6. Interactions between grazing and burning

6.1 Introduction

Consideration of the interactions between grazing and burning is of importance as the main reason for management by fire is to improve conditions for stock (including grouse), in particular by altering vegetation composition, structure and nutrient content (see 4.3.1). The effect of burning or grazing will clearly be dependent to some extent on the management history which has resulted in the current vegetation composition, and it is very difficult to separate out the different impacts of burning and grazing (including trampling and enrichment from dung), particularly as some drainage operations are usually carried out in association with these activities.

The interactions between burning and grazing on the vegetation of heather moor have been considered in studies by Grant *et al.* and Gimingham (see Hobbs & Gimingham 1987), but there have been no direct studies on blanket bog, although there is some anecdotal evidence (see below). Much of the general loss of 'heather moorland' over the past century (other than from conversion to pasture or forestry) has been attributed to a combination of heavy grazing and poor burning practices, particularly since the 1940s (see *e.g.* Anderson & Yalden 1981; NCC 1989; Hester & Sydes 1991 & 1992; Thompson *et al.* 1995c) by dominance passing from heather to grassland (when grazing is heavy, regular management by burning helps to spread grazing pressure – see below).

Radford (*in* Bunce 1989) states that in Wales, a combination of severe burning and sheep grazing has resulted in the disappearance of much heathland and in the removal of heather and other dwarf shrubs from extensive areas of blanket bog, with heather only persisting unchecked in situations where access is difficult for grazing. Many Welsh examples of blanket bog are subject to severe gullying and erosion attributed to the effects of grazing and burning, leading also to drying out of the mire's surface and loss of the *Sphagnum* cover. There has been a decline in heather burning on Berwyn in recent decades (Walker & Elias 1989), which was partly attributed to the decline in heather due to overgrazing (see also Hester & Sydes 1992). Conversely, the former authors also state that some previously managed heather has become 'rank' probably as a result of the decline in burning.

On grouse moors, an 'under-burned' moor is one on which there are few patches of young heather, which are grazed in preference to old heather stands by both sheep and grouse. This creates increased grazing pressure on these patches, and hence increases competition between grouse and sheep. On a moor which is well managed by burning, moderate levels of sheep grazing can benefit both sheep and grouse, by maintaining the heather in the more favoured pioneer and building phases (Whitby & Grant, 1990). This has the added benefit of increasing the interval needed between fires, with concomitant reduction in the adverse impacts of burning.

Thompson *et al.* (1995c) suggest that around 80% of the moorland vegetation (including blanket bog) in England and Wales that has been lost or has deteriorated since 1947 has some potential to regain cover at least of dwarf shrubs with a reduction in grazing and improved burning practices (although these are not specified). Figures are not available for Scotland. Attempts to restore cover of bryophytes (specifically Sphagna) and possibly *Calluna* may depend on susceptibilities to atmospheric pollution.

6.2 Effect of grazing on vegetation recovery after burning

In north-western Scotland, as elsewhere, farmers and crofters often burn to obtain an 'early bite', particularly for cattle, which tend to concentrate strongly on recently-burned areas (A. MacDonald, SNH 1995, *unpublished filenotes*). Rawes & Welch (1969: *cit.* Rawes & Hobbs 1979) noted that under a free-grazing regime, the early flush of *Eriophorum* spp. resulting from a winter fire attracts sheep, and densities of 0.33 sheep ha^{-1} may be maintained on a post-fire Eriophoretum. Limited grazing on blanket bog retards, but does not usually prevent, heather regeneration after fire (Lance 1983), and *Eriophorum* may dominate temporarily. However, burning and grazing can reinforce and accelerate each others effects, and changes may be considered undesirable, for example in increasing the amount of bare ground, and accelerating the disappearance of *Calluna* in heavily-grazed places through a rapid expansion of graminoids and prevention of regeneration by the actions of sheep grazing (e.g. Pearsall 1941, Ratcliffe 1959, Rawes & Hobbs 1979; see also 6.4).

Rawes & Williams (1973: *cit.* Smith & Forrest, 1978) showed that grazing at an intensity of less than 0.1 sheep ha^{-1} on blanket bog can have a detectable effect on *Calluna* production during development after burning, shoot weight being reduced by 30–40 % compared with growth in exclosures. In addition, better *Calluna* growth was obtained with the light grazing regime alone, suggesting that conditions for grouse might be improved if sheep numbers were increased rather than burning continued (see also Rawes & Heal, 1978).

An exclosure erected on the North York Moors in a severely fire-damaged area demonstrated that a reduction in grazing pressure lead to faster recolonisation by moorland species (see NYMNP 1991).

6.3 Interactions between burning and grazing patterns

On heather moorland, Grant & Hunter (1968, *cit.* Grant & Armstrong, 1993) showed that sheep concentrate on newly-burned areas and can move freely over and graze heather up to *c.* 20 cm. Patches of taller heather help to provide shelter and food in the winter, but may restrict movement around the moor. Burning in small patches can encourage sheep to disperse and graze more widely across their range than if large patches are burnt, and can help to reduce the impacts of high stocking rates. Thus, the pattern of burning can help or hinder dispersal of sheep across a moor, a factor which may be more important where shepherding is limited. The preferential grazing of young heather by sheep helps to prolong the pioneer phase, thereby improving the habitat for grouse and hares. It is also beneficial to golden plover which prefer shorter heather for feeding and nesting, although will disfavour birds which prefer to nest in long heather, e.g. Merlin, Hen Harrier and Short-eared Owl (see Section 8 and Coulson *et al.* 1992).

