7.2.7 *Erica tetralix–Sphagnum papillosum* raised & blanket mire (M18)

***Climate**:* relatively low rainfall: 800–1200mm annual precipitation with 140–180 wet days a^{-1} (considerably less than *Scirpus cespitosus–Eriophorum vaginatum* blanket mire or *Calluna vulgaris–Eriophorum vaginatum* blanket mire). Centred in moderately oceanic conditions.

A raised and blanket bog community, generally dominated by Sphagna, with ericoid sub-shrubs and monocotyledons often playing a subordinate role. Commonest associates are *Calluna*, *Erica tetralix* and *Eriophorum vaginatum*, with *Scirpus cespitosus* less frequent. *Calluna*, *Scirpus* & *E. vaginatum* are more prominent on drier ground. Wet hollows have *Rhynchosporion* pool vegetation. A typical community of lowland raised bogs, but can also be found within tracts of blanket mire. Typically widely affected by burning and draining (and peat cutting). Examples can be found at Moor House (Cumbria) and Silver Flowe (Kirkcudbrightshire) and on many Welsh uplands, e.g. Elenydd, Berwyn, Migneint.

Floristic and structural differences between the sub-communities are strongly related to variations in ground moisture, and thus partly reflect differentiation of surface relief. At higher altitudes, in particular, peats may become dissected by erosion channels (Pearsall 1941: *cit.* Rodwell 1991), with drying of the surface and concomitant shifts in floristic composition: dominance among the Sphagna shifts to *S. capillifolium*; *Cladonia* and hypnaceous mosses become more prominent among the increasingly tussocky *E. vaginatum* and *Scirpus* and vigorous *Calluna,* and *Empetrum* spreads on the eroding surfaces. Vegetation approaches that of drier forms of the *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17), and may lose such species as *Vaccinium oxycoccos* and *Andromeda polifolia*.

The *Sphagnum–Andromeda* sub-community tends to be most susceptible to drying and burning, recovering only slowly, or not at all if damage sustained. *Andromeda* can positively thrive after burning, even though the richness of the accompanying flora has been lost, at least temporarily (*e.g.* Sinker 1962: *cit.* Rodwell, 1991). The *Empetrum–Cladonia* sub-community is characteristic of the drier peats, and may be favoured by some kinds of treatment, especially surface/marginal drainage or surface damage by burning, although may subsequently be overtaken by growth of sub-shrubs (especially *Calluna*), *E. vaginatum* and *Scirpus*, or even *Molinia* . Continuation of this trend would be expected to convert the M18 to *Scirpus cespitosus–Erica tetralix* wet heath (M15), with the loss of *E. vaginatum* and luxuriant *Sphagnum* lawns, and it is often possible to find a complex patchwork vegetation intermediate between the two. May be followed by establishment of dry Calluno-Ulicetalia dry heath, or invasion by trees such as *Betula* spp. or *Pinus sylvestris*. Long-term grazing may be instrumental in conversion of M18 to *Eriophorum vaginatum* blanket & raised mire (M20) (see below).

7.2.8 *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19)

Climate: cold and wet: most stands lie between 500–700 m and experience 1200–1600 mm annual precipitation with 160–200 wet days a^{-1}, and mean annual maximum temperatures of 21–25°C.

The *Calluna vulgaris–Eriophorum vaginatum* blanket mire comprises vegetation which is generally dominated by mixtures of *E. vaginatum* and ericoid sub-shrubs, and is typical of high-altitude ombrogenous peats in the uplands of northern Britain, where the peat is moist, but not surface-waterlogged. There is a fairly well-defined altitudinal separation between M19 and the *Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17). M19 typically has a less rich and luxuriant element of Sphagna than in M17 or M18, but more extensive

than in *Eriophorum vaginatum* mire (M20), to which this type of vegetation can be converted by burning and grazing by a reduction in the abundance of the ericoid sub-shrubs. The 'conversion' can sometimes be only temporary, so transitions are common.

The vegetation may include some *Vaccinium myrtillus*, *V. vitis-idaea* and/or *Empetrum nigrum* ssp. *nigrum*, and these can become abundant for some time after burning or where grazing has been withdrawn, provided rhizomes are not damaged, although usually eventually overtopped by *Calluna* (Ritchie 1955; Ratcliffe 1959; Gimingham 1964, 1972; Bell & Tallis 1973: all *cit.* Rodwell, 1991). This may be more permanent where drier peat surfaces have become bared by erosion, where *E. vaginatum* and *Calluna* are typically less vigorous than usual.

There is considerable variation in the floristic composition of the community, particularly with respect to climate and altitude. However, management, including burning and grazing, is very important in affecting the floristic composition and structure of the community throughout its range, and often leads to high spatial diversity within individual stands (as seen at Moor House). Much of the current knowledge of the effects of management on upland bog communities (see Sections 4 and 5), is based on research carried out at Moor House (e.g. Heal & Perkins 1978, Rawes & Hobbs 1979) where much of the vegetation is comprised of the *Empetrum* sub-community of M19 together with the more impoverished *Eriophorum vaginatum* mire (M20).

