10 *Grassland restoration*

10.1 Introduction

What happens when a grassland becomes unmanaged?

In the absence of effective grazing or other positive management, short and often species-rich swards can become dominated by a combination of coarse grasses, tall herbs and scrub. These species are able to outcompete less vigorous herbs and fine-leaved grasses for water, light and nutrients. A litter layer can develop after a number of years. This may further suppress plant growth and increase the soil nutrient status.

Loss of species diversity and structural variation usually leads to a decline in the botanical interest of the site. However, rank grassland does provide a habitat for reptiles, invertebrates and small mammals, so benefiting other species such as bats and birds of prey.

10.2 Factors that lead a grassland to become rank

10.2.1 Stopping or reducing management

Grazing, mowing and burning maintain grassland communities by:

- restricting the growth of shrub and tree species by removing their growing points.
- preventing coarse grasses and herbs from achieving dominance by giving low growing species a chance to compete.
- removing leaf litter and limiting the return of nutrients.
- allowing seedlings of short-lived species to establish in gaps in the sward produced by grazing animals.

A decline in the profitability of farming on marginal land has led to many areas developing into rank grasslands and scrub. Coarse grasses such as upright brome *Bromopsis erectus* and tor-grass *Brachypodium pinnatum* previously kept in check by grazing have become dominant over large areas of chalk and limestone. This has been exacerbated by the decline in rabbit grazing following the myxomatosis epidemic of the 1950s (see Chapter 5, section 4, sub-section 4.4.3).

Undergrazing can also lead grasslands to become rank. Animals are selective feeders and will avoid tough fibrous grasses and scrub seedlings when other herbage is available. Uneaten herbage builds into a litter layer which is unpalatable. This situation occurs particularly when stocking densities are too low, relative to the amount of herbage that the sward produces.

10.2.2 An increase in nutrients

An important feature of unimproved semi-natural lowland grasslands is their low fertility compared to improved swards. Their conservation interest is directly related to this factor. Vigorous competitive species are frequently present in grassland communities, particularly on soils of a naturally high nutrient status eg clays and loams. Rainfall, rock weathering and `biological fixation' by the growth of tree and shrub species all supply nutrients to the system. Any increase in the fertility of grasslands tends to favour nutrient responsive species.

- The removal of well-grown scrub can expose nutrient-rich soil which may become dominated by weeds or coarse grasses.

- If cuttings are left *in situ* after mowing, these will decompose and add nutrients to the soil.

- Ash from burning contains nutrients, the release of which can lead to an increase in undesirable species unless mowing or grazing is introduced.

- An influx of nutrients from surrounding agricultural land through run-off or groundwater leaching may lead to rapid uptake by nutrient responsive species.

- Concentration of animal dung, in latrines or against shelters such as walls and hedges, can lead to localised nutrient enrichment.

- It has been suggested that an increased aerial input of nitrogen has been partly responsible for the spread of tor-grass in Europe (Bobbink & Willems 1987).

The length of time it takes for a grassland to become rank depends on a number of factors including:

- soil nutrient status: nutrient-rich soils such as clays or loams are likely to become dominated by coarse, competitive species more quickly than grasslands on naturally poor soils;

- the proximity to a 'source pool' of colonisers also plays a role in determining the rate at which a grassland becomes invaded by coarse grasses, herbs and scrub.

10.3 First steps in grassland restoration

(see also Chapter 3)

- Assess the current nature conservation value of the site.

- Research the ecological and management history of the site, including reasons for its present condition.

- Consider what type of grassland the site might support and whether it is feasible to return to it by introduction of appropriate management.

" Would changes in the management regime (or the introduction of management) damage or improve the conservation value of the site?

" Consider management objectives which might include the following:

- Introduction of management to diversify the grassland structure and increase plant species richness
- Creation of specific conditions for certain species
- Checking scrub invasion/removal of scrub
- Maintenance of some areas of unmanaged grassland if appropriate

" Assess the likely chances of fulfilling these objectives considering both the costs and the benefits. What resources might be available to restore the site and maintain it once restored?

" There may be some occasions where it does not make good conservation sense to try and restore a grassland. The removal of well-grown scrub can cause problems, especially if nutrients have accumulated through successional stages or bare ground has developed. In these instances, coarse species may invade once scrub has been removed (see Chapter 12, section 3). It is important to consider previous site records if available, and resources for follow-up treatment.