6.4 Interactions between grazing/burning and other environmental variables

6.4.1 Drainage

Drainage is often carried out in order to improve the quality of vegetation for grazing stock or grouse, and thus can have an indirect effect on the impacts of grazing or burning through effects on the vegetation and wetness of the substratum (see e.g. Ratcliffe 1959). However,

Stewart & Lance (1991) indicate that there is a presumption among land managers that drainage of moorland exerts a separate additional effect, which is neither nullified by burning and grazing, nor dependent on them to bring a response. Successful restoration of blanket bog or wet heath badly damaged by management practices may depend on attempting to block the ditches, as well as controlling burning and grazing.

Thompson *et al.* (1995c) provide a schematic diagram of the changes in vegetation typically occurring as a result of grazing and burning, coupled with drainage and waterlogging, for the major upland bog and heath communities (see Figure 7.1).

6.4.2 Erosion

Several authors have associated peatland erosion with either burning or grazing, or both (see 4.2; 4.6.2; 5.4). However, in a survey of upland Scotland, Grieve, Davidson and Gordon (1995) found that 6% of land comprised eroded peat, but could find no clear correlation between land management and erosion, suggesting that a combination of factors were operating at a more local scale (e.g. extreme rainfall events and relief). These authors suggested that there was a need to map those areas considered most 'at risk' from erosion, in order to target resources on prevention, for example by restricting grazing or burning. Similarly, Bradshaw & McGee (1988), in investigating the extent and time-course of mountain blanket peat erosion in Ireland, concluded that human activity (including disturbance by domestic animals and aerial pollution) and changes in land use merely intensified erosion that probably originated from peat flows to the development of natural drains in mature peat masses developing on sloping ground.

The problem of continuing susceptibility to erosion is certainly one of the main factors which needs to be addressed in the restoration of degraded areas of blanket bog, as for example in the southern Pennines and North York Moors.

6.4.3 Regional differences in management

Bardgett & Marsden (1992) investigated heather condition and management in the uplands of England and Wales (see also Bardgett, Marsden & Howard 1995). Areas of blanket bog were distinguished, but it is not clear from the analysis presented if these were treated differently from heather moorland. However, it is of interest to note the evident regional trends in management. For example, there appeared to be a strong relationship between the extent and condition of heather and moorland management practices within countries and upland biogeographical zones. In Wales, south-west England and the West Midlands, a large proportion of the heather was suppressed and/or showing signs of heavy grazing; here the majority of the heather moorland was stocked at > 1.5 ewe equiv. ha^{-1} a^{-1}, with heavy autumn grazing and few areas burnt. By contrast, in the North York Moors and NE England, heather moorland was stocked at lower levels throughout the year, burning was more widely practised, and less heather showed signs of damage or 'neglect'. These differences are probably largely attributable to the management of the latter areas as grouse moors.

6.5 Effects of not grazing or burning

Much of the current blanket bog and upland wet heath resource lies below the theoretical tree-line, and although change may be slow at high altitude, in some situations some degree of management may be necessary to prevent succession to scrub/woodland unless natural

grazing pressure is sufficient (see e.g. Hill, Evans & Bell 1992). In the lowland situation, where left unmanaged, heather can enter the degenerate stage of growth (7.3.1), and may eventually die out, leaving areas susceptible to tree invasion. In the uplands, there is some evidence that this does not happen so readily, particularly where there is an extensive carpet of *Sphagnum*, as this promotes 'rejuvenation' of the heather by layering (e.g. Hobbs 1984 – see 7.3.1) or where there is a lack of tree seed source. The increase in plantations on moorland means that these provide a ready source of propagules should grazing/burning fall below 'critical levels' (Walker & Elias 1989 – *levels not specified*). There is some evidence that grazing and burning tend to reduce the accumulation of nutrients in the systems, thereby inhibiting natural trends for the replacement of heather by grasses, trees or bracken which might occur in their absence (Gimingham 1995), and of continued management practices resulting in excessive impoverishment of the systems (see Section 5.2.1).

Doyle (1982) noted that in the west of Ireland, islands within blanket bog pools, protected from burning and grazing by water, supported a more diverse flora than on the main bog surface, for example, including such species as *Juniperus communis*, *Empetrum nigrum* and more graminoids, bryophytes and lichens. In addition, on the islands, mature *Calluna* bushes were dominant, and *Molinia* often more abundant than on the bog surface.

However, there is some evidence that grazing/burning may be of importance in the maintenance of blanket bog vegetation. For example, Chapman & Rose (1991) suggested that changes in land use as a result of afforestation may have been important contributory factors in the changes in the vegetation of the open areas of bog at Coom Rigg (Northumberland) over a 30-year period – although it is recognised that the evidence is circumstantial, it is suggested that lack of low-level grazing and autumn burning may have contributed to the decline in *Sphagnum* abundance, perhaps through the accumulation of standing dead material from grass and sedge species. Clearly, such observations have important implications for future management of *Sphagnum*-dominated communities.

