5. General effects of grazing

5.1 Introduction

Grazing by domestic livestock has long been an important component of land use in the uplands of Britain. As for burning (Section 4), grazing pressure has been stressed as a contributory factor in the initiation of blanket peat (e.g. Smith *et al.* 1981). However, in recent years, agricultural policies have encouraged the overstocking of many hill grazings, especially on common land, which has decreased the area of dwarf-shrub heaths, damaged the structure of some blanket bogs and degraded fine grassland to coarse grassland (e.g. Dixon 1984, Thompson *et al*, 1995c). It is generally accepted that the intensity and extent of damage varies according to the stocking rates, wetness and condition of the site, species of grazing animal, time of year and length of time on site (e.g. RSPB 1995). However, it is difficult to separate out the effects of these factors and to determine their interactions. Much of the work on the effects of sheep grazing in the uplands relates to 'dry' heather moorland. Reviews can be found in Milne & Grant 1987; Hobbs & Gimingham 1987; Grant & Maxwell 1988; Mowforth & Sydes 1989; MacDonald 1990; Coulson *et al.* 1992; RSPB 1995.

5.2 Direct and indirect effects of grazing on flora and fauna

5.2.1 Vegetation

Depending on intensity, grazing can reduce competitive vigour, or even kill plants through defoliation and direct damage, and overgrazing is commonly thought to be a major cause of loss of heather moorland. The effects of heavy grazing pressure have been studied both experimentally and by field observation (e.g. Grant *et al.* 1978, 1982; Welch 1984: see Mowforth & Sydes 1989); damage to heather and its causes have been reviewed in detail by MacDonald (1990). In many parts of the uplands, high densities of grazing animals (sheep and deer) probably limit tree and scrub establishment (see Hester & Miller 1995), although in some areas it is possible that trees may be held in check by *Calluna*.

Grazing can have a profound effect on species composition, for example, tussocks of species more tolerant of grazing, such as *Molinia* and *E. vaginatum* are likely to become more prominent, resulting in a shift in microtopography (RSPB 1995). Similarly, less palatable species are likely to increase in abundance. Doyle (1982) considered grazing (mainly by cattle) coupled with burning to have had a fundamental influence on the floristic composition of blanket bog in the west of Ireland (see 6.5).

Impacts of grazing on characteristic blanket bog plant communities and species are considered in more detail in Section 7.

Trampling/ Poaching

Damage caused by poaching is summarised below, mainly based on comments by RSPB (1995):

- The amount of damage depends on stocking densities, and will be concentrated around fence lines and feeding stations.

- The ratio of weight to hoof size is important in determining the degree of damage, with larger animals causing most damage.
- Wet areas are more susceptible than dry to poaching damage – the margins of pools can be severely damaged, leading to loss of Sphagna and development of areas of bare peat.
- Sphagna are particularly susceptible to trampling, which may thus cause changes in microtopography and species distribution, for example a reduction in hummock-forming Sphagna such as *S. papillosum*. However, *S. tenellum* may benefit as it commonly colonises wet bare peat (as may be left by burning) and is often associated with poached areas and animal tracks.
- Disruption of the physical structure of the surface peat can result in wastage and oxidation of the peat, and can presumably also increase the risk of erosion.
- Trampling, especially by cattle, causes stem breakage and bruises leaf tissues, thereby rendering them liable to winter browning (Watson, Miller & Green 1966 *cit.* Bunce & Fowler, in Bunce 1989).

Enrichment

- Evidence seems contradictory on the relationship between grazing and enrichment of the substratum.

  It is thought that supplementary feeding may introduce more nutrients into the system, unless the animals are taken off the site overnight (RSPB 1995). Defecation and urination can raise the soil's nutrient status, giving competitive advantage to faster-growing graminoids (Bunce 1989 – *no source given*). This may also cause a shift from ombrotrophic to mesotrophic communities (*e.g.* dominance by *Juncus* spp., *S. recurvum* or *Narthecium ossifragum*), although the effect is likely to be localised (RSPB 1995).