If treatments are drastic, or frequent or long-maintained, they can induce more substantial qualitative changes in the vegetation: in some cases such changes can be reversed, but in others, they may initiate a run-down of the community, and contribute to the destruction of the underlying peats.

Burning

The immediate effects of burning are to destroy a proportion (or all, if intense) of the above-ground biomass, producing a fertile ash and increasing light penetration to the ground (Rawes & Hobbs 1979). However, species which die back at the end of the growing season (*e.g. E. vaginatum* and *Rubus chamaemorus*), may survive winter and early spring fires, with the ground layer given further protection by increased wetness in the peat surface. *E. vaginatum* may dominate for up to two decades after burning (Eddy, Welch & Rawes 1969: *cit.* Rodwell, 1991; Rawes & Hobbs 1979) and *R. chamaemorus* may respond by increasing its standing crop and fruit production (Taylor 1971; Taylor & Marks 1971: *cit.* Rodwell 1991). If there is no grazing during this period, the sub-shrubs (e.g. *Vaccinium myrtillus*, *V. vitis-idaea* and/or *Empetrum nigrum* ssp. *nigrum*) can gradually recover, although *Calluna* usually eventually dominates. New growth from stools and seed diversifies the age-structure of the population with time, though the degenerate phase of growth commonly seen in *Calluna* in drier situations may not develop because of the smothering of the older stems by the *Sphagnum* carpet which promotes layering (Rawes & Hobbs 1979).

Grazing

The most obvious effect of grazing is on the balance between *E. vaginatum* and the palatable ericoids *Calluna* and *Vaccinium myrtillus*. The latter can both be grazed to extinction, while the shoots of *E. vaginatum* are well-protected within the tussock structure (Wein 1973). Alternatively, the ericoids may be encouraged by enclosure (Rawes 1981; 1983). The less palatable subshrubs (*Empetrum nigrum* ssp. *nigrum* and *Vaccinium vitis-idaea*) tend to persist longer in grazed stands. On shallower peats, grazing may also increase the proportion of

Juncus squarrosus and, where trampling decreases aeration along pathways, *Scirpus cespitosus* may spread.

Moderate levels of grazing can maintain a stable diversity in M19. Rawes & Hobbs (1979) considered that at Moor House, the community could support *c.* 1 sheep per 2.5 ha, without any burning, and continue to produce sufficient food for stock and grouse.

Rubus chamaemorus also benefits from protection from grazing providing the surrounding vegetation does not become too dense (Taylor 1971; Rawes & Hobbs 1979; Rawes 1983).

Trampling can also disrupt the *Sphagnum* cover, destroy larger *Cladonia* species and favour an increase in crustose lichens, acrocarpous mosses like *Campylopus paradoxus* and some leafy hepatics on exposed peat surfaces. Thus, variations in grazing pressure can lead to fine-scaled mosaics between stands.

Combined treatment effects

Frequent burning and heavy grazing contribute to the conversion of M19 into *Eriophorum vaginatum* blanket & raised mire (M20), where ericoids, Sphagna and hypnoid mosses are of very patchy occurrence, and *E. vaginatum* overwhelmingly dominant. However, at Moor House, reversion of M20 back to M19 has been demonstrated after only 15 years without burning or grazing (Rawes 1983).

Burning, particularly deep, catastrophic fires and heavy grazing can contribute to the development of erosion, leading to the characteristic hagg patterning features and erosion gullies, by increasing the exposure of areas of bare peat (Radley 1962; Shimwell 1974; Tallis 1981; Tallis & Yalden 1984: all *cit.* Rodwell 1991), a situation which is exacerbated by drainage. Sheep tracks and footpaths may also disrupt the cover of surface vegetation (*e.g.* Tallis 1973, Shimwell 1981). Atmospheric pollution and drainage have also contributed through the exposure of extensive areas of bare peat (Tallis 1985). These factors can have a drastic effect on the cover of Sphagna (*e.g. S. capillifolium*), and influence the prospects for restoration.

Severe drainage can convert M19 into heath or grassland, with a reduction in vigour of *E. vaginatum*, and increase in prominence of subshrubs. Drainage combined with grazing can produce a Nardetalia sward, or even a Cynosurion pasture, if combined with liming and fertiliser inputs. Less intense improvement can lead to the spread of *Juncus squarrosus*, although enclosure of a *Juncus squarrosus* pasture at Moor House showed a reversal of the trend, with vegetation beginning to develop into M19 after 25 years (Rawes 1981).

