In many cases there may be justification for deliberately extending the area of certain habitat types, such as bare sandy exposures or pools. For those species requiring bare sandy surfaces for burrowing or basking, mangement as described above for sand lizards is appropriate.

Building on the observation that dragonfly populations have benefited from past human activities, such as peat cutting or clay mining, new dragonfly habitats have been successfully created on some heaths in Surrey and Dorset by digging or even the use of explosives. Shallow, warm, moderately acid pools with plenty of aquatic vegetation, especially *Sphagnum,* are usually best. Quite small waterbodies can support large numbers of larvae, but the number of adults is greatly restricted by territorial behaviour. Territory size is larger for the larger species; for example a small pond will never hold more than one larger hawker (*Aeshna*) male. Small pools of about 20 m in circumference, with sides sloping gradually to a sump no deeper than 1.5 m in the middle, may serve to encourage the smaller species, but would be inadequate for *Aeshna* spp. It is important for dragonflies that heathland ponds should not be shaded by trees.

Plants

Most of the plant species of special interest in heathland communities have characteristics of morphology or life-cycle that have enabled them to withstand the effects of traditional management practices. In most cases, therefore, they do not require special management for their conservation, so long as the management regime is directed towards heterogeneity of heathland vegetation (Chapter 11).

Plants of dry heaths The two dwarf species of gorse, **dwarf gorse and western gorse**, which are so characteristic of southern English heaths, are examples of plants that regenerate vegetatively after burning or cutting and develop alongside heather to re-establish the typical mixed stands. In communities containing **bell heather** *Erica cinerea,* this species also regenerates vegetatively, sometimes more quickly than heather. Where heather is slow to regenerate after a particularly severe fire, or where the stand was too old before burning to allow vegetative regeneration, bell heather commonly establishes well from seed on the drier soils and may dominate the area for between six and 10 years before being overtopped by the gradually increasing heather. In the heather-bearberry heaths of Scotland (H16 - see Chapter 3), **bearberry** *Arctostaphylos uva-ursi* benefits from burning management because, being a low-growing species, it is confined to gaps or open areas in the stand, and fire gives it a chance to sprout quickly from clusters of buds near the 'crown' and to spread before the heather cover redevelops.

Common gorse is an important component of heathland vegetation for certain animal species, both invertebrate and vertebrate. Although in some places it is inclined to be invasive and may therefore require active control measures (Chapter 9), in others management may be directed towards maintaining or even establishing patches of gorse.

Gorse provides shelter, for example in spring for emerging reptiles, food for a large number of invertebrate species (e.g. Lepidoptera, Coleoptera, Thysanoptera etc.) and hence for their predators, and nesting sites for various heathland birds such as wren, stonechat, linnet, chaffinch and yellowhammer. In parts of the south of England it provides a vital component of the habitat of the rare Dartford warbler.

Management of gorse for the benefit of the fauna requires that patches and thickets should be maintained in the pioneer to mature phases and prevented from becoming degenerate (usually when they exceed 15 years of age). As far as possible, therefore, all areas of gorse on a reserve should be brought into a 15 year rotation (i.e. 1/15 managed each year). This can be done by cutting (with saw or swipe, preferably in late winter), or where practicable by burning. If the bushes are less than about 15 years old they will regrow from the base, and, if litter is raked up and burnt, seedlings will generally appear in numbers on the bare area. Unfortunately resprouts and seedlings are especially attractive to rabbits, and rabbit-proof fences may be needed. If older stands are cut or burnt there may be adequate regeneration from a seed bank, but this may extend the period of recovery by about five years.

If it is found necessary to create new gorse areas, plots of about 0.25-1 m^2 may be prepared by hand with a spade or by using a rotovator, producing a fine tilth. It is often desirable to add ash from burnt areas to provide potassium. About three 2-3 year-old gorse seedlings should be planted in each plot.

Plants of humid heaths Cross-leaved heath is another species that regenerates well after burning or cutting, and it may for a time become dominant on humid heath soils after management. **Dorset heath** *Erica ciliaris* is a species of very restricted distribution in Britain and is therefore of special interest where it occurs. It also belongs to the more humid heaths and will regenerate vegetatively after burning or cutting, but generally speaking humid heaths require little management.

Another nationally rare species, the **marsh gentian** *Gentiana pneumonanthe*, also belongs to humid heath, and here there is some evidence that occasional fires are beneficial. It appears that this plant flowers and sets seed better in dry years and after fire. Germination and establishment are best in open sites, such as are provided by burnt patches where competition from other species is reduced. Similarly, grazing may also help to create regeneration niches. However, burning of humid or wet heaths is always attended by the risk of an increase in purple moor-grass and so should only be undertaken infrequently and with care (Chapter 5).

Plants of wet heaths Wet heath is often rich in species, some of them rare. Amongst the characteristic plants are bog asphodel *Narthecium ossifragum*, devil's bit scabious *Succisa pratensis*, meadow thistle *Cirsium dissectum*, the sundews *Drosera* spp., common butterwort *Pinguicula vulgaris*, orchids such as *Dactylorhiza maculata* and *D. fuchsii*, and various sedges *Carex* spp. and bryophytes, including *Sphagnum* spp. Examples of plants of special interest include yellow centaury *Cicendia filiformis*, wavy St. John's-wort *Hypericum undulatum*, pale butterwort *Pinguicula lusitanica*, three-lobed crowfoot *Ranunculus tripartitus*, pale dog-violet *Viola lactea*, marsh club-moss *Lycopodiella inundata* and brown beak-sedge *Rhynchospora fusca*.

In certain cases, if hydrological conditions remain unchanged, some wet heaths may require little management. However there is often a problem with the vigorous growth of purple moor-grass which tends to outcompete other plants of wet heaths. Light grazing, particularly with cattle or ponies (Chapter 8) is then appropriate. Burning should be used with considerable caution, when other methods of management are not possible.

Some rare species of open situations may benefit from habitat creation by judicious use of vehicle tracks, such as the pigmy rush *Juncus pygmaeus* and capitate rush *Juncus capitatus* at the Lizard, or by maintaining mown firebreaks, as for example lesser butterfly-orchid *Platanthera bifolia* and pale dog-violet at Presceli, South Wales. In some wet heaths where species such as common sundew *Drosera rotundifola,* great sundew *D. anglica,* common butterwort, pale butterwort, marsh club-moss or lousewort may be of particular interest, slicing off the turf to expose small patches of bare peat, or other very local disturbance, may be effective.

Bryophytes Moist, humid and wet heaths are often rich in mosses and liverworts and may contain rare species. The maintenance of a diverse bryophyte flora depends to a considerable extent on the presence of gaps in the heather canopy, or small open areas, but exposure to desiccation is detrimental. The bryophyte flora associated with pioneer heather is largely different from that which develops in the gaps in a degenerate stand, so, for maximum representation of species, parts of an area should be managed to produce pioneer stands while other parts should be allowed to become mature, degenerate or uneven-aged. While burning itself and the subsequent bare phase may damage or destroy mosses and liverworts already present in an area, some survive (e.g. cushions of *Leucobryum glaucum,* which hold much moisture). Others will colonise during the post-fire succession if the surface is sufficiently moist. However, burning reduces bryophyte diversity and encourages carpets of common colonisers, such as *Campylopus introflexus* or *Polytrichum* spp., and therefore should generally be rejected as a management technique for the conservation of cryptogams. In wet heath especially, burning may damage species that take a long time to establish, such as *Sphagnum imbricatum.* Where the bryophyte flora is to be encouraged, management of the heather stands by cutting or grazing may be preferred to burning. Where *Sphagnum* spp. are to be encouraged, it is neccessary to maintain overall water levels and to keep a balance between pools, hollows and hummocks. If drainage has been attempted in the area, it may be necessary to prevent drying out by blocking drains and to keep intact as large an acid catchment as possible in order to retain the water. Alternatively, the ground level may be lowered locally, relative to the water table, by digging artificial pools (which should have shelving rather than steep sides).

Lichens tend to be characteristic of dry heaths, where they are often rich in species. As with bryophytes, open patches are required. On lichen-rich heaths all but very light sheep grazing should be avoided, as many lichens are extremely sensitive to trampling. Burning should never be permitted.

If the heather canopy becomes too dense it can be reduced by mowing. On the Breckland grass heaths, rabbit grazing is important to keep the vegetation low and to ensure continued availability of small bare patches suitable for lichen colonisation (Chapter 8). Sometimes it may be necessary to achieve this artificially by shallow disturbance (e.g. rotovation) of the surface (e.g. on sandy heaths).

Macrofungi Fruiting bodies of macrofungi are not abundant in heather-dominated areas, probably because of chemical inhibitors present in the soils. They are more numerous where there is admixture with other species, for example bearberry, or (in wet hollows) creeping willow *Salix repens.* Hence management aimed at producing uneven-aged stands of heather with canopy gaps occupied by other species, or a mosaic of patches of different vegetation

components, is likely to increase the diversity of fungi, especially if there is variation in depth of the water table below the soil surface. However, there is little information on management for the benefit of macrofungi in heathland areas.

Summary

1 **Good management** of a heathland ecosystem as a whole ensures a diversity of vegetation structures and provides habitats for a wide range of species. However, the needs of rare or specially interesting species may sometimes require additional measures.

2 **Smooth snake and sand lizard** These prefer mature dry heath with open patches of bare sandy soil. Burning is damaging to the habitat in the short term. Management should allow much of the heather to become mature. Bare ground up to 2-5% of the total area should be created (unless already present), either as open patches or in certain circumstances as ploughed tracks. Fire protection is important.

3 **The natterjack toad** is now almost lost from its former stations in the wetter parts of southern lowland heaths. The habitat requirements of this species include short vegetation with much open ground (tree cover minimal), and ponds for breeding that are not too acid (pH 6-7).

4 **Dartford warbler** This scarce bird is confined to certain heaths in southern England and needs a fair proportion of gorse of between six and 12 years of age in a matrix of heath vegetation. Mature heather touching compact gorse bushes is the preferred nest site.

5 **Nightjar** The nightjar nests on patches of bare ground close to small trees on heather-dominated heathland, and requires a source of large invertebrates (mainly moths) for food. Positive management for nightjars includes both the provision of potential nest sites by creating bare patches in areas of existing heather and creating glades by clearing birch or Scots pine, and maximising the heath/woodland edge to provide songposts, roosts and foraging areas.

6 **Woodlark** The woodlark requires extensive areas of bare or sparsely vegetated ground for feeding, such as short turf, grasses, mosses or lichens, with patches of taller vegetation for nesting, such as grass tussocks and heather, and isolated young trees for perching.

7 **Invertebrates** Habitat diversity including areas of firm (not churned up) bare ground the heath/scrub ecotone and heather stands of a variety of ages lead to maximum species richness. Acidic pools with plenty of aquatic vegetation (e.g. *Sphagnum)* encourage dragonflies. Silver-studded blue butterflies need pioneer or early building-phase heather, with warm microclimates, and the presence of ants *Lasius niger* and/or *L. alienus.*

8 **Plants** Many heathland species withstand traditional management practices (e.g. *Erica* spp., bearberry, the two dwarf species of gorse). Common gorse may be managed by

cutting or burning to prevent patches exceeding 15 years of age. It may be introduced to an area by planting 2-3 year old seedlings in small rotovated plots to which ash has been added. Fencing against rabbits may be needed.

Dorset heath belongs to humid heaths of south-west England; marsh gentian also requires wet or humid heath and its regeneration may be encouraged by fire. Some plants of wet heath, especially bryophytes, may be damaged by burning, which should generally be avoided there. Certain species may be encouraged by the creation of small bare areas, by slicing off the peat surface.

Other species require small depressions in the soil surface (e.g. vehicle tracks, or patches from which the surface has been skimmed).

Bryophytes need open patches and protection from desiccation. Maximum floristic richness is achieved where part of an area consists of pioneer stands and part of mature, degenerate or uneven-aged stands.

Most lichens do not tolerate a closed heather canopy. They are susceptible to heavy trampling, e.g. by cattle. Light sheep grazing may provide suitable management for cryptogams (or rabbit grazing in grass heaths). Where renewal of surfaces for lichen establishment is necessary, surface disturbance of small patches may be achieved by rotovation.

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11 GUIDELINES FOR MANAGEMENT PLANNING

Preceding chapters have shown that with a few exceptions heathland ecosystems have to be managed if they are to be conserved. There are, however, various options available to the manager, which have been discussed in some detail. Decisions on which of these to use and how to plan the management of a reserve or other heath area are not easy, and this chapter sets out some of the relevant considerations.

Survey

A detailed survey of the area is an essential prerequisite for management planning. This should culminate in the preparation of a map showing all the habitats and plant community types occurring in the area, preferably on a scale of 1:2,500. It is not the purpose of this handbook to describe survey methods: useful guidance is given in the *Handbook for Phase 1 habitat survey* (Nature Conservancy Council 1990). It is recommended that the National Vegetation Classification (NVC) be followed where possible for plant community types, and detailed Phase 2 vegetation mapping undertaken. The locations of particular animal and plant populations, breeding sites etc. should also be recorded.

Management plan

It cannot be emphasised too strongly that the second vital prerequisite for management is a thorough and detailed management plan. (For detailed guidance see *Site management plans for nature conservation,* Nature Conservancy Council 1988). The preparation of such a plan should ensure that management objectives have been carefully formulated and decisions taken as to the choice of methods to achieve these objectives. The existence of the plan should result in the systematic application of prescribed management practices and provide the standard against which to check adherence to the programme. This is not to say that the plan, once drawn up, should be inflexible: it should in fact be revised at prescribed intervals to allow for experience gained and observed developments.

In drawing up a management plan it is important to state clearly why the area is of special value. This may be because it is the best example of its type in the UK or the region, or because it is a habitat for species or communities of particular concern, or because it is highly regarded for purposes of recreation, scientific research or education. It may also have high aesthetic and landscape appeal. Next it is necessary to record the most important features of the site, for example whether it consists of a single well-developed vegetation type or a mosaic of patches and transitional zones. The management plan should also indicate the type of organisation on whose behalf management is to be carried out (e.g. a Wildlife Trust, English Nature, RSPB, local authority etc.) and any specific object of conservation (e.g. the marsh gentian or Dartford warbler).

Management plans should include a commitment to record management undertaken. Standard project recording forms are given in *Site management plans for nature conservation,* Nature Conservancy Council 1988. These should be supplied to English Nature and the County Biological Record Centre.

Every management plan has to be adapted to the needs of the particular area, but all heathland plans have to be developed in the light of a number of considerations, which are discussed below.

Objectives Objectives must be determined for both the area as a whole and for each of its separate parts.

1 The main objective is to conserve the heathland ecosystem as a whole. Management should incorporate the requirements of rare and specially interesting species (Chapter 10).

2 Management should also seek to create a mosaic containing the maximum diversity of heathland vegetation structures. This involves breaking up the area of heathland into sectors, including some managed on a long rotation allowing the development of uneven-aged mature and degenerate stands. A useful aim to have in mind is that the area should contain a series of heather stands of increasing age from zero to about 30 years (although this may be too long for heather in Breckland where it may become degenerate after about 13 years), in approximately five-year steps. For this purpose, burning or cutting are often the appropriate methods of management. There is a dilemma in that the adoption of long intervals between treatments, to produce mature or degenerate stands, is inclined to permit the entry of unwanted species (such as trees and shrubs or bracken) as gaps develop in the heather canopy or bare ground is exposed because of slow regeneration after treatment. In suitable cases, a varied community structure can be maintained by careful grazing management.

Habitat diversity The conservation value of many heathlands is greatly enhanced by the presence of wet hollows, which support humid or wet heath, bog and sometimes standing water. The management plan should recognise the importance of these. Their continued existence is very dependent on the survival and good management of the surrounding dry heath (whereas the latter does not depend on the continued presence of wet areas). In general, wet heath should be kept free of burning (see Chapter 5). Where purple moor-grass is dominant, cattle grazing may be very beneficial in checking its growth. Patches of grass-dominated vegetation are valuable, as a contribution to both plant and invertebrate diversity, so long as they are not allowed to spread to the exclusion of heath species.

Control of undesirable species The management plan should include prescriptions for tackling incipient invasion by unwanted species. These may include provision for cutting out unwanted trees (with application of herbicide to the stumps as necessary) or pulling saplings (Chapter 9). However, a certain number of trees and areas of scrub or copse usually enhance a heath and can be allowed for in the plan. Where bracken is a problem, provision may be needed to prevent its further advance by cutting or spraying at the margins of bracken stands or where it shows signs of invading heather areas (Chapter 9). Whether or not an attempt should be made to clear bracken from places where it is dominant should be considered carefully in the light of costs and the predicted benefit in terms of the extension of heathland. The same applies to areas of acid grassland.

Selection of methods of management The management plan has to specify the methods to be used, chief among which are grazing, burning and cutting (details in Chapters 6-8), or, on occasion, rotovation and turf-stripping. The choice depends on a number of factors; for example, the past history and tradition of the area may be important. Thus areas that until recently have been grazed are likely to be better suited to grazing as the means of management than those that have not, and much the same may be said of burning. Where turbary (Chapter

4) was practised in the past it may at the time have largely taken the place of other uses and management, and this may be a good reason for considering its re-instatement, if practicable.

However, although tradition may be a pointer to suitable choices at the present time, it should not preclude consideration of all the options. The final choice will be determined in the light, firstly, of which method seems best suited to achieving the stated objectives; secondly, of the practicability of the various methods in local circumstances; and thirdly, of their cost (Appendix 8). A further consideration may be the public perception of what is acceptable on a reserve. This may be inclined to inhibit the use of burning or herbicides, for example, although objections can often be overcome by good public relations and on-site interpretation and explanation. Where appropriate, participation of volunteers in management may go a long way in meeting objections.

Local variations in management

While much of what has been said in this chapter and in Chapters 5-8 applies to most types of heathland, management plans must take into account the particular types of ecosystem represented and allow for any special measures required for their conservation.

Local variations in soil and climate Variations in climate throughout the British Islands affect the choice of methods of management. Thus in the drier regions of south and south-west England, grazing or cutting are the main options and burning generally plays a lesser role than in the rest of the country. Much of the effort expended in heathland management is directed at arresting processes of succession towards scrub, woodland or other types of vegetation. Successional trends, however, are strongly influenced by the combined effects of soil and climate. Where soil nutrient status is very low (especially phosphorus storage) and the climate is warm and dry, there may be little evidence of succession. Heaths in such conditions may be relatively stable over long periods of time and require little management. Examples are to be found in the extreme south of England (e.g. parts of Dorset), but they are exceptional. Dry lowland heaths with somewhat higher nutrient levels and intermediate capacity for phosphorus storage are prone to invasion by common gorse, especially where disturbance has occurred, and management may have to be directed towards its control. In moister, cooler climates with higher soil nutrient levels, succession towards birchwood (or colonisation by other trees or shrubs) is more evident, while bracken becomes an acute problem on the deeper, relatively freely-drained soils with moderate to good nutrient levels. It is under these conditions (which are widespread, especially in the heaths of central and eastern parts of southern England and towards the north of Britain) that management requirements are greatest, if the heathland is to be preserved and change prevented.

Some of the invasive species, notably birch and bracken, in addition to shading out heather increase nutrient levels in the upper 15-20 cm of the soil where most of the feeding roots of heather and grasses are located. This is inclined to promote the growth of grass species (or bracken) at the expense of heather and emphasises the need for management to prevent unwanted changes.

As indicated in Chapter 2, some heathland soils show signs of nutrient accumulation. Reasons for this include inputs from rainfall that has been 'enriched' from industrial or agricultural sources, abandonment of traditional forms of land use that removed nutrients from the heath,

and the effects of birch or bracken litter. The result may be an increase in the proportion of grass species and the decline of heather. Here, in addition to normal management it may be necessary deliberately to reduce the nutrient capital of the area. Mowing and removal of the cut heather in bales (Chapter 6) may be an effective, if gradual, way of achieving this. In certain areas (e.g. parts of the Breckland) where heath communities have almost disappeared, experiments have included more drastic measures such as complete removal of the vegetation, ploughing and then cropping for a year or two with a high nutrient-demanding crop such as rye. Re-establishment of heath vegetation is then attempted, as described in Chapter 13.

Humid and wet heaths These are generally less subject to change than dry heaths. A policy of non-intervention may be acceptable unless there is clear evidence of undesired trends in community composition. On soils that are saturated, or where drainage is impeded, invasion by trees, shrubs or bracken is unlikely to be a problem. Heather, if present, requires little or no management since it regenerates vegetatively by layering in moist peat or peaty humus and in any case is not exclusively dominant but merely one among a number of abundant species.

However, wet heaths are dependent upon the maintenance of their water source and are subject to the effects of changes in drainage pattern or other aspects of the hydrology of surrounding areas. A careful watch needs to be kept on this and representations made if there appears to be a risk of adverse effects (or even total loss) resulting from operations on land adjacent to the site.

Other problems may on occasion arise in the shape of trends in one of two possible directions. On the one hand, heather may become increasingly dominant to the exclusion of some of the characteristic wet heath species. This would suggest that the wet area is progressively drying out, either because inflow of water has decreased or, more often, because drainage in the surrounding region has been improved for agricultural or forestry purposes. Management of the hydrology of the locality is the only way to tackle this problem, but the expansion of heather may be reduced or delayed by light grazing. This has been successfully accomplished in South Wales (Dowrog Common; see Case Study no. 5) with cattle or horses, which are preferred because some surface disturbance is often advantageous for maintenance of floristic diversity.