" It is important to take into account factors that might be beyond control, such as the use of fertilisers on surrounding fields.

" Consider the management options for achieving objectives, choose the most appropriate technique for the prevailing circumstances.

" Implement chosen management.

" Monitor effectiveness.

10.4 Management guidelines

There are a range of techniques that can be used to restore unmanaged grasslands.

These are:

" Grazing
" Mowing
" Burning
" The use of herbicides

10.4.1 Grazing to restore derelict grasslands

Chapter 5 gives detailed information on the types of stock suitable for grazing rank swards.

Grazing enables low growing and less competitive plants to compete with coarse, vigorous species. The trampling action of hooves helps to break up the litter layer and open up the sward allowing short-lived species to recolonise.

Cattle can be very efficient at restoring rank swards. They are able to remove long or rank vegetation fairly quickly, due to the wrap around and pull action of the tongue. Sheep generally prefer shorter more succulent herbage.

Cattle are heavier than sheep and are better able to trample down long grass and break up the litter layer. Sheep, on the other hand, cause less trampling damage on slopes. They can be effective restorers of rank grassland, given time, especially if some sort of pre-treatment is included eg mowing or grazing with cattle in the previous season.

In general, animals of the hardier breeds of both sheep and cattle are more suited to restoring unmanaged grassland swards than pure-bred and some cross-bred lowland stock (see Chapter 5, subsection 5.4). This is due to their ability to survive with poorer nutrition. Extensive beef and sheep rearing enterprises are far more suited to restoration grazing than intensive livestock systems, due to the higher nutritional requirements of the latter.

Grazing with ponies

Hardy ponies can be a useful management tool in reclaiming neglected grasslands:

- They trample down and eat coarse grasses.
- Some breeds of pony eg Shetland and New Forest are tolerant of quite poor grazing.
- Horses and ponies are not reared for milk or meat production so their exact levels of nutrient input are not critical.

NB: Most non-hardy breeds of horses and ponies require considerable care during the winter months, including supplementary feeding. Consequently, they are not generally suitable for restoring rank swards.

Timing of grazing and stocking density

Timing of grazing is not critical except where the dominant grass is particularly unpalatable.

Some species, such as tor-grass and purple moor-grass, are more palatable when young leaves are being produced in spring; greater suppression is achieved if grazed in this period. For the same reasons, grazing during spring is beneficial for scrub control.

There are a number of options for stocking density:

- Grazing at a high stocking density for a short period in the spring when the target coarse grasses are growing vigorously.

- Grazing at lower rates over a longer time period.

Both methods of grazing are suitable for reclaiming unmanaged grasslands. The preferred type of management will depend on site characteristics and conservation objectives. Table 5.6 in Chapter 5 provides guidelines: adjust stocking density upwards or downwards accordingly.

Remember:

- Grazing at lower stocking densities over a longer period is more sensitive to invertebrate requirements.

- Grazing hard in the spring is an unsuitable option where management for ground nesting birds is a priority.

Some kind of rotational management may be necessary to overcome these problems (see Chapter 5).

Mowing

Mowing can be used as a technique for grassland restoration. It can be particularly useful as a pre-treatment to reduce the sward height prior to grazing with sheep.

Cutting does not exert the same localised pressure on the sward as do the hooves of cattle and sheep. Consequently, mowing does not break up the litter layer to the same extent as grazing. This problem can be tackled by using a chain harrow to break up the mat of dead material after cutting. Flailing can help open up the turf to allow seedlings to establish (care must be taken, however, as this could encourage the establishment of undesirable species).

For a detailed account of the types of cutting machinery and the situations to which they are most suited see Chapter 6.

Remember:

- Cutting rank grasslands can have a great impact on invertebrate populations. A survey prior to restoration work is desirable.

- Leave parts of the site uncut, where appropriate, as refuges for the less mobile species.

- Where appropriate, vary the height of the cutter bar to take into account the flowering and seeding times of important plants.

- It is essential to remove cuttings to help prevent nutrients from returning to the system, and to avoid the smothering of low-growing herbs and fine grasses.

- Avoid damaging anthills which may be hidden by the long grass.