  In the long term, grazing may lead to a reduction in soil fertility as nutrients are either locked up in the peat or constantly leaving the system in the animals (Harrison 1985; Marrs, Rizand & Harrison 1989). In wet areas, this may help initiate a shift from *Callunetum* to a grass-sedge community, although other factors may be of importance, including climatic deterioration or change in burning frequency (Chambers 1983). Estimates have been made of the exports of nitrogen in livestock and wool, and this is considered to represent only a small proportion of that available (see Coulson *et al.* 1992).

  Rawes & Heal (1978) discussed the nutrient interrelationships between different habitats available for sheep grazing at Moor House (including blanket bog and grassland) and concluded that there was little or no net income to or loss from the bog of N, P, K and Ca as a result. The transfers of nutrients between ecosystems by fauna were considered small compared with transport by water.
- There may be introduction of 'alien' plant species from animals (including birds) feeding on other sites, or from supplementary feed.
- Death of an animal usually leads to uncharacteristically lush growths of vegetation in and around the site of enrichment (RSPB 1995 and pers. obs.).

- Deposition of dung can be beneficial in increasing the invertebrate food supply for some birds.
- Several coprophilous mosses (e.g. *Splachnum* spp. *and Tetraplodon mnioides*) are characteristic of dung and other animal remains on blanket bog (Lindsay *et al.* 1988).
- Lindsay *et al.* (1988) refer to some blanket bogs (unspecified) which have been subjected to substantial enrichment by Ca, N and P from long-established colonies of breeding gulls. Localised enrichment and modification of the vegetation may also be caused around perching sites used by birds, and defecation sites for foxes.
- The impact of grazing on the nutrient status of the soil will clearly be influenced by the effects of atmospheric inputs, and is therefore likely to vary geographically.

5.2.2 Fauna

Changes in vegetation composition and structure can lead to concomitant changes in the associated fauna, for example, loss in heather dominated vegetation leads to a reduction in the distribution of red grouse, loss of blaeberry *Vaccinium myrtillus* could lead to a reduction in capercaillie, and loss of dwarf shrubs on mountain plateaux to a loss of ptarmigan (see Hudson 1995). These impacts can result from heavy grazing intensities by herbivores. The specific effects of grazing on birds are not considered in the present report (see Appendix 1). The effects of grazing on invertebrates are considered in Section 8.3.

5.3 Specific effects of variation in management practices:

5.3.1 Type and breed of grazing animal

Different animals graze in different ways, for example, sheep graze by biting and shearing and tend to produce an even, short sward, while cattle wrap their tongues around the vegetation and pull, tending to produce a more uneven vegetation structure (Rowell, 1988). The effect of grazing on the structure and floristic composition of the vegetation will therefore differ between herbivores and will depend on other factors, such as the relative amounts of different vegetation types, stocking densities and timing etc. RSPB (1995) provides a summary of the functional grazing attributes of different animals, and seasonal variation in plant species selection.

Cattle

Cattle tend to be less selective than sheep, and graze most components of a community, although this difference is more pronounced in grasslands than on heaths and blanket bog (Grant *et al.* 1987). Cattle diets tend to contain a greater proportion of *Eriophorum* spp. than sheep (Grant *et al.* 1987), and will eat more *Nardus stricta* than sheep or deer (Grant, Bolton & Torvell 1985) and may produce a tussocky sward favoured by breeding waders (Cadbury 1993).

Grant *et al.* (1987) compared diet selection between cattle and sheep on a blanket bog and heather moor, and showed that sheep diets were slightly more variable than cattle diets, but there were many components which were selected or avoided in common by sheep and cattle and the cattle diet included more dead components of the vegetation. Species which were avoided included *Calluna*, *Erica* spp. and *Empetrum nigrum* – these species were mainly eaten outside the main growing season when the preferred species were less available (see

also Gordon, 1989b). On the blanket bog, species which were selected included *Molinia*, other grasses, *Carex* spp and *Scirpus cespitosus*. Cattle graze *Calluna* less discriminately than do sheep, removing more of the shoot length, so that risks of shoot death and of broken or uprooted shoots are increased. Grant *et al.* (1987) suggest that if cattle are to be used in the management of dwarf-shrub communities, this should be in mixed communities, where the aim of the management is to control the plants associated with the dwarf shrubs. Hodgson *et al.* (1991) extended this work to provide information on seasonal variations in ingestive behaviour and herbage intake of sheep and cattle on different vegetation-types. These authors suggest that cattle may be excluded from "higher quality" communities by sheep once these have been grazed very short, but that there may be some scope for complementary grazing management using sheep and cattle, particularly in grass-dominated communities.