On the other hand, there may be a tendency for a species such as purple moor-grass to gain the upper hand. It may not be easy to pinpoint the cause, but increased inputs of nutrients or injudicious burning may be implicated. Remedies must be directed towards weakening the purple moor-grass and may include a period of heavy grazing, especially by cattle, in spring when the young leaves are being produced, annual cutting back of the foliage, if practicable, or the use of a dalapon spray. If the amount of food reserve transferred to the swollen stem base is progressively reduced and competitor species allowed to spread during the summer, purple moor-grass may be reduced to manageable levels over a period of a few years.

Wet heaths usually occur in the context of larger areas of dry heath, in hollows, areas of impeded drainage or where for other reasons water accumulates or seeps slowly down a gentle slope. Conservation of wet heaths depends more on the proper management of the surrounding dry heath than on intervention on the wet heath itself, because if the former is allowed to develop into woodland or change in some other way the chances are that the wet heath will gradually dry out. While light grazing, especially by cattle, is often a suitable form

of management for wet heaths (Chapter 8), they may also benefit from some turf-cutting, which provides niches for species of the early stages of succession. Burning may lead to drying out but may be employed if other means are excluded, in particular (i) where rank growth has to be cleared before introducing grazing to increase diversity, and (ii) where it is desired to promote the regeneration of marsh gentian (Chapter 10). In both instances burning should be used very sparingly.

Maritime heaths Management of maritime heaths is covered in detail in the *Sea-cliff management handbook for Great Britain* (Mitchley & Malloch 1991) and only brief mention will be made here. In general, the guidelines set out in this handbook for managing inland heaths may be applied also to maritime heaths, bearing in mind that the more extreme climatic conditions often limit the tendency for succession to proceed to scrub or woodland. Exposure to strong wind may induce a low, creeping growth-form in heather, which is usually associated with a variety of other species, some of which are typically maritime in their distribution, such as sea plantain *Plantago maritima* and spring squill. Where this is the case, little or no management is necessary, but in more sheltered conditions it may be essential to manage in order to maintain species diversity and prevent grass species becoming dominant. Very often such areas have traditionally been grazed, and then a moderate grazing regime using sheep, cattle or even ponies may be an appropriate form of conservation management. Cutting or burning may also be used if necessary.

Because of the low productivity of vegetation in exposed habitats, where maritime heaths are managed by grazing there is a risk of overgrazing and care must be taken to keep stocking rates at a level compatible with maintaining the composition and structure of the heath. This will often be as low as the equivalent of 0.5 ewe per ha per year or less.

Pony grazing, at a low stocking rate, is a traditional use of maritime heath in parts of the Lizard peninsula, Cornwall, and has proved to be an effective way of managing for conservation. Shetland ponies now replace the extinct Goonhilly breed. They control the spread of common gorse and maintain the mixture of maritime heath (including such species as Cornish heath and spring squill) and herb-rich grassland.

Local or regional heathland management strategies

Where a reasonable network of heathland reserves exists, good management will help to secure their future. In some parts of the country, however, encroachment of development into the remaining heathland areas constitutes such a threat that the several conservation agencies, acting independently, may be unable to mount effective opposition. In view of the continuing loss of heathland habitats a strategy for the future of all surviving remnants of lowland heath is urgently needed. Many different landowners are involved and agreement on conservation objectives and management is essential. This is beginning to take shape in certain areas.

A good example is the Sandlings Project in Suffolk, where co-operation between conservation bodies and local authorities has resulted in the formation of a committee called the 'Sandlings Group'. Apart from areas owned by conservation bodies, many of the surviving fragments of heathland in Suffolk are privately owned and many are registered Commons. The group has gained the co-operation of numerous owners and Commoners. It has co-ordinated funding, undertaken a comprehensive survey and set up a management programme for the whole series

of heaths. This includes re-introduction of grazing, regeneration of heather, mowing management, bracken control, scrub control and reinstatement of heath vegetation in some places from which it had disappeared.

In Surrey, following the publication in 1988 of *A strategy for Surrey Heathland* by the Surrey County Council and the then Nature Conservancy Council, a 'Heathland Countryside Management Project' has been set up. Apart from areas in the ownership of conservation bodies, much of Surrey heathland is in the hands of the Ministry of Defence, while some is privately owned. Common rights still exist in some cases but here are rarely exercised. The objective of the Project is to facilitate a co-ordinated approach to heathland management on the part of all interested parties and individuals, in order to secure the future of these heathlands. It has the support of the three Surrey Boroughs, the Surrey County Council, English Nature and the Countryside Commission. It employs a Project Officer and Assistant and organises and trains volunteer work parties.

A Strategy Plan for Dorset heathlands, in which seven local authorities and a 'Dorset Heathland Forum' of six conservation bodies are collaborating to protect remaining heaths in the area, is now in place and approved by the District Councils. In Dorset the Royal Society for the Protection of Birds is undertaking a project entitled 'Action for Heathland' (part funded by British Petroleum). The aim is to manage heathland, with the co-operation of landowners, on a county-wide scale, rather than just on specific reserves. Special attention will be given to the removal of invading pine, rhododendron and birch and the reinstatement of heath on land from which it has disappeared.

Summary

1 A detailed survey is an essential prerequisite for management planning. This should culminate in the preparation of a vegetation map.

2 The second vital step is to produce a management plan. Management plans should meet the requirements of rare and specially interesting plant and animal species identified during the survey.

3 There should be a commitment to record all management operations that are carried out on a site.

4 The objectives of management should be clearly specified in the management plan. A general objective is to create a mosaic containing the maximum diversity of heathland vegetation structures. Features such as firm (not churned up) bare ground and areas of scrub and grassland are also of considerable value (Chapter 10).

5 Management planning should take account of local variations in soil and climate and the types of heathland such as humid, wet and maritime heath that are present.

6 Local and regional heathland management strategies can play a key role in promoting the conservation of lowland heathland.

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12 GUIDELINES FOR MONITORING RESULTS OF MANAGEMENT

In too many instances a lack of management monitoring and the application of remedial measures if necessary is the weak link in conservation practice. Hence it is vital to set up an effective monitoring programme.

Rationale of monitoring

Stress has been laid on the need for management in heathland reserves, and for clearly identified objectives of management. Correspondingly, it is essential to monitor the results of the management practices adopted, in order to determine the success with which declared objectives are being met and to judge whether or not the management plan is yielding value for the time and money spent on it. The results of management are often slow to become apparent and monitoring must therefore be an on-going process, directed towards a periodic re-assessment of the plan and decision as to whether it should be continued or modified.

A monitoring programme should therefore be planned to show as clearly as possible whether, over a stated period of years, the ecosystem is apparently stable or undergoing change. It should be sufficiently sensitive to detect changes in the composition and structure of the vegetation and in the populations of those species of plants and animals that are regarded as particularly important. However, detailed measurements of these quantities at frequent intervals are extremely time-consuming. There is often a temptation at the outset to set up a regular monitoring system, involving a considerable commitment of time and effort, that may be difficult to modify at a later stage if the amount of data generated proves to be more than necessary to answer the original questions. It is preferable to target monitoring so that it is related to key management objectives. Thus monitoring might be geared specifically to total heather cover or each growth phase, or the amount of scrub or bracken fronds. Targeting increases the number of samples that can be taken, improving precision.

While it is important to avoid attempting the impossible or unnecessary, systematic monitoring is indispensable. Too often in the past, records of management and its results have been made only in the memory of the warden or manager. If (s)he is unavailable to pass on the benefit of his or her experience to a successor, the latter has to start again from first principles. Furthermore, without written records, or even if data are available but their analysis and dissemination are lacking, the accumulated wisdom is not available to others who could benefit from it. All this is especially important where, as is still often the case, management is experimental in nature.

Hence it is necessary to decide at the beginning (i) the exact questions the monitoring system is required to answer, and (ii) the appropriate methods to obtain reliable answers to these questions, without a disproportionate input of time and effort. This will require an explicit and objective consideration of the desired degree of precision and the costs involved in achieving it, with an assessment of the optimum trade-off beween these two elements.

This chapter will address these questions in rather general terms, as they apply to heathland management. It is unnecessary to go into details of methodology as these are covered in other publications, especially the chapters on 'Evaluation of management techniques' and 'Monitoring of vegetation' in *The peatland management handbook* (Rowell 1988).

Guidelines for monitoring heathland reserves

The purposes of monitoring are not only to provide an objective record of any changes but also to warn when acceptable levels of change are in danger of being exceeded. These should be identified in the management plan and may be set, for example, in terms of:

- minimum areas of heather dominance;
- minimum areas of particular heath plant communities;
- minimum populations of species which may be at risk (such as Dartford warbler, smooth snake, marsh gentian or silver-studded blue);
- maximum areas of invasive species, such as bracken, or scrub cover.

An indication that these limits have been reached is a signal for remedial management to be initiated.

It is important at an early stage to divide up the site into a number of compartments, based usually on topographical and vegetational features. If this is not practicable, a grid can be superimposed on a map of the site. The compartments, or sectors of the grid, will each have their own provision for monitoring and also serve as the basis for recording events in the area as well as the results of management.

Methods of monitoring are often divided into three levels.

Level 1 Complete coverage of the site, but relatively non-specific. At this level the aim is to provide basic information on the site and its vegetation.

Level 2 Complete coverage, specific but not very precise or detailed. This involves repeated systematic survey, including use of infrequent but regular air photography, to determine and map changes in community or species boundaries. This might include rapid animal surveys to record numbers present in the form of an index or the boundaries of territories.

Level 3 Specific, precise, detailed, but usually incomplete coverage (though may be complete if sufficient finance is available). This involves detailed examination of vegetation and fauna by rigorous sampling at regular intervals, to gain precise estimates of changes in abundance or condition of critical features or species.

What to monitor?

Monitoring is needed on several different size scales. On a broad scale (Levels 1 and 2), monitoring should provide:

- a record of all management practices, including the areas subjected to treatment (e.g. burning, cutting, grazing), with dates, best indicated on maps;

- the areas occupied by different animal species or vegetation types, e.g. the NVC categories, and by stands of heather of different growth phases. These should be mapped and remapped at intervals of three to five years.

On a smaller scale (Level 3), monitoring should aim to distinguish between changes that are a direct result of management and those that are part of long-term natural trends or fluctuations. (This distinction is important; there is sometimes a tendency among conservationists to exaggerate the implications of short-term fluctuations and to become too concerned with detail.) Thus, while monitoring effort may be concentrated in areas that are receiving the greatest management input (e.g. burning, grazing), control (unmanaged) areas are also necessary if the efficiency of management is to be assessed.

Monitoring on this scale needs to:

- record structural changes in the main vegetation types, e.g. by the use of regular fixed-point photography;
- record the detailed occupancy of selected permanent sample areas;
- record the composition of the main types of plant communities (floral diversity and abundance of species), by means of quantitative analysis;
- record the population size of important individual species (both plant and animal) by appropriate sampling at regular intervals. Examples of species in this category are those mentioned in Chapter 10 as having special conservation value and management requirements.

In assessing the results of Level 3 monitoring it is necessary to be able to distinguish inconsequential fluctuations about a mean from 'genuine' changes. For this reason detailed monitoring needs to be continued over a considerable period of years, if reliable conclusions are to be drawn.

Broad-scale monitoring

Mapping Periodic mapping provides evidence of change in the extent and distribution of community types (or, in the case of trees and animals, sometimes individuals). This kind of information can be entered on to a base derived from Ordnance Survey maps at a scale of 1:25,000 or 1:10,000. (In the NCC's Upland Vegetation Survey, communities were mapped from aerial photos at about 1:24,000, enabling patches of sizes down to 0.25 ha to be distinguished. For field work, enlargements of the air photos at a scale of about 1:12,000 were used.) Mapping onto transparent overlays, using aerial photographs, makes both recording and storage easy. Where heather has been managed by burning or cutting, homogeneous stands of differing age since treatment are usually separated by distinct boundaries, often visible in air photos. All such uniform stands, if more than about 0.25 ha in area, can be marked on the transparent overlays and annotated with the date of burning or cutting, where known, or an estimate of the age of stand derived from stem sections. (For this purpose a sample of, preferably, 20 stems taken at random, should be used so that a mean age and standard error can be calculated. Stems should be cut near the base and sections examined under a powerful hand lens or dissecting microscope. The annual rings, although sometimes not very distinct, can usually be counted without much difficulty, especially if the section is stained with a lignin stain such as phloroglucin in HCl. With experience, counting of annual rings can be done in the field. A drop of stain can be placed on the cut end of the

stem and the rings counted under a lens as the colour deepens. A mean age of stand determined in this way is usually fairly accurate but may underestimate the time since last management by a year or two because a short time may elapse after burning or cutting before regeneration begins, and in any case there may be little lignification in the first year of growth.)

Whether or not the heather has been managed, there may be considerable variation in stand structure on heathlands. Several categories can usually be recognised (as given in MacDonald & Armstrong 1989) and indicated on maps by different codes. (This is an important aspect of monitoring, as changes over time from one category to another will indicate the success or otherwise of management and whether or not the heather areas are stable or declining.) The categories are as follows:

a recently burnt heather with a low vegetation cover

b young regenerating heather stands (canopy height less than 15 cm)

c areas of well-developed, taller heather (heather erect and usually taller than about 30 cm)

d areas with a mosaic of small, heather-dominated patches (less than about 30 x 30 m) among other vegetation

e areas of complete heather dominance that are neither very short regenerating stands nor tall mature-to-old stands

f areas of tall, mature or older heather, more than 30 cm tall, with gaps developing in the canopy

g areas where heather forms a short carpet or mat, less than 15 cm tall, of densely packed intertwining branches

h areas where the heather bushes are taller than 15 cm and have compact rounded canopies of densely packed, contorted and intertwined branches and shoots ('topiary' heather)

i areas of 'drumstick' or 'mop' heather in which bushes consist of lengths of bare woody stem ending in a small mass of contorted shoots

j areas of dead heather.

Areas occupied by acid grassland communities, bracken, scrub or trees should also be mapped as accurately as possible in order to detect encroachment on the heath vegetation, where it occurs. The position of isolated trees, which may become parents of a crop of seedlings ultimately forming a thicket or 'island' of scrub or woodland in the matrix of heathland, should be shown. The position and type of any adjacent woodland should be recorded, as well as areas of recently felled woodland. (The latter may have initiated scrub development from which heathland may be recoverable without too great an effort) (Chapters 9 and 13).

Whenever new air photos become available the mapping system should be transferred to these, thus incorporating a check on the outlines that have been entered since the date of the previous photo. Details of the availability of air photos can be obtained from the Ordnance Survey (for England), the Welsh Office and the Scottish Development Department. MacDonald & Armstrong (1989) supply further guidance on the use of air photos under their heading 'Monitoring method 3'.

Smaller-scale monitoring

Fixed-point photography Repeated fixed-point photography, supplemented by site notes, provides an important visual back-up for use in conjunction with mapping and may help to reveal unexpected changes in vegetation. As far as possible, the whole site should be covered from selected viewpoints, but if this is impossible attention should be focused on:

1 areas undergoing management by burning, cutting or grazing,

2 areas where changes are most liable to occur, e.g. patches of old heather, or localities where there is potential for the invasion of bracken or trees, and

3 permanent quadrats.

Full practical advice for fixed-point photography is given by MacDonald & Armstrong (1989). It is essential that systematic appraisal of the information obtained on successive occasions is carried out.

Periodic recording of vegetation composition and structure

This is needed in addition to the overview of vegetation change at various scales provided by mapping and fixed-point photography. It should be planned both to assess the degree of stability or change in unmanaged areas and to follow the effects of management.

There are two main approaches: first, the regular recording of vegetation in permanently marked sample areas, and second, periodic quantitative analysis of the communities. In both, random (or restricted random) sampling should be used wherever possible.

Permanent samples These usually take the form of permanently marked quadrats, the size of which varies according to the objectives of the work, the type of data to be collected and the total number of samples to be monitored. In heathland, permanent quadrats are frequently 1 m^2 (for fairly detailed records) or 4 m^2 (for more generalised recording). Generally, sample areas larger than 1 m^2 become difficult to search thoroughly for plant species and difficult to work in without damaging the vegetation. It is most important to chose a reliable method for marking and identifying quadrats, to minimise the risk of loss while avoiding undue conspicuousness. Suitable methods are described in *The peatland management handbook* (Rowell 1988).

The basic data to be obtained from permanent quadrats are the complete list of species present and some quantitative estimate of their relative proportions. The latter can be an eye estimate of percentage cover or a scoring according to a 'cover-abundance' scale (e.g. the Domin scale

- see Appendix 7), although for scientific purposes actual percentage cover figures are much more useful. Eye estimates, however, can show substantial variation, not only between observers but also as obtained by any one observer. If time is available and the extra effort is justified by the proposed use of the data, a point method of cover estimation is to be preferred (100 points are needed to register a 20% change in cover as significant at p=0.05). As an alternative to recording cover, local frequency can sometimes be an effective way of comparing the contribution of the various species to the community on successive occasions. Here the quadrat is gridded into a large number of small squares, and species presence in each is recorded and the number of occurrences expressed as a percentage of the total number of small squares.

However, permanent quadrats lend themselves not only to obtaining quantitative data on species representation but also to repeated spatial mapping of their occurrence in the sample square. This can be done in two ways:

a direct mapping to scale (e.g. on to graph paper), using a gridded quadrat to assist in the process, and

b subdividing the square into a large number of small sub-units, e.g. 4 cm^2 or 25 cm^2, and recording the presence of each species on a plan of the whole quadrat. This is a relatively quick and objective method which provides (i) a value for local frequency, and (ii) a reasonably sensitive plot of the spatial distribution of each species in the quadrat, allowing comparisons (showing e.g. expansion or contraction) over time.

Advantages

(i) Permanent samples afford an exact and objective record of change in a given patch of vegetation, which is particularly useful if continued over a long period. They reduce sampling error where it is necessary to sample rather heterogeneous vegetation.

(ii) They may provide valuable information on the mechanisms and developmental aspects of change.

(iii) They are invaluable as an indication of the success or otherwise of management. When successive photographs of permanent quadrats are available, they provide a striking presentation of the results that, to the public or to a landowner or manager, may be more telling than a table of data.

(iv) They may be especially important where new or experimental management is being introduced.

Disadvantages

(i) Setting up, re-finding and detailed recording are all time-consuming.

(ii) It is impossible to cope with more than a small number of permanent samples; hence they can never be truly representative of a large area, or if representative at first they may in the course of time become unrepresentative.

Comment Direct comparison of successive records from any one individual quadrat does not require statistical methods (unless the method of recording has employed a process of subsampling within the permanent quadrats, i.e. it was a two-stage sampling scheme). However, a statistically valid indication of change for a given area of a plant community (e.g. a patch that has received management treatment such as burning or a change in grazing regime) demands a number of randomly located replicates. Because of the time and effort involved it is essential to be selective in setting up permanent samples and to use them efficiently to monitor changes (bearing in mind the need for 'controls' in untreated areas), rather than scatter them indiscriminately across a wide spectrum of variation. It is best to be selective in choosing the stands or features to be monitored and then sample randomly within those selected.

An alternative approach, commonly adopted when the time available dictates a systematic rather than random arrangement of samples, is to lay down a small number of permanent **transects** across the area, along which quadrats can be placed at regular intervals. Although the locations of quadrats are not independent, this is a quick way of representing much of the variation in community composition contained within the area and is especially useful if there is a clear gradient from one side of the site to another, when transects should be aligned along the gradient (e.g. from wet to dry, or from foot to crest of slope).

Any decision to establish a set of permanent samples involves a considerable commitment for the future and should not be undertaken lightly. It represents an investment, the value of which increases with time, while failure to maintain the periodic recording involves a corresponding wastage of effort.

Ordination of data from permanent quadrats Data from a number of permanent quadrats can be ordinated, i.e. plotted against two or more axes to display similarity or difference in composition and trends in variation. Where records have been repeated at two or more time intervals, the advantage of this approach is that the successive quadrat records can be incorporated into the same ordination, and the positions of a given quadrat in the ordination plot at the different dates of recording can be shown by lines joining the points ('trajectories'). If a number of quadrats show similar trajectories, this provides good evidence that the changes represent general trends.

Quantitative analysis of vegetation community composition

Monitoring change in the overall composition of vegetation in an area of heathland may require statistical comparison of random samples recorded at different times (e.g. intervals of one or more years). Owing to the variability of the vegetation, quite large numbers of samples may be needed to obtain results that command confidence. It is important therefore to be clear as to the uses to which the data are to be put and to choose the type of recording accordingly. The chief possibilities are these.

1 **Presence/absence of species (i.e. frequency) in a series of samples** This is an objective and quick method of obtaining values useful for comparative purposes (e.g. comparing different treatments, or the same treatment or area at different times). It gives a good indication of the entry or disappearance of species to or from an area and of broad changes in their quantitative representation. However, the actual values are

relative and give little indication of absolute quantities (e.g. cover or density), and they depend upon the size of the quadrat and the dispersion (degree of clumping or spatial aggregation) of the species. However, for management purposes, relative measures may be perfectly adequate. In general it is better, for measuring frequency, to use more small quadrats (e.g. 50 x 50 cm or 10 x 10 cm) than fewer large ones. The size of the quadrat can be varied to make the method sensitive to particular species, according to their abundance. Thus for any species which is likely to show important changes or is of special significance to management, the quadrat size can be tuned to provide data that will reflect changes in the presence of this species within a critical range. If there are several such species, 'nested' quadrats of sizes appropriate to each can be used.

2 **Cover estimations** These are often eye estimations of cover to the nearest 5-10%, or the use of a cover or cover-abundance scale (e.g. Domin scale), but attention is directed to their limitations (see above). With experience, such estimates by any one observer may become moderately consistent but different observers may tend either to over- or under-estimate. Results may be improved by calibration of visual estimates against point sampling in the same quadrat (e.g. 400 points will give an estimate of cover accurate to $\pm$ 5% with 95% confidence limits). Estimations are easier and more accurate, the smaller the quadrat; hence in heathland, 50 x 50 cm may be recommended, unless the vegetation is very simple and homogeneous, when 1 m^2 may be appropriate.