Experiments have been carried out using exclosures to investigate the effects of cessation of grazing. In exclosures on a *Juncus squarrosus* grassland at Moor House, the general tendency was towards a blanket bog vegetation dominated by *Eriophorum vaginatum* and *Calluna vulgaris*. *J. squarrosus* declined very quickly in the enclosed plot, but there was also a decline, although slower, in the grazed one (1.4 sheep ha^{-1}). A significant increase in *Calluna vulgaris* occurred only in the enclosed plot (Rawes 1981; Marrs, Bravington & Rawes 1988). Exclusion of sheep from hill pastures in Snowdonia (Hill, Evans & Bell 1992) resulted in an increase in cover of dwarf shrubs such as *Calluna* and *Erica cinerea*, although this was apparently through release of suppression of existing plants rather than recruitment, and in some plots the plants eventually degenerated again. In the absence of sheep, voles became the dominant herbivore. Ball *et al.* (1981a, p136) describes experimental exclosure plots that were set up on upland grasslands at Redesdale (Northumberland; MAFF), Snowdonia (Gwynedd; NCC) in addition to those described at Lephinmore (Argyll; Grant *et al.* 1976) and at Moor House (Rawes & Heal 1978; Rawes & Hobbs 1979).

There have been recent moves to introduce a policy to reduce sheep grazing in the uplands either as part of an extensification scheme, or for conservation purposes. In an attempt to provide predictive information about the potential effects of reduced sheep grazing pressure, Marrs & Welch (1991) reviewed relevant literature and surveyed the vegetation from a total of 74 upland sites where sheep grazing was known to have ceased for varying periods of time. Sites were chosen from across the country (south-west England to northern Scotland), and

included wet heath and blanket bog, although different habitats were not distinguished in the results presented[1]. However, it is useful to note their main findings:

a) Where *Calluna* was already present in the vegetation it tended to increase at a rate of between 0–5% per year. On some sites large amounts of dead heather had developed and this implied that careful aftercare moorland management must be included as part of any reduced grazing scheme. [Note: this would depend on the conservation objectives]

b) Where *Calluna* was absent, its invasion and subsequent growth was impossible to predict, and here a grassy bog, tall grass, scrub or woodland vegetation community developed in different places depending on initial floristic composition, nearness of seed sources and niche availability.

c) Lichens tended to increase in some sites, particularly in wetter sites, and where *Calluna* growth seemed to be restricted by adverse environmental factors such as exposure or waterlogging.

d) There was some evidence to suggest that the species richness of some plant communities declined.

[1] More detailed analysis of these data would probably provide useful information for the proposed Upland Management Handbook.

7. Effects of burning and grazing on the principal plant communities and species of upland blanket bog and wet heath

7.1 Introduction

The above review has considered the general effects of burning and grazing on the vegetation of blanket bog and wet heath; the following account provides a summary of the main effects which have been specifically identified for the plant communities and species of particular relevance to this report. Much has been taken from Rodwell (1991), but supplemented by other sources where possible.

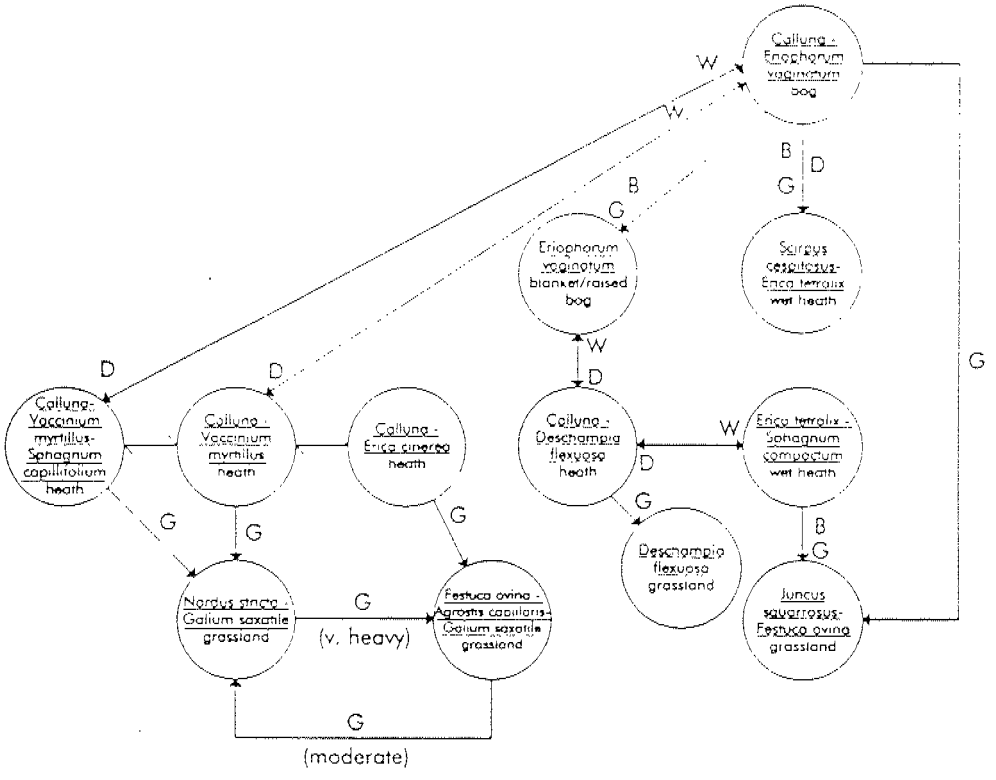
Rowell (1988) lists[1] several blanket bog and wet heath communities for which burning, often in combination with grazing, is a major factor in the development: *Scirpus cespitosus–Erica tetralix* wet heath (M15), *Erica tetralix–Sphagnum compactum* wet heath (M16), *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19), *Eriophorum vaginatum* blanket & raised mire (M20) and *Molinia caerulea–Potentilla erecta* mire (M25). The author notes that these may still be liable to damage through over-grazing, and includes *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17), and *Erica tetralix–Sphagnum papillosum* raised and blanket mire (M18) on the list of communities which are easily damaged by grazing and particularly affected by fire owing to a drastic effect on *Sphagnum*.