7.2.9 *Eriophorum vaginatum* blanket & raised mire (M20)

Climate: cold and wet: 1200–1600 mm annual ppt, with 160–200 wet days, mean annual max. temperatures *c.* 21–25°C. Most stands lie at an altitude between 500 and 700 m.

The *Eriophorum vaginatum* blanket & raised mire comprises species-poor ombrogenous bog vegetation dominated by *E. vaginatum*, the tussocks of which form an open or closed canopy, 10–30 cm high. Ericoid sub-shrubs are patchy in occurrence. Sphagna are scarce and typically of low cover, with *S. capillifolium* and *S. papillosum* the most frequent. Hypnaceous mosses and lichens also poorly represented. The community is characteristic of ombrogenous peats on bogs where certain kinds of treatment have become of overriding importance in determining the nature of the vegetation: mainly long-continued and heavy grazing together with burning, but also affected by drainage and aerial pollution. These factors have also

contributed to gross erosion of the underlying peat. Around the margins of blanket bogs, the thinning of the peat cover is generally marked by a transition to Ericetalia wet heath over gleyed podzols (e.g. M16), or Calluno-Ulicetalia heath or Nardetalia grasslands over more free-draining podzols or rankers.

Many stands seem to have been derived from M19 (*Calluna vulgaris–Eriophorum vaginatum* blanket mire) by impoverishment of the flora according to the intensity and duration of the treatments, and the floristic gradation between the two communities is continuous. Such replacement can be seen throughout the range of the *Empetrum* sub-community of M19, but is especially extensive in the southern Pennines, where M20 is the prevailing type of blanket bog over many square km.

Burning and grazing (especially over a long period), are particularly important in the reduction of cover, or even elimination of some of the major sub-shrubs. Burning can result in the total destruction of the above-ground parts and sometimes the stools and rhizomes of the ericoids (Gimingham 1960; Bell & Tallis 1973: *cit.* Rodwell 1991), stimulating an expansion in the abundance of *E. vaginatum* (Wein 1973; Rawes & Hobbs 1979) and of *Rubus chamaemorus* (Taylor 1971; Taylor & Marks 1971: *cit.* Rodwell 1991).

In some places, M20 may represent just a temporary phase of vegetation following a burn, although repeated fires may maintain the community by continually setting back regeneration of the sub-shrubs. Conversely, judicious burning at regular intervals (*e.g.* grouse moors on blanket bog) can stabilise the cover to yield a constant supply of building-phase *Calluna* (*e.g.* Gimingham 1972). In the absence of grazing, the sub-shrubs (e.g. *Vaccinium myrtillus* or *Empetrum nigrum* ssp. *nigrum*) may show a gradual recovery from burning, but usually these are eventually overtaken by *Calluna* (Eddy, Welch & Rawes 1969; Rawes & Hobbs 1979) – at Moor House, enclosure and lack of burning has allowed a progression from M20 back to *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) within 25 years (Rawes 1983).

Long and intensive grazing (either alone, or with burning) is likely to lead to the development of M20 from M19 (or sometimes M18), even at quite modest grazing intensities (1 sheep per 2 ha; *e.g.* Rawes & Hobbs 1979) which can extinguish *Calluna* & *V. myrtillus* (see M19 account, above), and shift the balance in favour of *E. vaginatum*. Somewhat lighter, or patchy grazing may allow sporadic persistence of subshrubs, particularly the less-palatable *Empetrum nigrum* ssp. *nigrum* (Bell & Tallis 1973). This species frequently shows dominance in M20, and in some places (*e.g.* Ilkley Moor, W. Yorkshire), has become abundant over large areas, masking the pattern of communities, especially at the margins of the mire (Dalby 1961; Fidler, Dalby & Duncan 1970; Dalby, Fidler & Duncan 1971: all *cit.* Rodwell 1991). M20 is often found in mosaics with M19, depending on the treatment. Sometimes the separation is clearly marked (*e.g.* by a fence line), but often the transitions are less well defined, for example, reflecting the gradual reduction in grazing intensity in moving away from adjacent stretches of more palatable grasslands (*e.g.* Pearsall 1941; Eddy, Welch & Rawes 1969; Rawes 1983).

Trampling by stock can disrupt the *Sphagnum* carpet and damage larger lichens (e.g. Rawes & Hobbs 1979), thereby also impoverishing the flora. However, shading by *E. vaginatum* may be of more importance than trampling in reducing the associated ground cover – the modest enrichment of the flora seen in the *Calluna–Cladonia* sub-community may be largely due to the sporadic occurrence of the sub-shrubs, through the shoots of which light can penetrate more easily. The dryness of the peat (which is often summer-dry), either natural, or induced by factors such as drainage and erosion, is also of importance in determining the

floristics of the ground-layer, for example, the paucity of Sphagna, although atmospheric pollution may also have played a role.