3 **Dry weight or 'standing crop'** For certain purposes, a measure of dry weight per unit area of the various species (or categories of species) may be required. The whole vegetation, cut at ground level, is removed from a number of random samples, sorted into species (or categories), oven dried (at 95° C) and weighed. This is a destructive sampling method and should only be used when specific data of this kind are required, such as the amount of forage available to herbivores.

Comment The question most frequently asked, in connection with random quadrats, is 'How many?' Unfortunately it is not possible to lay down rigid guidelines; the answer depends on the size of quadrat, the variability of the data and the type of comparisons to be made (e.g. a coarse comparison of quantities of major species only, or a more detailed comparison of the amounts of all species including the less frequent ones). If frequency (presence/absence) only is being recorded, the number of quadrats will depend on the precision required (and the time available): where a species frequency in quadrats of a particular size does not diverge too greatly from 50%, 100 quadrats will provide a frequency estimate to $\pm$ 10%, or 400 to $\pm$ 5%, with 95% confidence limits.

The general principles on which to base a decision are discussed by Rowell (1988) in the *Peatland management handbook.* Inevitably a judgement has to be made as to the range of species for which statistically significant comparisons are desired, in relation to the time available for recording. It is always worth doing a pilot study on a representative area, from which the number of quadrats needed to achieve significance for given levels of change (or difference) in particular species can be estimated. This provides a basis on which to decide the minimum acceptable number of samples for the purposes of the study. It may be particularly useful, where feasible, to identify indicator species or those expected to be

undergoing quantitative changes and to relate the monitoring method and the size and number of samples to these species.

However, a pilot study will only provide an estimate of the number of quadrats needed to achieve a particular degree of precision for the amount of heterogeneity existing in the vegetation at the time of sampling. It is possible that the variance in the data may increase from one monitoring occasion to the next (if for example a particular species is not uniformly grazed throughout the area). This is another reason for preferring a simple method such as frequency in a large number of small random quadrats.

The **advantage** of quantitative community analysis using random quadrats is that, where comparisons are required either between different treatments at any one time or between records on the same site at different times, differences that are statistically significant for certain species can be identified. Also, the sampling approach gives an overall analysis of the vegetation of the given area, to serve as a basis for comparison with repeated sampling at a later date. This contrasts with records from permanent quadrats, in which any evidence of change is strictly applicable only to the individual quadrat in which it has occurred, except in the unlikely event that data are available from a large number of quadrats in the study area.

For valid comparisons of plant community analyses (or permanent quadrats) it is essential that records should always be made at the same time of year, ideally in late June or July.

Monitoring of individual species

It is frequently desirable to monitor population numbers, density or other quantitative attributes of individual species. The appropriate methods differ greatly as between plants and animals and between different species (e.g. rare plants, insects, birds, reptiles or mammals). It is impossible to cover all cases here; indications of suitable methods are given in Goldsmith *et al.* (1990) and specialist publications, some of which are listed in the Bibliography to Chapter 10.

Where management involves grazing, what is often needed is an assessment of heather utilisation in order to detect over- or under-grazing and, if there is a risk of damage to the heather, to adjust the grazing regime. Full details of methods that have been used in the uplands are given in MacDonald & Armstrong (1989).

Monitoring of habitat conditions

Generally, changes in vegetation give a good indication of changes in the habitat and suggest the type of management response that may be necessary. (For example, the immediate effects of late frost or drought on the vegetation may be monitored using the methods described above.) It is not the province of this handbook to consider the recording of climatic change, atmospheric (or other) pollution etc., important as these are. Management practices may initiate slow changes in soil conditions (e.g. organic content, nutrient content, acidity etc.), but these are often difficult to detect because of the great local variability in these factors. Burning, cutting etc. of the vegetation may also markedly change the local microclimate.

A factor of major importance to any area of heathland is its general hydrology, and this may be affected by land-use changes in the neighbourhood as well as to some extent by management in the area itself. To gain some indication of change in hydrology and plan appropriate action if required, reference to the guidelines given in the *Peatland management handbook* (Rowell 1988) is recommended.

Summary

1 Monitoring is essential to determine success, or failure, of management. It should be planned to show whether the system is stable or undergoing change.

2 Limits for acceptability of change should be set in advance. Remedial action is needed if these are exceeded.

3 Methods of monitoring are divided into three levels:

(i) complete but non-specific coverage, providing basic information on the site and its vegetation.

(ii) complete and specific (but not very precise and/or detailed) coverage, involving survey, use of air photos etc. to map plant communities, important habitats and the location of particular species.

(iii) specific, precise and detailed but usually incomplete coverage, involving sampling of vegetation and fauna.

4 Periodic mapping to a scale of say 1:25,000 or 1:10,000, often using air photos and transparent overlays, provides a valuable indication of changes, some of which may be the result of management. This should be supplemented by fixed-point photography, together with site notes.

5 More detailed recording of structure and composition of the vegetation involves two main approaches.

(i) Permanent samples - i.e. permanently marked quadrats within which the vegetation can be mapped or records made of local frequency or cover of the species. Permanent samples involve a considerable investment of time and effort and should be undertaken only if future recording can be assured. Data from successive recordings can be ordinated to display trends of change.

(ii) Quantitative analysis of aspects of community composition (e.g. frequency, cover, biomass), based on adequate random sampling, can be used for statistical comparisons between areas receiving different treatments, or between records from one area at different times.

6 The variety of methods for monitoring the populations of other plants and animals is such that specialist publications should be consulted.

7 It may be necessary to monitor the general hydrology of an area of heathland if undesirable change is to be detected and remedied.

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13 HEATHLAND RESTORATION

This handbook is concerned mainly with the management of existing heathland for nature conservation. However, it would be incomplete without some reference to methods for restoring heath vegetation on sites from which it has disappeared, or even establishing it in new locations, because the need for this may arise both in conservation and amenity areas. It is a large subject, still being actively investigated, and can only be touched on briefly here. The aim is to give general guidance on the best approaches to reconstruction or rehabilitation and to direct those who require more detail to fuller treatments and accounts of experimental studies.

A major review of the subject has been published by British Gas in conjunction with the Environmental Advisory Unit, University of Liverpool, called *Heathland Restoration: a Handbook of Techniques* (Putwain & Rae 1988). This contains an extensive bibliography of references on the subject. The Peak Park Joint Planning Board has also published a review of restoration techniques by Penny Anderson Associates entitled *Moorland Restoration: a review of experience in the Peak District and elsewhere* (Anderson & Radford 1988). Although concerned mainly with upland areas, there is much in this that is relevant to lowland heaths.

The re-establishment of a vegetation that at least resembles the former lowland heath in places from which it has disappeared, or its creation *de novo* in suitable environments, is technically feasible, though often not easy. The extent to which the structure and composition of the resulting community approximates to any of those of the local heathland types varies according to conditions and methods used; usually, restoration is regarded as successful if the leading dominants are re-established and the appearance of a heath regained. Although characteristic associated species may reappear in the course of time, this is a very slow process and the return of a full complement of species may be an unattainable goal. However, in view of the decline of lowland heaths and their value both for nature conservation and amenity, even limited success may be well worth while.

The immediate objective of heathland restoration is usually to establish heather, and other heath species as appropriate (such as bell heather, bilberry, cross-leaved heath etc.), in sufficient abundance that, even if not completely dominant, they control the appearance of the vegetation. This can only be achieved if the essential ecological conditions are present, together with a sufficient supply of seeds or other living plant parts capable of regeneration.

Ecological conditions

Soil Soils under dry heathland are generally acidic and relatively low in available nutrients (notably calcium, phosphorus and nitrogen). They tend to be freely drained and podsolic, with a layer of raw humus (of varying thickness) at the surface, overlying the mineral material. Although germination and establishment of heather and *Erica* species will occur on mineral material, it is generally more successful on organic substrates (largely because of their better moisture retention). In dry areas restoration usually demands an acid, organic topsoil of about 5 cm in thickness over a mineral surface, but the former must be moderately compacted, because establishment may fail on loose material with excessive undecomposed litter. Successful establishment can take place on mineral surfaces, however, if rainfall is sufficient and relative humidity high enough (especially in summer) for seedling survival. Surface

erosion may be a major factor militating against successful restoration, so surfaces must be made as stable as possible, sometimes by the use of companion species, especially grasses.

Although high nutrient levels are unfavourable for the establishment of a heathland flora (encouraging vigorous growth of grasses and weed species at the expense of heather and its associates), it may also be inhibited on substrates that are extremely deficient in available nutrients.

Microclimate Even where germination of seed has been successful, the seedlings of heather and other Ericaceous species are very susceptible to exposure and desiccation. Hence, re-establishment in open situations demands the presence of micro-sites that afford some degree of protection and moisture retention. These may include small hollows, ruts, or shelter provided by grass tufts or other plants.

Approaches to restoration or re-establishment

The approach to renewing heath vegetation will vary significantly according to the nature of the site, its immediate past history and whether there is any sign of heather (or other heath species) surviving in the area either as scattered individuals or as seed in a soil seed bank.

1 **Where heather is present as a minor component of the existing vegetation** In some instances, where heather has given place to dominance by grass species such as wavy hair-grass (in dry heaths), bent-fescue grassland (on the better soils) or purple moor-grass (in wet heaths), close examination may reveal surviving heather plants among the grass, even though they may be unnoticed on casual inspection. This situation may arise where fires have been too frequent (or, in the absence of grazing, after an accidental intense summer fire). On the other hand, it may sometimes be a consequence of continued heavy grazing of a former heath by sheep or cattle. Although the heather may have been severely cut back and many individual plants killed, it is often the case that trailing stems survive for some time in the turf and continue to put up vertical shoots, which may be nibbled off at their tips as they reach the height of the sward.

   There is a chance that a complete rest from grazing may allow the surviving heather to expand and gradually overtop the grass sward. Disruption of the turf in areas from which heather has almost completely disappeared may help to encourage its return by the establishment of seedlings (derived either from a soil seed bank or from seed parents in neighbouring areas). However, the composition of the vegetation must be carefully monitored, because if conditions have altered materially in favour of the grasses (for example by a build-up of nutrients in the soil), a more drastic treatment (see below) may be needed.

2 **Where there is no living heather, but a substantial seed bank is present in the soil** Many heathland soils contain a considerable bank of viable seeds in the top 5-10 cm, notably of heather, bell heather and, to a lesser extent, some of the other heath species. (For example, tests have yielded 500-1,700 seeds of heather m^{-2}, depending on soil type and former vegetation). Seeds of these species may remain viable for many years, whereas those of most grasses die if they fail to germinate within a few

years. Such a seed bank may be present, for example, under a plantation from which heather has been completely shaded out, or in areas where former heathland has been disturbed or destroyed by construction work or entirely replaced by a grassland community. Removal or opening up of existing vegetation may result in conditions becoming favourable for germination of seeds newly exposed at or near the soil surface. Minor disturbance may do no harm or may positively encourage germination by bringing buried seeds to the surface, but it is important that the general soil profile should remain undisturbed, as the vast majority of seeds (over 90%) are contained in the top 5 cm of the soil. Rolling the surface with a heavy roller or even driving over it with a vehicle ensures good seed contact with the soil, improves microhydrology and hence increases seedling establishment.

Heather seeds require exposure to light and, preferably, fluctuating temperatures around 17° - 25°C for germination. Provided there is adequate moisture, these conditions exist in places where the surface is exposed. There may be a flush of seedlings of heather (and bell heather), which, because of the much greater number of seeds in the bank, outnumber those of competitor species and make possible the re-establishment of a heath community. However, seedling survival fails if the water supply in the soil surface falls below field capacity or if the seedlings are exposed for any length of time to a desiccating atmosphere (or to waterlogging). Thus if heathland restoration via germination from a seed bank is planned, autumn rather than spring is usually the best time because seedlings have longer to establish prior to dry summers. However, germination of heather seeds is intermittent and fairly prolonged, so if one crop of seedlings fails, more may be expected when conditions again become favourable (though by this time more propagules of potential competitors may have arrived in the area).

Before planning for restoration of heath vegetation by means of seed germination from a soil seed bank, tests should be carried out to verify the presence of an adequate seed supply. A number of samples of the top 5 cm of soil should be collected and spread out over sterilised sand or soil in small seed trays and placed in a greenhouse or even on a windowsill. If kept moist by frequent watering or spraying, a crop of heather or other ericaceous seedlings will appear in 5-6 weeks if there is an abundant seed bank.

3 **Where there is no surviving heather and no soil seed bank** In most situations where restoration or introduction of a heathland flora is to be attempted, neither living plants nor seed are present on site. It becomes necessary to introduce one or the other, the choice of method depending on the nature of the site and what treatment of it, if any, may be possible.

Seed sources Possible sources include:

(i) Living plants. These may be introduced to a site either in turves cut from a donor site or as rooted seedlings or cuttings. Cuttings of heather grown in biodegradable paper tubes or fibre mini-pots have been successfully transplanted into field sites. Cuttings must be taken between late spring and early autumn, but it is possible to raise heather or bell heather from seed at any time of the year under glass. These methods, however, are labour intensive, requiring rather lengthy preparation, and are appropriate

only for quite small areas. Transplanting turves is a more commonly employed technique, but can be recommended only if there is a suitable donor site where damage can be accepted (perhaps because it is scheduled for subsequent destruction, or because turf-stripping is being used as a form of management). The functional roots of heather are largely confined to the upper, organic, layer of the soil, usually the top 15 cm. Turves may be cut down to about this level and are generally readily lifted from the top of the mineral horizon. If set into a similar organic-rich substrate that effectively retains moisture, they normally establish successfully.

(ii) There are three main ways in which heather seed may be collected for use in an area to be restored.

a) Harvesting seed capsules from a heather stand. Capsules may be harvested, often without too much damage to a stand, by cutting with a forage harvester set to mow a little below canopy level, in the period mid October - end November. (Seed dispersal takes place during and after this period, but it is a gradual process with many seeds remaining for a time in the capsules.) It is unlikely to be worth harvesting after the beginning of December, but the length of the collecting season can be determined by examining a sample of capsules under a hand lens to check how many seeds they contain. Best results are obtained from fairly young, uniform stands of heather which have flowered profusely. If a double-chop forage harvester is used, the short sections of green shoots with which the capsules and seed are mixed are also suitable for spreading on the sites to be restored. On surfaces such as bare peat or eroding ground, this mixture provides a useful mulch that may sometimes be substituted for grass nurse crops (see below), giving a degree of protection to the developing seedlings. As an alternative to the forage harvester, a combine harvester can be used. If the harvested material (which consists mainly of young shoots bearing capsules) is not to be used immediately, it should be dried before storage, as it will begin to compost very quickly.

Another method is to cut the heather at a lower level with a flail and collect it with a baler. Bales can than be stored outside until spring. When harvesting heather for seed capsules it may be useful to cut in such a way as to provide firebreaks on the donor site.

b) Lifting litter from beneath a vigorous heather stand. This litter is usually a rich source of seed, though it is wise to check the content of germinable seed before collection. (It is also wise to avoid areas close to stands of birch or other trees, where the litter may contain many tree seeds.) The litter can be readily obtained without damage to the heather stand. The time of year at which it is collected is less critical than for harvesting seed capsules, although early spring (February, March), after all the previous season's seed has been shed, is probably best.

Litter can be collected by hand if quantities required are not too great. (30-40 kg of dry litter can be collected per man day, on sites where it is abundant).

However, a 'Billy Goat' vacuum litter collector can be effective if the vegetation is not too tall and if the ground is not too wet, when the rather small wheels may sink in and damage the surface. Previous raking of the area can be helpful. Amounts collected vary from 80-100 kg of litter per machine per day.

On areas of older heather that are due for regeneration in any case, a procedure involving flailing, raking off the debris, light rotovation of the top 5 cm of substrate and then collection of the loose material with a 'Billy Goat' has been used. Once dry, the litter can be stored for three or four years with little decline in the viability of the heather and bell heather seeds.

c) Importing heath topsoil from another site. This is often carried out when a donor area is to be demolished. Its advantage is that in addition to providing a seed source the topsoil can be used to reconstitute a suitable habitat on exposed mineral surfaces lacking an organic horizon.

After the vegetation has been cut by flail, the organic horizon is rotovated, usually to a depth of 5-8 cm. If time allows, the optimum depth should be determined by tests to show the distribution of the soil seed bank. (Where the organic horizon is shallow, rotovation should be omitted, as incorporation of mineral material reduces the concentration of seeds). The organic material is then lifted to the required depth using a bucket attached to a tracked vehicle.

Topsoil contains not only seed of heather and bell heather but also viable propagules (seed, stem bases, rhizome fragments) of other heathland species, such as common gorse, the dwarf gorses, bilberry, purple moor-grass, cotton grass etc. A fairly diverse flora may be introduced in this way to the new area, but, to avoid the risk of drying out, the topsoil should be stored for no more than a few weeks and spread on the new site in autumn.

It is also possible to obtain heather seed commercially, but at present seed of British origin is not available, and its use in any quantity involves considerable expense (about £100 per kg).

Spreading the seed source

The seed-containing material should be applied either in autumn or early spring. The cut shoots or litter help to bulk the material for spreading and also act as a mulch. Spreading can be done by hand from the back of a trailer, or else a spreader may be used. It is difficult to indicate a preferred rate of application, as the number of seeds contained in the harvested material and its moisture content vary greatly. Normally, however, it is large (e.g. 7 million seeds per kg), and a rate of application of freshly cut heather shoots with capsules of between 600 and 1,000 g m^{-2} (or 6,000-10,000 kg ha^{-1}) has been suggested. As a rule of thumb, the harvested material can usually be spread over twice the area from which it has been cut. Larger quantities would be required if bigger stem fragments are being used. A recommended application rate for heather litter is 1,000 - 1,500 kg ha^{-1}.

Suitable conditions for germination and establishment do not occur every year, and one or two seasons may be required before there is much evidence of success. Seedlings resulting from autumn germination may be killed by a combination of frost and desiccation in late winter; equally a crop of young seedlings may succumb to drought in summer. When cut shoots are used as the seed source, their mulching effect can help to ameliorate these extreme conditions at the soil surface. Even if losses do occur, there should be ample seed for further germination when conditions are suitable.

The presence of suitable microsites is important. Surfaces may be improved by 'raking' with the teeth of an excavator bucket or by using a ribbed roller to produce small hollows, which favour germination and establishment. If surface erosion is a problem, substrates must be made as stable as possible. In exposed areas, a cover of forestry brashings has been used, but these are often liable to blow away. Cut heather containing large bushy pieces has also been tried but suffers from the same disadvantage. However, double-chop forage-harvested material spread over the ground seems to stick well, especially after rain, and usually provides adequate protection for the seedlings.

Assuming the receptor habitat is suitable, transplanting turves or spreading topsoil are often the most reliable methods, though applicable only in a minority of cases. While the use of litter or harvested capsules has been effective in a number of instances, the degree of success has been more variable, owing largely to the risk of loss by wind or surface erosion. Means of reducing these risks are considered in the next section.

Sites for heathland restoration

The choice of source of inoculum and the methods adopted depend on the nature of the site. Sites for heathland restoration generally fall into one of four main categories:

a **Clear-felled forestry plantations** These areas may still have a soil seed bank of heather and bell heather, etc. If not, it is necessary to introduce seed, in the form of either harvested capsules or heather litter. It will not normally be necessary to use topsoil, as there will be an adequate organic horizon remaining after removal of the trees. As loose litter of tree needles etc. does not provide a good seed bed, it should be stripped. Surface scarification may sometimes be needed to create open spaces for germination.

b **Exposed mineral surfaces** e.g. disused mineral workings, redistributed mineral material on abandoned construction sites, eroded sandy surfaces. For reasons already explained, exposed mineral surfaces are best covered with topsoil obtained from a donor site, if available, to a depth of about 5 cm. If there is no area in the neighbourhood suitable for stripping, light rotovation to 4-5 cm of a nearby site, to produce a thin layer of litter and organic material, will yield a seed source and topsoil while allowing the donor site to regenerate.

If the exposed surface is very deficient in available nutrients, and especially if companion grasses (see below) are being used, some addition of fertiliser may be necessary (e.g. ground limestone at 1,000 kg ha^{-1} and low rates of balanced NPK such as 15-150 kg ha^{-1}). In many cases, however, this is unnecessary, and it is

always important not to add more than a minimum of fertiliser, to avoid excessive competition from grasses.

Protection from surface instability is important. This may involve grading the site before sowing to remove unstable slopes. Where serious erosion or gullying has occurred on steep slopes as a result of damage by fire, motor bikes etc., infilling and surface stabilisation will be necessary. Spreading forestry brashings over an area on which heather seed has been spread has been said in some cases to encourge establishment, by providing some protection from the wind.

The success of heathland restoration on exposed mineral surfaces may be enhanced by the use of transplanted turves, either in addition to or, in small areas, instead of the above procedures.

c **Abandoned agricultural land** This may present even greater problems for the establishment of heath vegetation, because in most cases its nutrient status will have been enhanced by fertiliser application. Soil analysis may indicate that steps must be taken to reduce soil fertility before trying to introduce heath species. As yet there is no really well-tried method of achieving this, though several approaches have been explored. It has been shown that taking a cereal crop such as rye for one or more years with no input of fertiliser can significantly reduce soil nutrient concentrations, especially if straw and stubble are, as far as possible, removed in order to avoid re-incorporation of nutrients into the soil. It has been pointed out, however, that the addition of inorganic nitrogen fertiliser to the growing cereal crop leads to greater extraction of phosphorus and other elements from the soil because of increased crop growth. In some cases this might be an appropriate procedure, although a proportion of the added nitrogen may remain in the system.