For information on the use of burning as a restoration technique see Chapter 9.

10.4.2 Case study 1: Control of tussocky *Molinia* at Nant Irfon National Nature Reserve (NNR), Wales

The Reserve is situated on Silurian shales in mid-Wales at an altitude spanning 290-380 metres above sea level, and in an area of high rainfall (2100 mm a year average in the period 1916 to 1950). The general aspect of the steep slopes is north-east. Extensive tussocky *Molinia* is found typically towards the base of slopes where the gradient lessens and the drainage is thus impeded and more widely where the grass tends to be of a less tussocky nature. Access for both machinery and grazing animals other than sheep is tortuous. An extensive conifer plantation covers the land uphill of the Reserve.

Eyewitness accounts, photography and quadrat data all demonstrate the increasing abundance of *Molinia* within its present stands and in parts invasion into areas previously free of the plant. National Vegetation Classification surveys have classified the swards as M25a[1] mire (wetter + more *Sphagnum/Juncus* spp.) and M25a[2] mire (drier + less *Sphagnum/Juncus* spp.), with patches of M6c/d mire, M15b/d wet heath and M23a rush pasture. To maintain the more diverse habitats, a programme of *Molinia* control was undertaken, especially to reduce its tussocky nature in selected areas thus providing suitable habitat for a wider range and coverage of plants normally associated with this vegetation type.

The vast quantities of feg (dead material) could be burnt off very readily but this process was excluded because firstly it was not considered a viable method to discourage the *Molinia* plant itself (it is often used to stimulate spring growth for sheep) and secondly the conifer plantation at the top of the steep slope presented an enormous potential for an extensive and damaging fire.

Cattle grazing was considered to be the most useful method of limiting the *Molinia* as it would be the least time-consuming and the cheapest. However, efforts to provide an acceptable access route have failed so far but are not excluded for the future.

Chemical control using Glyphosate was tried on a small scale and found to be effective but the tussocky nature of the site precluded a scaled up version with machinery, even an ATV with carpet wiper.

Hence direct mechanical control has been developed (to occur along with a continuance of seasonal sheep grazing). Swipes (whether chain or blade) rapidly got clogged or broken with large quantities of feg wrapped around them. Flails left a mulch that smothered other species and could not be gathered. Reciprocating cutter bars were good around the edges but could not cope with tussocks. The combination finally settled on and still used is a 30 HP compact tractor with four-wheel drive (not unduly heavy for this very soft ground) with a triple-disc mower. The mower used is a Kuhn GMD 33N (the smallest available) which does not clog due to the small length of blade exposed. This mowing leaves the dense parts of the tussocks less their sprouting vegetation. The cut material is then rowed using a Haybob 300 which, given its robust construction, also gives the remaining parts of the tussocks a knock thus weakening and loosening some (the degree to which this can be achieved safely must be carefully considered - it must be relatively gentle particularly the first time round), and the rowed vegetation gathered into an ATV trailer. A better method of collection is still being investigated. Further

work on this type of ground in the same season (normally September when the water levels are at their lowest) would cause unacceptable damage to the 'turf' so it is left for the winter frost and rain to work on the exposed tussocks. The following September the whole process is repeated (mow, row, and gather) but at this time many more tussocks are loosened. Areas within the site vary but usually on the third attempt the process becomes a lot easier and a smoother vegetation type emerges which can subsequently be managed by occasional topping with a flail. This should readily maintain the *Molinia* in a non-tussocky form. The possibility of using a small baler to aid the gathering process is currently being investigated as at the present this is a highly labour-intensive operation.

Some areas of tussocky *Molinia* are purposely left for small mammals and invertebrates. The object is not to create a uniform short-sward.

Key to NVC types (see Rodwell 1991)

M25a = *Molinia caerulea - Potentilla erecta* mire *Erica tetralix* sub-community.

M6c = *Carex echinata - Sphagnum recurvum/auriculatum* mire *Carex echinata* sub-community.

M6d = *Carex echinata - Sphagnum recurvum/auriculatum* mire *Juncus acutiflorus* sub-community.

M15b = *Scirpus cespitosus - Erica tetralix* wet heath. Typical sub-community.

M15d = *Scirpus cespitosus - Erica tetralix* wet heath. *Vaccinium myrtillus* sub-community.