Thompson *et al.* (1995c) provide a schematic diagram of the changes in vegetation typically occurring as a result of grazing and burning, coupled with drainage and waterlogging, for the major upland bog and heath communities. This has been reproduced in Figure 7.1. A combination of grazing and burning is associated with the conversion of *Erica tetralix–Sphagnum papillosum* raised and blanket mire (M18) and *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) into *Eriophorum vaginatum* blanket & raised mire (M20). Similarly, grazing and burning, coupled with drainage, may lead to shifts in vegetation composition from *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) or *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17) to *Scirpus cespitosus–Erica tetralix* wet heath (M15). Figure 7.2 develops these ideas, summarising only apparent shifts between communities under burning, heavy grazing or drainage, excluding natural zonations found with altitude, drainage and aspect (see Thompson & Miles 1995, Figs 34.1 & 34.3). However, it should be noted that the figure is rather speculative, it being acknowledged that further work is required to verify the nature of these relationships, the factors involved and the actual 'natural' condition of the different communities.

A useful diagram of suggested relationships between NVC communities, physiographic features and land management in the Kielder Forest (Northumberland) is provided by Wallace, Good & Williams (1992) – see Figure 7.3.

[1] Largely based on information provided in draft chapters for *British Plant Communities* (Rodwell, 1991)

(a) Heather moor communities



(b) Blanket bog communities

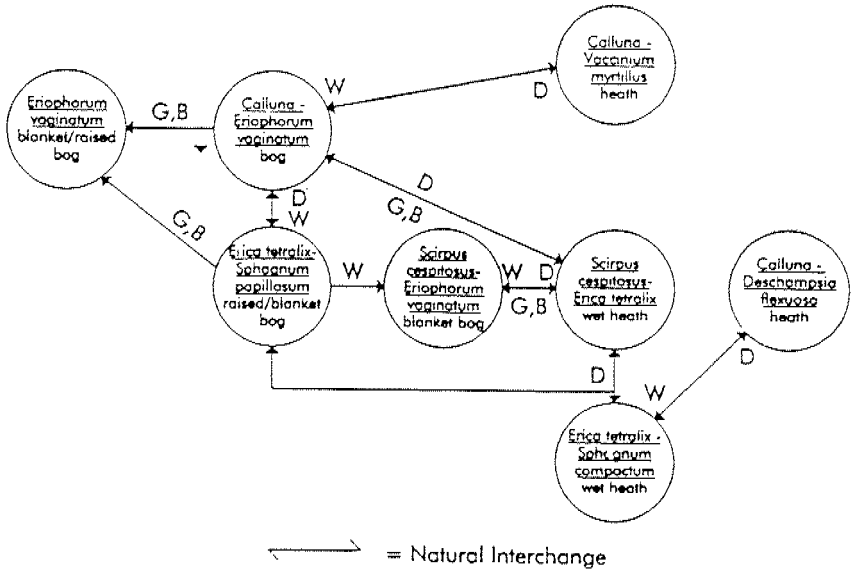


Figure 7.1 Successional changes in the main upland heath and bog plant communities, as affected by burning (B), heavy grazing (G), waterlogging (W) and drainage (D).

(Reproduced from Thompson *et al.* 1995c, with kind permission from Elsevier Science Ltd. The Boulevard, Langford Lane, Kidlington OX5 1GB, UK)