As indicated above, an alternative approach to depletion of soil fertility may be topsoil stripping. This can have the added benefit of removing seeds of arable weed species, which are potential competitors with newly established heath plants. Sale of the stripped topsoil may also yield some income.

Once sufficient nutrient depletion has been achieved, heathland re-establishment may be attempted using one of the methods described above.

d **Pipe-line crossings** Oil or gas pipe-lines have on a number of occasions been routed across heathland, although nowadays in view of the strength of the conservation lobby most companies will avoid the expense and inconvenience of the necessary habitat restoration. If, notwithstanding, pipelines are constructed across heaths, there is a need to ensure minimal disruption and successful rehabilitation of the disturbed vegetation. Fuller information on recommended methods is available in Putwain & Rae (1988) and elsewhere. Details will vary according to site conditions and the size of the pipeline to be laid, but for lowland heaths the following outline indicates the type of procedure that has been shown to offer the best chance of successful re-establishment. The guiding principle is to cause minimum disturbance to the vegetation.

The whole operation of trench excavation, installation of the pipe and refilling any particular section should be completed as quickly as possible. For small pipelines (15-20 cm diameter), completion within two days is a reasonable target, but up to two weeks is more realistic for larger steel pipes. The main area of topsoil stripping should be limited to the trench line. The working area will be between 8 m and 30 m wide, depending on the size of the pipe, and should be fenced. The trench is normally located towards one side, which allows a narrow belt for depositing topsoil on geotextile sheeting (e.g. Terram) over the existing vegetation. The depth from which topsoil is lifted will vary according to the site but will usually be between 10 and 15 cm, corresponding to the depth of the organic horizon. If present, the grey leached horizon should also be removed and stored in a separate pile from the topsoil. The other side of the trench is generally used for vehicle movements. The vegetation is again covered with Terram sheeting. A narrow belt close to the trench is left for purposes of pipe welding, and within the remaining area a sand or gravel road can be laid using the subsoil lifted from the trench. When the pipe has been laid, the subsoil which formed the road is returned to its former position and the terram sheeting is taken up. The heather on either side will be flattened but not destroyed if the work can be completed within a few days. However, the woody stems of heather are very susceptible to crushing, and where operations must take longer than this it is usual first to cut the heather across the working area in order to promote later regrowth from stem bases. Along the trench, regeneration from fragments of plants and the seed bank in the topsoil is usually successful. Better re-growth can be expected where it is possible to lift whole turves complete with their vegetation from the area of the trench before digging. These can be stored temporarily beside the trench and returned as nearly as possible to their original positions after infilling. Cutting the heather beforehand enables the turves to be removed and replaced more easily and has the added advantage that the cut material can be raked back over areas that may require some shelter to encourage initial regrowth and seedling establishment.

Pipe-laying should preferably take place between late spring and summer, when the soil is relatively dry. This reduces churning and damage to soil and vegetation. Similarly, wet or waterlogged areas should be avoided as far as possible because it is more difficult to minimise damage and successful restoration is much less likely.

Fencing

Grazing may seriously retard or inhibit regeneration of heath vegetation. Fencing against stock is generally necessary and should be retained where possible for at least 4-5 years. In some areas rabbits may also be a problem, and rabbit- proof fences may be necessary.

Shelter and stabilisation

If cut heather shoots are used as a seed source, they will themselves considerably improve the microclimate at the soil surface and encourage germination and seedling establishment. Bare peaty ground is subject to frost-heave and subsequent disruption by wind or rain. Erosion and gullying on slopes also produce unstable surfaces. Where heather seed has been applied in situations of this kind, stabilisation has been achieved with some success by sowing companion (or 'nurse') species, usually grasses, which also provide shelter and protection for

developing heath vegetation. A good species for this purpose is Highland bent *Agrostis castellana,* which forms a loose, open sward in which heather and bell heather can readily become established. As the seeds of Highland bent are very small, the quantities required are relatively small. It germinates best on the surface of the ground in summer. A number of other species have been tried, including sheep's fescue, fine-leaved sheep's fescue *Festuca tenuifolia,* red fescue *Festuca rubra,* common bent *Agrostis capillaris,* brown bent *Agrostis vinealis* and bristle bent *Agrostis curtisii* (suitable only in its native area in southern England; not available commercially). The fescues, with their larger seeds, germinate best with a shallow soil cover, in spring or autumn. The use of wavy hair-grass is not generally recommended on lowland heaths because it tends to be an invasive species. Recommended sowing rates are 10-15 kg ha^{-1} in stable areas and 15-25 kg ha^{-1} on eroding areas. Purple moor-grass may be used on wet sites.

Good establishment of the companion grass species may require the addition of fertilisers (especially nitrogen and phosphorus) and lime (on very acid soils). As indicated above, however, it is important to keep fertilizer additions to a minimum.

Heathland translocation

The transplanting of heathland vegetation from one site to another has been attempted in a few cases where a valuable community has been threatened by development. In several instances, in Suffolk and elsewhere, encouraging results have been achieved. The environment of the receptor site should be as similar as possible to that of the donor site, and (assuming it is devoid of natural vegetation) the site should be covered with topsoil derived from the donor area after swiping the standing vegetation. Where pioneer or young building heather communities are to be moved, turves about 1 m wide can be cut using a Ryan turfing machine, then carefully rolled and transported to the receptor site and laid as soon as possible. The depth to which the turf is cut varies according to circumstances. It may be as little as 3-5 cm, but then the turves are very susceptible to drought. If it is desired to transfer the rhizomes and roots of species such as sedges and cotton-grass, as well as a proportion of the soil fauna, a depth of at least 20 cm is needed. Older heather (mature, degenerate) can be lifted using a 1.8 m (6 ft) wide front bucket on a 4-wheel drive JCB, in turves measuring about 1.8 m (6 ft) x 1.2 m (4 ft) and 15-30 cm (6-12 in) in depth. These are placed on a flat bed trailer and, after transporting to the receptor site, laid intact, preferably in shallow trenches. Topsoil and heather cuttings from the donor area are spread after the turves have been relaid, to fill gaps and to provide seed for germination in the new site. Generally the best survival rate is achieved when pioneer or young building heather is moved, but in favourable conditions mature and degenerate heather and bell heather also survive. Usually, prolific seed germination can also be obtained beneath old heather, or from introduced topsoil.

Translocation of heath vegetation is a laborious and costly process. In one instance the cost (in 1987) of hiring a Ryan turfing machine for one day with operator, a JCB for five days with operator, and two tractors and trailers for two weeks, came to £1,269. The total cost of the operation involving two teams of eight conservation workers was £5,076, or £4,250 ha^{-1}. (These costs do not include labour charges as the work was carried out by MSC Community Programme teams under the auspices of the Suffolk Wildlife Trust.)

A rather cruder form of heathland translocation has been tried by simply scraping up the surface of the donor site, transferring it in dumper trucks, tipping it out and spreading it with a bulldozer, and then turning as much as possible of the shallow turf the right way up. After adding double-chop forage-harvested heather seed to the barer areas, reasonable regeneration has been obtained at a cost little more than that for obtaining and transferring topsoil. (Translocation by this method in one grassland area cost on average £4 m^{-2}, but this depends on the distance over which the material is transported.)

Because of its cost, translocation is likely to be attempted only as a last resort when a valuable site is about to be destroyed and a suitable receptor location is available. In one case in Suffolk a site occupied by a population of silver-studded blue butterflies was threatened, and survival depended on translocation not only of the vegetation but also of nests of the associated ant species, *Lasius niger* and *L. alienus*. Five nests were lifted using a JCB and replaced, in the same orientation as before, in prepared holes on the receptor site. As yet it is not possible to judge the success of this operation. In general, translocation is a hazardous process and the re-creation of the full diversity of the former community cannot be expected, even in the most favourable circumstances. It must never be perceived as an alternative to the conservation of important communities in their natural habitats.

Summary

1 Establishment of a vegetation resembling former heath in habitats from which it has disappeared, or its creation *de novo* in suitable environments, is feasible though not easy.

2 The immediate objective is usually to establish heather and a few other heath species so that they control the appearance of the vegetation.

3 Requirements include a soil with reasonable moisture retention, surface stability and preferably a degree of shelter. In dry areas a moderately compacted organic topsoil not less than 5 cm deep is best, but where rainfall and atmospheric humidity are adequate germination and seedling establishment may be successful on mineral surfaces.

4 Where heather is present as a minor component of grass- dominated vegetation, a complete rest from grazing for a time may allow surviving heather to expand.

5 Where there is no living heather, but a substantial soil seed bank of heather (also bell heather and sometimes other heath species), removal or opening up of existing vegetation may permit germination. Minor disturbance of the soil surface may help. Autumn or spring are the best seasons; if one crop of seedlings fails, more may be expected later.

6 Where there is no surviving heather and no seed bank, living plants or seed must be imported to the site.

(i) Heather (and other heath species) may be raised from seed or cuttings in containers and planted out. More often, turves lifted from a donor site (where damage can be accepted) are transplanted to a new site, if the habitat is suitable.

(ii) Seed may be spread over the new area, having been obtained in one of the following ways:

a by harvesting seed-containing capsules from a flowering heather stand between mid-October and the end of November, usually with a forage harvester;

b by lifting seed-containing litter from beneath a heather stand; or

c by the removal of heath topsoil (containing seed) from a heather stand.

Spreading can be done by hand or with a spreader, in autumn or early spring. Pretreatment of the surface with a ribbed roller or toothed digger bucket may help to improve the microclimate at the soil surface.

7 Sites for heathland restoration usually fall into one of four categories:

(i) clear-felled plantations, where loose litter should be removed and surface scarification may help to open up the site for germination from a soil seed bank;

(ii) exposed mineral surfaces, which usually require a cover of topsoil containing seed, to a depth of at least 5 cm. Fertiliser addition may be necessary, but should be kept to a minimum;

(iii) abandoned agricultural land, where depletion of available nutrients may be necessary before sowing with heather seed. This may be effected by taking one or more cereal crops (e.g. rye) without fertiliser addition;

(iv) pipe-line trenches, where topsoil should be carefully removed (lifting intact turves if possible) for storage separately from the subsoil. Backfilling should restore the topsoil to its original position, with final replacement of the turves, if available. Fencing against livestock is essential.

8 Forestry brashings laid over a seeded surface may provide shelter for developing seedlings but are liable to be blown away. Generally, double-chop forage-harvested material containing seed, when spread over the ground, is not easily dispersed and provides a useful mulch. Where necessary, companion grasses may be sown along with the heather seed. Fertiliser is then generally necessary.

9 Translocation of heath communities, by lifting whole turves measuring about 1.8 m x 1.2 m and up to 20 cm or even 30 cm in depth, careful transportation and relaying in a new site, has been fairly successful in a few instances.

10 Areas of heather that are growing from seed may require protection from grazing for 4-5 years.

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14 CASE STUDIES

1 Arne Nature Reserve, Dorset (C H Gimingham)

The Arne Nature Reserve (SY 973882) occupies a peninsula located about 6 km east of Wareham, Dorset. To the west and north it is bounded by the Wareham Channel and to the east by Poole Harbour, while southward it is continuous with the extensive heathland of Hartland Moor. The Reserve is owned and managed by the Royal Society for the Protection of Birds. Part of the area is wooded with both deciduous wood and naturally regenerated Scots pine, but most of the rest is heath (*c.* 340 ha), representing one of the largest remaining fragments of the formerly extensive Dorset heathlands. The peninsula is fringed with saltmarsh.

The majority of the heath at Arne belongs to the *Calluna vulgaris-Ulex minor* (H2) dry heath type. This grades in the moister parts to *Ulex minor-Agrostis curtisii* (H3) humid heath and to the *Erica tetralix-Sphagnum compactum* (M16) wet heath. There are scattered stands of common gorse and bracken. Much of the importance of the area lies in the presence of the heath types H2 and H3, which have very restricted distributions. The humid heaths afford habitats for the Dorset heath and marsh gentian, both extremely localised species in Britain. The avifauna includes the rare Dartford warbler and the nightjar, while all six British reptiles are present, including the southern heath specialists smooth snake and sand lizard. There is a rich invertebrate fauna, including rare dragonflies and many southern species at or near the northern edge of their ranges.

The Reserve has been fortunate in escaping the worst of the accidental fires that have been so numerous on neighbouring heaths (apart from a 40 ha area burnt in 1973). The age and structure of the heather stands are varied, but there are still large areas of very old heather, many of them unmanaged since the 1939-45 war.

Objectives

The area is managed to maintain the heathland habitats and ecosystems generally and to conserve the diversity of the flora and fauna. Within this overall objective, attention is given to sustaining the populations of the scarce heathland species, notably those named above. The following detailed objectives are listed by Pickess *et al.* (1989):

1 to manage areas of old heather, by burning and cutting;

2 to break up areas of even-aged heather;

3 to remove areas of heather/gorse that have died owing to physical factors such as cold winters or summer drought;

4 to provide areas of the correct age-class of heather, gorse or trees for scarce members of the heathland fauna;

5 to remove trees and bracken invading the heath;

6 to provide open sandy areas on the heath (necessary for successful breeding of sand lizard and hymenoptera);

7 to provide firebreaks;

8 to provide areas of open water in the humid heath (important for dragonflies and some uncommon plants).

Management problems

In the past, management involved periodic or sustained removal of part of the standing crop of heather and accumulated litter by grazing, turf-stripping and mowing (and to some extent also by fire). Most of these traditional practices had ceased when the RSPB took over in 1966, and large blocks of heath had not been managed for a considerable time. To secure the future of the heath, these stands have to be brought back into regular management and structural diversity re-introduced. Because turf-stripping is obsolete and there is now little interest in heathland grazing in this area, management options are limited to burning and cutting.

Heather management is complicated by damage caused at irregular intervals by severe summer droughts (e.g. in 1976 and 1989, when die-back took place over quite large areas). There is also an ever-present risk of accidental fires in summer. These factors, together with occasional periods of severe frost, tend to open up patches to invasion by bracken or trees. Heather beetle, though present, rarely causes significant damage. Regenerating heather is liable to damage by rabbit and deer grazing, leading to the development of a mat of mosses and lichens in place of heath.

In parts of the area it has become necessary to control the invasion of pine into the heath and to 'push back' the margins of dense, naturally regenerated pine stands. There is some difficulty with the spread of bracken, and in parts an even more acute problem is caused by the invasion of rhododendron from thickets in adjacent woodland. There is little risk of excessive spread of birch or gorse at Arne; indeed the value of gorse to a variety of bird species, including Dartford warbler, is such as to warrant management to maintain and even increase the amount of gorse.

Methods of management

a **Dry heath** Most of the heather is being brought into a management regime by controlled burning and forage harvesting aiming at a rotation of about 30 years. Forage harvesting is undertaken in November or December on sites where the ground is fairly even. Controlled burning is now confined to the areas of uneven ground unsuitable for the forage harvester, and is carried out in small patches (0.1-1 ha) in February or March. Before burning, each patch is outlined by swiping a protective swathe of 3-4 m in width and placing the debris within the patch. At Arne, back-burning in relatively calm and dry weather (wind force 2-3) is favoured. The intention is to produce a relatively intense, slow-moving fire, which consumes much of the litter as well as the above-ground vegetation and thereby reduces nutrient accumulation.

Vegetative regeneration after fires of this kind may be restricted, especially since most of the stands being burnt are rather old, but is supplemented by vigorous seed regeneration. In an area where neither bracken nor birch present too much of a problem, this is acceptable. A 'fire engine' (water tank with sprayer) is in attendance at all fires.

In the past, small areas were cut with a swipe, but as this method requires the raking up and removal of cut material and is thus labour-intensive, it is now used less frequently.

b **Humid and wet heaths** Humid heath is managed in the same way as the dry heath, but requires less attention. Dorset heath and dwarf gorse both regenerate satisfactorily after fire, while marsh gentian appears to benefit from occasional fires. No management has been found necessary for the wetter heath for more than 23 years.

c **Fire-breaks** These vary from 8-10 m wide and are rotovated each year between the beginning of the second week of May and the end of the month. They are regarded as an insurance policy, providing both a barrier against the spread of fire and access routes for fire-control equipment. Both sand lizards and many invertebrates find the open sandy patches created by firebreaks a valuable additional habitat for basking, nesting and egg laying (so long as rotovation is confined to the period indicated above, when the former are least vulnerable).

d **Gorse**, which supports a rich invertebrate fauna and thus provides food as well as shelter and nesting sites for Dartford warblers and a number of other birds, requires management to prevent it becoming too tall and straggly. Where possible it is managed by cutting at intervals of about 15 years. Burning is an alternative method, but may be hazardous and is normally used only in areas otherwise scheduled for burning. Stands older than 15 years may also be cut, using a tractor-mounted swipe and lifting the debris and some of the accumulated litter with a JCB -type digger, or they may be burnt. Regeneration then is largely from seed germination rather than resprouting.

In locations where gorse is lacking, small areas (e.g. 1.5 x 0.5 m) have been planted using 2-3 year old seedlings. Fencing against rabbits and deer is usually necessary.

e **Heathland spread** To allow the heath to expand, the margins of areas that have been invaded by pine have been progressively thinned. After the removal of timber and brash, surviving heather is able to spread. Where there is no surviving heather, the pine litter is removed down to the mineral soil, allowing heather to recolonise from the buried seed bank.

Some pine on the heath, however, benefits both birds and invertebrates. Management aims at producing a scattering of large trees in clumps and smaller bushy individuals in a matrix of heather.

f **Management for reptiles** This involves creating bare sandy patches, where these are lacking. Apart from the firebreaks, they are dug by hand in May or early June, preferably on south-facing slopes, 1-2 m long by up to 1 m wide, and where possible below clumps of mature to degenerate heather. A recommended frequency is about 5-20 of these per hectare.

g **Ponds** When acquired by RSPB the area contained a number of ponds which provided both habitats for invertebrates, especially dragonflies, and also emergency water supplies in case of fire. A further 22 ponds have been created in the humid heath areas, some of them constructed by hand and others using a JCB. On two occasions the army have created ponds in areas inaccessible to machinery by using controlled explosions. The ponds require occasional management to remove excessive growth of aquatic plants or *Sphagnum.*

h **Bracken control** This is necessary where woodland has been cleared and in places where expansion of the heath can be encouraged by pushing back the margin of the bracken stand. Asulox is used, applied mainly with a Micron ULVA. For spot spraying a 1.25 litre Hozelock ASL Polyspray 2 has been used.

i **Rhododendron clearance** A programme is in progress which includes (i) digging up or winching out small stumps, which are then burnt; (ii) cutting the larger bushes, burning or chipping the branches, and killing the stumps *in situ* using supersaturated Amcide (ammonium sulphamate) solution inserted in 8-10 cm deep holes (1 cm diameter) bored in the cut stem bases. Any regrowth is weed-wiped with Roundup (glyphosate) with additive 'Mixture B', which helps penetration of the waxy leaves. (Garlon 4 is now also being tried for this purpose.)

Results of management

These can be assessed from general indications and several detailed studies of specific aspects, though there is no overall programme of vegetation monitoring.

The intensive programme of heather management is proving successful in maintaining the heather communities and introducing diversity of age-classes and structure. Regeneration after treatment has usually been good, and there are few problems of invasion by other species after fire, except here and there by bracken. Areas that were mown after damage in the 1976 drought have recovered very well. A satisfactory proportion of the older stands have been brought into the rotation, and this has benefited both Dorset heath and dwarf gorse, which regenerate well after fire. The latter reaches maximum abundance about seven years after burning, and bristle bent also thrives for a few years after burning. Occasional burning of the humid heaths may have increased the populations of Dorset heath and marsh gentian and opened up habitats for other species such as sundews, bog asphodel *Narthecium ossifragum* and white beak-sedge *Rhynchospora alba.* The ponds have also provided additional

habitats for plants such as oblong-leaved sundew *Drosera intermedia* and marsh St. John's-wort *Hypericum elodes,* as well as for dragonflies.

Removal of rhododendron and reduction in the areas occupied by pine and bracken have led to the expansion of heath communities. Areas cleared of bracken require follow-up by spot spraying of fronds in the regenerating heath.

Reptile populations are healthy and the cycling of gorse, with additional plantings, appears to have improved the survival of Dartford warblers in hard winters.

Sources

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2 Aylesbeare Common RSPB Reserve, Devon (Ceri E Evans & Peter Gotham)

Aylesbeare Common (SY 059 903) is located 12 km east of Exeter in Devon. The site comprises a complex mosaic of wet and dry lowland acidic heaths with associated mire and basic flushes with a wooded boundary, developed on Triassic Pebble Beds overlying Permian marls. The site is the best example of a series of heathlands known as the East Devon Pebble Bed Commons, and forms the northern section of the 1,112 ha East Devon Pebble Bed Heath SSSI. The site is scheduled as an NCR site, an Area of Outstanding Natural Beauty, and Invertebrate Site Register Grade A.

Aylesbeare Common is owned by the Clinton Devon Estates, and 184 ha are leased to the RSPB who employ a full-time warden to manage the site.

The higher, drier heathland areas support the *Ulex gallii- Agrostis curtisii* communities (NVC H4 a, b, d), which comprise varying proportions of western gorse, bristle bent, heather, purple moor-grass, bell heather and cross-leaved heath. A series of shallow valleys support sharp transitions to wet heath and mire with *Erica tetralix-Sphagnum compactum* wet heath (NVC M16a) and *Molinia caerulea-Potentilla erecta* mire (NVC M25a) communities, grading to *Narthecium ossifragum-Sphagnum papillosum* (NVC M21) valley mire. The local occurrence of mineral-rich flushes support the *Succisa pratensis-Carex panicea* sub-community of the *Erica tetralix-Sphagnum compactum* mire (M16b), and more strongly basic flushes support *Schoenus nigricans-Narthecium ossifragum* mire (NVC M14).

