Moorland 6

Tables

Definition and location of moorland

6.1 Definition of moorland

In this handbook the term moorland is used to refer to the unenclosed land of the English uplands. This supports dwarf-shrub heaths (wet and dry), blanket mires, other mires, scrub and grassland. Woodland, freshwater, montane and rock habitats also occur in the unenclosed uplands, but are covered in separate chapters. Bracken *Pteridium aquilinum* is also very widespread in the unenclosed and enclosed uplands and is discussed in Information Note 6.

Dry dwarf shrub heath is a vegetation community in which ericoid dwarf shrubs (heather *Calluna vulgaris*, *Erica* spp., *Vaccinium* spp, and crowberry *Empetrum nigrum*) or western gorse *Ulex gallii* form more than 25% of the cover in relatively dry situations. Wet heath can be defined by the same cover of ericoid dwarf shrubs but in wet situations and where peat depth does not exceed 0.5 m. Mires are wetlands supporting vegetation which is normally peat-forming, and occur where the ground is permanently or periodically waterlogged (Lindsay 1995; Rodwell 1991). Blanket mires cover extensive areas of land, including slopes, and are found on blanket peat bodies usually deeper than 0.5 m. Grasslands, where grasses are the dominant species and where dwarf shrubs form less than 25%, are widespread.

These vegetation types frequently occur as an intimate mosaic of habitat types, and within them are also found areas of bracken, shrubs and occasional trees. The National Vegetation Classification (NVC, Rodwell 1991, 1992) describes the many plant communities of the moorlands of England and those covered by this chapter are listed in Table 6.4. A number of the mire communities found in the unenclosed as well as the enclosed uplands are covered in Chapter 7 Meadows and enclosed pasture.

6.2 Location and extent of moorland

Moorland areas are found throughout the uplands of England. They occur in all the upland Natural Areas of England identified by English Nature, a map of which is shown as Figure 1.1.

Countryside Survey 1990 (Barr *et al* 1993) reported that semi-natural vegetation covered over 73% of upland landscapes in Great Britain. In England, heath / moor grass covered 34% (1,515 km²) of upland habitats with bog 2.7% (119 km²) and bracken (5.6% (245 km².

The extent of moorland in the Less Favoured Areas (LFA) of England was estimated to be 798,969 ha (MAFF Moorland Map of England 1992). Moorland was defined as semi-natural rough grazings consisting mainly of plant species characteristic of grassy and shrubby heaths and moors. Open moors, enclosed land on the margins of the uplands which had reverted to a more natural state, and rock land associated with moorland vegetation were all included. As part of this study (but not recorded in the final report), the presence of dwarf shrub vegetation was also recorded. It was found to occur in 3,060 one kilometre grid squares (over 50% dwarf shrub cover) and 6,400 one kilometre grid squares (5-50% dwarf shrub cover, I. Condliffe, pers comm). The area of upland heath has also been estimated to be 269,000 ha (Felton & Marsden 1990). Blanket peat is thought to cover some 215,000 ha of England (UK Biodiversity Group 1999).

For further details of the location of particular moorland habitats and species, see section 6.5 below.

Habitats and species of moorland

6.3 Why moorland areas are important

A great number of moorland habitats and species are recognised as being of nature conservation importance, either internationally, nationally or at a more local level. Dwarf shrub heath, for example, is extensive in Britain, but has become fragmented and of limited extent in the rest of Europe (Gimingham 1975). Heathland containing gorse *Ulex* species is widespread in the uplands of south west England but no other continental hills have a comparable extent of vegetation dominated by *Ulex gallii*. Blanket mire is globally rare and 10-15% of the world resource is thought to occur in Britain, with the majority in Scotland (Lindsay *et al* 1988).

As well as being important for the plant communities present, moorland areas support many animal and plant species of conservation interest. Heather moorland in particular is rich in species of conservation value (Usher & Thompson 1993, see section 6.4 below). Moorlands are also important because they form the largest extent of undeveloped wildlife habitat remaining in the country (Ratcliffe & Thompson 1988).

The peat of blanket bogs represents a rich archaeological archive which, once lost, cannot be restored or rehabilitated (Brooks & Stoneman 1997). Moorland deposits also make an important contribution to the geological record, especially records of climate change (see Chapter 4).

