation of bare ground. Removal and management of invasive native and non-native species can be an important issue. Examples include removal of gorse scrub, removal of rhododendron and shallon *Gaultheria shallon*, suppressing bracken, removing secondary woodland, and managing heathland regeneration after removal of conifer plantations. A relatively recent problem is the geographical expansion of non-native piri-piri burr *Acaena novae-zelandiae*, which is spreading quite rapidly in sandy heathlands in Suffolk and in coastal sites in Northeast England, Scotland and Ireland; and it is proving difficult to control (Animal and Plant Health Agency, 2018).

Dune heath is a rare habitat threatened by physical disturbance, due to a thin surface layer, 15-20 cm of acid, low nutrient sand overlying calcareous sand and invasion by trees and scrub. A rare example of successful restoration of dune heath invaded by conifers and scrub was undertaken at the Montagu Road Triangle site in Sefton, Liverpool City Region. Careful cutting and removal of trees was followed by hand raking up of surface pine litter. Comparison of raked and non-raked areas demonstrated there was more rapid and prolific establishment of *Calluna* heathland from the exposed residual seed bank (https://www.dynamicdunescapes.co.uk). Refer to Dune Management Case Study Template and Denning *et al*. (2024) for detailed information.

Figure 12.

Restoration of dune heath with volunteers raking up pine litter following removal of trees.

Photo credit: Natalie Hunt.

Figure 13.

Regeneration of heather after two years with raked/not raked comparison.

Photo credit: Natalie Hunt.

Removal of conifer plantations

Several experts (Walker *et al*., 2004; Ausden *et al*., 2010; Fairhurst *et al*., 2023) provided evidence that the most successful restoration of former heathland degraded by plantation forestry has been achieved by removal of existing trees usually when felled as part of forestry rotation. Once afforested, soils will remain undisturbed until clear-felled in 30-60 year rotations. Substantial populations of dormant viable seeds of *Calluna* and *Erica* species persist under conifer plantations in upland and lowland sites for at least 40 and up to 70 years (Pywell *et al*., 2002). A similar approach has successfully created lowland dry heath after removal of naturally colonised birch woodland (Wilton-Jones & Ausden, 2005).

After felling, ideally leave tree stumps short and close to the pine litter surface to facilitate machinery access. It is then necessary to remove residual foliage and smaller branches (brash). After this, the layer of loose pine needle litter can be scraped up using a small 360° excavator fitted with a bucket suitable for the gap distance between stumps, or as a preference stumps can be ground down to facilitate more efficient mechanical operations. The RSPB has used custom-made tractor-mounted rotary brushes to loosen litter combined with a powerful vacuum pump to suck up the pine needle litter (Symes & Day, 2003). The dormant seed pool is located in the organic soil horizon beneath. Chemical control of ruderal 'weeds' may be necessary in the first and second growing seasons following litter removal, but a progressive increase in heather abundance should occur without further intervention. Use of herbicide can be substantially reduced by using tree poppers or 'Extractigator' tree pullers to uproot young invading silver birch and pine. This can also be done using an excavator fitted with a grab (Cruickshank, 2023). Birch must be pulled out, as cutting will result in regrowth from basal buds on the stem. An excellent case study is Dunwich Forest in Suffolk (Fairhurst *et al.*, 2023). Here the RSPB undertook extensive restoration of heathland (and acid grassland) following clear felling of Corsican pine *Pinus nigra*. In the period between 2009 and 2020, significant areas of NVC H1 heath community were created. They now support a characteristic assemblage of heathland birds including woodlark, yellow hammer and nightjar, plus a new colony of silver-studded blue butterfly.

Cutting, burning and grazing

Traditional management of lowland heathland involved cutting heather for thatching, gorse and trees for fuel, and bracken for animal bedding. Thus, ecological succession was prevented. In the uplands, bracken poses a serious invasive threat to both heathland and acid grassland. Bracken has a large underground rhizome system which stores energy and plant nutrients and thus is very difficult to eradicate once invasion has occurred. For several decades, control of invasive bracken to enable heathland restoration relied on application of the herbicide Asulam (that kills ferns) in July or August combined with cutting once or twice per year. Use of Asulam is now banned by DEFRA in England and by the Scottish, Northern Ireland and Welsh governments and was withdrawn in the Republic of Ireland in 2012 under European Law. Repeated cutting of bracken has been used to return bracken-dominated sites back to acid grassland/heathland mosaics (Cox *et al*., 2008). At a site in Derbyshire, long-term experimental research (17 years) by Rob Marrs and his associates (Alday *et al.*, 2023) has demonstrated good control of bracken using repeated cutting of bracken 2 or 3 times per year for 8 years. Over a further period of 10 years when no cutting occurred on the same area, regrowth of bracken was minimal.