The site is of national importance for breeding Dartford warblers, and the nationally rare southern damselfly *Ceriagrion mercuriale* has been recorded on site.

Management objectives

Aylesbeare Common has a Management Plan, and the main objectives (set in 1989) are as follows:

1 To maintain the rich diversity of nationally important heathland and mire communities. This will be achieved by a management programme of controlled burning, mowing and grazing to maintain a diversity of heathland types and ages, and the control of invasive species.

2 To maintain and increase the areas of common gorse for the benefit of the nationally important population of Dartford warblers. This will be achieved by burning or coppicing existing stands and bracken clearance to promote colonisation of gorse from the seed bank.

3 To implement a fire plan. This will involve the provision of fire fighting resources, increasing existing areas of open water, and the maintenance of fire breaks.

4 To encourage research opportunities and carry out necessary survey and monitoring properly to assess changes in important fauna and flora.

Management problems

1 Lack of past management has given rise to uniform even-aged stands of heathland with no age or structural diversity, and an inadequate system of fire-breaks.

2 Bracken covers 30 ha of the site, and there is evidence that it has spread into areas of degenerate gorse, especially in the last 15 years.

3 39 ha of wet heath and mire communities are dominated by purple moor-grass.

4 Scrub has encroached onto the heath from the wooded boundaries. Oak, aspen, birch and pine have colonised the drier heath, whilst willow species have invaded the wet heath.

Methods of management

Burning and mowing The aim is to regenerate some 5% of the 66 ha of dry heath annually to enhance age and structural diversity. When both weather and labour resources permit, dry heath is regenerated by controlled burning of strips (approx. 10 m x 500-1,000 m) in January-February. This method also provides 2-3 year fire-breaks. When the weather is adverse to the burning method, similar size strips are turbo-mowed and the litter removed by tractor and front-loader and tractor/trailer, or bulldozed and carted away (typically 250-400 cubic metres per ha).

Grazing management Grazing was introduced on an experimental basis in 1990 on 20 ha to promote floristic interest and structural diversity of wet heath/mire communities in an area becoming dominated by purple moor-grass. There is a range of NVC communities present in the experimental area that the cattle are allowed to range over (including H4a, d, M14, M16a, M25a). Suckler cows at an average density of 1 cow per ha were put on from November to mid January, with supplements of high protein mineral blocks. Future grazing management will be monitored and reviewed annually, and is likely to be extended into the spring and summer to help control purple moor-grass.

Gorse management Blocks of common gorse are managed specifically to favour Dartford warblers, which use dense gorse for cover, nesting and foraging. The most beneficial common gorse bushes for this species are between 1-1.5 m high (4-10 years old, in the building to mature stage), dense enough to withstand a heavy snow cover. When common gorse degenerates (10+ years here) it loses compactness and is of less value to Dartford warblers. As patches of gorse degenerate they are regenerated by burning or coppicing in the winter months. Coppicing is carried out with 'saw-bladed' brushcutters, chainsaws or bow-saws. This is very labour intensive and burning in situ is easiest. Burning can be risky however, and requires precise weather conditions, ample labour resources and fire precautions. With such a high proportion of the gorse in the degenerate stage, the management emphasis is on regenerating

gorse to the pioneer stage rather than coppicing because very old plants do not coppice well.

Bracken control Bracken control is aimed at removing at least 3 ha per annum. Bracken invading dry heath communities is cut in early June and July using a tractor-mounted swipe or brushcutter on rough ground. Pure stands of bracken are sprayed with the herbicide asulam (Asulox) using a Micron Ulva sprayer in late July - mid August, followed-up by spot-spraying (the following year) of regenerating bracken using a knapsack sprayer. Litter is raked off either manually or with a tractor-mounted front loader buckrake and is sold as a mulch or bedding compost (500 cubic metres sold in 1990).

Scrub and tree control Selective felling is carried out in the winter months, removing some 200 20-year-old trees per annum. Stumps are treated with Garlon 4 in diesel to prevent regrowth. A scattering of trees are left for the benefit of invertebrates, and nesting, perching and foraging birds.

Results of management

It is probably too premature to assess the results of heathland management, as current intensive management has only been in operation since 1987, coinciding with the establishment of a full-time warden on site. The current emphasis is on monitoring the effects of management on priority bird, invertebrate and botanical species/communities.

Monitoring

A permanent quadrat monitoring scheme was set up in 1988 to record vegetation changes related to burning and mowing management, and the same recording methods are used to monitor the effect of grazing on communities (with control areas). Quadrats are recorded every two years. The colony of southern damselflies is monitored as part of the grazing experiment. A full breeding census of priority heathland birds is undertaken annually. Weekly transect walks for heathland butterflies and colony counts for silver-studded blues are carried out from April to September using standard ITE methodology.

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3 Blaxhall Common SSSI, Suffolk (C FitzGerald)

Blaxhall Common (TM 380564) is situated approximately four miles south of Saxmundham in the Sandlings region of Suffolk. The 114 acre (46 ha) registered Common is bisected by the B1069 road and rises to about 50 ft (15 m) above sea level.

The Common is bounded on all sides by Forestry Commission plantations and is an isolated fragment of the once extensive Sandlings Heath of coastal Suffolk. In many ways it typifies the management problems and constraints presented by the small heathland remnants and, as a case study, particularly illustrates some of the techniques employed in the control of bracken and of birch.

The survival of this area of lowland heath is due to its status as registered common land; it has been associated with the village of Blaxhall since records began. There is no registered owner nor are there any registered Commoners; liaison on management is conducted with Blaxhall Parish Council.

In 1987, after nearly five years restoration and management work carried out by the Sandlings Project, the common was notified as an SSSI for its heathland habitat. In 1982 Suffolk Wildlife Trust entered into an informal management agreement with Blaxhall Parish Council, and Blaxhall Common is now a Suffolk Wildlife Trust (SWT) Reserve.

Historically, Blaxhall Common, surrounded then with open heath, supplied the village with bracken, which was cut for animal bedding and for potato clamps, and with whins (gorse) which were cut and faggoted for sale to the local bakeries for fuelling the bread ovens. One source in 1911 talks of adders "that were often carried into neighbouring farmyards among loads of gorse, brakes (bracken) and heather brought from the heath". Such activities combined with rabbit and sheep grazing plus the traditional Suffolk practice of firing the gorse on November the 5th conspired to maintain heathland habitat. There were 2,000 sheep in the parish of Blaxhall at the beginning of the 19th century. The local shepherd's house survives today on the common and an iron age urn burial tumulus, to be found to the north of the road, is still known as Liney's mount, where the shepherd would stand and overlook his large flock of Down and Norfolk sheep scattered amongst the gorse bushes.

Today, this pleasant stretch of open country, in an intensively agricultural landscape and within the holiday area of The Suffolk Heritage Coast - an AONB - is coming under increasing recreational pressure. Many tracks traverse the area and the Parish Council are unwilling to restrict parking. There have been as many as 100 vehicles counted on the common on a summer bank holiday week-end. Problems with motorbikes, and more recently four wheel drive clubs, attracted by a steep-sided sand pit on the common, are ever present. Despite the pressures from walkers and their loose dogs, the ground-nesting nightjar and the rare woodlark continue to breed successfully on this small area.

The heath is of the *Calluna vulgaris-Festuca ovina* type, H1, according to the National Vegetation Classification. The heath slopes down towards a central valley through which the road passes. The northern half of the site has sizeable stands of

mature and degenerate heather, which support a good variety of *Cladonia* lichens and mosses. Bell heather occurs locally amongst a mosaic of heather and acid grassland. Bordering the road are large stands of sand sedge, which is one of the features of Sandlings heathland. Elsewhere, there is acid grassland composed chiefly of common bent and sheep's fescue grasses with characteristic herbs such as heath bedstraw *Galium saxatile* and harebell *Campanula rotundifolia*. Bracken dominates all the remaining area, together with scattered gorse and silver birch. Similar heathland communities occur to the south of the road, although heather is less extensive. Managed areas of acid grassland contain a rich variety of herbs, including bird's-foot trefoil *Lotus corniculatus*, spring vetch *Vicia lathyroides*, common stork's-bill *Erodium cicutarium*, mouse-ear hawkweed *Hieracium pillosella* and heath speedwell *Veronica officinalis*. Where there is more bare, sandy ground, other species, such as sand spurrey *Spergularia rubra*, birdsfoot *Ornithopus perpusullus* and early hair-grass *Aira praecox* occur. The effects of trampling on paths and car parks are very important, since the habitat they maintain is favoured by several species limited in Britain to eastern areas, e.g. mossy stonecrop *Crassula tillaea*, bird's-foot clover *Trifolium ornithopodioides* and suffocated clover *T. suffocatum*. The site is notable for breeding nightjars, three pairs of woodlarks, and nightingales. Common lizard and adder are to be found.

Objectives of management

The main aim of management work on the common is the conservation of the flora and fauna of a representative Sandlings heathland ecosystem. This is to be achieved, in broad terms, by producing a satisfactory balance between heather, bracken and other species (that can realistically be maintained in the long term), whilst also catering for the habitat requirements of species such as nightjar, woodlark and bare ground living invertebrates. A further aim is the preservation of the open treeless heathland landscape as an example of a traditional feature of this area of Suffolk.

Management problems

In 1983 the Sandlings Project surveyed this heathland and analysed the vegetation as 19% heathers, 10% acid grassland, 4.4% gorse, 16.6% trees and 44.4% bracken, with 5% bare ground and tracks. Study of aerial photographs from 1972 and local knowledge confirmed the rapid loss of heather and grasslands to bracken within the last twenty years. There is a continuous and prolific germination of both Scots pine and silver birch seed over the whole site. Management plans were constrained by the wishes of the Blaxhall villagers, who were on the whole pro trees and anti sprays.

Methods of management

Management of the common got under way in 1982 with the inception of the Sandlings Project. This is a regional heathland conservation scheme that aims to bring under active conservation management all remnants of the Sandlings heathlands, an area of some 3,500 acres. In the early days the project made use of the labour source provided by the SWT Manpower Services Commission community project. Funding was provided by an *ad hoc* consortium of conservation bodies known as the Sandlings

Group. For nine years the Sandlings Project has been actively managing these heathlands, including Blaxhall Common.

Work started with the removal of pine and birch from the surviving heather stands. By removing some trees but leaving an open network of glades it was possible to provide conditions that promoted the regeneration of heather whilst also accommodating the needs of nightjars and the wishes of the local parishioners.

An early decision was taken to maintain mature stands of heather to either side of the central road. These were not to be cut or burnt, in an effort to promote an uneven-aged structure. Instead, the mature stands with their interrupted canopy and assemblages of mosses and lichens were to be left unmanaged except for hand weeding. A diversity in the age structure of the heather on site was to be provided by reclaiming bracken areas on an annual basis. Compartments where heather was still to be found, moribund, under bracken or trees, were prioritised and a mowing regime was initiated.

Project equipment, consisting of a Massey Ferguson 168 70 hp tractor and a Bush Hog rotary swipe, fitted with blades, was employed. Bracken was cut three times a year during the growing season. Broad swathes were mown on boundaries between bracken and heather stands, and around additional yearly target areas. Over nine years some excellent results in bracken control have been achieved by this method. Once tight heather-and-grass swards had been produced it became possible to reduce the frequency of mowing to once a year in most cases, though it should be noted that swiping has not eradicated the bracken, and should the management regime cease for any reason re-invasion is likely to be swift. The cost of using a tractor-mounted swipe is estimated at £46 per hectare or £19 per hour, allowing for high breakage rates under typical rough heathland conditions. 23% of the area of the common was under this mowing regime in 1991.

To further expand the area of heather at the expense of bracken, it became necessary to tackle some of the dense stands with deeply accumulated litter layers. Little or no regeneration of heath could be expected in these areas without first removing this litter layer. In 1985, '86 and '88 about 14% of the surface area of the common was top-stripped. A local firm of nurserymen was employed. They used a forage harvester, adapted to pick up the dense material by the replacement of the conventional spout with a conveyor belt. After this process a compacted mineral substrate was revealed. The Project was paid £1.15 per cubic metre of collected bracken mulch, which is used as a medium for the growing of heathers and azaleas. In 1985 430 cubic metres of mulch were removed, then 320 cubic metres in 1986 and 280 cubic metres in 1988. After bracken stripping, the area was treated with asulox (where the villagers agreed). This treatment, applied with a tractor-mounted boom sprayer belonging to the project, was estimated to cost £88 per ha. After these treatments, compartments with a viable seed bank were rapidly colonised with heather, from seed. By 1991 there were some very pleasing results, with 100% heather cover achieved. However, the process has also greatly aggravated the seedling birch problem, as discussed below.

On one compartment of about a hectare in extent, there was little or no regeneration of heathers. This was presumably due to the absence of a seed bank. Possibly heathers had never been present. To overcome this a heather seeding technique was employed. Heather was cut and collected by forage harvester (New Hollands double chop) in November, as the seed capsules were fully formed. On the Sandlings Project a forage harvester has proved an excellent tool for the management of heather. Regeneration from root stock is rapid and clippings and accumulated organic matter are removed by the machine. Since no heather stands were to be cut on Blaxhall Common, heather was taken from the RSPB reserve at Minsmere. The compartment to be seeded was carpeted to a depth of a few centimetres with heather clippings. These were spread by hand from the back of a tipping trailer. The clippings were not incorporated but left as a mat on the bare sand surface. After the second year germination of heather was good, with, in 1991, perhaps a 75% heather cover. Again, seedling birch germination was greatly encouraged. Cost of forage harvesting of either heather or bracken is about £82 per ha. An estimate of forage harvesting, transporting and spreading heather clippings would be 14p per square metre, or £1,400 per ha.

Top-stripping - and indeed any soil disturbance on this common -results in phenomenally-increased germination of birch seed. A jaundiced interpretation of the results of top-stripping might be that it has replaced one problem species, bracken, with the equally problematic birch, and at almost equal density! Birch and pine seedlings are routinely cut or pulled over the whole area. Where birch carpets have resulted from soil disturbance, this method is impractical. A solution to the large-scale treatment of birch needs to be devised.

In 1987 some birch was sprayed with Krenite, using knapsack sprayers, but results have been indifferent, probably due to poor application technique. In 1990 about 2 ha of sapling birch were treated using a Mobi-Cord weedwiper and a 1:1 mixture of Round-up (glyphosate) and water. The Mobi-Cord is designed so that the wick runs continuously through a reservoir of herbicide, giving an increased application of chemical, when compared with other models. Results of this (despite late application during drought conditions) were encouraging. Perhaps a 50% kill was effected, the surviving birch probably being too low to be touched by the wicks. Therefore swiping to even-up the heights, with follow up applications, is planned. The treatment costs 7 litres of Roundup at £15 per litre (£105) and was carried out by contractor at a cost of £50.

Elsewhere on the Sandlings, a flock of Welsh hill sheep belonging to the SWT Project have been employed with great success to destroy birch swards. Continuous defoliation by grazing throughout the growing season will destroy birch. Problems with access, particularly by dogs, may mean that the flock cannot be used on Blaxhall Common, but negotiations to bring this about are planned.

Results of management

Results are monitored by quadrats, one per compartment throughout the site. These quadrats, though not visited in recent years owing to lack of labour resources, will still

provide some valuable base data for future survey work, and a photographic monitoring file also exists. Results as described above have on the whole been most encouraging, the biggest challenge now being the long-term maintenance of the heathland that has been reclaimed, and managed, over the last nine years.

Sources

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4 Dinnet Moor NNR, Grampian (C H Gimingham)

Dinnet Moor (NJ 445 000) is situated 35 miles west of Aberdeen in the valley of the River Dee, Grampian Region, north-east Scotland, at an altitude of about 160-180 m. Except to the south, where the river forms a boundary, it is ringed by hills. The topography is varied, including a number of glacial landforms such as kames and eskers, meltwater channels and two large kettle holes now occupied by lochs. It was declared a National Nature Reserve in 1977 and is managed on the basis of an agreement with the landowner.

In addition to heath, the reserve includes aquatic and loch-side habitats, small acidic basin mires, birchwood and a few stands of aspen *Populus tremula.* On the lower ground heathland was formerly extensive, but since the end of the 1940s it has been progressively invaded by birch. The surrounding hills are largely heather covered, apart from some areas where there is natural regeneration of Scots pine and birch. The NNR also incorporates some forestry, grazing and arable lands. For both the heath and the lacustrine habitats, Dinnet stands in an intermediate position between lowland and upland types.

The area is important partly because of its diversity but also partly because of the excellent example of the species-rich variant of *Calluna vulgaris-Arctostaphylos uva-ursi* heath (H16a) that has developed over the fluvio-glacial sands and gravels of the low ground. This heath type has a very restricted distribution (Chapter 3). On the hill slopes there are typical examples of *Calluna vulgaris-Vaccinium myrtillus* heath (H12).

The *Calluna-Arctostaphylos* heath contains a number of interesting species such as intermediate wintergreen *Pyrola media,* petty whin *Genista anglica,* slender St John's-wort *Hypericum pulchrum,* lesser twayblade *Listera cordata,* bitter vetch *Lathyrus montanus,* mountain everlasting *Antennaria dioica* and the moss *Dicranum spurium.* Important animals in the reserve include otter and slow worm, a large avifauna and a long list of invertebrates including the Kentish glory moth *Endromis versicolora.* There is also a strong archaeological interest.

Objectives

These are directed towards conserving the landforms and maintaining the diversity of communities, including the lochs, bogs and heath types, while allowing natural succession to proceed towards birch on parts of the low ground and Scots pine on the hills. Other objectives involve the integration of nature conservation with existing estate land uses - farming, forestry and sport. Scientific research is encouraged, so long as it is compatible with the primary objectives.

Management problems

Conditions in the heather-bearberry heath are very favourable for invasion by birch (mainly silver birch *Betula pendula).* Soils are truncated podsols, freely-drained, with only slight accumulation of raw humus on the surface. Prior to the late 1940s the moor was grazed and managed for grouse by regular burning, and this prevented extensive birch invasion. However, during and after the war, with a reduction in

sheep grazing and abundant input of seed from neighbouring birch woods and scattered trees, much of the former heathland has been colonised. Occasional, as opposed to regular, burning has in fact created particularly favourable opportunities for birch seedlings to establish and create even-aged thickets, which have gradually eliminated the heath species and led to the development of a grassy ground flora. Most of the heath is ungrazed, except by roe deer (and occasional visits by red deer).

Methods of management

Because one of the reasons for declaring Dinnet Moor an NNR was that it contains a fine example of a scarce heath type, conservation of this community is of prime importance. It has become evident that active management is essential if it is to be saved from disappearance under birch. Two areas where young birches are relatively few, have been set aside for management to conserve the heath. All birches in these areas have been cut or pulled by hand. In parts of these designated heath areas management will be restricted to further removal of birch saplings by hand as necessary, and the heather stands will be allowed to become uneven-aged, in the expectation that cyclical processes will operate and the gaps left by degenerate bushes will provide niches for the associated flora. In one sector, however, an experiment has been started to compare the effects of a short-rotation burning management regime (each patch to be burnt once in seven years) and a long-rotation regime (once in 15 years). The aim is to discover whether the former would be useful to encourage the lichens, mosses and other species of pioneer and early building phases, and if the latter would encourage the species associated with mature and degenerate stands. (Both regimes will be contrasted with a control area in which hand cutting of birch is the only form of management.) Burning is done in quite small patches, and because of the potential danger of fire spreading into neighbouring birch stands a foam spreader has been obtained and found satisfactory in confining the fires to small areas.

Except in the heath conservation areas, the development of birch will be allowed to proceed, in the expectation that it will be patchy and that small areas of the heath vegetation will persist, especially on the raised morainic knolls and eskers.

Results of management

Past experience has shown that the heath can be maintained by regular burning, but it will be some time before the success of short- and long-rotation burning in meeting their objectives can be judged. It seems probable that the latter will have to be supplemented by hand-pulling of establishing birch saplings. In the meantime, the experimental area is being monitored.

Sources

MARREN, P. 1979. *The Muir of Dinnet: portrait of a National Nature Reserve.* Peterborough, Nature Conservancy Council.

MARREN, P. 1979. *Muir of Dinnet National Nature Reserve. First Management Plan 1978-1984.* Peterborough, Nature Conservancy Council.

5 Dowrog Common, Pembrokeshire (S B Evans)

The interior of the windswept and steeply-cliffed St David's Peninsula, the most westerly promontory of Wales, is a 40-70 m plateau with many poorly-drained, saucer-shaped basins. The largest depressions have much unenclosed land once owned by the Church and still subject to Rights of Common. These commons support a mosaic of wet heathland and fen vegetation, varying in response to minor topographical patterns in the underlying, severely gleyed local and calcareous Irish Sea boulder clay. Although the layer of clay is relatively thin, it provides an impervious lining to the depressions in the ancient igneous and sedimentary rock. Traditional practices of rough grazing and regular winter burning continued until the 1930s, and as with other lowland heaths in Britain, such activities guaranteed open, unwooded habitats supporting a wealth of plants and animals.

Dowrog Common (SM 775273) is the largest of these Pembrokeshire 'fen mosaic' lowland heaths. Its 101 hectares are owned by the National Trust but are managed under lease by the Dyfed Wildlife Trust. Since the start of the lease in 1977, the Wildlife Trust have been guided by a broad-based management committee, with representatives from the Commoners, the Community Council, the District Council, the Pembrokeshire Coast National Park Authority, the local Gun Club and the Nature Conservancy Council (now the Countryside Council for Wales). The Dyfed Wildlife Trust occupies the chair, and amongst the other members on the committee are the county bird and plant recorders.