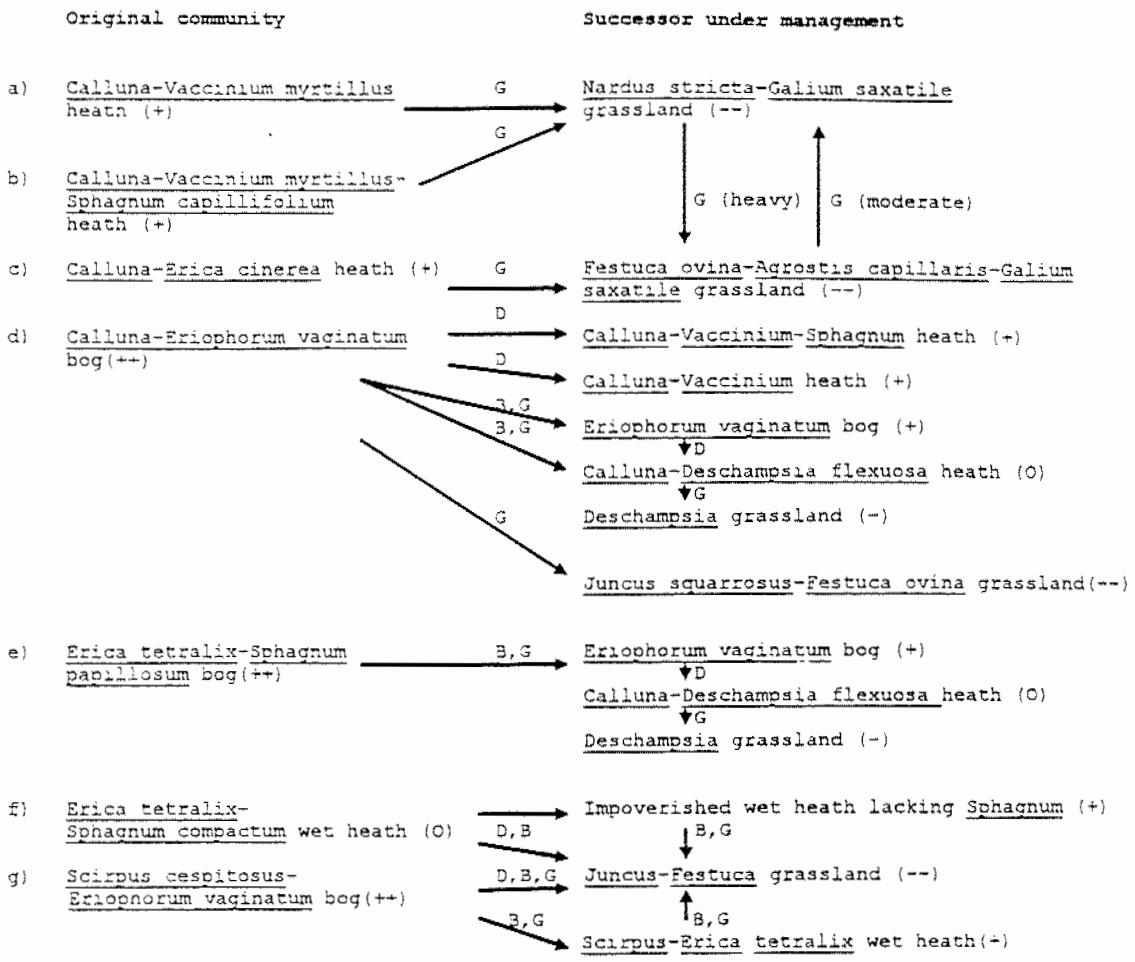


Figure 7.2 Successional shifts in moorland plant communities of Great Britain under human influence. G = heavy grazing; B = burning; D = drainage. Naturalness is indicated along a continuum from ++ (highly natural) through 0 (semi-natural) to – – (highly anthropogenic). Part of the original figure was adapted from Miles (1988) and Thompson *et al.* 1995c).

(From Thompson & Miles 1995: Crown copyright is reproduced with the permission of the Controller of HMSO)

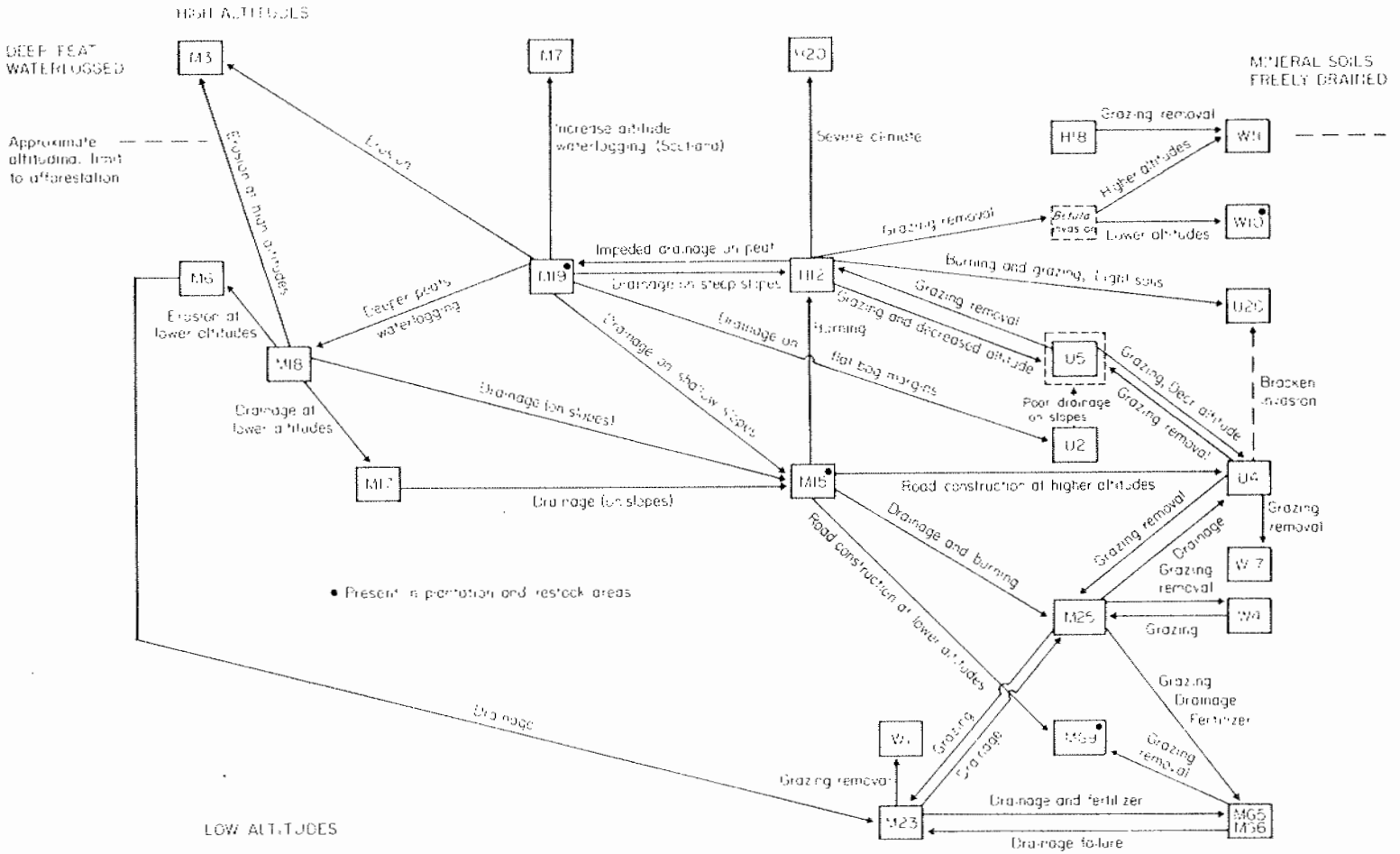


Figure 7.3 Suggested relationships between NVC communities, physiographic features and land management in the Kielder Forest (Northumberland). The diagram is laid out in relation to broad altitude and soil types. NVC communities found more commonly at higher altitudes are at the top, those of the lowlands at the bottom, those associated with peaty soils to the left and those of mineral soils to the right. The diagram also includes communities not recorded at Kielder which may be found in other upland forests of Northern England and Southern Scotland.