M23a = *Juncus effusus/acutiflorus - Galium palustre* rush-pasture. *Juncus acutiflorus* sub-community.

10.4.3 Case study 2 - grassland restoration

Magdalen Hill Down is managed by the Hampshire and Isle of Wight Branch of Butterfly Conservation.

The site consists of 23 acres of steep, south-facing hillside one mile east of Winchester. It is notable for the typical range of downland chalk flora and fauna which it supports. This includes plants such as rock-rose *Helianthemum nummularium*, horseshoe vetch *Hippocrepis comosa*, kidney vetch *Anthyllis vulneraria*, birds-foot trefoil *Lotus corniculatus*, dropwort *Filipendula vulgaris* and clustered bell-flower *Campanula glomerata*. The down is also a notable site for brown argus *Aricia agestis*, green hairstreak *Callophrys rubi*, chalkhill blue *Lysandra coridon* and marbled white *Melanargia galathea*. Upright brome *Bromopsis erectus* dominates the sward.

Restoration work began in December 1989. At that time the down had been totally neglected for decades, with probably no grazing since the 1940s. The sward had become coarse and rank and scrub had taken a firm hold with some trunks up to 9 inches in diameter. Many areas of ground flora had been completely or partially shaded out.

A management plan was prepared which divided the down into four sub-divisions of roughly equal size, each with a different prescription eg 90 per cent of scrub by ground area to be removed, thickets to be

left *in situ* where ground reduced to bare earth, edges to be scalloped, stumps exceeding 2cm in diameter to be painted with Amcide etc. 95 per cent of the work was undertaken by contractors.

Initial clearance of a third of the down was completed in December 1989/January 1990. Initial clearance of the other two-thirds was completed September to December 1990.

Stumps were treated with Amcide in the autumn and winter but this only achieved a 50 per cent kill rate and did not kill privet *Ligustrum vulgare*. In the summer after the initial clearance, the stumps were re-cut and re-treated with herbicide.

Privet bushes were manually grubbed-out using a mattock and in some cases privet was weed-wiped with glyphosate in June/July (50 per cent kill rate achieved).

One of the lessons learnt from the exercise was that some of the thicker scrub, where bare ground existed underneath, should have been left *in situ*. Where scrub was cut in some of these areas, creeping thistle *Cirsium arvense* has invaded and is proving difficult to deal with.

The site is now divided into three paddocks and grazed on a rotational basis by Scottish blackface sheep and Shetland ponies.

Scrub is now under control and the floristic interest of the sward has greatly increased.

Update of 1992 case study

The creeping thistle is no longer a problem. The invasion subsided largely of its own accord but was hastened by some cutting. A certain amount of creeping thistle is welcome because it is an important nectaring flower for butterflies.

The east and west extremities of the original reserve suffer from excessive rabbit grazing. Marksmen and ferreters are licensed in an effort to contain this problem but seem to have small effect on rabbit numbers. A limited amount of gassing has been tried: this is effective for a time but is expensive and has to be repeated. Rabbit-proof fencing has been erected around one of the paddocks; and rabbit-proof exclosures have been erected in two of the other paddocks. The difference in vegetation inside and outside the exclosures is spectacular.

The scrub was so firmly established before the Branch's restoration of the original reserve that scrub regrowth still has to be continually checked. This is done by grubbing out or low cutting of unwanted scrub: chemical treatment has been used on only a very small scale. Numerous thickets have been left *in situ* and some of these are coppiced on a 12 year rotational cycle.

The grass is kept in order by light rotational sheep-grazing in autumn together with very occasional cattle grazing in summer.

The original reserve now consists of good quality chalk grassland dotted with thickets of scrub. Near adjoining arable land, the flora is not as rich. This may be because of spray-drift or because decades ago this area, being comparatively flat, was agriculturally improved. Further away from the arable land, the flora is species-rich; in particular rock-rose *Helianthemum nummularium* is abundant.

The main butterfly species breeding on the site have continued to do well, as shown by the following 1997 transect annual indices:

Brown argus *Aricia agestis*	727
Chalkhill blue *Lysandra coridon*	1,487
Green hairstreak *Callophrys rubi*	62
Marbled white *Melanargia galathea*	425

The brown argus and green hairstreak indices are higher than for any other site in Hampshire.