The site lies in a hyperoceanic climatic zone with largely frost-free winters and cool but sunny summers. A shallow 1.5 m deep pool of some 6 ha in winter occupies one of the major depressions on the common. Its rich swamp vegetation includes major stands of greater tussock-sedge *Carex paniculata*, water horsetail *Equisetum fluviatile*, bulrush *Typha latifolia*, bogbean *Menyanthes trifoliata*, branched bur-reed *Sparganium erectum* and marsh cinquefoil *Potentilla palustris*.

The flood plain of the diminutive River Alun has abundant fen vegetation where it passes through the common. Dense stands of greater pond-sedge *Carex riparia* occur, and in places these sedge-beds grade into a mixed fen with species such as meadowsweet *Filipendula ulmaria*, yellow iris *Iris pseudacorus*, hemp-agrimony *Eupatorium cannabinum*, purple-loosestrife *Lythrum salicaria*, common fleabane *Pulicaria dysenterica* and wild angelica *Angelica sylvestris* (M27).

The fen grades into species-rich marshy grassland dominated by tussocky purple moor-grass *Molinia caerulea*, (M23 and M25), and this in turn extends into large areas of classic wet heathland with heather, cross-leaved heath and western gorse, with scattered creeping willow *Salix repens* (M16a and M16b). The driest heath (H8) has much bell heather, while the more open heath supports sea plantain *Plantago maritima* and lesser butterfly orchid *Plantathera bifolia*. Patches of common gorse grow on the driest edges, and small areas of grey willow *Salix cinerea* carr occur in wetter places. Birch *Betula pubescens* is absent from the whole peninsula, and bracken is confined to the driest margins of the common.

Rare plants are especially numerous, with the heathland supporting large populations of yellow centaury *Cicendia filiformis*, three-lobed crowfoot *Ranunculus tripartitus*,

pale dog-violet *Viola lactea* and pillwort *Pilularia globulifera*. Rare fen plants include lesser tussock sedge *Carex diandra* and wavy St. John's-wort *Hypericum undulatum*. The common is equally important for invertebrates, e.g. the marsh fritillary butterfly *Euphydras aurinia*, the scarlet tiger moth *Callimorpha dominula*, the small red damselfly *Ceriagrion tenellum* and the scarce blue-tailed damselfly *Ischnuria pumilio*.

The diversity of wintering wildfowl and birds of prey is high. Hen harriers, short-eared owls and merlins are regular visitors, and there is an important hen harrier roost. Bewick's and whooper swans, teal, wigeon, shoveler and mallard occur in winter, along with snipe, water rail, coot and moorhen, especially in the vicinity of Dowrog Pool. Otters are regular visitors, and harvest mice and water shrews have been recorded.

Objectives

Since the inception of the reserve, the complexities of the habitats and their different management requirements have been recognised. The 1976 draft management plan's stated objectives for heathland were to "investigate events that have produced the heath as we see it today (e.g. burning, and grazing by both horses and cattle) - then attempt to maintain status quo". In early 1978, a comprehensive report highlighted the variety of habitat types and advocated a rotational management programme for each habitat. The main emphasis was on water table maintenance and restoration of traditional practices, in particular grazing by cattle and ponies. Controlled burning of heathland and the maintenance of firebreaks were seen as an integral part of traditional pastoral practices.

Problems

- How to restore the wide range of traditional practices now that economic and cultural forces make them impractical
- How to graze a registered common bisected by roads, including a trunk road
- How to differentially manage the fine mosaic of habitats in the absence of traditional shepherding
- How to protect the site from harmful outside influences such as eutrophication from adjacent modern farms or accidental fires started on the margins
- How to maintain support within the local community for the overall approach and for the individual proposals
- How to be sure that there is sufficient knowledge of habitats and species (particularly invertebrates) to plan, implement and review management
- How to fund all this effort.

Methods of management

Between 1979 and 1990, the general recommendations of the 1978 report were translated into detailed proposals by the management committee, and implemented.

Burning In February 1979, a firebreak system was initiated, and in 1980 a burning programme was agreed. Between 1981 and 1988, 10 ha of heath were burnt by small, controlled winter burns. Unfortunately, there were a further 35 ha of uncontrolled burns, largely of heathland, but mercifully all during the winter. As a result, the original target of 20 ha of controlled burns for this period was considerably exceeded. Continued efforts to extend and maintain the firebreak system have reduced such excesses and will guard against the nightmare of a summer fire. Firebreaks are cut with a tractor and swipe in the autumn of each year. Roadside firebreaks are also burnt periodically. In one wet area, a wide linear pool has been dug to act as a water firebreak where tractor and swipe could not operate. The controlled burning is carried out by one of the commoners, who is also the honorary warden for the reserve, with assistance from local children and with the full knowledge of the St David's Fire Brigade.

Grazing Since September 1979, when the committee approved efforts to restore grazing, some 10 ha have been grazed each winter by ponies belonging to one of the commoners. Unfortunately, no other commoners have been persuaded to exercise their grazing rights. Sporadic summer grazing by cattle has occurred, and one experimental winter grazing by three eight-month-old Welsh Blacks and six in-calf Friesian heifers was deemed unsuccessful. These cattle were enclosed on wet heath and their condition deteriorated such that they had to receive considerable supplementary feeding with hay. Until the winter of 1987/88, when the grazing area was increased to 20 ha, half of the grazed area was wetland rather than heath. The pony grazing is controlled by temporary electric fencing, which is regularly moved. Eighteen ponies are the normal number, although this has increased to 23 in recent years, and they prosper on the wet heath. Summer cattle numbers have been about 70 head, and they have grazed over the whole site without electric fencing, often concentrating their grazing in the wetter fenland vegetation. Stocking rates for the grazing regimes on wet heath are difficult to specify, but would lie between 0.5 and 1.0 pony per ha during the winter months. This seems to create a hummocky mosaic of ericaceous species with sedge-rich swards in between. Supplementary feeding is not needed, but a little hay is fed to help control the animals. Stocking rates above 1 pony per ha during the winter at Dowrog appear to convert classic wet heath to short, sedge-rich turf.

Summary

Over the first 10 years of the reserve, the approximately 50 ha of heath - half of the 100 ha reserve - have received the following management:

	Grazing	Burning	Non-intervention
Annually	10% has been winter grazed (increased to 20% by 1987/8)	10% has on average been winter burnt	80% has had no management
Over the full 10 years	20% has received winter grazing at least once	60% has had at least one winter burn	20% has had no management

Other management has included digging and maintenance of heathland pools, some limited willow clearance and maintenance of the important open poached and disturbed habitats along the old cart tracks.

Results of management of Dowrog's heathland

In the mid-1980s, the Nature Conservancy Council commissioned *'A review of the management of lowland wet heaths in Dyfed, West Wales'* by Fiona Evans. This study was completed in 1979, and it drew heavily on the experience at Dowrog. Her findings confirmed the need for continued active management. Moreover, her work emphasised the vital importance of traditional grazing. The concept of basing long-term heathland management largely or partly on a winter burning rotation was seen as unsound for the wet heaths of west Wales. Controlled burning should be viewed as an emergency short-term measure or as a supplementary device to support a rough grazing regime. Interestingly, it would seem that where burning is pursued, there are floristic advantages in a rotation of less than 10 years - burning when the heath is 20-30 cms tall.

If we look back over the first 10 years on Dowrog, with the benefit of the *Review* it is clear that for a number of very good reasons too much of the heath has been managed by fire and too little by grazing. This becomes particularly acute if one broadens the issue to consider the wetland half of Dowrog, much of which needs, and is not receiving, regular grazing. Moreover, it seems likely that the continued emergence of Dowrog as a prime invertebrate site will call for yet further emphasis on the restoration of grazing. More grazing would also reduce the risk of uncontrolled fires and reduce the level of resources at present devoted to firebreak maintenance and controlled burning.

The current difficulties and uncertainties with agriculture make grazing of places like Dowrog even less attractive. At present, efforts are being made to instal an extra cattle grid and to try out an experimental scheme to offer financial incentives to all the commoners to graze with ponies in winter and cattle in summer.

6 Rossie Moor, Montrose, Tayside (C H Gimingham)

Rossie Moor contains one of the rather few remaining examples of lowland heath in north Scotland. It lies at an altitude of between 100 and 130 m on a low, undulating plateau between two rivers, 8 km south-east of Montrose, near the east coast of Scotland (NO 650540). In addition to heath the site comprises a series of oligotrophic to mesotrophic mire communities, acid grassland, willow scrub, birchwood and areas of gorse.

The area of the site is 132 ha, of which about half is covered by heath. The drier parts are mainly heather-dominated, sometimes in pure stands, but elsewhere mixed with bell heather and bilberry. Extensive patches have become covered with wavy hair-grass, and there are dense thickets of gorse. Wet heath with cross-leaved heath merges into fen communities in the hollows.

The site, which is divided between two owners, is scheduled as an SSSI because of the extensive tracts of scarce lowland heath, mires and damp woodland with diverse flora, including some species that are very local in distribution, and an invertebrate fauna of national importance. It is a very good example of a site supporting a mosaic of habitats.

Management objectives

The following objectives were listed in the NCC's Management Plan for 1987-1991:

1 conservation and regeneration of *Calluna* heath and associated flora and fauna, on up to 70% of the SSSI;

2 conservation of the full range of wetland habitats and associated flora and fauna;

3 conservation of the diverse range of other semi-natural habitats associated with heathland, namely birch woodland, scrub and unimproved grassland, without prejudicing **1** and **2** above;

4 maintenance of 'naturalness', as far as possible, given **1** - **3**, by minimising human impacts.

Management problems

The main problems lie in the realisation of objective **1**. Succession from heather to gorse or birch scrub is currently in evidence, probably because of abandonment of former heather management. Gorse, in particular, now covers some very extensive patches. In addition, replacement of heather by wavy hair-grass has occurred and there are some quite large areas which are pure stands of this grass. It seems possible that it has replaced heather where severe fires have caused the failure of regeneration, for example after burning stands that had been allowed to get too old, or after intense accidental fires in summer. Other problems include heavy rabbit grazing (which by reducing the competitive vigour of heather may also have favoured the dominance of wavy hair-grass.

Conifer plantations near the site boundary may reduce management options where heather burning may create a risk of accidental fire.

Methods of management

The existing heather stands are to be brought into rotational management by burning in the part of the site subject to a management agreement. Since recent neglect of management has caused some large areas of heather to degenerate, care must be exercised in bringing them into rotational management, especially to avoid excessively hot fires. Equally important are measures to control succession and to begin to restore heath to areas presently occupied by unwanted species. Invading gorse and birch will be removed where possible, and a start is being made on an experimental basis in clearing gorse and re-establishing heath vegetation. The problem is that gorse enriches the soil and burning or cutting gorse without further treatment leads to its replacement by grasses, particularly wavy hair-grass and Yorkshire fog. An experiment has therefore been set up, on an area from which gorse has been cleared by cutting, to test methods of surface treatment to try to reinstate heath vegetation and to find out if there is a viable seed bank of heather in the soil profile, or if additional seeding would be necessary to establish adequate heather cover. At the same time it is hoped to show whether rabbit grazing is likely to prevent heather regeneration. The trial area has been surface treated in two different ways: one strip with a scarifier and another with a blade rotovator, cutting away the surface vegetation and litter, which was cleared and removed using a bulldozer. Four plots have been set up (each incorporating both surface treatments). Two were left unseeded and two were seeded with material obtained from a nearby area using a forage harvester set about 10 cm above the ground, the cut material being blown into a trailer. One seeded and one unseeded plot have been enclosed in a rabbit-proof fence, the other pair remaining unfenced.

Preliminary results of germination tests on surface soil samples taken after the experiment was started indicate that there were few seeds of ericaceous plants in the soil surface of unseeded plots, but that abundant seed was introduced on those that were seeded. The results of this experiment will be monitored and will guide future plans to restore some of the heathland.

Sources

NATURE CONSERVANCY COUNCIL. 1998. *Rossie Moor Management Plan, 1987-1991*. Peterborough, Nature Conservancy Council.

7 The Stiperstones NNR, Shropshire (T A Rowell)

The Stiperstones (SJ 370000) comprise a series of tors outcropping along a quartzite ridge south-west of Shrewsbury, Shropshire. The hill rises to 536 m and supports heath intermediate between southern lowland and northern upland types. It is scheduled as an SSSI because of its heathland significance and also because of the geological significance of its tors, stone circles and stone stripes.

Part of the SSSI is owned by English Nature and managed as a National Nature Reserve. The Stiperstones NNR is also within an Area of Outstanding Natural Beauty and, as such, is an important component of the local landscape.

Overall, Stiperstones is heather-dominated. However, the south-facing slopes have a great deal of western gorse and bell heather, while the north-facing slopes have bilberry and *Sphagnum* spp. On higher ground, cowberry *Vaccinium vitis-idaea* and crowberry *Empetrum nigrum* become more important. Other habits include wet flushes, woodland and coppice. Breeding birds on heathland include red grouse (here at its most southerly point in England, apart from Dartmoor), stonechat and whinchat.

Objectives

Management of the site is not for conservation purposes only. There are extant grazing rights attached to local properties, and some sporting rights, and these have to be taken into account. The site is managed to maintain heather dominance, and this is approached by bringing about 75% of the site with 50% or more heather cover into active management. The remaining 25% is left unmanaged, and this tends to be the more inaccessible and difficult areas such as the steep valley sides. Active management is designed to establish a varied heather age structure; the aims are to conserve the heathland system in general and to encourage red grouse.

Management problems

Management for conservation on The Stiperstones NNR began in a concerted way in 1986 with the appointment of a warden. Efforts had been made by the NCC's Regional staff between 1982 and 1986 to ensure that some burning and fencing were carried out. However, there was still a great deal of old heather to be brought into management. The grazing rights are of little help as they are used by only two commoners, who between them put on a few sheep and also some cattle; the hill is seriously under-grazed. Burning and mowing are the two options for managing heather in this situation. However, NCC staff had experienced problems with controlled burning, especially on steep slopes. The large number of neighbouring properties (about 40) means that considerable effort has to be put into providing letters of notice whenever burning is intended; these lapse within seven days if the burn cannot be completed. There is also a great deal of local pressure to burn, preferably the whole site at once; arson is common. Much of the site is littered with stones, making mowing difficult and leading to heavy expenditure on spare parts when mowing is undertaken. Scrub encroachment (mainly rowan with some birch) is becoming a problem because of the low levels of grazing, and bracken poses a threat now that areas are being opened up by cutting or burning.

Methods of management

Grazing at The Stiperstones is mainly by sheep at a stocking rate of about 1 ewe per ha. They are mainly Welsh Mountain, but there are many cross-breeds. Sheep can be on the hill at any time except during lambing, shearing and dipping. Some cattle, mainly suckler cows, are also grazed on the hill. A few goats are kept on the common, but these tend to be restricted to the fringes and have little significant effect. In general, as noted above, the hill is very under-grazed.

Heather is cut using a Parmiter swipe on a Ford 5610 4WD tractor. Chains were found to break easily and have been replaced by blades. Strips of 20-30 m width are cut to variable length up to 1,000 m. Once cut, heather has either been left lying (sometimes double-chopped and, in some cases, dispersed by hand if clumped), or rowed up with a Vicon acrobat and burnt, or picked up using a loader wagon. The loader wagon picks up without the need for rowing up, and works well over quite rough ground. Baling has also been tried. Policy is now to pick up all cut heather, and a Pottinger loader wagon has now been purchased for this purpose.

It is intended that the heather be brought into a 10-15 year rotation, but slow recovery of old heather means that an additional three years may be needed before the second cut.

About 12 ha of heather is cut each year, and disposal is a considerable problem. Considerable thought has been given to ways of utilising cut heather produced at The Stiperstones, including its use in composts and mulches, as a medium for bio-filtration, as fuel, for thatching, and as a seed source for heathland restoration. Trials with brushwood chippers have been held to test the potential for production of mulch on-site, but even machines claiming to be able to handle heather failed. Disposal remains a problem.

The costs of cutting and gathering using the loader wagon have been estimated at £131 per ha, taking into account only labour, running costs of the tractor and repair costs of the swipe (late 1989 prices). Based on trial work (and using the same basic costs), baling heather at The Stiperstones costs about £171 per ha, or 57p per bale.

Burning of heather is also done in 20-30 m wide strips, but these are relatively short in length compared with mown areas. While some burning is done on the main expanse of the hill, it is the only possible management on steep slopes. Few firebreaks are cut, and then mainly along the tops of slopes. They are not very effective at stopping fire, but improve access for control. A foam unit (comprising a Hathaway pump, bowser, 1" hose and Expandol) is kept on standby during burning, and the recent purchase of a PTO pump and a ½" hose, useful for damping down hot-spots, has extended the fire control capability at The Stiperstones. Also used for fire control are a number of Solo 425 knapsack sprayers modified for alginate use. The 2 mm nozzles on these units make them ideal for fire control work..

A cell phone has proved an important piece of equipment at the Stiperstones during burning management. Not only can it be used to inform the fire brigade of the start

and finish of burning, but is invaluable if things get out of hand, or if a hospital case arises.

Burning has to be carried out using contractors and this, coupled with the difficult ground and old heather with few firebreaks, accounts for the high cost of burning, at around £385 per ha for labour alone (1989 prices).

Scrub control is mainly by uprooting, where saplings are small enough, or by stump treatment with Garlon 4 following cutting with bow saws. Cutting is done by volunteer labour and, for a while, much of the cut scrub was not treated. This could result in a great deal of follow up work. Now, all cut stumps are treated, and any regrowth is sprayed. A spot gun was tried in 1990 for treating regrowth, but with little success.

Until recently, bracken was controlled only on grassy areas, either by application of Asulam or by cutting. Now, all areas cut or burned are treated, if bracken invasion is a threat. On steep slopes, use of herbicide is difficult but is still practised as the most effective means of dealing with this species.

Results of management

The Stiperstones have been under conservation management only since 1986, so it is too early to interpret the success or otherwise of the techniques employed. Certainly, a great deal of effort has gone into solving the site's special problems. Early worries about the response of old heather to cutting and burning (heather seemed largely to disappear, being replaced by a heavy infestation of wavy hair-grass) have largely evaporated. It is notable, however, that old heather responds here best to a hot burn, only achieved by illegal or accidental, uncontrolled burns. In these cases, abundant germination of seed gives the heather a good start. Mowing and cooler, controlled burns result in little germination, and regeneration is from cut stems only.

Monitoring

Monitoring at The Stiperstones consists of a recently initiated program of fixed-point photographs. There is also a collection of aerial photographs.

Sources

ROWELL, T.A. 1990. *Markets for cut heather. Feasibility study. The Stiperstones NNR.* Unpublished report to NCC West Midlands Region (Contract No. WMR 363/89).

8 Thursley Common NNR, Surrey (T A Rowell)

Thursley Common NNR (SU 915410), Surrey, contains about 200 ha of heath. It is listed as a key heathland site in *A nature conservation review* and is scheduled as an SSSI because it is an extensive example of some of the finest remaining heathland on the Lower Greensand in southern England. It is managed by English Nature as a National Nature Reserve.

Some 80% of the heathland at Thursley is H2 - almost pure heather. There are small patches of purple moor-grass, dense common gorse and areas dominated by wavy hair-grass. All these are treatment-derived from H2. About 75% of the heather is even-aged, having been burnt by an extensive uncontrolled fire in 1976. Some 80% of the remaining degenerate-phase heather was burnt accidentally in 1990, with only about 20 ha now remaining.

The heath is important for its populations of sand lizards and smooth snakes, and is a rich site for birds (including Dartford warbler and nightjar) and invertebrates. Unfortunately, the sand lizard habitat has now been lost and only one small colony remains.

Objectives

The ideal management objectives for Thursley that are pertinent to heathland are quoted below from the management plan.

1 To maintain and enhance sufficiently large tracts of plagio-climax open dry heathland, dominated by heather. This heathland will be managed to exhibit structural and age-class diversity, so as to maintain the diversity of flora and fauna associated with each stage, and will be increased in size to the upper specified limit.

2 To maintain and enhance the size and diversity of the peatland and wet heath habitats with an increase in size to the upper specified limits.

3 To maintain and enhance representative examples of deciduous and coniferous woodland ranging from recently invaded heathland through to stable climax oak and Scots pine stands.

4 Specific management should be carried out in appropriate locations to maintain and enhance those populations of rare and fragile species that have a close or specific association with the heathland and peatland habitats and would be lost or reduced in number without specific attention.

Management problems

Thursley has an acute problem with invasive birch. There is also some invasion by pine, and bracken is a serious post-fire pest. The even-aged nature of much of the heather means that it is desirable to introduce some heterogeneity, and, at the same time, the requirements of heathland reptiles must be taken into account.

Access is unlimited, owing to Thursley's common land status. Bridleways cross the site, but riders often leave these, destroying sandy paths and patches which are important for reptiles and aculeates.

The NNR is seriously under-resourced, having only one warden and an estate worker. A four-wheel drive tractor is available on a shared basis. Attempts to re-introduce grazing management to the site have been seriously stalled by the common land status of the site.

Methods of management

About 20 ha of the Common are managed by mowing from the end of January, through February and, sometimes, into March. This timing reduces the likelihood of frost damage and erosion of the sandy soil, which can occur following autumn mowing. If woodlarks appear, then mowing is stopped.

Instead of heather being cut in blocks, at Thursley areas are cut experimentally in meandering swathes. In subsequent years, further swathes are cut which cross earlier ones. This technique creates very small-scale heterogeneity and is intended to reduce the distance that fauna have to travel to re-colonise newly mown or developing areas.