It is thought that the enclosed *Juncus squarrosus* swards at Moor House may have developed as a result of very heavy grazing of blanket mire on thinner peats, and that these may also show some recovery if grazing ceases (Rawes 1981). However, Rodwell (1991) considered that it is doubtful whether the *Eriophorum* mire common in the southern Pennines would be able to show similar recovery, because there has been particularly severe erosion of the underlying peats. This can also precipitate a progression from the *Calluna–Cladonia* sub-community to dry heath along the freely-draining tops of the drainage channels. Extensive marginal wasting can lead to replacement of the vegetation by *Juncus–Festuca* grassland. There may be a small amount of regeneration of the mire within some of the more gently-sloping channels, or in blocked areas, although these sometimes contain Caricion nigrae vegetation (e.g. M6).

7.3 Plant species

The following notes are confined to comments on the responses of the main blanket bog and wet heath plant species to burning and grazing (where known) and are not intended to provide detailed information on their biology or ecology. However, the classification of species into two groups based on their response to burning by Fraser (1933, *cit.* Elliot 1953) is a useful one to bear in mind:

1. Caespitose species in which winter buds and food stores are protected by a dead matting of leaf sheaths and last year's leaves (e.g. *E. vaginatum*) and plants whose winter buds and reserve food stores lie below the surface of the ground (e.g. *E. angustifolium*). Plants of this group are scarcely affected by fire; even when burned and defoliated in the early growing season, they soon recover.
2. Sub-shrubs and other plants with winter buds at or near the surface of the ground, and with their food reserves stored in the stem and which do not regenerate readily from roots (e.g. *Calluna*). These are more readily destroyed by fire than those in group 1.

Some species are intermediate, for example, *Vaccinium myrtillus*, which has wintering buds on aerial stems and underground rhizomes. However, it should be noted that Reader, Mallik, Hobbs & Gimingham (1983) found that grouping species by life-form was of limited value in interpretation of inter-specific variation in the timing of shoot regeneration after fire in a heathland.

Similarly, Rowe (1983: *cit.* Lindsay *et al.* 1988) describes four different basic types of plant response to fire:

1. **RESISTERS**, such as *Eriophorum vaginatum*, which can tolerate and survive fire;
2. **ENDURERS**, such as *Arctostaphylos uva-ursi,* and *Empetrum nigrum* which regenerate from below-ground organs;
3. **EVADERS**, which are species able to set seed in the peat and germinate after fire;
4. **AVOIDERS**, such as *Hylocomium splendens* which cannot tolerate fire and rely on long fire cycles to allow reinvasion and recovery from populations surviving elsewhere.

Ball *et al.* (1981a) provide a table of the impacts of different management practices on 35 species that are important in upland grassland/moorland or trees/shrubs that frequently spread into upland pastures and heaths. Although largely based on "general ecological understanding" rather than experiment or observation, it provides some useful summary information. Consideration of the responses to management of individual species is important, as it is often the response of a few species initially present which can determine the future composition of the sward (see e.g. Welch & Scott 1995).

7.3.1 *Calluna vulgaris*

Much of the literature relating to the effects of burning and grazing on heather has already been reviewed by other authors, including Mowforth & Sydes (1989) and Coulson *et al.* (1992), and is only summarised here. Damage to heather and its causes have been reviewed in detail by MacDonald (1990). Most of the literature relates to 'dry' heather moorland/heath. General comments on the effects of burning and grazing on heather can be found in Sections 4 and 5.

- *Calluna* is a perennial, evergreen shrub which provides a useful source of feed for sheep, particularly in winter, when the availability of grass is limited.
- When undisturbed, *Calluna* plants go through a sequence of phases known as 'pioneer', 'building', 'mature' and 'degenerate', each lasting 3–10 years, *i.e.* plants have a life-span of 30–40 years in broadly-favourable habitats (Watt 1947, 1955: see Gimingham 1995). The building phase is the most productive in terms of edible material, and the *Calluna* is at its most competitive and exclusive: management prevents it passing into the mature or degenerate phases, when the plants become tall and woody, less palatable and less accessible to grazing animals (Gimingham 1995); left to itself, *Calluna* could be expected always to give place, sooner or later, to other species. However, in some situations, these phases may be prolonged, or even perpetuated. For example, on blanket bog, the building phase may be maintained by layering of *Calluna* stems through the production of adventitious roots into a covering layer of *Sphagnum* or humus, with only a small proportion of the plants entering the degenerate phase (e.g. Rawes & Hobbs 1979; Legg 1995; MacDonald, Kirkpatrick, Hester & Sydes 1995). Some heather stands are known to have survived for at least 60–70 years without having been subject to fire, and are still vigorous, which is attributed to this ability to root adventitiously. Several authors also mention the possibility that snow may be a factor in facilitating layering of *Calluna* by pressing shoots down to the ground (e.g. Forrest 1971).
- *Calluna* grows more slowly in wet areas: this will affect its response to management.