(Reproduced from Wallace, Good & Williams 1992, by permission of Blackwell Science Ltd.)

7.2 Plant communities

7.2.1 *Sphagnum auriculatum* bog pool (M1)

Climate: mainly confined to the more oceanic parts of Britain – especially to the far west, where annual precipitation exceeds 1200 mm with > 180 wet days a^{-1}, and to south-western valley mires in an Atlantic climate.

The *Sphagnum auriculatum* bog pool community typically consists of floating masses or soft wet carpets of Sphagna with scattered vascular plants growing on or through them or in areas of open water between. It is confined to pools and wetter hollows on ombrogenous and topogenous mires with base-poor and oligotrophic raw peat soils, and is more oceanic in distribution than M2. In the far-west of Britain, the distribution broadly coincides with *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17), as, for example, in western Scotland and the Lake District, Wales and the South-West Peninsula.

No specific published information has been found regarding the effects of burning and grazing on this community. Rodwell (1991) considers that where mires are burnt or grazed, the wetness of the ground affords some protection to the vegetation, but it is severely affected (damaged or destroyed) by drainage and peat cutting. Personal observations also suggest that the margins of such pools may be damaged by trampling of animals using them for drinking water.

7.2.2 *Sphagnum cuspidatum/recurvum* bog pool (M2)

Climate: characteristic of areas where the annual precipitation is generally between 800 and 1200 mm with around 140–180 wet days a^{-1}.

The *Sphagnum cuspidatum/recurvum* bog pool community is typically dominated by soft, wet carpets of *S. cuspidatum* and/or *S. recurvum*, with only scattered individuals of vascular plants such as *E. angustifolium* and *E. tetralix*. It is found in lawns and pools on ombrogenous (and topogenous) mires, mainly in the less oceanic parts of Britain than M1, forming part of the characteristic patterning on undisturbed blanket and raised mires; its range coincides closely with that of the *Erica tetralix–Sphagnum papillosum* raised and blanket mire (M18).

This community is particularly associated with very wet conditions, and is therefore severely affected by drainage. Little published information has been found regarding the effects of burning and grazing on this community, but, as for the *Sphagnum auriculatum* bog pool (M1), the wetness of the ground is likely to afford some protection to the vegetation from burning and grazing. Drainage converts the mire surface to Ericion tetralicis wet heath, but fragments of bog pool may survive on the drying peats. Personal observations also suggest that the margins of such pools may be damaged by trampling of animals using them for drinking water. Rawes & Hobbs (1979) investigated changes in a bog pool area 21 years after exclosure; their results are reproduced in Table 7.1. The driest habitat, occupied by *Calluna*, *E. vaginatum* etc, increased by 14%, whilst the wettest area, usually open water, with the zone of *S. cuspidatum* and *E. angustifolium*, decreased by 12%. However, whilst the changes may have occurred as a result of the exclosure, the authors considered that they may also have been brought about by climatic changes (e.g. decrease in precipitation in spring).

Table 7.1 The effect of protection of sheep grazing for 21 years on the vegetational cover (%) of a bog-pool site (Rawes & Hobbs 1979)[1].

Zone	Year 0	Year 21
Calluna vulgaris (with *E. vaginatum, Sphagnum rubellum* & *Cladonia impexa*)	40	54
Sphagnum rubellum	15	6
Sphagnum papillosum	10	18
Sphagnum cuspidatum	6	3
*Sphagnum cuspidatum–Eriophorum angustifolium**	29	17
Eriophorum angustifolium	–	2

* zone of standing water

7.2.3 *Eriophorum angustifolium* bog pool (M3)

Climate: no detailed information, but can occur in upland and lowland situations.

This community is typically found as small stands on barer exposures of acid raw peat soils in depressions, erosion channels or shallow peat cuttings on a wide range of mire types (and is not confined to 'bog pools'). *E. angustifolium* can expand rapidly by vegetative growth and become dominant on natural or artificial exposures of peat. It is commonly considered as a degraded vegetation type, formed as a result of grazing, burning and/or erosion. For example, it is found on the surface and margins of Pennine blanket mires where the peat has been worn down in gullies or redistributed (e.g. Bower 1961, Tallis 1985: *cit.* Rodwell, 1991). Guile (1965) also describes the community from similar situations in the Brecon Beacons.

7.2.4 *Scirpus cespitosus–Erica tetralix* wet heath (M15)

Climate: almost totally confined to areas with an annual precipitation > 1200 mm and generally with > 1600 mm. At least 180 wet days per year, but largely a lowland community. Can be found at progressively higher altitudes in drier areas, as in the Cairngorms. On north-facing slopes the community can occur on steeper slopes.