In lowland heath, bracken can also be diminished by regular cutting but is also killed effectively by treatment with glyphosate, applied either as a spot treatment or a more extensive application using a suitable weed wiper. Inevitably there will be some collateral damage to desired heathland species. An initial application of glyphosate followed by annual cutting of surviving fronds may provide the best long-term outcome. Shellswell *et al*. (2016) provided a useful guide to aftercare management of regenerating lowland heathland that encompasses control of bracken, rhododendron, scrub and gorse. Although controlled burning is much less used as a management technique currently, in the Peak District National Park, a combination of cutting, burning and grazing has been an effective short-term method of restoring purple moor-grass dominated grassland towards heather moorland without the use of chemical herbicides to control the grass (Smith & Bird, 2005). Prescribed burning in lowland heath is recommended as an effective restorative technique by Shellswell *et al*. (2016). The efficacy of differing options was reviewed in relation to site type and time to achieve desired habitat condition.

Removal of trees, scrub and gorse

Lowland heathland is constantly undergoing successional change via scrub to closed canopy woodland and once restored requires regular management for the foreseeable future. Silver birch and oak develop woodland on dry sites, Scots pine *Pinus sylvestris* and downy birch develop woodland on humid sites, and rhododendron thickets occur on wetter sites. Larger trees should be cleared using tree shear equipment and stump grinding, smaller trees can be cut and stumps spot treated with glyphosate. Not all gorse should be removed (RSPB, 2019; London Biodiversity Partnership, 2006); retained gorse clumps should be coppiced on a rotational basis on a 10-15 year cycle. Guidance on the proportion of the heathland to remain as gorse varied from <10% (Berkshire, Buckinghamshire & Oxfordshire Wildlife Trust, 2023) to between 10-20% for total tall shrubs (London Biodiversity Partnership, 2006). This will provide a habitat for invertebrates including pollinators and a range of nesting bird species such as stonechat and Dartford warbler (Woodrow *et al*., 1996).

Invasion by rhododendron has often created dense and extensive thickets in secondary woodland and on blanket peats and heathland that are very difficult and expensive to eradicate. Higgins (2008) reviewed for the National Parks and Wildlife Service in Ireland all options for killing and/or removal of rhododendron including young plants, isolated large plants, and dense stands. Treatment of stumps or stems with high strength glyphosate or triclopyr is effective and there is minimal soil disturbance. But if chemical treatments are not an option, the only alternative method of eradicating rhododendron is to extract the entire rootstock, which involves extensive soil disturbance, loss of residual heathland seed bank, and possible soil erosion. The large-scale rhododendron control, Dulra project, is being undertaken currently in Connemara at three Special Protection Areas (SPA's). This project provides useful insights into approaches to large-scale restoration (https://www.dulraproject.com/). Edwards (2006, 2008) provides guidance on rhododendron control relevant to both Scotland and England.

Translocation

Translocation of turves

Translocation of dry heathland can be achieved successfully by lifting and re-locating turves or soil from donor to receptor sites. Published evidence (Pywell *et al*., 2011) clearly showed that translocation of turves has provided more effective outcomes for retention or enhancement of habitat quality than translocation of soil layers. However, a synthesis of evidence of 46 field experiments (Gerrits, 2023) demonstrated that soil translocation (including turf transfer) led to plant community development towards reference plant communities much more effectively than where only plant propagules were added. There is probably an augmentative role of transferring soil biota in successful restoration outcomes. Although rarely undertaken, it is possible to translocate wet heath successfully (Box *et al*., 2011) but the cost per unit area could be very high due to the requirement to create a structure with a suitable and sustainable hydrological regime. The following paragraphs discuss both these processes of translocation.