In 1995, Butterfly Conservation acquired an adjoining area consisting of two acres of unimproved chalk grassland and a 30 acre (*c.* 12ha) arable field. During 1996 and 1997 the Branch brush-harvested wild flower and grass seed from Hampshire chalk grassland nature reserves (Martin Down, Old Winchester Hill and Farley Mount) and in September 1997 sowed this seed (plus bought-in wild flower seed from a known nearby source) on the ex-arable field, which had been prepared by harrowing and three successive applications of Round-up (Glyphosate). The results are now being monitored by counting species in 40 random quadrats over a period of five years. The counting is being done by branch volunteers but there is objective professional supervision.

The seed was sown at the rate of 5.95 kg per acre and included at least 10 species of grass and 36 species of wild flower.

The whole (ie 32 acres/13 ha)) of this adjoining area will be managed by the branch as an extension of the original 23 acre (9 ha) reserve. A perimeter sheep-proof, and mainly rabbit-proof, fence has been erected round the extension. This fence is 6m inside the perimeter hedges, which are most attractive and contains diverse species of trees and shrubs. A water supply to the extension has been laid on from the adjoining cemetery. (The original reserve has its own separate water supply.)

10.5 Management and control of tor-grass *Brachypodium pinnatum*

Although tor-grass is a natural component of calcareous grassland in north-west Europe, it has become dominant in some chalk and limestone areas eg within south-east England, particularly Kent, the Yorkshire Wolds, the Cotswolds and on the Purbeck Limestone of Dorset.

10.5.1 What is the problem?

Tor-grass is a perennial species, 30cm-120 cm high which spreads from scattered shoots to form clumps. It is tough, unpalatable and has a low nutritional value. It grows vigorously and can suppress or out-compete other plants, especially low-growing or fine-leaved species. If not managed it eventually forms dense tussocky swards with a deep litter layer. Hurst (1997) studied a range of East Sussex sites and found that soil nitrate levels were higher within tor-grass stands than in surrounding chalk grassland. If this effect occurs more widely, then this will need to be taken into consideration when deciding on appropriate management strategies.

When tor-grass invades a species-rich sward and is left unmanaged, the nature conservation interest of the site usually declines due to a reduction in species numbers and diversity. Figure 10.1 illustrates the relationship between percentage tor-grass cover and species number and diversity.

It has been suggested that tor-grass has spread as a result of several factors.

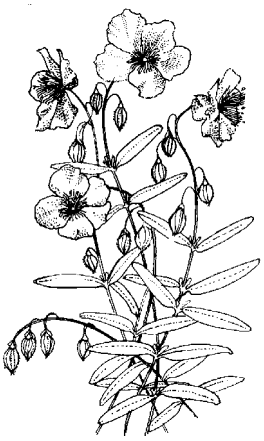
- A reduction in or cessation of grazing. This is often due to the decline in profitability of livestock farming on agriculturally unimproved grassland or a shift from mixed farming systems to arable, especially in chalk areas.

- The introduction of myxomatosis in the early 1950s which severely depleted the rabbit population.

- Stock generally will only graze tor-grass when it is young and succulent.

- A nutrient-limited ecosystem such as calcareous grassland is sensitive to 'nutrient enrichment'. Any factor which increases the fertility of unimproved grasslands tends to favour nutrient responsive species such as tor-grass. The spread of tor-grass on oolitic limestone areas such as the Cotswolds has been attributed to the traditional practice of burning, and the resulting fertilising effect of the fire ash, coupled with a relaxation in grazing. Dutch studies suggest that the spread of tor-grass in the last decade in north-west Europe has been significantly assisted by an increased nitrogen input from the atmosphere linked to atmospheric pollution (Bobbink & Willems 1987). Baxter (1994), however, concludes that the increase in tor-grass in the UK is due to a decrease in management intensity rather than the result of the deposition of atmospheric nitrogen.

  Areas dominated by tor-grass tussocks are of potential interest for a range of invertebrates, eg the Duke of Burgundy *Hamearis lucina*, and support some uncommon species such as the Lulworth skipper *Thymelicus acteon* and wart-biter cricket *Decticus verrucivorus*. However, in general, mosaics of vegetation types and structures support a greater diversity of invertebrates.