Use of cattle gives a higher risk of trampling damage (5.2.1), although Gimingham (1995) considered that cattle could be used in some circumstances to manage heather moor (*type unspecified*). Grant *et al.* (1987) also suggest that use of cattle could be considered in wet areas, at least in summer, for example, where large areas of *Molinia* and *Calluna* occur together. Rawes (1971) considered that the greater poaching damage caused by cattle compared to sheep provided ideal conditions for the invasion of *Juncus* spp, while in Ireland, Watson & O'Hare (1979) noted that *J. effusus* and *Myrica gale* grew abundantly on flat blanket bog where poached by cattle.

The use of cattle in hill farming has declined over the last 200 years in Wales whilst sheep have increased (Dixon, 1984). Similarly, on Shetland, there has been a trend away from mixed cattle/sheep grazing on peatlands towards primarily sheep (Birnie & Hulme 1990).

Sheep

Sheep have more select feeding preferences than cattle, preferring the more palatable grasses and young heather, where available (see above and Grant & Armstrong, 1993). Sheep graze by biting and shearing and tend to produce an even, short sward (RSPB 1995). Grant & Armstrong (1993) summarised the relative sheep grazing preferences on different vegetation types (see Table 5.1).

When restricted to blanket bog, *Calluna* and *E. vaginatum* form the main part of the diet of sheep in the winter while *Scirpus cespitosus* and *Molinia* are preferred in the early summer (Grant *et al.* 1976; 1987). Grazing pressure on different vegetation types will vary depending upon species, as well as environmental factors such as climate, topography and aspect, and social behaviour (see also 5.3.4). In areas supporting mosaics of different vegetation-types, native grass communities are likely to attract a higher grazing pressure throughout the year than blanket bog or wet heath communities, and shepherding may be required to maintain a more even grazing pressure (5.3.6). Ball *et al.* (1981a) and Dixon (1984) suggested that the type of the stock may also have a differential influence on the impacts of grazing – they considered that the decline in the numbers of older wether sheep on the hills because of a preference for lamb over mutton has probably resulted in reduced grazing of coarser, less palatable vegetation as lambs and ewes are more selective than wethers in their feeding, having a higher requirement for minerals. An increase in *Nardus* on hill grazings in Snowdonia has also been attributed to the absence of wethers (Roberts, 1959: *cit.* Rawes & Heal, 1978). However, in some areas, there is a tendency for retaining lambs for longer on improved pastures, where available, thereby reducing impacts on hill vegetation to some extent.

Table 5.1 Relative sheep grazing preferences on different vegetation types (from Grant & Armstrong 1993)[1]

Vegetation type	Spring	Summer	Autumn	Winter
Agrostis–Festuca grassland	***	*****	****	***
Nardus	***	**	**	**
Molinia	**	**	*	*
Eriophorum	***	*	*	**
Calluna	*	*(*)	*	**

Grant *et al.* (1987) showed that the superior feeding value of blanket bog (*Calluna–Eriophorum–Scirpus*) vegetation over virtually pure stands of heather is due to the contribution of the various grasses and sedges to the diet – indeed, over the year as a whole, heather alone provides an inadequate diet for sheep to thrive, and their diets must contain a proportion of grass (Maxwell *et al.* 1986, *cit.* Grant & Armstrong 1993). Grant *et al.* (1987) also suggested that the differences in diet between sheep and cattle were mainly attributable to the greater ability of sheep to select from fine-scale mixtures, rather than differences in grazing height, although Hodgson *et al.* (1991) indicate that these studies and others emphasise the influence of the vertical distribution of sward components upon the selective behaviour of grazing animals. Where sheep are to be kept on a satisfactory economic basis as well as for conservation management, it will normally be necessary to supplement the moorland diet by integrating the use of supplementary winter feed (5.3.4) and fenced pasture (Grant & Armstrong 1993).