Key guidance on habitat translocation was provided by Anderson (2003) who suggested that successful implementation of a translocation project is based on seven stages and that the successful implementation of each is a prerequisite for achieving the objectives/good quality outcomes. The stages include (modified from Anderson, 2003):

- Setting objectives as part of pre-planning.
- Selection and preparation of the receptor site.
- Detailed project planning.
- Selecting the mechanism of translocation and the equipment that will be used.
- Agreeing the contract specifications.
- Creating a management plan for pre and post translocation.

Translocation of heathland turves (sometimes a heathland/acid grassland mosaic) or heathland topsoil is a feasible method of conserving habitat when a major development would destroy the existing heathland; but must be considered as a last resort when no other process of heathland restoration is possible. However, turves and topsoil sometimes become available when over mature undermanaged heathland is being ecologically enhanced by creation of bare ground for faunal habitat. When planning a translocation, the archaeological status of both donor and receptor sites must be considered. If archaeological interest is suspected, a prerequisite will be an archaeological desk study followed by field investigations if required by a local authority archaeological unit or other experts (Hawley *et al*., 2008). Checking for the presence of utilities services at both donor and receptor sites should be a routine action. Developments may include mineral extraction sites, pipeline installation, road construction, onshore wind farms, electricity transmission cables, and large commercial building projects. The translocation option may only be financially viable if there is a suitable available receptor site in close proximity to the donor site (e.g. <5 km) that provides a very similar soil profile with closely aligned physical and chemical soil properties and similar hydrological characteristics. Preferably the location of the receptor site should add to or link to another heathland site. There are similar requirements for upland and lowland dry and humid heath. Thus, appropriate ground investigation surveys, sampling for soil physical and chemical analysis and a hydrological survey are an essential prerequisite to inform the translocation process or indicate that it would not be feasible. Seasonal timing of translocation is an important factor in determining success. The optimum months for upland heathland are mid-September to mid-November, but in southern lowland sites, October to mid-December is feasible and January to March is possible if ground conditions are suitable (i.e. not frozen and in a dry period when soil moisture is well below field capacity).

Before commencing the translocation process a detailed ecological survey and description of the donor plant community (e.g. NVC assessment and vegetation physical structure) is necessary to provide a baseline for subsequent comparative monitoring of vegetation change in the receptor site. Ideally, a baseline sampling survey of selected invertebrate groups such as ants, spiders, springtails or bugs could be undertaken in the summer before translocation occurs. Financial constraints and the availability of specialist entomologists would restrict feasibility to major developments.

It must be accepted at the outset that translocation will rarely maintain the faunal and floral species assembly unchanged (Pywell *et al*., 2011). Subtle (or not so subtle) differences in soils, hydrology, topography, aspect and grazing management (where relevant) between donor and receptor sites will ultimately determine ecological outcomes. Despite these potentially negative outcomes, translocation will assist preservation of existing fauna to some extent including invertebrates such as ants, spiders, beetles, bugs, butterflies and moths, and also soil fungi including ericoid mycorrhiza associated with roots of *Calluna* and *Erica* species.

Translocation of donor vegetation is most likely to be successful with heathland recovering from previous cutting or burning with up to 4 years of regrowth of dwarf shrubs or on grazed sites where the height of vegetation is <25-35 cm. Older, taller vegetation can be cut to 25-30 cm using cut and collect machinery and ideally given one season of regrowth before stripping. Mature stands are less likely to regenerate from shoot buds and will rely mainly on germination of dormant seeds. The receptor site should have a substrate very similar to the donor site for physical and chemical soil properties and similar topography and hydrology. It will be necessary to undertake a soil survey for chemical and physical properties including extractable phosphorus, potassium and calcium, pH, soil organic matter and soil textural analysis. The formation of soil profiles should also be examined on both donor and receptor sites to ensure that the receptor is compatible with the donor. This will inform the depth of turves translocated.

The key stages for heathland turf translocation are:

1. Initial preparation of the receptor site may involve removal of existing trees and other woody vegetation and also will involve relieving compaction of bare mineral substrates using a power harrow or rotavator followed by light consolidation using a ring roller (e.g. Cambridge roller).