Mowing has been completed successfully with both a tractor-mounted flail (complete with vacuum device for removing brash), and a pedestrian-operated Rasant sickle-bar mower with a cutting width of 1.6 metres. The latter proved to be just as fast as the small flail, cutting even old heather cleanly in a single pass, and with the advantage of being able to work slopes of up to 80°.

Gorse is maintained at Thursley for Dartford warblers and stonechats. About 10% is allowed to mature, but not to become degenerate. The remainder is coppiced at about seven years on a random bush basis.

Some 10-15% of the heath is being allowed to over-mature to provide habitat for sand lizards. The remainder, not under any of the regimes described above, is managed to control invasive species.

Some birch is maintained for general invertebrate interest, such as lepidoptera and arachnids, with dead wood being left for *Formica sanguineum.* Stands of various ages, from seedlings to about 4 m in height, are maintained in blocks. The edges of the more mature blocks are scalloped to encourage nightjars.

Over much of the site, however, birch needs to be controlled. Very short growth is weed-wiped with glyphosate at label strengths, but applying the weaker mix in May and increasing the concentration as the season progresses and the plants become less susceptible.

For stems between 0.3 and 1.5 m tall, several methods have been tried. Krenite has been found adversely to affect ericoids and is very labour intensive. It has therefore been rejected for use at Thursley. Trials of glyphosate applied by knapsack sprayer

and Selectokil spot gun have resulted in the adoption of the latter as standard practice. The metered 5 ml dose from the spot gun results in little or no run-off, and the standard charge of 5 litres will treat 1,000 trees in 1-1½ hours. Spot gun application practice is important; moving the gun vertically down the plant results in a concentration of chemical on the ground in front of the operator (possibly affecting non-target species), whereas moving downwards diagonally reduces this effect.

Larger trees are cut with a chain saw and the stumps treated with glyphosate applied by brush at the recommended rate. The chemical is mixed with a red dye to make it more visible. Some standing dead trees are desirable as song perches, so a number of trees are notched with a chain saw or drilled, and glyphosate applied to the cut. Krenite has also been used for stump treatment but was found to be expensive at the high rate required.

Bracken is controlled by the standard practice of cutting two or three times each year. The litter has been bulldozed up and sold as mulch. Asulam has also been used, applied by ultra-low volume sprayer. Before being treated chemically, bracken had to be cut in the previous year to reduce its height so that it could be walked through. Bracken is increasingly being controlled using chisel ploughing using 18 inch tines following two intitial cuts to pre-stress the rhizome. The ploughing mechanically disrupts the rhizome and this method is resulting in a very good rate of kill. About 5 ha have so far been dealt with by this method.

A system of major 10-12m wide firebreaks, cut with the equipment described above, intersects the site breaking it up into 30-40 ha blocks. Once cut, they are largely maintained by rabbit grazing and trampling by horses. The major firebreaks are then further subdivided by 2m wide 'fire traces' which break up the blocks of heather allowing access by firefighting vehicles and staff and will, to a certain extent, check side-burns from uncontrolled fires.

Heathland reinstatement from invasive conifers has been very successful. About 12 ha of 35 year or so old Scots pine is due to be felled by 1993/94 and so far about 40% has been removed. Following pine clearance, scraping off the litter layer with a bulldozer and rolling the surface has resulted in very encouraging heather regeneration.

Results of management

The current management regime has now been in place for some eight years and this allows quite strong predictive statements to be made concerning management. In particular successful methods of birch control using herbicide, bracken control by mechanical means and heathland reinstatement from Scots pine have been evolved.

Monitoring

English Nature's Project Planning and Recording System is operated at Thursley, ensuring all management activities are logged. This is essential if responses to management are to be linked to practice.

In addition, the effectiveness of small-scale mowing is being monitored photographically and by sampling beetles by pit-fall trap to compare mown and unmown areas. It is intended that spiders and vegetation structure will be monitored in the future. Birch control is also monitored photographically.

9 Thurstaston Common, Merseyside (T A Rowell)

Thurstaston Common (SJ 245851) is about 3 km north-west of Heswall on the Wirral. Wet and dry heath, acidic marshy grassland and birch-oak woodland have developed on podzolic soils over Triassic sandstone. The site contains the best and largest remaining example of a lowland heath in Merseyside, albeit only 30 ha in extent, and is scheduled as an SSSI. It is also a Local Nature Reserve.

Thurstaston Common is largely owned by the National Trust, but is managed by Wirral Borough Council's Department of Leisure Services who maintain a staff of Countryside Rangers who are responsible for management.

Most of the heathland areas are dominated by heather, giving way to bell heather and western gorse in the driest areas. Wet heath occurs in damp hollows and is characterised by cross-leaved heath and purple moor-grass. The wet heath contains the most interesting assemblages, including common sundew and marsh gentian. Open heath is being invaded by birch, an initial phase in the development of the woodland also found on the site. The site is important locally for passage, wintering and breeding birds.

Objectives

Thurstaston Common has a well-defined management programme with the following objectives, set in 1987:

1 to continue the existing sheep-grazing experiment;

2 to further reclaim open heathland from scrub woodland;

3 to prevent any shift in the successional status of open heathland to woodland or bracken-dominated heath;

4 to manage woodland margins to optimise their potential for 'edge' species;

5 to actively manage selected areas of open heath on a rotational basis to encourage a varied and competitive heathland flora;

6 to actively manage wet heath areas to improve the chances of survival of rare plant species;

7 to encourage appropriate recreational usage of the Common;

8 to promote an awareness amongst users of the Common of the importance of lowland heathland.

Management problems

Invasive species, mainly birch with some pine, are a major stimulant to management. Bracken is also present, but is mainly in marginal or localised patches and, at present, does not pose too great a problem.

A relict population of marsh gentian poses a management headache as it consisted of just two plants in 1989.

As the site is used by the public on an open access basis, control of dogs within the grazing experiment, which must remain accessible, was thought to have been needed. This is potentially a major constraint to proper management of many lowland heaths.

Like many other conservation sites, Thurstaston Common has relied on volunteers as a labour source for certain management tasks. Volunteer support has fluctuated, but there appears to be increasing interest from National Trust local groups and from BTCV mid-week groups.

Methods of management

The management programme for Thurstaston gives detailed prescriptions for each management task. Space does not permit full reproduction of these, but the prescription for mowing is given in Table 14.1.

In practice, mowing of trial areas has been done with a Huard Mini-swipe attached to a Yanmar YM186 4WD mini-tractor (18hp). Disposal of the raked-up brash was mainly off-site, though some has been used for restoration purposes.

Burning as a management technique was rejected by the management plan because of the risk of imitative behaviour and worries about ecological damage to a small site. However, following heather beetle attack in 1987, burning was tried in February 1989 with good regeneration resulting. Firebreaks were cut with a Turner turbo-mower mounted on a Ford 3600 tractor, although stumps proved a problem. Areas of less than one hectare were back-burnt to a firebreak or to a previously burnt area. Moribund heather that would not ignite was burnt with a flame gun. As a result of this experience, it is felt that burning would be a good technique to use over rocky or stump-ridden ground where machinery will not go or is easily damaged. Grazing has been undertaken on an experimental basis. It has only recently got on a firm footing, with the purchase of 25 lambs (Welsh Mountain x Border Leicester ram). These will be herded in a system of set-stocking involving a three-paddock rotation. Purchase of both lambs and fencing was grant-aided by the NCC, and the National Trust contributed towards the mile of fencing; Wirral Borough council has funded the shepherding. The fencing not only encloses and controls the stock but also checks access, giving visitors an opportunity to read notices about the aims of the experiment and to put their dogs on leads before entering the paddocks over stiles. Staff feel that this approach to the control of dogs is successful, though two sheep have been lost through worrying since October 1989.

Table 14.1 Thurstaston Common management programme: mowing

Cut and remove litter - building and mature phases	
Aim	Cut to provide for regeneration of small blocks of heather and to provide firebreaks. Removal of litter to prevent build-up of nutrients and provide a source of seed for application elsewhere.
Method	Flail-cut small blocks of approximately 25 x 25 m at a height of 5-7.5 cm above ground. An irregular-shaped cut looks better.
Notes	This operation is best carried out during November and December after ripening of heather seeds. Any cutting of cross-leaved heath or bell heather should take into account the earlier ripening of seeds, if a source of seed is required.

Birch control is a two-tier process. Stems up to one metre tall have been treated with Krenite applied by knapsack sprayer. The very short application period of Krenite does cause problems. Stems taller than one metre are cut, and the stumps treated with Garlon 4 applied by brush. It is hoped that this will reduce the need for follow-up treatment, which was high when stump treatment was omitted.

Signs are erected during herbicide spraying to both warn and inform the public. These include information about what plants are being treated and why, and what chemicals are being used.

Cut birch is disposed of by chipping with a tractor-mounted chipper. The current machine is an Exenco 160T requiring 40 hp for 10 cm diameter timber, 60 hp for 15 cm, and 90 for 23 cm. This works well, but ties up a tractor, so a self-powered chipper is being considered for purchase. Wood chips have been used for path surfacing, and for mulching new plantings of trees or hedges elsewhere on the property.

A Micron Ulva low volume sprayer has been tested for bracken control, but has been rejected because of problems of drifting and eddying. As the bracken problem is small at Thurstaston, cutting with the turbo-mower is now the favoured treatment. Litter is raked up, when possible, but is often left lying.

Results of management

Where grazing pressure has been near to optimal, results have been very encouraging in terms of opening up heather areas and controlling birch. Good effects have also

been noted on wet heath where heather dominance has been reduced, allowing sundews and sedges to expand.

Burning has produced very good results in terms of heather regeneration, but there has been too little experience to date to comment further. However, it now seems likely that mowing will not become a major management practice, as regeneration is not as good as when areas are burnt. This is particularly so with old heather, which responds poorly to cutting.

The birch control methods used up until 1989 achieved 60-70% kill, but this should improve with the use of stump treatment. The poor success rate is attributed to problems of timing of treatment with Krenite. Cutting of bracken is considered to be completely successful.

Monitoring

There has been permanent quadrat monitoring associated with management at Thurstaston since 1981, but methods have not been consistent, and as a result it is difficult to interpret the data. Methods have now been tightened up as a result of advice from the NCC, and further permanent quadrats were established in 1989. An exclosure has been made around one quadrat within the grazing experiment, to act as a control. Eight fixed-point photography stations have been established with up to 360° coverage at each.

Sources

NATURE CONSERVANCY COUNCIL. 1987. *Thurstaston Common heathland management programme 1987-1992.* Peterborough. (Unpublished.)

SSSI schedule

10 Weeting Heath NNR, Norfolk (P Dolman)

Weeting Heath (TL 7588) in the Norfolk Breckland is an SSSI and NNR of 139 ha, owned by the Norfolk Naturalists Trust and jointly managed with English Nature (NCC for England).

In addition to an area of valley pasture and fen, Weeting Heath contains one of the finest remaining Breckland grass heaths covering about 100 ha. This supports populations of a number of rare Breckland plants and is a significant site for rare lowland heathland, and Breckland, invertebrates. It is also important for ground nesting birds, including stone curlew, wheatear and (pre-myxomatosis) common ringed plover and woodlark. The land use of the heath since the 16th century is known and consisted of periods of sheep grazing and rabbit warrening, interspersed with periods of arable cultivation. In addition the heath was subject to other forms of physical disturbance, including trackways, a marlpit, digging for gravel and the construction of defences against gliders during World War II. This is typical of the human influence which produced and maintained the Breckland heathlands.

The usual Breck heath community, H1, *Calluna-Festuca ovina* (heather/sheep's fescue), is absent from the site. Approximately 14 ha of the heath are covered in dense bracken. The remainder of the heath consists of a mosaic of acidic and calcareous grass heath. Areas of the grass heath vary in the length of time since cultivation was abandoned.

The acidic communities consist of U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* (sheep's fescue/common bent/sheep's sorrel). In a discrete area of oligotrophic acidic sand the lichen sub-community *Cornicularia aculeata-Cladonia arbscula* is well developed. The majority of U1 consists of the 'typical' sub-community and areas transitional towards the *Anthoxanthum odoratum-Lotus corniculatus* (sweet vernal-grass/common bird's-foot-trefoil) sub-comunity. The *Erodium cicutarium-Teesdalia nudicaulis* (common stork's-bill/shepherd's-cress) sub-community of ephemerals occurs on rabbit scrapes and burrows.

Calcareous grass heath, CG7 *Festuca ovina-Hieracium pilosella-Thymus praecox* (sheep's fescue/mouse-ear hawkweed/wild thyme), is extensive, both as a pure stand and in a mosaic with U1 resulting from periglacial sorting of the soil. The CG7 consists of the *Cladonia* spp. sub-community, known only from Breckland and the Porton Ranges. Undergrazed areas have developed to species-poor, tussocky heath, with increased meadow oat-grass *Avenula pratensis*. In other areas lichen rich CG7 persists. In a small area of shallow chalky soil resulting from human disturbance, elements of the rare moss sub-community *Ditrichum flexicaule-Diploschistes muscorum* exist. One area of CG7 differs floristically, being dominated by red fescue *Festuca rubra* and spreading meadow-grass *Poa subcaerulea* with common couch *Elymus repens*, owing to residual fertility resulting from the application of inorganic fertiliser during cultivation in 1944-1946.

Objectives of management

1 Management must maintain the spectrum of grass heath communities.

2 In particular it must maintain and enhance the sparsely vegetated, disturbed, oligotrophic, lichen-rich, and ephemeral-rich sub-communities of both U1 and CG7. These have seriously declined in extent within remaining Breckland heaths, with detrimental consequences for numerous populations of rare Breckland plants, invertebrates and ground nesting birds dependent on the physiology and microclimate of this habitat.

3 An ideal objective would be to continue to maintain the grass heath by rabbit grazing, backed by sheep grazing as necessary. Weeting Heath is one of the few areas of remaining Breckland grass heath primarily maintained by rabbit grazing, as distinct from those managed by contemporary sheep-grazing regimes. Rabbit grazing appears essential to maintaining lichen-rich and ephemeral-rich grass heath sub-communities.

4 Specific management is carried out to maintain and enhance populations of a number of rare Breckland plant species.

5 An important consideration in determining management is the provision of habitat for breeding stone curlew. This is largely encompassed within aims 2 and 3.

Management problems

Ideally, rabbit populations should be maintained at a high level. However, population crashes result from severe outbreaks of myxomatosis, coccidiosis, or low survival of young during wet breeding seasons. During periods of low rabbit abundance, particularly if, as in the mid 1980s, this results from a run of relatively moist summers, the grass heath vegetation rapidly deteriorates, becoming taller, tussocky and lichen and bryophyte-poor. In the future, sheep grazing may be used to reduce this problem.

Predation reduces the rate at which the rabbit population can recover, as well as having serious detrimental effects on the productivity of breeding stone curlews.

The area dominated by bracken increased by about a third between 1947 and 1979. The bracken is now very dense with a deep litter layer. It also harbours predators, particularly foxes.

The large number of visitors poses a risk of disturbance to nesting birds.

Methods of management

The bracken front was controlled by regular cutting in the early 1970s and by spraying with Asulam in late summer of most years from 1976 until 1987, successfully halting its advance. In 1989 a programme of cutting the bracken area was introduced, to reduce its dominance and ideally to restore U1 vegetation. In view of the need to avoid disturbance to nesting stone curlew, cutting is restricted to a single annual cut in late summer.

In some areas where grazing has been at a low level for a number of years, hand pulling of tree seedlings has been necessary.

After the myxomatosis epidemic, adjacent landowners put pressure on the reserve managers to control the recovering rabbit population. In 1959 a 16 ha enclosure was rabbit-fenced. This allowed a high density of rabbits to build up. Rabbit populations in the northern part of the heath continued to be controlled, until the remainder of the perimeter was fenced in 1971. Predator control has also been carried out. In 1990, after a crash in the population, 90 rabbits were introduced into the enclosure.

When flowering and seeding, the populations of spiked speedwell *Veronica spicata* and the introduced population of Spanish catchfly *Silene otites* are protected from rabbit grazing by fenced enclosures. Afterwards, these are opened to allow grazing.

After myxomatosis, about 2 ha of CG7 in the north of the heath were swiped annually from 1959 to 1965. The treatment was discontinued as rabbit numbers recovered. From 1960 areas of grass heath to the north of the heath were rotavated annually, on six plots totalling about 2 ha. The rotovation benefited stone curlew, which nested on rotovated plots during 1961-1964, before increasing rabbit numbers restored the surrounding heath. Rotovation was initially discontinued in 1973 when rabbit numbers reached a high level. However, some further rotovation occurred up to 1977, and two plots were re-rotovated in 1980.

Following a reduction in the rabbit population, forage harvesting was carried out in 1989 over an extensive area of the heath. A programme of rotavation was also started in 1989, to provide open disturbed habitat to benefit birds, to increase the range of micro-habitats available to invertebrates, and with the long-term aim of restoring lichen-rich sub-comunities by reducing soil fertility. Rotovation is currently being carried out on a two-year rotation, providing a range of disturbed and re-vegetating habitats. In addition, in 1989 an area of about 3 ha of CG7 was ploughed, primarily for nesting stone curlew.

To compare the effect of different soil disturbance treatments and forage harvesting on the soil and vegetation structure and composition, an experimental block was set up in 1989. This is located in the area of CG7 vegetation modified by residual agricultural fertility.

The central area of the heath, containing a mosaic of the major sub-communities, has retained a high rabbit population since the early 1960s. This area has not been included in programmes of forage harvesting or soil disturbance.

Wardens are on site throughout the summer and liaise with the public. Two pairs of hides allow visitors to view nesting stone curlew.

Results of management

With the reduction in rabbit numbers in the mid 1980s, much of the vegetation in the northern part of the heath became tussocky and species-poor. However, plots

repeatedly rotovated in the 1960s and left undisturbed for nine or 17 years, retained characteristic vegetation, with significantly shorter grass, greater rabbit activity and a higher abundance of lichens, acrocarpous mosses and winter annuals. The soil of these previously rotovated plots also contained less organic matter than the surrounding undisturbed grass heath.

Soil disturbance since 1989 has been beneficial to nesting stone curlew. On those compartments of the heath that contain rotovated or ploughed areas, in all five compartments in 1989 and in four out of five in 1990, stone curlew nests were on treated areas. A breeding pair, which might otherwise have been lost, were retained in an under-grazed area of the heath.

Results from the experimental area show that a single forage harvest has few effects that persist as long as 20 months. Soil disturbance treatments initially result in a number of infrequent species being lost from the surviving vegetation. With rotavation the percentage cover of a number of components is reduced. However they remain present which, combined with an increased species density, allows a fair degree of in situ regeneration. In addition rotovation has beneficial effects on vegetation height, rabbit activity, the percentage cover of bare ground, winter annuals, summer annuals, saxicolous lichens and acrocarpous mosses. In contrast, ploughing treatments produce fewer beneficial effects and a more severe initial impoverishment of the vegetation.

Monitoring

The English Nature Project Planning and Recording System is operated at Weeting Heath, providing a record of all management operations.

The vegetation and soil fertility resulting from the different treatments in the experimental plot are being monitored. In 1989 a programme of pitfall trapping was carried out on various areas of the heath. In addition a continuous programme of pitfall trapping is carried out on the experimental plot. A butterfly transect is operated as part of the ITE monitoring scheme. Breeding success of stone curlews is closely monitored.

Sources

CROMPTON, G. 1972. *Weeting Heath: Land use 1580-1971.* Unpublished report to East Region, Nature Conservancy Council.

DOLMAN, P.M., & SUTHERLAND, W.J. 1992. The ecological changes of Breckland grass heaths and the consequences of management. *Journal of Applied Ecology*, 29, 402-413.

Appendix 1 Summary of regulations governing heather and grass burning

A England and Wales: The Heather and Grass etc. (Burning) Regulation 1986 (SI 1986 No. 428) as amended by The Heather and Grass etc. (Burning) (Amendment) Regulations 1987 (SI 1987 No. 1208)

The Regulations control the burning of heather, rough grass, bracken, gorse and *Vaccinium* in England and Wales. They do not apply to pleasure grounds, private gardens or allotment gardens, except to the extent that they are adjacent.

The following controls apply throughout the year:

- the burning of heather, grass etc., must not commence between sunset and sunrise
- sufficient people and equipment must be on hand at all times to control the burning
- all reasonable precautions must be taken to prevent injury or damage to persons and to adjacent property
- at least 24 hours but not more than 7 days' notice of intent to burn must be given in writing to the owners or occupiers of the land concerned and persons in charge of adjacent land; this should include dates, time, place and extent of the burn
- railway authorities burning cut vegetation on railway land are not subject to the notice requirements in the above point. In the case of uncut vegetation, instead of the requirement to notify persons in charge of adjacent land, the authorities must give notice of any proposed burning at least 7 days and not more than 28 days before burning is to commence by publicising details in one or more local newspapers and by other suitable means.

Licences

The remaining controls relate to burning during specific times of the year; between 15 April and 1 October in upland areas and between 31 March and 1 November elsewhere. This can only be done under licence.

Licence applications must be made in writing to your local office of the Ministry of Agriculture, Fisheries and Food (MAFF) or of the Welsh Office Agriculture Department (WOAD) in Wales:

- at least 28 days before burning is to commence
- no more than 56 days before burning is to finish

Application forms are available from local MAFF offices. Applications must include the date(s), place, method and area of the burning and sufficient information to show that it is necessary and expedient for the purpose of improving the land (or in the case of railway land for good maintenance or pest control). No later than the date of application, written notice of it and of the information it is required to contain must be given to the owners or occupiers

of the land concerned and to persons in charge of adjacent land[1]. Recipients of the notice must be informed that they may make representations to the office of MAFF/WOAD dealing with the application within 7 days of receipt of the notice. On common land, the notice must be prominently displayed on that land.