Burning

- *Calluna* is well able to regenerate after fires, by sprouting from buried stools or basal shoots, or even by the rapid establishment from seed, which helps to diversify the age-structure of the population, although the recovery depends on the severity of the fire (4.4) and whether the area is grazed (6.2). Recovery of *Calluna*, both vegetatively and from seed, proved better at Moor House under short rotation (10-year) burning than long-rotation (20-year) (Rawes & Hobbs 1979), although frequent burning can lead to degeneration of the sward. Heather may cover the ground completely within 2–3 years of burning if it regenerates from stools, but may take much longer from seeds (Watson

& Miller 1976), although this may depend on location: A. MacDonald (SNH, 1995, *unpublished filenotes*) observed that dwarf-shrub regeneration after fire in oceanic areas is usually very good, probably being promoted by the generally continuously-high humidities and low risk of droughting of seedlings. In the Peak District, Elliot (1953) showed that burning in a cycle of < 15 years resulted in faster recovery of *Calluna* as it was less dependent on regeneration from seed, and also resulted in a faster suppression of associates such as *Vaccinium myrtillus*, *Empetrum nigrum* and *Deschampsia flexuosa*.

- Periodic burning (or cutting), which keeps *Calluna* in the building phase, tends to lead to very species-poor vegetation because it is highly competitive (Gimingham 1995). Stands may be re-juvenated to a young 'building' stand in 1–2 growing seasons following carefully-controlled burning, but where control is poor, regeneration may be slower, and may result in a seral stage dominated by other dwarf shrubs, such as *Erica cinerea* (on drier soils), *Erica tetralix* on peaty ground, or *Vaccinium myrtillus*.
- Frequent or severe burning can kill both heather plants and any buried seeds, leaving gaps for competitors (Miller, Miles & Heal 1984). A delay until the degenerate phase of heather, and excessively hot fire, or burning followed by heavy grazing, can similarly weaken or completely kill heather, especially on wetter western moors (Watson & Miller 1976). Burning can lead to a replacement of *Calluna* by deciduous species such as *Molinia* and *Eriophorum*, leading to an increase in the amount of litter and lowering of the winter stocking capacity.

Grazing

- *Calluna* is most vulnerable to grazing in autumn, when both its carbohydrate reserves and overwintering shoots will be damaged (Grant, Bolton & Torvell 1985). The nutritional quality of *Calluna* is highest in June/July (Milne 1974; Powell & Malcolm 1974 *cit.* Salt *et al.* 1994) and in new growth, which can be stimulated by grazing and is also preferentially grazed (Grant & Hunter 1968: *cit.* Grant & Armstrong 1993). Old or leggy heather is less tolerant of grazing than young heather, and takes longer to recover from over-grazing (Grant & Armstrong 1993). Similarly, after severe fire or when old heather is burnt, regeneration depends almost entirely on seedlings. *Calluna* is preferentially grazed in the winter, when the availability of other, more palatable species is low. Young plants are grazed freely.
- Work by Grant *et al.* (1978; 1982: see Coulson *et al.* 1992) has shown that on dry heather moors, young, vigorous heather can be damaged if more than 40% of the annual production is removed by grazing each year for a number of years. Removal of > 80% of the shoots, resulted in the death of some shoots, a decline in stand density and productivity, and appearance of bare areas.
- Various alternatives to burning and grazing have been tried in the management of heather-dominated vegetation. For example, in an experiment at Moor House, Gore (1975) showed that frequent clipping of *Calluna* resulted in its decline in favour of *E. vaginatum*, an effect similar to that achieved by grazing, while on Ilkley Moor, Cotton & Hale (1994) showed that flailing heather produced a similar effect to burning. Brown (*in* Whitby & Grant 1990) indicated that different areas of the country have experienced differences in the relative value of cutting *vs.* burning heather. [Note that

the use of alternative techniques for the cost-effective conservation management of blanket bog or wet heath has not been considered in the current project.]

7.3.2 *Empetrum nigrum* ssp. *nigrum*

- *E. nigrum* is less palatable than some other sub-shrubs, so can persist on grazed *Calluna–Eriophorum* mire. In the *Eriophorum vaginatum* blanket & raised mire community (M20), somewhat lighter, or patchy grazing may allow sporadic persistence of subshrubs, particularly *E. nigrum* (Bell & Tallis 1973). This species frequently shows dominance in M20, and in some places, (*e.g.* Ilkley Moor, W. Yorkshire), has become abundant over large areas (Dalby 1961; Fidler, Dalby & Duncan 1970; Dalby *et al.* 1971: *cit.* Rodwell 1991).
- Much of the work at Moor House has been on the *Empetrum* sub-community of *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) (see 7.2.8).
- *E. nigrum* can attain great abundance after fire, provided burning is not so intense as to destroy rhizomes, dominating until over-topped by *Calluna* (*e.g.* Ritchie 1955 *cit.* Rodwell 1991). Anderson (1986) noted a slow recovery of *Empetrum* from a severe accidental fire on moorland in the Peak District (which is renowned for the abundance of this species).
- Gimingham (1972) provides information on the ecology of *Empetrum*.