2. On most sites receptor areas should be reasonably level or only with a very shallow slope.

3. A grid system should be implemented to map the donor site and ensure that turves are laid on the receptor site in the identical pattern thus retaining continuity of mosaic patterns. Keeping existing small-scale variation in topography will enhance ecological diversity.

4. On sites with an existing vegetation cover, this should be stripped to a depth equivalent to the strip depth of the translocated turves. Large turves will be less prone to desiccation and root disturbance and therefore turves should be approximately 1.2 x 2.4 m (macro-turf) or 1 x 1 m if there is restricted access.

5. Depth of removal should be based on the boundary between topsoil and subsoil which in a typical lowland dry heath might be about 25 cm but could be significantly less on upland grass heath, unless heath vegetation had developed on deeper peat.

Figure 14.

Heathland turf being lifted using a hydraulic cutter.

Photo credit: William Bond.

6. It is preferable to use custom cutting equipment hired from specialist contactors. Typically, the hydraulic cutter will have guillotine bars to cut the vertical sides and tines for lifting the turf, although a modified excavator bucket is a less efficient alternative. Each site will require joint consideration and agreement between ecologist, designer and contractor about the most appropriate equipment to use in relation to project objectives and site characteristics (Anderson, 2003).

7. Ideally turves should be cut, lifted, transported on a flatbed and laid in position on the same day. It is possible to transport two or three layers on the flatbed using metal 'shelves' to support the turves. Turves should be packed together closely without gaps between. If any gaps occur, the majority should be filled by hand with turf fragments or topsoil (or subsoil if there is no topsoil available) from the donor site.

8. In lowland heath, leaving a few small gaps will create new habitat for invertebrates and reptiles. If it is not possible to relocate on the same day, turves should be stored for as short a period as possible, laid on a level area of geotextile and packed closely together.

9. In the case of linear features such as pipelines or electricity cables, where relatively short sections are excavated and restored sequentially, storage of turves on geotextile at the edge of the easement will be required for days or 2-3 weeks. Storage for longer will be detrimental to covered vegetation. Rarely, it may be necessary to make provision for irrigation of turves depending on time of year and forecast periods of drought. Planning to undertake the work in the autumn or early winter will maximise successful recovery.

10. Low ground pressure machinery should ideally be used and tracking over the receptor area should be minimised. Forward planning of the logistics of turf translocation is clearly a crucial element of the operation.

11. Factors determining cost include:
    (i). Preparation of the donor site, mainly cutting and removing arisings.
    (ii). Preparation of the receptor site that potentially may require removal of trees or stripping of topsoil and removal of arisings.
    (iii). Distance from the donor to the receptor site, use of a public highway and ease of off-road access.

Translocation of wet heath has rarely been attempted due to the difficulty in creating a suitable hydrological regime. Most wet heaths in Britain (including NVC M14, M15, M16) are examples of poor fen, minerotrophic, peat-forming, base-poor and acid wetlands. Destruction of these habitats must be prevented unless there are very exceptional reasons. Where translocation is required due to unavoidable and wholly exceptional circumstances, for example due to a Nationally Significant Infrastructure Project (NSIP), rescue from destruction must be undertaken. In these rare instances, translocation must consider other factors relevant to sustainable habitat persistence. Specifically, this includes assessment to confirm the presence of appropriate hydrogeological conditions which ensure success of the translocated habitat, including assessment of water flows, chemistry and fluctuating water table levels (Mountford *et al*., 2005). A suitably qualified hydrogeologist should undertake the appropriate assessment. A cautionary example is provided by the project at Gadle Knapp in Dorset. A constructed receptor cell enabled good hydrological management, which provided a plant species assemblage similar to the target wet heath community for a period of 7 years (Box *et al*., 2011). Unfortunately, after that time, poor aftercare management of the inflows, the habitat and the weir controlling the water levels ultimately allowed extensive invasion by birch. Having taken all of these measures into account, translocated wet heath is unlikely to replicate the donor flora, fauna and ecosystem structure in the long term due to differences in hydrology and mineral nutrient input.

Translocation of topsoil

Translocation of topsoil may be an alternative to turves when donor soil has a high sand content and turves disintegrate, or when existing heathland consists of scattered dwarf shrubs within acid grassland and there is probably a residual seedbank of heathland plants. Initial site investigations of both donor and receptor sites and soil preparation of the receptor site should be as described for turf translocation. The translocation procedure is described below:

Existing vegetation should be cut short and arisings removed using a tractor mounted flail, cut and collect machinery, or a suitable forage harvester depending on site topography.