Few comments have been found on the different impacts that might be expected from the use of different breeds of sheep. Sheep can be divided into three classes, small (e.g. Welsh mountain), medium (e.g. Scottish Blackface or Swaledale) or large (e.g. Greyface or Mules), which have been shown to require increasing annual intakes of vegetation (see Grant & Armstrong, 1993). Ratcliffe (1959) comments that Welsh Mountain sheep and the Cheviot fare best on grasslands, whereas the Black-face sheep will thrive on a diet mainly of heather, and that local moorland management in Wales reflects the breed stocked. Birnie & Hulme (1990) pointed out that regulations regarding stocking levels should take into account the increasing trend towards the use of large sheep breeds, as well as the biological productivity of the available grazings and the nutritional requirements of the animals, rather than being based solely on stock numbers.

Goats

Goats are more selective feeders than sheep and will browse woody vegetation (Cadbury 1993). Grant, Bolton & Russel (1984: *cit.* Hooper, 1987) observed that goats readily grazed rushes even when grass was in plentiful supply, and on blanket bog vegetation, *E. vaginatum* and *Calluna* were grazed earlier in the season and more heavily grazed by goats than by sheep. Gordon (1989b) found that goats preferred heath communities over grassland types (see also Grant & Armstrong 1993).

[1] Reproduced by kind permission of Chapman & Hall from Grant & Armstrong (1983), Table 3, page 85.

Ponies

There are nine major breeds of hardy pony in Britain, many of which graze on mountains and moorlands, and are increasingly being seen as a useful management option for conservation (Oates 1994). They are important grazers on blanket bog in certain areas, for example in the south-west and in Shetland.

Ponies are selective feeders, preferring grassland to heather and can graze closely to the ground (Rawes 1971; Mowforth & Sydes 1989; Gordon 1989b). They will eat heather, and may damage it by trampling.

Rawes (1971) noted that horses tend to utilise specific areas habitually for defecation, whereas sheep and cattle do not. This leads to localised enrichment, often with 'unsightly' patches of vegetation which remain ungrazed.

Red deer (Cervus elaphus)

In most of the literature concerning red deer, there is usually no distinction made between 'wet' and 'dry' moorland habitats. However, some general comments can be made.

Red deer prefer a similar habitat to sheep, selecting grass swards where available, leading to competition for the preferred plant species and exacerbating damaging impacts due to sheep grazing (RSPB 1995). Deer favour a more varied diet than sheep (Staines 1970, *cit.* Cadbury 1993), and eat proportionately less grass (Osborne 1984). Feeding ecology differs between males and females (Gordon 1989b). Mitchell, Staines & Welch (1977: *cit.* Staines, Balharry & Welch 1995) considered that red deer would rarely cause succession from dwarf shrub heath to graminoid vegetation in open situations, whereas hill sheep are frequently responsible. Staines *et al.* (1995) considered that management for deer was probably more important in affecting heather moorland than the direct effects of natural deer grazing, for example in provision of supplementary feeding stations (see also 5.3.4) and fertilisation of swards. Hewson (1976) observed that deer seemed to graze with difficulty on pioneer heather, and showed a preference for mature heather.

Staines, Balharry & Welch (1995) reviewed the management of land for red deer, highlighting the conflicts between deer and the 'natural heritage' – major areas of concern are regeneration of native woodlands, loss of dwarf shrub and tall herb communities, effects on rare plant species (especially alpines) and, in some districts, soil erosion. However, in most places, the deer and sheep share the same range, and so it is difficult to quantify their relative impacts.

Hobbs & Gimingham (1987) reviewed the interactions between red deer and their habitat, although found few data on the effects of habitat modification on deer populations (or *vice versa*). Miles (1971) showed that deer will preferentially graze recently-burnt areas of *Molinia*-dominated vegetation because of the increased availability of shoot material, while other studies have demonstrated a preference of deer for older heather over pioneer heather and that high stocking densities (2.5 'hind-equivalents' ha^{-1}) can affect the cover of *Calluna* (although it is noted that the overall stocking density of red deer in Scotland is around 0.1 ha^{-1}). Browsing of young trees by deer may be an important factor in preventing succession to woodland in some areas.