The *Scirpus cespitosus–Erica tetralix* wet heath community is rather a variable community-type, with a wide variation in pattern of the dominance and in the associated flora. The vegetation is typified by mixtures of *Molinia caerulea*, *Scirpus cespitosus*, *Erica tetralix* and *Calluna*, although any of these may be absent, varying with climate, as well as treatment. There are usually some Sphagna, but without a luxuriant cover. The most frequent species are *S. capillifolium* and *S. subnitens*. Other bryophytes are found at moderate frequency. Lichens can be locally prominent.

M15 is characteristic of moist, acid peats and peaty mineral soils in the wetter western and northern parts of Britain, being especially associated with thinner or better-drained areas of ombrogenous peat. It has essentially the same distribution as *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17), but is characteristic of better-drained and usually shallower peats, on steeper slopes with concomitant loss in the variety and luxuriance of the *Sphagnum* carpet (the typical sub-community of M15 may form a transition zone). Much of the floristic variation between the sub-communities occurs in response to water regimes. Continued

[1] Reproduced by kind permission of the British Ecological Society.

grazing by stock and deer, and sporadic burning are probably sufficient to prevent succession to woodland.

Activities such as burning and drainage have probably extended the range of the community onto the wasting margins of once-wetter peats, although Keatinge, Coupar & Reid (1995) consider that examples of the M15 in Caithness and Sutherland represent a distinct community (conceivably a seral precursor to *Scirpus cespitosus–Eriophorum vaginatum* blanket mire) on thinner peats with greater slopes – it was not often found on deep peats suggesting that in this area, it is not derived from related deep-peat communities as a result of drainage or burning.

Within the community, drainage and burning tend to shift the composition of the vegetation away from the more *Sphagnum*-rich kind of the Typical sub-community through the more *Calluna*-rich to the 'heathy' *Cladonia* sub-community. The latter is especially well represented on the deforested morainic country of the western Highlands, and, at higher altitudes, on ground that has probably been much burnt. In extreme cases, *Calluna* and the other ericoids have been virtually eliminated and *Scirpus* reduced to scattered tussocks, with much of the cover made up of hummocks of *Racomitrium*, patches of *Cladonia* spp. and a surface crust of lichens, often with bare ground of gravel and stones (McVean & Ratcliffe 1962). Where wastage has not been so extreme but where ericoids have been virtually lost, cessation of burning may favour a vigorous recovery of *Molinia*, rather than *Scirpus*, or there may be a progression to woodland. Frequent, but more carefully controlled burning, may encourage *Calluna* as a dominant, particularly where the community extends into less oceanic regions – in the east-central Highlands, stands of the Typical and *Cladonia* sub-communities form part of poorer-quality grouse-moors (Birse 1980: *cit.* Rodwell 1991).

Less severe burning and/or grazing can mask transitions between vegetation types. More severe treatments can have a more drastic impact: it is likely that many stands of M15 have been derived from blanket mire as a result of climate change, drainage, burning and grazing. For example, Sphagnetalia communities tend to lose their luxuriant carpet of Sphagna and to show an increase in either *Racomitrium lanuginosum* and lichens or Nardetalia herbs and hypnoid mosses (McVean & Ratcliffe 1962), as in the *Cladonia* and *Juncus–Rhytidiadelphus* sub-communities of the *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17). Elimination of *E. vaginatum* from these vegetation-types can produce the *Cladonia* or *Vaccinium* sub-communities of M15. These can form extensive mosaics on many areas of degenerating ombrogenous peat. A mixture of burning and heavy grazing may be partly responsible for the composition of the *Vaccinium* sub-community – this species is grazing-sensitive, and present only at small covers, but is often accompanied by mixtures of Nardetalia herbs and hypnoid mosses. Severe burning/grazing/drainage can convert M15 into various forms of acid grassland (e.g. *Festuca ovina–Agrostis capillaris–Galium saxatile* (U4), *Nardus stricta–Galium saxatile* grassland (U5)).

In the far west, it may be possible for blanket mire to regenerate following burning, particularly in less-disturbed areas of wet ground (McVean & Ratcliffe 1962). However, in many areas, it seems unlikely that progression to M15 wet heath (or beyond) can be readily reversed. Cessation of burning may result in a vigorous expansion of *Molinia*, especially on peat that is naturally well-aerated or drained, and, in some areas, blanket mires and wet heath seem to have converged into vast tracts of *Molinia*-dominated grasslands in which Sphagnetalia or Sphagno-Ericetalia species play a relatively minor role. This has occurred at Elenydd in mid Wales and in the Brecon Beacons in S. Wales (M. Yeo, *pers. comm.*). It is

possible that this effect may be exacerbated by increases in atmospheric pollution (e.g. N deposition) although further evidence is required to substantiate this possibility.

Nolan, Henderson & Merrell (1995) reported on a study in progress on the vegetation dynamics of upland wet heaths in relation to sheep grazing intensity. Experimental plots have been established at three sites to investigate the effects of a range of sheep grazing intensities (0, 0.4, 0.8 and 1.2 sheep ha^{-1}) on wet moorlands differing in structure and species composition: Redesdale (Northumberland), Claonig Estate (Tarbert, Argyll) and Dundonnell (Wester Ross). The vegetation at Redesdale is equivalent to *Scirpus cespitosus–Erica tetralix* wet heath (M15), dominated by *Calluna* and *Molinia* with some *E. vaginatum* and *Vaccinium myrtillus*. Preliminary results after three years at this site showed that utilization levels of *Calluna* generally increased with increasing stocking rate. An exception was the high grazing treatment on the stand of mature heather, where the heather showed lower utilization than in the pioneer stands, presumably because other species were preferred. In contrast to *Calluna*, both *Molinia* and *Carex nigra* showed a relatively greater increase in cover at the high grazing treatment compared with the no-grazing control, as they were not being grazed preferentially. *E. vaginatum* and *Deschampsia flexuosa* both decreased more on the control than in the heavy grazing plots, as the former became dominated by taller species.