7.3.3 *Erica tetralix*

- Interactions with *Calluna* are probably largely related to waterlogging – *Calluna* can germinate and establish over a wider range of soils than *E. tetralix*, and in particular in conditions of fluctuating or low water levels. *E. tetralix* germinates better than *Calluna* on wetter, humic surfaces and maintains itself better in mixed populations under wet conditions which can adversely affect *Calluna*.
- In wetter habitats, *Erica* may be able to regenerate better following fire than *Calluna* because its semi-prostrate lower branches are protected to some extent by the *Sphagnum* carpet and litter (Fritsch & Salisbury 1915; Bannister 1966: *cit.* Rodwell 1991). Thus, *E. tetralix* may dominate initially following a fire (Gimingham 1972), but is probably exceeded by *Calluna* if there is a long interval between fires.
- As for *Calluna*, *E. tetralix* is grazed mainly in winter (MacLeod 1955, Welch 1984: *cit.* Rodwell 1991), when other sources of food are more scarce. Young plants are freely grazed.

7.3.4 *Eriophorum angustifolium*

- *E. angustifolium* is an important coloniser of bare peat. Young shoots are shaded by *Sphagnum* carpet or amongst vigorous growth of other vascular plants, but if this is reduced, it can expand rapidly by vegetative growth of its rhizome system and become dominant on natural or artificial exposures (Phillips 1954: *cit.* Rodwell 1991).
- *E. angustifolium* tends to be grazed in late summer (Grant *et al.* 1976).
- In studies on revegetation of burnt blanket bog at Moor House, *E. angustifolium* spread rapidly following the fire, and in some plots, formed a dense mat with *E.*

vaginatum (Hobbs 1984). A similar response was noted in the Peak District by Anderson (1986) where burning was not too severe.

- In an exclosure experiment at Moor House, Marrs, Bravington & Rawes (1988) showed that *E. angustifolium* declined in the enclosed plot, but not in the area where grazing was maintained (1.4 sheep ha^{-1}).

7.3.5 Eriophorum vaginatum

- This species can form very robust tussocks, up to 20–30 cm above the bog surface. The foliage dies back annually, but the remains can persist intact for many years (see Rodwell 1991, p195). The plant is thus afforded some protection from winter fires.
- *E. vaginatum* is often one of the first species to recover from fire and can dominate temporarily after fire in blanket bog, assuming permanent dominance if the community is burnt frequently (Rawes & Hobbs 1979; Hobbs 1984; see also Tallis 1969 and Anderson, 1986).
- On blanket bog, *E. vaginatum* tends to be eaten by sheep in winter and early spring, and may be grazed in preference to *Calluna* in late summer (Grant *et al.* 1987 (see Mowforth & Sydes 1989). Rawes & Hobbs (1979) concluded that increased grazing pressure allows *E. vaginatum* to become dominant at the expense of dwarf shrubs. However, Grant, Bolton & Torvell (1985) obtained results somewhat at variance with those of Rawes & Hobbs (1979) in that both *Calluna* and *E. vaginatum* declined with increased stocking rates, suggesting that the difference could be attributed to the starting composition of the sward, coupled with the difference in timing and level of utilization in relation to the seasonal patterns of growth of the species present. Rawes (1981) reported the fast elimination of *Juncus squarrosus* when a grassland on blanket peat at Moor House was enclosed, with rapid replacement by *E. vaginatum*.
- The growing points are well protected within the tussocks (Wein 1973) so *E. vaginatum* tends to attain prominence over sub-shrubs under heavy grazing pressure where these can be grazed to extinction (Eddy, Welch & Rawes 1969; Rawes & Hobbs 1979: *cit.* Rodwell 1991).
- Gore (1975) showed that regular clipping of blanket bog vegetation at Moor House, resulted in the development of fairly stable, *E. vaginatum*-dominated communities, at the expense of *Calluna*, similar to those produced by grazing.
- Rawes (1971) noted that *E. vaginatum* has the capacity to grow at lower temperatures than most plants and the flowering shoots may appear at any time during the winter.
- *E. vaginatum* is the dominant species of the *Eriophorum vaginatum* blanket & raised mire community (M20) (see 7.2.9).