Coulson *et al.* (1992) also provide a summary of relevant information relating to red deer.

Other

Red grouse are strongly dependent on heather (9.4), which is also an important part of the diet of such species as ptarmigan, black grouse and mountain hares, particularly in the winter when there is less other vegetation available (Cadbury 1993 *unsourced*). Hobbs & Gimingham (1987) provide an account of the relationships between food supply on heathlands and grouse numbers, and cite studies which suggest that even at maximum densities, grouse eat only about 5% of the annual production of dry matter of *Calluna*. Grouse favour the young shoots of heather, which is the main reason for the widespread burning practice on grouse moors (see Section 4).

Mountain hares are most numerous on the grouse moors of NE Scotland, where *Calluna* forms an important part of their diet (< 100% in winter). Hares favour heather in the pioneer phase, and heavy grazing can produce short, lawn-like *Calluna* bushes, thereby prolonging the pioneer phase (Hewson, 1976; 1989; 1995). There appears to be some competition between sheep and hares for the *Calluna*, although not with rabbits, and hares moved away from previously-used feeding areas when these were grazed by sheep, cattle or red deer (Hewson 1989). On moorland in Orkney, the number of mountain hares was found to be positively correlated with the burning of many small patches of heather (Hewson, 1995). Hobbs & Gimingham (1987) review the literature on hares. Where they occur, rabbit grazing can prevent heath species from recolonising after fire, and reduction in grazing pressure usually leads to an increase in dwarf shrubs and regeneration of trees.

Short-tailed field voles are widespread in the uplands, up to 1,300 m. Population densities on blanket bog are low – a preference is shown for the rank *Molinia* and *Juncus*-dominated communities which have become more prevalent under heavy grazing and burning pressure. Hill, Evans & Bell (1992) showed that when sheep were excluded from hill pastures in North Wales, voles became the dominant herbivore and exerted a considerable effect on the vegetation.

An assessment of the impacts of grazing clearly needs to take into account the effects of herbivores other than 'domesticated' ones, including birds, small mammals and invertebrates.

5.3.2 Intensity of grazing (stocking rates)

There are considerable problems in determining stocking rates and their impacts on blanket bog vegetation, as this will depend on various contributory factors, for example, type and breed of stock, and availability of alternative food sources. In addition, it is not always clear what is being quoted, for example, numbers of ewes may be given, without apparently taking lamb numbers into account, and a 'ewe unit' may include other grazers such as horses. Similarly, the period of grazing will strongly influence the effect (see 5.3.3), and land may be understocked in the summer and overstocked in the winter where there is a fixed, year-round stocking density (Lance 1983). Thus, stocking density alone is not always the most useful parameter to use in comparisons: assessment of the impacts of herbivores needs to take into account seasonal diet, distribution through the habitat and also type of grazing species and the interactions between them.

Financial incentives over the last few decades in order to increase production have lead to a large increase in sheep numbers over most of the uplands in England and Wales. The effect of increased grazing pressure is also often coupled with the switch away from management for grouse shooting and decrease in available area of rough grazing. On Berwyn (Wales), this is said to have been probably the single most significant change in hill farming to affect the

heather within the last 40–50 years, leading to a decline in dwarf shrubs in favour of grassland (Walker & Elias 1989). Improvements in the lower pastures have not decreased the pressure on the mountain, as sheep numbers (and individual body weight) have often increased. Similarly, Anderson & Yalden (1981) pointed out that the loss of heather moorland in the Peak Park was related to increase in sheep numbers from 0.7 ha^{-1} in the 1930s to 2.07 ha^{-1} (all year) in the 1970s, and in Cumbria overgrazing is also cited as the main cause of heather loss (see Marsden, in Thompson & Kirby 1990). In Scotland, there has apparently been little overall change in sheep numbers, but grazing pressure has intensified through increased numbers of hill cattle (see Coulson *et al.* 1992). However, Birnie & Hulme (1990) argue that overgrazing on Shetland peatlands originated in the mid-19th century, and although there may have been little change in stock numbers, there has been a trend away from cattle towards sheep and latterly towards larger breeds of sheep. Stevenson & Thompson (1993) suggest that there has been considerable replacement of heather moorland by grassland over the past 1–4 millenia, and attribute this largely to heavy grazing.