- If the work is undertaken in the period mid-October to late December, cut seedling heather can be retained and spread over the translocated soil at the receptor site.
- Strip depth at the donor site should be determined by the depth of the litter layer and the humic organic horizons that contain the majority of the seed bank of heathland plants which is frequently about 50 mm (Putwain & Gillham, 1990).
- Ideally soil should be lifted, transported and spread on the same day or, if unforeseen circumstances prevent this, storage on geotextile for no more than 2 weeks is recommended in heaps with a maximum height of 1.5 m (this will minimise the impact of anaerobic digestion of organic material and prevent or greatly reduce the release of phytotoxic compounds such as ammonia and hydrogen sulphide).

- Topsoil can be spread ideally using a rear discharge agricultural manure spreader set to spread about 25 mm of soil, lightly firmed using a ridge roller (Cambridge roller) that will create a pattern of shallow depressions that will provide a favourable soil moisture and local enhanced humidity that enhances germination of ericaceous dwarf shrubs. Tractor tyre depressions provide a similar micro-environment.

- On smaller or irregularly shaped sites it may be preferable to spread soil using a small 360° excavator being careful to completely avoid tracking over the receptor area unless using a low ground pressure machine.

- Similar to when brush harvested seed or heather litter is spread on a bare receptor surface, soil surface stabilisation is recommended for exposed upland sites where there is a moderate or steep gradient due to rain splash, wind impacts and frost heave. The optimum approach is to sow companion grasses at a low target population density using wavy hair-grass or sheep's fescue as described in the section 'Brush harvested seed and capsules'.

- Companion grass seed should be broadcast using either a battery powered handheld spreader for areas measured in hundreds of square metres or using a tractor-mounted seed/fertiliser spreader for thousands of square metres, before firming the soil with a Cambridge roller if the terrain is suitable. At low rates of application, seed can be mixed with fine dry sand or sawdust at a ratio of 2:1 sand: seed and thus facilitate an even density of seed spread.

- On the great majority of lowland heathland sites, companion grasses are not necessary and may even suppress establishment of dwarf shrubs (Gilbert & Anderson, 1998).

- On less exposed sites, protection of seedlings will be provided by a light covering of harvested heather brash which, if cut and spread in autumn/early winter, has the additional benefit of adding additional seed of dwarf shrubs.

- On steep slopes where gulley or surface erosion is probable it will be necessary to utilise a biodegradable, open textured geotextile (e.g. geojute or a coir blanket) pegged down cover to provide surface stability and to apply additional harvested heathland seed or litter.

What to Consider / General Principles

Table 4 lists a selection of topics and general principles to consider when planning and implementing heathland restoration, creation or translocation. Dedicated guidance on project planning and implementation has been provided as part of this series which is applicable to all restoration projects (see Overarching Topic - Project Planning and Implementation).

Table 4: Things to consider during heathland restoration projects

Topic	What to consider (not exhaustive)	Potential risks/opportunities
Mitigation hierarchy	The mitigation hierarchy of avoid, mitigate, restore/enhance, compensate should be followed.	This means doing everything possible to avoid losing valuable heathland habitat in the first place, and that translocation or a loss followed by creation of new habitat should be a last resort.
Data/survey	What habitats/vegetation communities are already present and in what condition? What are the soil conditions/hydrology? Are there archaeological considerations? Did heathland exist on the site decades or centuries previously? For translocations, this information is required for both the donor and receptor sites.	Survey information is essential for identifying suitable sites and providing a baseline for monitoring success. Protected and/or notable species should be identified if present. Soils should be sampled to determine nutrient content and pH. The hydrology of the site is important for maintaining wetter habitats and should be understood.
Location	Is the soil type/substrate suitable? Does the soil have the right pH and nutrient levels? Is the topography/altitude suitable for restoration and management? Is the hydrology suitable for the desired habitat? Is there good access for management? What position does the site occupy in the wider landscape and is there connectivity to other heathland sites? For translocations, is the receptor site located as close as possible to maximise success?	Restoration can be more successful if the site is located where heathland once existed or is adjacent to existing heathland habitat. If the site is unsuitable there is a risk of the restoration failing. Where nutrient levels or pH are not suitable an alternative site should be considered. Measures can be taken to treat high fertility if appropriate. For wetter habitats the hydrology should be compatible. Sites should have a topography that allows for future management.
Equipment/ machinery	Is the machinery suitable for the site? Has suitable access been agreed? Is equipment available/affordable? Are there any alternatives/new innovations?	Large and heavy machinery can cause damage, particularly to wetter sites. Appropriate use of machinery can save time and reduce overall costs.
Timing	Can you get on site at the optimal time of year? What are the ground conditions likely to be like when you need access?	Work should be undertaken at the most optimal time for the restoration technique considered. A site may become inaccessible during winter months. Excessive drought conditions may result in failure of establishing plants.