7.3.6 *Molinia caerulea*

- *M. caerulea* is a tussock-forming, deciduous grass, which is resistant to fire because the buds are protected within the tussock.
- Burning and grazing of heath and blanket bog affect the balance between ericoids, *Molinia* and *Scirpus*. In situations where *Molinia* is dominant (e.g. in the north west of Britain and Brecon Beacons), it is sometimes burnt annually to remove the leaf litter in order to expose the more palatable young shoots for sheep or deer (Guile 1965;

Miles 1971: *cit.* Rodwell 1991); such regular burning is thought to disfavour *Calluna* (Lindsay *et al.* 1988) and thereby lower the winter stocking capacity (Lance 1983). A sheep grazing regime also tends to favour the spread of *Molinia* as it is not preferentially grazed over the summer, and, being deciduous, escapes winter grazing (Coulson *et al.* 1992). Intensive grazing of the tussocks in spring also helps to improve summer grazing (Grant, Hunter & Cross 1963). Conversely, lack of management may lead to the formation of large *Molinia* tussocks (especially in conditions of widely fluctuating water tables) which are then difficult to remove.

- Preliminary results from studies at Redesdale reported by Merrell *et al* (1993) suggested that *Molinia* increased in cover with increasing grazing intensity, particularly on burned *Calluna* plots.
- Guile (1965) suggested that surface consolidation and repeated burning of the Molinietum in the Brecon Beacons favoured *Scirpus* over *Molinia.*
- Severe burning of heath communities (e.g. M16) which destroys both ericoid stools and buried seed may give *Molinia* an advantage in the long term (Tansley 1939; Rose 1953; Ratcliffe 1959: all *cit.* Rodwell 1991). This grass can also benefit by the burning off of choking litter and the quick release of nutrients from the ash; for example, Aerts (1990) showed that *Erica* and *Calluna* are crowded out by *Molinia* when nutrient availability increases and it is possible that increased levels of atmospheric pollution may have contributed to the expansion of this species, as in parts of Wales.

7.3.7 *Rubus chamaemorus*

- *Rubus chamaemorus* is strongly preferential to the *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19), particularly at higher altitudes. It does not put up its shoots until May, and therefore will be unaffected by winter, or early spring fires. However, its flowers provide a nutritious source of food for lactating deer and sheep (Taylor 1971) which thereby often restrict fruiting.
- *R. chamaemorus* may dominate initially on blanket bog after fire, by extensive spread of underground rhizomes (Hobbs 1984), but is usually succeeded by heather (Taylor & Marks 1971: *cit.* Rodwell 1991) during long intervals between fires. The latter authors found that burning can increase the mean dry matter production of aerial parts, giving greater shoot density and larger shoots. If grazed following burning, a large number of small shoots were produced, with virtually no flowers or fruits developed (see also Taylor 1971).
- *R. chamaemorus* benefits greatly from protection from even light grazing (0.13 sheep ha^{-1}), provided surrounding vegetation does not become too dense, resulting in greater standing crop, with increased shoot density, and larger shoots with many more flowers and fruits than the grazed plots (Taylor 1971; Rawes & Hobbs 1979; Rawes 1983).
- In management trials on blanket bog at Moor House, Rawes & Hobbs (1979) reported that *R. chamaemorus* was considerably more abundant when short rotation (10-year) burning was combined with removal of grazing.

7.3.8 *Scirpus cespitosus*

- *Scirpus cespitosus* provides edible material in the spring and early summer when the young leaves appear.
- It may spread along pathways in bogs where trampling decreases aeration (Rodwell 1991). Guile (1965) suggested that surface consolidation and repeated burning of the Molinietum in the Brecon Beacons favoured *Scirpus* over *Molinia.*
- *Scirpus cespitosus* tends to replace *E. vaginatum* in bogs in northern Scotland, and becomes similarly dominant under frequent burning regimes (Lindsay *et al.* 1988).
- see also Sections 7.2.4 (*Scirpus cespitosus–Erica tetralix* wet heath (M15)) and 7.2.6 (*Scirpus cespitosus–Eriophorum vaginatum* blanket mire (M17)).

7.3.9 *Sphagnum* spp.

Sphagnum species are an important component of the ground layer of blanket bog and wet heath communities.