Most animals graze differentially, increasing the intensity on favoured areas, and controlled grazing can lead to mosaics of vegetation with different characteristics. In general, grazing selectivity (5.3.1) is likely to be more evident at low stocking densities (e.g. Grant *et al.* 1976), which can increase *Calluna* cover and shoot production (Rawes & Williams 1973; Hewson 1977; *cit.* Hobbs & Gimingham 1987). Reduction in grazing intensity can thus help the recovery of stands of badly-degraded *Calluna* (e.g. Merrell *et al.* 1993). Conversely, on blanket bog *Calluna* may be reduced at high stocking densities (e.g. 3.4 sheep ha^{-1}), or where growth is poor, in favour of *E. vaginatum* (Welch & Rawes 1966; Rawes & Hobbs 1979) – *Calluna* is very susceptible to winter 'browning' (wind and frost damage) if sheep or cattle are grazing it heavily, or if it is in the pioneer or degenerate phases (Watson & Miller 1976). 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. In a study on blanket bog in Argyll, Grant *et al.* (1976) found that the impact of increasing the stocking rate of sheep depended on the availability of the preferred species. They considered that changes in the floristic composition of the bog vegetation were likely to ensue when levels of utilization are reached such that the productivity of any species is reduced. Sydes & Miller (1988, *cit.* Thompson *et al.* 1995c) suggest that sheep stocking rates of > 0.5 ewes ha^{-1} on western and northern blanket bogs could cause a change from heather moorland to grassland or sedge-dominated bog.

The presence of *Juncus squarrosus* in heavily-grazed bogs (0.75 individuals ha^{-1}) suggests that heavy grazing may result in a development towards a *Juncus*-dominant sward (Smith & Forrest 1978). However, Marrs, Bravington & Rawes (1988) analysed data from an exclosure experiment set up on *Juncus squarrosus* grassland at Moor House in 1966, and found that, contrary to previous indications (*e.g.* Rawes 1981) the vegetation in both grazed and ungrazed plots was showing a tendency to change in the same direction, *i.e.* towards blanket bog dominated by *Calluna* and *E. vaginatum*, although the rate of change in the ungrazed plots was much faster.

The adverse effects attributed to grazing, such as trampling and localised enrichment (see 5.2) will clearly be exacerbated by increasing stocking rates. As noted above (5.3.1) red deer prefer a similar habitat to sheep, leading to competition for the preferred species and exacerbating damaging impacts due to sheep grazing (RSPB 1995).

5.3.3 Timing and length of grazing period

Sheep preferentially graze different species at different times of year (5.3.1), for example, when restricted to blanket bog, *Calluna* and *E. vaginatum* form the main part of the diet of sheep in the winter while *Scirpus cespitosus* and *Molinia* are preferred in the early summer (Grant *et al.* 1976; 1987). Sheep preferentially graze the more palatable grasses in the spring, but tend to eat the heather in the summer and autumn (Salt, Mayes, Colgrove & Lamb 1994). *Calluna* is most vulnerable to grazing in autumn, when both its carbohydrate reserves and overwintering shoots will be damaged (Grant, Bolton & Torvell 1985). In the winter, the older heather may be eaten, when food is scarce. The impacts of grazing will therefore to some extent depend on the timing and length of the grazing period, and will also interact with the effects noted above in relation to stocking rates (5.3.2), and adverse effects of trampling and localised enrichment (5.2).

Utilisation of blanket bog / wet heath vegetation during the grazing period will also depend on the alternative food sources available. Grant *et al.* (1976) considered that free-ranging sheep would probably scarcely utilize blanket bog in spring, if other pasture types, such as grassy flush areas were available.