7.2.5 *Erica tetralix–Sphagnum compactum* wet heath (M16)

Climate: *no specific information – mainly found in the lowlands.*

This community is one of acid and oligotrophic mineral soils or shallow peats that are at least seasonally waterlogged. It is largely confined to the relatively dry lowlands of Britain, and hence is of marginal relevance to this review. However, in Scotland, and locally on the upland fringes in Wales and England, it does extend on to thin ombrogenous peats, such as occur on the margins of blanket peat areas, particularly at higher altitudes. In some sites, drainage has allowed the community to develop on once-wetter peats, but in general lowered water tables have been detrimental. The most characteristic *Sphagna* are *S. compactum*, *S. tenellum* and the scarcer *S. molle*. In the upland situation, the most usual form is the *Juncus–Dicranum* sub-community, with *Molinia* becoming scarcer in the continental climate, and *Calluna* and Nardo-Callunetea associates increasing, perhaps in response to treatment.

The community lies below the tree line throughout its range, and would probably progress to some kind of woodland if neither burnt nor grazed. On the upland fringes, occasional burning and grazing are of importance in maintaining the community, and have a marked effect on floristic variation and local patterns of dominance and richness of the associated flora. Conditions of controlled burning, deliberately to maximise the proportion of building-phase *Calluna*, may account for the consistent predominance of *Calluna* in the *Juncus–Dicranum* sub-community in NE Britain: this sub-community also has an abundance of *Cladonia* spp. which is typical of the middle years of regrowth in regularly-burned heaths. More severe burning of the community can destroy both ericoid stools and buried seed and probably gives *Molinia* an advantage in the long term (Tansley 1939; Rose 1953; Ratcliffe 1959: all *cit.* Rodwell 1991, p163).

The community is protected to some extent where the ground is wet, but burning can be particularly deleterious to the associated flora, with the typical bryophytes only recovering very slowly, and these may be completely eliminated by frequent fires. Fire is especially destructive when combined with drainage. The survival of the community is thus dependent on the maintenance of a relatively high water table.

7.2.6 *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17)

Climate: confined to those parts of the country with a consistently wet climate, generally where there are > 1200 mm precipitation annually, or > 160 wet days per year (Ratcliffe 1968; 1977: *cit.* Rodwell, 1991), and where cool and cloudy conditions maintain high humidity throughout the year. Most extensive in areas with > 200 wet days per year and over 2000 mm precipitation, but largely restricted to sites below 500 m, where the annual temperature range is comparatively small.

Characteristic blanket bog vegetation of the more oceanic parts of Britain, especially at lower altitudes, where extreme humidity is combined with relative mildness. To the south and east, the community is of more restricted occurrence, and can occur at higher altitudes, where moderately heavy rainfall is maintained (*e.g.* Lake District, Wales, Dartmoor, Bodmin Moor), although may be replaced by the *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) in less oceanic areas.

The floristics and structure of the community have been widely affected by a variety of treatments, including burning, grazing, draining and peat cutting, which have often contributed to the deterioration and loss of the community.

Burning of the community has a particularly drastic effect on the *Sphagnum* cover, even very wet carpets becoming susceptible to fire-damage in periods of drier weather in spring and summer, and it produces the kind of dominance by *Scirpus* tussocks and *Racomitrium* hummocks characteristic of some tracts of the *Cladonia* sub-community (McVean & Ratcliffe 1962) Indeed, the development of the *Cladonia* sub-community may have been accentuated, and perhaps sometimes initiated, by treatments such as burning, peat cutting and draining which lead to surface drying.

Where differences in surface drainage are very marked, burning can sharpen up the vegetation boundaries by allowing different species to become prominent on wetter or drier ground. For example, *E. vaginatum* may become locally dominant after fire in the *Scirpus–Eriophorum* mire, but not in the adjoining heath. In other cases, burning may impose a fairly uniform dominance of *Scirpus* or *Molinia* throughout the sequence, blurring zonations among the associates, and some tracts of such fire-climax vegetation may have been partly or wholly derived from the community. Burning has probably also played a major role, along with drainage and peat cutting, in the surface drying of peats that causes more dramatic changes in the vegetation (*e.g.* through the *Cladonia* sub-community to the *Cladonia* sub-community of *Scirpus–Erica* wet heath (M15), with the elimination of *E. vaginatum* and impoverishment of the *Sphagnum* carpet). In oceanic regions, *Erica cinerea* seems to increase under these conditions with conversion of the vegetation to *Calluna–Erica* heath (H10).

At higher altitudes, in areas with a drier climate, there may be a trend for conversion of the *Juncus–Rhytidiadelphus* sub-community (a rather 'run-down' form of M17) to the *Vaccinium* sub-community of the *Scirpus–Erica* wet heath (M15), where *Vaccinium myrtillus* can become an important subshrub, perhaps presaging a switch to *Calluna-Vaccinium* heath (H12). Grazing and further improvement may convert the community to grasslands of various kinds.

Some information on the utilization of this community by grazing sheep and its response have come from the Lephinmore field station of the HFRO, which includes areas of *Scirpus–Eriophorum* bog, as reported, for example, by Grant *et al.* (1976) (Section 5).