- A *Sphagnum* carpet can prevent the degenerate phase of *Calluna* developing because the stem bases are smothered, thereby encouraging 'layering' (Rawes & Hobbs 1979).
- Trampling by stock can disrupt the *Sphagnum* carpet, in particular damaging the typical microtopography associated with the hummock-forming species such as *S. papillosum.*
- Clymo & Duckett (1986) showed that new shoots of *Sphagnum* arose on peat discs taken from at least 30 cm below the surface and water table and from regions in which the *Sphagnum* appeared to be brown and dead, from material possibly 25–60 years old.
- *Sphagnum tenellum* seems to colonise wet, bare (± burnt) areas well (*e.g.* Lindsay & Ross 1994), and is common in areas which have been trampled, such as sheep tracks.
- In an exclosure experiment on *Juncus squarrosus* grassland at Moor House, Marrs, Bravington & Rawes (1988) found that the abundance of *S. capillifolium* was greatest in the grazed plot throughout the experiment (1966–1984) and even increased slightly, although there were considerable changes in the dominance of the vascular plants.
- A wet *Sphagnum* carpet may help to protect rhizomes of woody sub-shrubs from fire. However, the hummock-forming Sphagna are susceptible to fire, particularly when dry, and the decline of the rare *Sphagnum imbricatum* on Cors Fochno (raised bog) has been attributed largely to the effects of fire (Slater 1976).
- The presence of *Calluna* may influence *Sphagnum* production through shading (Smith & Forrest, 1978).
- Pearsall (1941: *cit.* Rodwell 1991) suggested that *Sphagnum* spp. seemed to suffer more from the effects of subsequent exposure to drying and the effects of burning and drying on the peat than from fire *per se.*
- We have found no studies which specifically address the question of the impact of controlled burning on and subsequent recovery of Sphagna on blanket bog which could help to provide definitive guidance on the appropriateness of occasional winter fires for management, particularly in sites which have not been also affected by drainage.

7.3.10 *Vaccinium myrtillus*

- A deciduous sub-shrub, which is typical of the *Empetrum* sub-community of *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19) and the *Vaccinium* sub-community of the *Scirpus cespitosus–Erica tetralix* wet heath (M15) (see above), preferring well-drained and acid soils.
- *Vaccinium myrtillus* can attain great abundance after fire, provided burning is not so intense as to destroy rhizomes, dominating until over-topped by *Calluna* (Ritchie 1955; Ratcliffe 1959; Gimingham 1964, 1972; Bell & Tallis 1973; all *cit.* Rodwell, 1991; Tallis 1969). Guile (1965) suggests that moderate burning favours the *Vaccinium* as it is more deeply rooted than *Calluna*, and that this could explain the greater abundance of the former in the Brecon Beacons.
- The green stems are grazed mainly in the winter when the more palatable grass species are not available, and can provide a rich source of minerals to grazing animals (see Mowforth & Sydes 1989). It is more palatable to sheep than *Calluna*.
- Gimingham (1972) provides some information on the ecology of *Vaccinium myrtillus* and *Vaccinium vitis-idaea*. Biological Flora accounts for these two species were provided by Ritchie in 1956 and 1955 respectively. Welch, Scott, Moss & Bayfield (1994) have recently published a useful account of the ecology of *Vaccinium myrtillus* and its management in British moorlands.

7.3.11 *Vaccinium vitis-idaea*

- *Vaccinium vitis-idaea* is typically found at higher altitudes than *V. myrtillus* or *Empetrum*. Comments suggest that response to burning and grazing is similar to the former, for example, it can attain great abundance after fire, provided burning not so intense as to destroy rhizomes, dominating until over-topped by *Calluna*, and being less palatable than some other sub-shrubs, it can persist on grazed *Calluna–Eriophorum* mire. [See also comments under *V. myrtillus*, above]

7.3.12 Others

Most attention in the literature (and hence in this report) has focused on the responses of the main dominants and characteristic species of blanket bog and wet heath communities to management. However, there is some evidence of changes in associated species:

- Rawes & Hobbs (1979) showed that exclosure of sheep from blanket bog at Moor House resulted in an increase cover and biomass of lichens after 21 years (see also Rawes 1981). Conversely, cover of *Cladonia impexa* was decreased to a very low value after a few years of heavy grazing (3.4 sheep ha^{-1}), while bare ground increased dramatically.
- Trampling on blanket bog (e.g. M19) can destroy larger *Cladonia* spp. and favour an increase in crustose lichens, acrocarpous mosses (e.g. *Campylopus introflexus*) and some leafy hepatics on exposed peat surfaces (see Rodwell 1991).
- Radford (*in* Bunce 1989) suggests that although light burning can be effective on blanket bog in achieving good heather regeneration, it can put at risk the more sensitive flowering plants such as *Listera cordata* and *Andromeda polifolia*. However, there is some evidence that *Andromeda polifolia* can positively thrive after burning,

even though the richness of the accompanying flora has been lost, at least temporarily (e.g. Sinker 1962 – see Rodwell 1991). Elliot (1953) also suggested that the decline in abundance in the Peak District of such species as *Erica cinerea*, *E. tetralix*, *Lycopodium* spp. and *Listera cordata* may have been due to burning, perhaps coupled with drainage.

- From observations made on the North York Moors, there is some evidence to suggest that there may be complex interactions between *Calluna* and *Campylopus introflexus* during recolonisation following a burn (Equihua & Usher 1993) leading either to an inhibition or facilitating the development of *Calluna* seedlings. Maltby *et al.* (1990) also suggest that the development of mosses and lichens on surfaces severely damaged by fire can retard the establishment of higher plants.