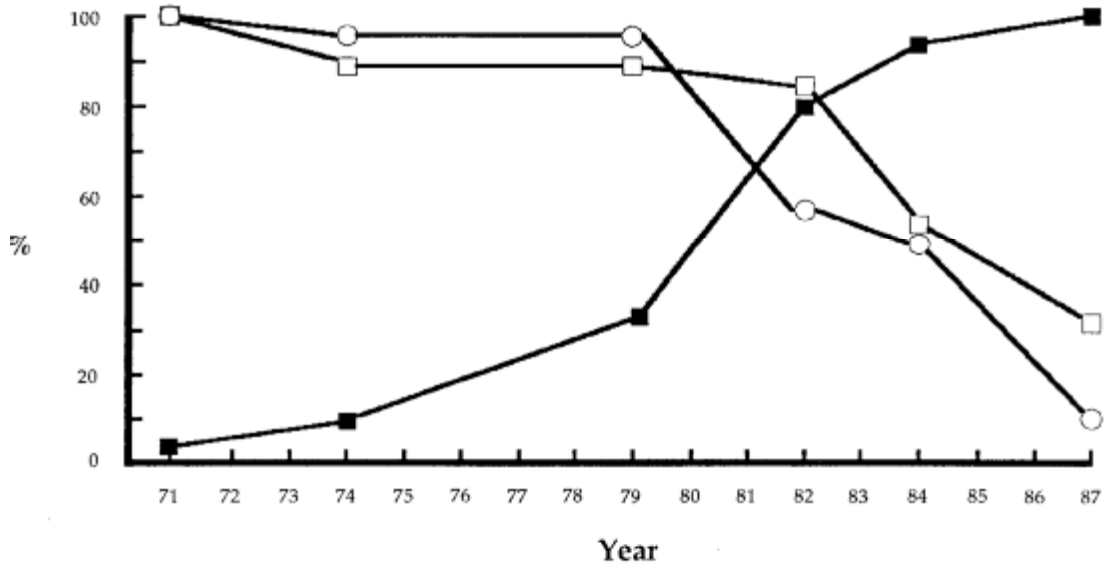


Figure 10.1

Relationship between cover of *Brachypodium pinnatum* ( ), species number (□) and species diversity index H' (o) in a permanent calcareous grassland plot measuring 10 m² on a N-facing slope in the Netherlands (Gerendal, South Limburg). The vegetation within the fenced plot was left unmanaged from 1971 onwards. Reproduced from Willems 1990 with permission of Bluntisham Books.

10.5.2 Management objectives

There are several characteristic lowland calcareous grassland communities (see Chapter 2) ranging from short turf communities such as *Festuca ovina - Avenula pratensis* (CG2) to the coarse *Brachypodium pinnatum* grassland (CG4). Currently there is an imbalance between rough tor-grass swards and other sward types in regions where tor-grass occurs. On thinner chalk soils management should aim to restore short turf but there is a role for medium and long swards in appropriate situations.

Because of its unpalatability, the expansion of tor-grass is reversible only with very great difficulty. Indeed it may only be possible to eliminate tor-grass at the expense of eliminating surviving elements of flora and fauna associated with less coarse swards. Objectives should be weighed against what is practicable and achievable, eg:

- To reduce the dominance of tor-grass and to encourage a more varied species-rich sward.

- To prevent further spread of tor-grass with continued management.

It is important to consider resources for follow-up treatment before embarking on any programme of restoration. If it is not possible to introduce a maintenance regime, is it worth trying to restore the site in the first place?

The main options are grazing, mowing, burning and herbicide treatment.

10.5.3 Management guidelines

Grazing

Management practices remain largely the same as those outlined earlier under section 10.4. The main difference is the extreme unpalatability of tor-grass.

Stock will eat tor-grass if stocking densities are kept sufficiently high. The use of urea licks is acceptable and can actually encourage stock to eat coarse dry vegetation. Most sites have some less valuable patches where these could be situated, eg at the top or the bottom of a slope, or in an area of cleared scrub. Cattle are particularly effective at trampling down and grazing tor-grass. Sheep tend to concentrate their grazing on patches of `sweeter' *Festuca-Avenula* turf, leading to localised overgrazing.