Topic	What to consider (not exhaustive)	Potential risks/opportunities
Earthworks	Have you got adequate plans for moving and storage of site material such as topsoil? Have you calculated the amounts and space needed? Does the material need to be removed from site and is this accounted for in the costs?	Archaeological sites must be protected during earthworks. There could be a significant depth of humic layer under secondary woodland such as old pine plantations. Where topsoil is removed, it should be enough to remove the roots/rhizomes of undesirable species (e.g. bracken) to prevent unwanted regrowth. Removal of topsoil to the mineral layer will also remove any heather seedbank.
Works supervision	Is supervision of contractors required? Do important decisions need to be made on site during the works?	There may be unforeseen circumstances and issues that need dynamic ecological advice on site.
Plant sources	Is there an available seed source at the site or nearby sites that can be harvested? Do protected and/or notable plant species need special measures such as seed collection by hand or growing specimens in a nursery?	Plant sources should be local to the site. Plants should be from a similar habitat to that to be restored and matched to the conditions.
Biosecurity	The potential transfer of pathogens or invasive non-native species should be considered in terms of moving soils and plant material, or buying seeds and stock.	A biosecurity risk assessment should be undertaken.
Responsibilities	Are the responsibilities of all parties involved clear and agreed? Do the responsible parties have the appropriate skills, training and experience?	Responsibilities for certain important elements of the restoration work should be clearly defined, e.g. suitability of seeds source, success of establishment, and on-going monitoring.
Consultation and consenting	Who do you need to consult? (e.g. local authorities, NGOs, landowners, local interest groups) Is planning permission required? Are statutory or non-statutory nature conservation sites affected? Are protected and/or notable species affected? Are archaeological sites/monuments affected? Are agri-environment agreements in place that need to be altered? Is the site on common land?	Consultation with the appropriate consenting organisations is required where protected nature conservation or archaeological sites are affected. It is vital that local groups are consulted in advance to prevent possible objections to the works. Planning permission may be required for some restoration works. Protected species licences may be required.

Topic	What to consider (not exhaustive)	Potential risks/opportunities
Establishment and long-term management	What is the process for monitoring establishment and any remedial actions required? Is there a long-term plan for management?	Certain techniques such as turf translocation or planting would be more at risk of failure during establishment than natural regeneration from the seedbank. Common risks include drought, erosion due to heavy rainfall, and weed growth. Long-term management of heathland habitat is essential.
Costs/funding	Have possible funding sources been investigated? How are costs monitored and what is the process for scope changes?	The scope of works should be clearly defined and the process for change management should be set out in contracts.

Monitoring

Monitoring of completed restoration projects is necessary primarily to identify any initial problems during the establishment of the habitat, when it is most vulnerable to factors such as drought, damage or competition with undesirable plants. Following successful establishment, ongoing monitoring should measure the attributes of the habitat against targets defined at the start of the project to meet the objectives. Monitoring should be carefully planned early on and should be cost effective and proportionate to the requirement to identify progress and any remedial actions needed. Once the objectives of a restoration project have been met then the monitoring could be continued for general recording purposes. Further details are provided in the Monitoring guidance provided as part of this series (see Overarching Topic - Monitoring). Further advice on monitoring specific to heathland restoration projects can be found in Michael (1996) and Symes and Day (2003). Long-term monitoring should include a combination of the following methodologies.