Special provisions again apply in respect of burning by railway authorities on railway land.

An applicant may make representations to an independent person if the Minister proposes to refuse to issue a licence, or to issue it for part only of the land, or to make it subject to conditions.

Fines

Any person who contravenes any provision of the Heather and Grass etc. (Burning) Regulations 1986, commits an offence under section 20(2) of the Hill Farming Act 1946, as amended by section 72(2) of the Wildlife and Countryside Act 1981. Such offenders may be liable to a **fine not exceeding £1,000.**

Other legal requirements

Also remember:

- it is an offence under the Highways Act 1980 (as amended in 1986) to light a fire so as to cause injury, interruption or danger to road users
- emission of smoke so as to be prejudicial to health or a nuisance constitutes a statutory nuisance under the Environmental Protection Act 1990
- emission of dark smoke from land occupied by an agricultural business is an offence under the Clean Air Act 1968
- it is an offence under the Health and Safety at Work etc. Act 1974 to endanger anyone including the public by burning operations
- there are special rules for Sites of Special Scientific Interest (SSSIs) under the terms of the Wildlife and Countryside Act 1981. Certain operations normally including burning can only be carried out after a specific procedure has been followed. Owners and occupiers of the land must:

  give written notice to English Nature or the Countryside Council for Wales of the proposed operation

[1]Notices may either be given to a recipient personally or left at or posted to his last or usual place of abode or business. For companies, notices may be delivered or posted to the secretary or principal officer of the company's registered or principal office. Alternatively, notices may be given or posted to agents or local representatives responsible for the management or supervision of the land to which the notice relates.

have received written agreement **unless** 4 months have elapsed since written notice was given

Failure to comply with the provisions may result in a **fine not exceeding £2,500.**

(the above is an extract from *The Heather and Grass Burning Code,* Ministry of Agriculture, Fisheries and Food and Welsh Office Agriculture Department 1992).

B Scotland

Burning in Scotland is governed by the Hill Farming Act, 1946. The provisions differ from those in England and Wales only in certain respects, among which are the following:-

Prohibition of muirburn at certain times

1 Subject to the provisions of this section it shall not be lawful to make muirburn except before the sixteenth day of April or after the thirtieth day of September in any year:

> provided that it shall be lawful for the proprietor of any lands, or for the tenant with the written authority of the proprietor or of his factor or commissioner, to make muirburn thereon during the period from the sixteenth day to the thirtieth day of April both days inclusive.

2 In the case of lands more than fifteen hundred feet above sea level the preceding subsection shall have effect as if for the thirtieth day of April there were substituted the fifteenth day of May.

3 The Secretary of State may in any year, if it appears to him necessary or expedient so to do for the purpose of facilitating the making of muirburn, direct that subsection 1 of this section shall have effect as respects such lands as may be specified in the direction as if for the sixteenth day of April there were substituted such day thereafter as he may deem proper, being a day not later than the first day of May or, in the case of lands more than fifteen hundred feet above sea level, the sixteenth day of May. Any such direction may be given as respects all lands in Scotland, or as respects the lands in any county or any part of a county, or as respects any particular lands or classes of lands.

Notice of the giving of any direction under this subsection (other than a direction given only as respects any particular lands) shall be published in one or more newspapers circulating in the locality in which the lands to which the direction relates are situated.

4 Any person who makes muirburn or causes or procures the making of muirburn on any lands in contravention of this section shall be guilty of an offence.

Right of tenant to make muirburn notwithstanding terms of lease

Subject to direction from the Secretary of State, a tenant may be given permission to burn despite prohibitions in his lease.

Regulation of muirburn

Any person who -

a commences to make muirburn between one hour after and one hour before sunrise; or

b fails to provide at the place where he is about to make muirburn, or to maintain there while he is making muirburn, a sufficient staff and equipment to control and regulate the burning operations so as to prevent damage to any woodlands on or adjoining the land where the operations are taking place or to any adjoining lands, march fences or other subjects; or

c makes muirburn on any land without having given to the proprietor of the lands or woodlands adjoining the land and, if he is a tenant, to the proprietor of the land, not less than twenty-four hours' notice of his intention to make muirburn and of the day on which, the places at which and the approximate extent to which, he intends to make muirburn; or

d makes muirburn on any land without due care so as to cause damage to any woodlands on or adjoining the land or any adjoining lands, woodlands, march fences or other subjects,

shall be guilty of an offence.

Notices as to muirburn

1 Any notice required to be given under either of the two last preceding sections shall be given in writing.

2 Any notice so required to be given to a proprietor shall be deemed to be given to the proprietor if it is given to his factor, commissioner or other local representative.

Appendix 2 Details and approximate costs for examples of motor-driven water sprayers and foam spreaders for fire control (1990 prices excluding VAT)

Water spraying equipment

	£
Fire trailer - 250 gals (Allan Fuller Ltd, Chepstow, Gwent)	2,000
Tractor pump - Silver Star	90
Hose - red rubber 19 mm bore - 100 ft	40*
Hose reel	90*
Branch - jet spray	50*
Angle iron for hose and fire-beater rack	ca. 50

* These items can sometimes be obtained second-hand from the county fire service.

A full range of fire fighting equipment can be obtained from: Williamsons, 8/18 Brook Street, Mumps Bridge, Oldham, Lancashire OL1 3HG.

Foam spreading equipment

	£
Tank (GRP*) for foam/water mixture (say 100 gals)	6-800 (depending on size)
4 x 18 m x 45 mm D500 firehose complete with Light Alloy Inst. couplings	100 (per assembly)
1 x Ind 225 foam inductor complete with pickup tube	190
1 x Med 225 foam branchpipe	172

* Tanks must be constructed of glass fibre (GRP) or stainless steel.

A drum of Expandol (25 l), which produces the foam, costs £24.50 and is mixed with water at 4%. In the above equipment it is pre-mixed but in alternative versions water and expandol are carried separately and mixed by a special pump at the time of application.

This equipment can be mounted on a trailer, costing approx. £1,200, or could be carried on a van or pick-up. The equipment is available from Angus Fire, Station Road, Bentham, Yorkshire, Tel. (UK Sales) 0524 35881. Macron Fire Eater, Great Yarmouth, Norfolk, Tel. 0493 859822, supply similar equipment.

Appendix 3 Suggested heath fire report form (R B Ninnes)

HEATH AND MOORLAND FIRE RECORD				Fire Number	
Recorder		Recording date		Date of Fire	
Site/Location				Planned Fire	
				Other Cause	
Sheet Number		Cross Ref			
Age of Heath (Number of Summers)		Height of Stand (cm)		Area (Ha)	
Heath Type					
Structure of Stand					
Wind Direction and Speed					
Time of Day Fire Started and Ended					
Moisture on Vegetation and in Litter and Soil Humus					
Proportion of Stems Unburned					
Unburned Moss/Liverwort					
Burned Soil Organic Horizon					
General Notes on Burn Characteristics and Material Left After Fire					
Personnel Present					
Equipment Used					
General Notes					

HEATH AND MOORLAND FIRE RECORD				CONTINUATION SHEET	
Sheet Number		Cross Ref		Fire Number	
Age of Heath (Number of Summers)		Height of Stand (cm)		Area (Ha)	
Heath Type					
Structure of Stand					
Moisture on Vegetation and in Litter and Soil Humus					
Proportion of Stems Unburned					
Unburned Moss/Liverwort					
Burned Soil Organic Horizon					
General Notes on Burn Characteristics and Material Left After Fire					
General Notes					

Notes on completing the heath and moorland fire recording form

Age of heath The number of full summers since the previous fire. If this unknown, the age should be estimated.

Height Record the vertical height and, if present, the length of layering stems.

Area If more than one sheet is used, give the area covered by each sheet and also record the total area on the first sheet.

Heath type Use a standard classification, with notes if necessary.

Structure Record the phase of development: building, mature, degenerate, or old self-regenerating heath. Include notes to cover other features.

Wind direction Put onto map as well and record any changes during the fire.

Wind speed Use the Beaufort Scale.

	MPH
0 - smoke rises vertically	under 1
1 - smoke drifts slightly	1 - 3
2 - leaves rustle	4 - 7
3 - leaves and small twigs move	8 - 12
4 - small branches move	13 - 18
5 - small leafy trees sway	19 - 24
6 - large branches in motion	25 - 31
7 - whole trees in motion	32 - 38
8 - breaks off twigs	39 - 48
9 - slight damage to buildings	49 - 54
10 - considerable structural damage	55 - 63
11 - widespread damage	64 - 75
12 - hurricane	75 plus

Moisture on vegetation, litter and soil organic horizon Note the degree of wetness in these three layers of the heath.

Material left after fire Estimate the proportion of stems; record whether stems are prostrate or upright; and make notes on any unburned moss/liverwort mats and burned soil organic horizons.

Personnel present The number of people and who they are.

Equipment used The number of items used. Note breakages and equipment worn out during the fire.

General notes Make any additional points that seem relevant. Notes on experience gained during the fire are likely to be particularly useful.

Map of fires Plot the extent of the fire on a map, mark the map with the date and fire number and add relevant details, such as the following:

- the points where the fire was started
- the location of fire-breaks, including natural ones
- where the fire was controlled and where it was extinguished without control
- location of any back-burning
- areas where burning was patchy
- areas where the fire progressed particularly quickly or slowly.

Appendix 4 Details and costs of examples of machinery for managing heath vegetation by cutting

Note: The following are examples only, to give an idea of the range of equipment available and their costs as at spring 1990 (excluding VAT). Much of the information was derived from Nix, J. (1990) *Farm management pocketbook*. Wye, Wye College.

1 Tractors - 2WD

Hp	£
36-45	10,000-11,000
47-54	11,000-12,000
57-66	12,000-13,500
67-75	13,500-15,500
76-89	15,500-17,000
90-100	17,000-21,000
101-120	21,000-24,000
125-140	24,000-28,000
150-175	28,000-32,000
4WD	
57-67	14,000-16,500
75-87	16,500-21,000
88-100	21,000-25,000
101-120	25,000-31,000
127-134	31,000-35,000
154-180	35,000-42,000

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2 Sickle bar (reciprocating) mowers

These can be either pedestrian-operated or tractor-mounted. The pedestrian machines are either multi-purpose two-wheeled tractor units to which the sickle bar is fitted as an accessory, or purpose-built machines.

Tracmaster Ltd, Teknol House, Victoria Road, Burgess Hill, West Sussex RH15 9QF, Tel. 0444 248561/247689/247680.

Brand name: BCS	£
Model 205: 5 hp 4-stroke petrol tractor	1,246
+ separate bar	
3 gears	
32" cutter bar	

		£
Model 715:	8 hp petrol or diesel tractor 4 gears 44" cutter bar	1,578 (add £550 for diesel)
Model 735:	10 hp petrol or diesel tractor + separate bar 7 gears 44" and 50" cutter bars	2,029 - 2,666

A 14 hp model is also available.

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Honda UK Ltd., Power Equipment Division, Power Road, Chiswick, London W4 5YT. Tel. 081 747 1400.

Tiller, Model F61OU:		£
	Tractor unit only (uses Tielburger bar) 5 hp 4-stroke 107 cm cutter bar 4 gears + hi/low ratio	995 + £575 for bar

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Anglia Engineering Services, Prickwillow Road, Ely, Cambs CB7 4TX. Tel. 0353 665884.

Jet II bank mower:	8 hp 4-stroke, purpose built, but with interchangeable blades Floating head for uneven ground 130 cm, 160 cm or 200 cm cutter bar 2 gears	£2,160 with 160 cm bar

****

Iseki UK Ltd., Broadway, Bourn, Cambs CB3 7TL. Tel. 0954 718981.

A400 two-wheel tractor:	5 hp 4-stroke tractor uses Tielburger cutter bar 107 cm cutter bar 8 gears	£990 + £575 for bar

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3 **Tractor-mounted sickle bar mower**

F W McConnell Ltd., Temeside Works, Ludlow, Shropshire SY8 1JL. Tel. 0584 873131.

Swingtrim: lightweight, linkage-mounted, sickle bar mower

	£
Hydraulic flow required:	2,197
14-21 litres per minute	(122 cm bar)
Cutting width 122 cm or 152 cm	2,388
	(152 cm bar)

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4 **Forage harvesters**

Estimated costs:	£
Double chop	5,000- 6,500

Manufacturers of forage harvesters:

Claas UK Ltd., Saxham, Bury St Edmunds, Suffolk IP28 6QZ. Tel. 0284 63100.

Ruston's Engineering Ltd., Brampton Road, Huntingdon, Cambs PE18 6BQ. Tel. 0480 455151.

John Deere Ltd., Langer, Nottingham NG13 9HT. Tel. 0949 60491.

Ford-New Holland, Cranes Farm Road, Basildon, Essex

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Table A4.1 An example of operating costs for heathland management using a forage harvester

	Capital cost (£)	**Cost per hour (£)**
Tractor (75 hp 4WD)	19,000	7.13
Flail forage harvester (Kidd 1.4 m)	5,000	8.33
Trailer (2.5-3.5 tonne)	1,500	0.45
Total	**25,500**	15.91
Labour cost @ £140 p.w.		4.38
Total operating cost		**20.28**

Note Work-rate 0.2-0.4 ha per hour, depending on terrain (from Rowell 1991).

5 Swipes

F W McConnel Ltd., Temeside Works, Ludlow, Shropshire SY8 1JL. Tel. 0584 873131.

Junglebuster: linkage-mounted chain swipe £1,956

Minimum power requirement: 40 hp
Cutting width 150 cm
Size of cuttings: anything you can drive a tractor over

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Ruston's Engineering Ltd., Brampton Road, Huntingdon, Cambs PE18 6BQ. Tel. 0480 455151.

Whoppa Choppa: linkage-mounted bladed swipe £2,695

Minimum power requirement: 40 hp
No gearbox
Can be driven backwards over largish bushes
Cutting width 183 cm
Size of cuttings: anything that the machine can be pushed over

****

6 Flails

Bomford & Evershed Ltd., Salford Priors, Evesham, Worcs WR11 5SW. Tel. 0789 773383.

Bomford Bandit: a range of linkage-mounted flails

1100HD: Minimum power requirement: 14-30 hp £1,491
Cutting width 112 cm
Maximum thickness of woody material 40 mm

1700HD: Minimum power requirement: 28-30 hp £3,314
Cutting width 170 cm
Maximum thickness of woody material 40 mm

2200HD: Minimum power requirement: 40 hp £3,800
Cutting width 220 cm
Maximum thickness of woody material 40 mm

****

F W McConnel Ltd., Temeside Works, Ludlow, Shropshire SY8 1JL. Tel. 0584 873131.

SMO mowers: linkage-mounted flails

Model	HP required	Cutting width	Diam. of cuttings	Price £
SMO 175	36	175 cm	100 mm	2,797
SMO 200	45	200 cm	100 mm	3,040
SMO 225	50	225 cm	100 mm	3,248
SMO 250	57	250 cm	100 mm	3,597

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7 **Loader wagons**

Ruston's Engineering Ltd., Brampton Road, Huntingdon, Cambs PE18 6BQ. Tel. 0480 455151.

Model	Capacity	Pickup width	Price £
LW432 Garant	32 m^3	165 cm	14,995
LW435 Garant	35 m^3	165 cm	18,365

Note These units can be used with the cutting blades removed, so that material collected is not chopped as it is loaded.

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SKH Ltd., Adderley Road, Market Drayton, Shropshire TF9 3SG. Tel. 0630 3501.

Pottinger self-loading wagons

Model	Capacity	Pickup width	Price £
Boss I	23 m^3	1.65 m	13,175
Boss II	28 m^3	1.65 m	14,105
Ladeprofi II	31 m^3	1.6 m	15,885
Ladeprofi III	36 m^3	1.6 m	19,155
Siloprofi II 'L'	36 m^3	1.65 m	21,440

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Claas UK Ltd., Saxham, Bury St Edmunds, Suffolk IP28 6QZ. Tel. 0284 63100.

Model	Capacity	Pickup width	Price £
445P	25 m^3	1.6 m	18,200
335P	21 m^3	1.6 m	14,750
300T	24 m^3	1.6 m	11,400

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Appendix 5 Examples of cost of fencing, as at spring 1990 (excluding VAT)

Fencing

Estimated costs for materials + erection (from Nix 1990):

	£ per metre
Rabbit	1.50 - 2.50
Stock	1.70 - 2.50
Deer	3.00 - 4.00

Electric fencing

Gallagher Agricultural Ltd (Europe), Curriers Close, Canley, Coventry CV4 8AW. Tel. 0203 470141.

Manufacturers of all components for both permanent and portable electric fencing systems. They produce a useful manual on power fencing, as well as a comprehensive components list.

[Their permanent system has little visual impact and is used by the National Trust on the Lizard. Unfortunately, it utilises 'Insultimber', an Australian hardwood. The company is coming under pressure to find alternative materials.]

Appendix 6 Details and costs (as at spring 1990, not including VAT) of examples of machinery used in scrub and bracken control

1 Brushcutters

Stihl Ltd., Stihl House, Goldsworth Park Trading Estate, Woking, Surrey GU21 3BA. Tel. 0483 750077.

Company markets a wide range (13 models) of brushcutters and clearing saws, including a backpack, flexible shaft version, costing from £229 to £529.

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Husqvarna, Oldends Lane, Stonehouse, Gloucestershire GL10 3SY

Chainsaws/scrubcutters.

****

F W McConnel Ltd., Temeside Works, Ludlow, Shropshire SY8 1JL. Tel. 0584 873131.

'Junglebuster' £1,600

****

2 Chippers

Michael Dalrymple Developments, Beare Green, Dorking, Surrey RH5 4QD. Tel. 0506 52354.

Model	Power source	Max. diam. of material	Feeder	Price £
0/5	self-powered diesel	12.5 cm	gravity	7,800
TMO	PTO (40-180 hp)	18 cm	gravity	5,800
Alpha/7-27	self-powered diesel	18 cm	gravity	9,600
Alpha/7-27	self-powered diesel	18 cm	roller	13,800

****

Bomford Turner Ltd, PO Box 18, Evesham, Worcestershire WR11 5SW

Eg T70 PTO driven (c 70 hp) maximum size material = 27 cm roller feed.

Bomford Turner also make larger and smaller models plus self-powered versions.

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Arbor Products International Ltd., Manor Farm, The Street, Tongham, Farnham, Surrey GU10 1DG. Tel. 02518 2826 (Freefone 0800 521035).

Company markets a wide range (20 models) of self-powered disc chippers ranging from £7,800 to £15,250.

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3 Spraying equipment

CDA Ltd., Three Mills, Bromyard, Hereford & Worcester HR7 4HU. Tel. 0885 482397.

	£
Micron Ulva 8 bracken control pack	52
Microfit Herbi lance and powerpack	65
Controlled droplet application tractor-mounted boom sprayer, 12 m width	from 3,960

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E Allman & Co. Ltd., Birdham Road, Chichester, Sussex PO20 7BT. Tel. 0243 512511

	£
'Allclear' protective spray pack: includes coverall, face shield, goggles, respirator, gloves, eye irrigator etc.	70
Kestrel Backpack sprayer, 20 l capacity	66
Allman-Jacto X15 Backpack sprayer, 15 l capacity	68
Tractor-mounted boom sprayers	from 860

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Hardi Ltd, St Georges Way, Bermuda Industrial Estate, Nuneaton, Warwickshire CV10 7QT. Tel. 0203 372054.

	£
K15 knapsack sprayer, 15 l capacity	72
RY2 knapsack sprayer, 20 l capacity	75
Tractor-mounted boom sprayers	from 720

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Selectokil Ltd., Abbey Gate Place, Tovil, Maidstone, Kent ME15 OPP. Tel. 0622 55471/761877.

	£
Forestry Spot Gun, for spot herbicide treatment of weed trees, e.g. birch. Could have a use in spot treatment of bracken.	98

Appendix 7 The Domin cover-abundance scale

Class		Cover
1		(With few individuals
2	< 4%	(With several individuals
3		(With many individuals
4		4 - 10%
5		11 - 25%
6		26 - 33%
7		34 - 50%
8		51 - 75%
9		76 - 90%
10		91 - 100%

Appendix 8 **Staff numbers, equipment and time required and cost of various management operations, per hectare (1992) (Auld, M.H.D., personal communication)**

Operation	Staff Required	Equipment	Time	Cost
Pine clearance (Material up to 35 years old giving 50% ground cover)	4	3 chainsaws + handtools, 2 tractors, silage trailer, woodchipper, safety equipment	35 hrs	£1,728
Birch clearance (Material up to 35 years old giving 50% ground cover)	4	As above + herbicide (Garlon 4), required protective equipment	36 hrs	£1,830
Rhododendron clearance (Material up to 30 years old giving 50% ground cover)	4	As for birch clearance	52 hrs	£2,669
Gorse management (Material up to 20 years old giving 90% ground cover)	4	3 chainsaws + handtools, safety equipment, water bowser, (material is burnt), posts, rabbit netting (regrowth is fenced off)	46 hrs	£2,300

Operation	Staff Required	Equipment	Time	Cost
Bracken clearance:				
swiping	1	Tractor, swipe.	3.5 hrs	£60
knapsack sprayer	3	2 knapsack sprayers, herbicide (Asulam), required protective equipment, water bowser	6 hrs	£353
ULVA (ultra low volume applicator)	3	2 ULVAs, other equipment as for knapsack sprayer	3 hrs	£238
6 m boom	1	Tractor, 6 m boom sprayer, water bowser, herbicide (Asulam), required protective equipment	1.5 hrs	£170
Heather foraging/ firebreak creation	2	2 tractors, 2 silage trailers, 1 double-chop forage harvester, rotovator	5 hrs	£168