Certain types of stock are not suitable for grazing tor-grass swards eg intensively farmed animals which are expected to put on weight quickly. In general, low intensity production systems of both sheep and cattle, particularly hardier animals ie upland breeds, are more suitable. (See Chapter 4 for further details on the suitability of different breeds for grazing.)

Hard grazing is likely to reduce the dominance of tor-grass more quickly and will force stock to eat vegetation they would otherwise reject. This can be particularly effective if stock are confined to small areas. The National Trust has had good success at Box Hill, Surrey using 20 Welsh blacks penned into small paddocks (Matthew Oates, personal communication).

English Nature has used Hebridean sheep to graze tor-grass swards in winter in the Yorkshire Wolds. They maintained a species-rich sward and kept tor-grass in check. Draft Swaledale ewes have also been used with success.

Although data is inadequate, ponies appear to be fairly good at tackling tor-grass and may prove to be the most appropriate animal for the task. As ponies are not raised for milk or meat their nutrient input is not critical. Hardy native breeds are preferable as they are less likely to lose condition.

Spring grazing can be particularly effective as tor-grass is rather more palatable to stock when the new shoots are growing. However, grazing at this time may have an impact on some early flowering plants, and on specific invertebrates. One option is to concentrate spring grazing in those areas most affected by tor-grass.

Mowing

Mowing, with the removal of cuttings, has been shown to be effective in maintaining less tussocky and more varied tor-grass swards (Green 1972). Mowing can be used as a pre-treatment to grazing by sheep. Hurst (1997) suggested a spring cut combined with summer grazing may increase the overall effectiveness of grazing as a management tool. Mowing will also enable rabbits to move in and maintain short turf (rabbits prefer to graze vegetation shorter than 10cm). In Britain, mowing calcicolous grassland is often impractical because of the steep and inaccessible nature of many remaining sites.

Dutch workers suggest that mowing early in the year is likely to reduce the dominance of tor-grass and result in a more species-rich grassland (Bobbink *et al* 1987; Bobbink & Willems 1991, 1993). In these

studies, tor-grass and the litter layer were strongly reduced by cutting and species diversity was stimulated. However, Bobbink & Willems (1993) found that cutting twice a year in early summer (May) and in autumn (September) was the optimum treatment.

Remember - mowing tor-grass swards removes breeding, feeding and shelter areas for invertebrates all at once, unlike grazing.

Burning (see also Chapter 9)

Burning without follow-up management should not normally be considered as a management technique. Burning removes growth and litter, but can increase fertility and remove competing species, promoting regrowth of tor-grass. The spread of tor-grass on Box Hill, Surrey was greatly accentuated by the swaling management carried out there in the 1950s and 1960s.

A combination of winter burning and hard spring grazing can help reduce the vigour of tor-grass. Burning, followed by heavy grazing, has helped to restore chalk grassland at Wye College and Great Shuttlesfield Down (Junghanns 1988).

Herbicide

Certain herbicides, notably glyphosate (Round-up) or Dalapon (**NB**: this grass herbicide is no longer marketed alone but is still approved for use), can be used to tackle small clumps of invading tor-grass. This treatment should be combined with a continuation of livestock grazing.

Hurst (1997) found that Glyphosate caused an initial reduction in tor-grass dominance but that re-colonisation with characteristic chalk grassland herbs was generally poor. Hurst found that tor-grass rapidly re-invaded after spraying although this problem was reduced by repeat treatment. Hurst recommends that herbicide should only be used on tor-grass where it forms discrete, distinct stands (eg less than 100 m^2) and concludes that treatment may be more effective late in the growing season (August/September). This is the period when tor-grass begins to re-distribute nutrients and carbohydrates from the shoots to the rhizomes.

At Martin Down NNR in Hampshire, English Nature has applied Glyphosate on tor-grass patches using a weedwiper and knapsack sprayer. Weedwiping reduced the dominance of tor-grass but it remained abundant. Knapsack spraying almost eliminated the tor-grass; however, thistles and ragwort have invaded the patches of bare ground created by the herbicide treatment. If tor-grass does increase soil nitrate levels (see sub-section 10.5.1) then where it is feasible such as in small invading patches it may be necessary to consider scraping-off the top soil to encourage colonisation by calcareous grassland species.

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