- **Fixed point photography** - taken at fixed points facing a particular direction and at the same time of year to allow comparison.
- **Vegetation sampling** - percentage cover, height and condition of plants using quadrat samples (either 1x1 or 2x2 m in size) at fixed or representative locations to monitor vegetation changes over time.
- **Species (or groups of species) surveys** - counts or estimates of abundance for particular rare or important plants or animals, such as important plants, lichens, reptiles, birds, butterflies, dragonflies, and other invertebrate groups.
- **Physical attributes** - such as soil pH, nutrient composition, and hydrology as necessary.

In most cases, monitoring should be undertaken annually for the first 5 years, then every 3-5 years thereafter. However, monitoring of the establishment of habitats in the first few years after restoration will require more frequent checks. In the context of heathland monitoring, long term could be several decades.

Constraints and Limitations

General constraints or limitations to a restoration project can include any of the items to consider above, and the process of planning the project should identify the constraints to be addressed prior to work commencing. Common constraints might be funding, site suitability, access issues, consenting or local opposition. It is essential that these constraints are properly considered and mitigated. Further guidance is provided in the Overarching Topic in this series - Project Planning and Implementation.

Table 5 outlines some possible problems that may arise during heathland restoration, creation or translocation despite good planning and mitigation of risks.

Table 5: Potential constraints and problems encountered during heathland restoration projects

Constraints	Problems & limitations	Examples	Troubleshooting
Weather & seasons	Site waterlogging or erosion. Dry or frozen ground.	Site unworkable at optimum time of year. Seeds or plants washed away by excess rain. Plants affected by drought.	Contingency planning and mitigation such as barriers to prevent erosion.
Earthworks requirements	Limitations of plant/ machinery. Miscalculation of materials amounts. Inadequate space for materials storage.	Not enough space for topsoil bunds. Excessively large topsoil bunds.	Pre-planning of quantities, space, logistics and plant/machinery required.
Scope of works	Unclear scope definition resulting in objectives not being met first time and repeat work required.	Not enough topsoil removed resulting in regrowth of undesirable species. Not enough trees removed resulting in excess seed rain.	Clear, signed agreements including robust change controls. Site supervision and audit.
Public interaction	Anti-social behaviour. Damage, erosion or fires. Public objections.	Opening up of habitat allows unauthorised use of the site by e.g. motorbikes, causing damage and erosion. Public protest. Theft of equipment or materials.	Public consultation. Adequate fencing and gates to prevent unauthorised access. Site wardening.
Establishment and management	Failure of seedlings, plug plants or turves. Failure of protective fencing.	Drought and desiccation. Excess growth of weed species suffocating new plants. Browsing damage.	Adequate planning for management. Watering and maintenance during establishment.

Biographies

Phil Putwain

Dr Philip Putwain MCIEEM Rtd. is concerned with soil properties and plant ecology relevant to restoration ecology. He is a former academic (Liverpool University) and an ecological restoration consultancy specialist. Phil's professional capability is based on experience gained from over 50 years of plant ecology research (125 publications) and provision of consultancy services, working with a range of industries (e.g. BP, Siemens, Shell), research institutes (UKCEH, Rothamsted Research), statutory bodies (Natural England) and government agencies (Defra, Welsh Office). In recent years he has delivered a wide range of habitat creation and ecosystem restoration projects focussing on soils, habitat creation and ecosystem services provision in rural, post-industrial, urban and active mineral extraction settings. These activities have focussed on the creation and management of heathland and species-rich mesotrophic and acid grassland.

Liz Allchin

Liz has thirty years of experience in ecology, much of which has been in researching and designing habitat management and restoration. Her interest in heathlands began with her PhD on heathland management in Dorset and Devon (supervised by co-author Phil Putwain) and she has worked on other heathland restoration projects across the UK, including habitat management plans for wind farms and heathland restoration as mitigation for road schemes in Scotland.

Mike Gibbs

Mike Gibbs CEcol MCIEEM is a botanist and ecological consultant with over 20 years' experience in vegetation survey and habitat creation, enhancement and restoration. His expertise includes providing assessments and design input for construction and development projects in order to maximise the benefits to biodiversity and ecosystem services. He is an Associate Director at AtkinsRéalis, having formerly worked at Thomson Ecology, Surrey Wildlife Trust, and as a self-employed consultant. Early in his career, he worked with a habitat management contractor, particularly on lowland heathlands. He is a committee member for the CIEEM Ecological Restoration Special Interest Group.