In recent years, other than in the far north, there has been a trend towards overwintering sheep on moorland, and providing supplementary feed (see 5.3.4), rather than taking them to lower-altitude pastures. This has obviously increased the grazing pressure in these areas. Dixon (1984) considered that heavy winter grazing of blanket bog in Wales by ewes and their absence from the hills in summer will favour *Scirpus* and *Molinia*. On Exmoor, there has been a trend for use of the moors in summer only, with the provision of winter housing for the more productive, but less hardy breeds of sheep (Miller, Miles & Heal, 1984).

Rawes & Heal (1978) compared the vegetation of a blanket bog grazed year-round with one that was summer grazed only (see Table 5.2). The former had lower cover (and biomass production) of *Calluna* and greater *E. vaginatum* cover. Species diversity was also increased, although this was largely due to inclusion of species such as *Carex nigra, Festuca ovina* and *Juncus squarrosus*. The change in the sward composition due to increased grazing pressure was considered be desirable from the point of view of sheep production.

Table 5.2 The effect of sheep grazing on botanical composition of blanket bog, expressed as percentage cover (from Rawes & Heal, 1978)[1]

	Year-round grazing (0.5 sheep ha^{-1})	Summer grazing (*c.* 0.01–0.3 sheep ha^{-1})[2]
Species stimulated by grazing		
Carex nigra	0.5	–
Deschampsia flexuosa	5.0	–
Eriophorum vaginatum	45.3	22.5
Festuca ovina	4.1	–
Juncus squarrosus	5.9	–
Luzula campestris	0.1	–
Species reduced by grazing		
Calluna vulgaris	10.5	59.5
Erica tetralix	–	1.7
Species indifferent to the treatment:		
Drosera rotundifolia, Empetrum nigrum, Eriophorum angustifolium, Listera cordata, Narthecium ossifragum, Rubus chamaemorus, Scirpus cespitosus, Vaccinium myrtillus, V. oxycoccos.		
Total number of species	48	42

5.3.4 Availability of other vegetation types

As noted above, sheep are selective feeders. Thus areas with a higher proportion of grass to heather can be predicted to support more sheep at a given annual intake of digestible material (Armstrong & Milne 1995), but it is possible for sheep on *Calluna*-dominated vegetation to select a diet with very little *Calluna*, providing the biomass of herbs growing between the heather is sufficient (Grant *et al.* 1987). At Moor House, Rawes & Heal (1978) noted that sheep largely neglected the bog as a food source, with a stocking density of *c.* 0.2 ha^{-1}, compared with *c.* 2.0 ha^{-1} on the *Juncus*, *Nardus* and *Festuca* swards and 7.0 ha^{-1} on the *Agrostis–Festuca* grasslands, although these authors further note that grazing of the bog vegetation can make a significant contribution to the total food consumption and reduce competition for the more favoured areas. Numbers are directly related to food quality but also influenced by other aspects of the environment (e.g. climate, topography) and sheep behaviour (e.g. use of dry resting places and social behaviour). Territory size (and shape) for sheep will vary according to the available habitats and landscape.

5.3.5 Use of supplementary feed

Hudson (*in* Jenkins, 1984) describes the supplementary winter feeding of sheep using feed blocks and provision of hay. Use of supplementary feeding stations can cause localised damage from poaching and overgrazing; it may also allow the introduction of more nutrients into the system through faecal deposition (especially if the animals are not shepherded – see 5.3.6) and introduce 'alien' species. Hay is often placed on old heather to stop it blowing away – which can lead to subsequent destruction of the heather through trampling. Grant &

[1] Reproduced by kind permission of Springer-Verlag GmbH & Co. KG, Berlin.

[2] not directly specified in the text; stocking rate shown is the range for blanket bog communities at Moor House given by Rawes & Welch (1969) (mean was 0.12 sheep ha^{-1})

Armstrong (1993) suggest that damage can be avoided by, for example, feeding hay away from the moorland, using feed blocks on many dispersed sites, avoiding placing the feed blocks on newly-burned or aged heather and by changing the location of the blocks when they are replaced.