Laura Moody

Laura Moody is an Associate Director in WSP's Nature Advisory team, specialising in botany and habitat ecology. She has over 18 years' experience as an ecologist; delivering habitat assessments, National Vegetation Classification (NVC) surveys, and designing habitat creation and management strategies across heathland, acid grassland, mesotrophic grassland and woodland systems. Laura leads complex UKHab classifications, condition assessments and habitat specifications, ensuring robust ecological baselines and highquality habitat outcomes for major infrastructure, local authority planning, and strategic nature recovery projects. She supports local authorities, landowners and developers in identifying opportunities for nature recovery and habitat enhancement, through nature finance initiatives, habitat mapping, offsetting strategies and longterm management plans that maximise biodiversity value and crossdisciplinary environmental benefits.

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At AtkinsRéalis, we are engineering a better future for our planet and its people. We strive to take a holistic approach to meeting the twin challenges of biodiversity loss and climate change. Our team of environmental experts help unlock funding for nature recovery and create a lasting legacy in habitat creation and restoration projects. We design and deliver major projects on the built and natural environments all around the world.

Heathlands provide some of the most beautiful and inspiring landscapes in the UK and Ireland, many of which are on our doorstep. By sponsoring this guidance topic in the Rebuilding Nature series, we are proud to help promote positive environmental change for the benefit of people and nature.

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Case studies

The re-creation of dry heathland and habitat for a nationally threatened butterfly at Prees Heath Common Reserve.

This case study describes the techniques used to create dry heathland on previously fertile arable land using soil profile inversion by deep-ploughing, chemical acidification, and sowing seed by spreading recently harvested heather brash. After eight years the aim of greatly increasing the area of suitable habitat for the silver-studded blue butterfly had progressed very well. After 16 years the population of silver-studded blue has increased from <1000 to an estimated 54,000.
Proceedings of the 11th National Heathland Conference, 18-20 March 2015. Sunningdale Park, Berkshire. February 2016.

https://www.researchgate.net/publication/292720939

Re-creating woodland and heathland on slate waste in Wales.

The transfer during quarrying of heath vegetation with associated peat to a slate waste site designated for restoration proved effective in establishing key heathland subshrubs. Bilberry re-sprouted easily from buried shoots whilst heather turf died, but within one year a flush of heather seedlings had germinated from the seedbank in the transferred peat. Three years on, there was complete ground cover of target heathland species, provided that sheep were excluded. Williamson *et al*., (2003).

https://www.researchgate.net/publication/260592226_Restoring_Habitats_of_High_Conservation_Value_after_Quarrying_Best_Practice_Manual_Section_I_The_framework_for_restoring_habitats_of_high_conservation_value

Restoring heathland and acid grassland following the felling of conifer plantation: a case study from Dunwich Forest.

This case study was focussed on monitoring undertaken by RSPB between 2009 and 2020 at Minsmere RSPB Reserve following re-creation of heathland and dry acid grassland on arable land using acidification with sulphur. See Ausden *et al*., (2010) and Fairhurst *et al*., (2023).

Rugeley sand and gravel quarry

CEMEX UK's restoration work at the quarry and surrounding heathland has contributed to Staffordshire's Local Biodiversity Action Plan Targets for lowland heath expansion. Bird species found at the site include woodlark, nightjar and tree pipit. Rare palmate and great crested newts inhabit the restored heathland and there are 41 species of mining bees and wasps, which bury into exposed sand around the site.

This work is described in a downloadable pdf available at https://www.cemex.co.uk/su-rugeley-quarry.aspx

Restoration of dune heath on the Sefton Coast, Liverpool City Region

The Montagu Road Triangle is a protected Site of Special Scientific Interest and a Special Area of Conservation for dune heath which is a scarce habitat. The aim of the project was to restore the site to a healthy dune heath; a mosaic of heather, gorse, grassland, bare ground patches, occasional pools and scattered trees, thus providing a wide variety of habitats and enhanced species diversity.

https://dynamicdunescapes.co.uk/case-studies/dune-heath-regeneration/

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