Introduction of winter feeding on Berwyn has increased the length of time sheep can stay on the mountain (Walker & Elias 1989) and has lead to a localised overgrazing of heather. In County Durham, Anderson (*in* Bunce 1989), gives an example where a 5000 ha estate lost 800 ha of heather over a period of 20 years as a result of winter feeding across the moor.

5.3.6 Stock control (shepherding)

Close shepherding has two main roles in grazing management: (i) to 'heft' a particular flock of sheep to a given area; (ii) to move the sheep around to ensure more even use of the available area including the less-favoured areas. The practice has become less common in recent years, and has probably lead to increased grazing pressure on the most favoured swards, with stock left to graze freely (see Coulson *et al.* 1992).

The exact vegetation type is not specified, but Hudson (1995) gives an example showing that where un-shepherded, sheep concentrating around a winter feeding area for several hours before and after feeding, result in localised damage of heather vegetation through both grazing and trampling.

Anderson & Radford (1994) showed that on Kinder Scout (Peak District) active shepherding (between 6 and 22 gathers each year) reduced grazing intensities from *c.* 2.5 ewes ha^{-1} to 0.18–0.43 ewes ha^{-1} and promoted revegetation of previously bare and eroding ground (peaty podzols) on slopes which had previously supported a *Calluna–Vaccinium myrtillus* vegetation community. Revegetation was initially to a *Deschampsia flexuosa*-dominated sward, but with increasing amounts of *Calluna* and *Vaccinium*. Advice to landowners in the Peak Park (Yalden, undated) is currently that active shepherding may help considerably in alleviating the problems of overgrazing by increasing the use of better-vegetated areas, and reducing the use of over-grazed areas. Similarly, Lawton (1990) recommends that shepherding and control of stock movement to winter feeding areas can help to alleviate many of the problems that lead to loss of heather on grouse moors.

5.4 Interactions between grazing and other environmental variables

Increasing wetness of the substratum is associated with a decrease in the productivity of blanket bog vegetation (Forrest & Smith 1975); thus vegetation on wet sites and areas is likely to be more sensitive to grazing (see Grant, Bolton & Torvell 1985). However, there is some evidence that wet ground communities are more resistant to the loss of dwarf-shrubs than those on dry ground – in some areas *Calluna* survives quite abundantly in plateau blanket bogs lying above hill slopes that have gone almost entirely to acidic grassland and bracken (D. Ratcliffe, *pers. comm.*). Drainage (gripping) is often carried out in order to increase the stock-carrying capacity of moorland. However, this may only have limited success, and it should be noted that drainage can reduce grouse productivity by destroying the wet areas which provide invertebrates (especially crane flies) on which the grouse chicks depend for survival (Hudson & Renton 1988 – see Bunce 1989).

Ratcliffe (1959) considered that the erosion which followed fire on the Carneddau (Wales), was exacerbated by grazing which helped to enlarge pockets of exposed mineral soil and

discourage recolonisation by vegetation which would bind the soil. The effects are worst on steep slopes. Similarly, erosion in some areas of the Peak District has been associated with a marked increase in sheep numbers (Anderson & Yalden 1981), although by no means the only cause (e.g. Tallis 1985; 1987; 1995).

As with burning, no specific information has been found on the influence of altitude on the effects of grazing, but it would be possible to make some inferences on species responses from variations in communities with altitude and published ecophysiological studies on the main species. Rawes (1971) suggested that grazing, together with climate were probably responsible for the replacement of *Calluna* by *Empetrum* at high altitude at Moor House.

5.5 General comments

In recent years, staff at the Macaulay Land Use Research Institute (MLURI) have been working on the development of models as aids to the development of suitable protocols for the management of heather moorland (e.g. Armstrong *in* Thompson & Kirby 1990; Grant & Armstrong 1993; Armstrong & Milne 1995). The models are based on data concerning the productivity and feeding value of the various vegetation types present and on foraging behaviour and diet selection of different breeds of sheep in order to examine different management options. They have recently been modified to look at a range of hill vegetation types (including "blanket bog") at any latitude and longitude, and to incorporate seasonality. Work in progress is aimed at using functional attributes of species to help predict the likely effects of management on blanket bog (H. Armstrong, *pers. comm.*).