6.4 Habitats and species of moorland, their nature conservation status and distribution

6.4.1 Vascular plants

The plant species of nature conservation significance in the moorland areas of England are shown in Table 6.2, with their nature conservation status and distribution in the upland Natural Areas. They range from species typical of heaths and blanket bogs to those characteristic of limestone grassland, flushes, ledges or metalliferous soils in the unenclosed uplands of England. While many have a wide altitudinal distribution and are also found outside the moorland environment, some are particularly associated with this situation.

Of particular note are those species identified as a priority for conservation action in the UK Biodiversity Action Plan (UK Biodiversity Group 1998; UK Steering Group 1995). These include an alchemilla *Alchemilla minima*, found in short, base-rich grassland in the North Pennines and Yorkshire Dales, and a euphrasia *Euphrasia rivularis* which occurs in bryophyte-rich flushes in Cumbria. Another euphrasia *E. vigursii* is found in damp, grassy heathland on Bodmin Moor and Dartmoor.

6.4.2 Bryophytes and lichens

Moorland areas support a range of bryophytes (mosses and liverworts) and lichens. In heathland and bogs, these can be very numerous and an important part of the plant community. *Sphagnum* moss, for example, is a vital component of bog vegetation because it acts as a sponge and retains water. Bryophytes are often the first plants to colonise newly exposed ground, such as burnt areas, and are important in stabilising the soil. They may also dominate in environments with heavy-metal-rich soil and some invertebrates depend on them for a food source.

Less is known about non-vascular plants of moorland than about the associated vascular plants, and consequently less information is included here. However, the important bryophytes in the moorland areas of England are identified in Table 6.3, along with their conservation status and distribution.

6.4.3 Plant communities

Heaths

Upland heathland lies below the montane zone (about 600 m in England) and usually above the upper edge of enclosed agricultural land, and is found across the uplands of England. Upland dry heath is dominated by ericaceous dwarf shrubs, particularly heather (also called ling). Other dwarf shrubs include bell heather *Erica cinerea*, bilberry *Vaccinium myrtilus*, crowberry, cowberry *Vaccinium vitis-idaea* and bearberry *Arctostaphylos uva-ursi*. Dry heaths tend to occur on mineral soils with humus-rich surface horizons or thin accumulations of peat.

Upland wet heath is also dominated by ericoid dwarf shrubs, and occurs on peat soils up to about 0.5 m deep, which isolates the plant roots from the underlying mineral soil and rocks (Nature Conservancy Council 1990a, for peat depths >0.5 m see blanket mire). Cross-leaved heath *Erica tetralix* is generally more frequent in wet heath, whereas it is usually no more than occasional in dry heath. Bryophytes, including *Sphagnum* spp., are generally abundant, although they may be absent in degraded stands. Purple moor-grass *Molinia caerulea*, heath rush *Juncus squarrosus* and deer grass *Scirpus cespitosus* may also be frequent or abundant. Wet heath can also occur in transitions from basin mires to heaths.

Dry heath communities are confined to the British Isles and the western seaboard of Europe. Those found in the UK are therefore of significance in an international context. The structure and function of these communities has developed over many generations of human influence in combination with specific local climatic and geological conditions. Of special significance are the communities found over calcareous strata in Cumbria.

Wet heath is restricted in its distribution to the Atlantic fringe between Scandinavia and Normandy. The majority of the wet heath resource in the EU is in the UK and it spans upland and lowland altitudes. Wet heath is usually found in a mosaic with blanket mire and dry heath communities, mainly in the western Pennines and in the south west.

The heaths of the English uplands are described by the National Vegetation Classification (NVC, Rodwell 1991, Table 6.4). Certain upland dry and wet heath communities are included in Annex 1 of the Habitats Directive. They are also included in the Biodiversity Action Plan programme (UK Steering Group 1995; UK Biodiversity Group 1999).

Heathland which occurs in lowland areas of England is covered elsewhere (English Nature & RSPB 1995; Gimingham 1992).

Mires

The uplands contain a great diversity of mire types, many of which are of significant nature conservation value. Many are included in Annex 1 of the Habitats Directive and they are also included in the Biodiversity Action Plan (UK Steering Group 1995; Blanket Bog Habitat Action Plan, DETR 1999).
Six basic types of mire can be distinguished (Heathwaite & Gottlich 1993, Table 6.1) and the National Vegetation Classification (NVC, Rodwell 1991) classifies mires into 38 categories, each further sub-divided (Table 6.4). They can also be sub-divided into fens, which are influenced by water from the surrounding land and range from nutrient poor to rich, and bogs, which are mires deriving their water exclusively from precipitation and generally having a low nutrient status (Tansley 1939).

Sphagnum

One particularly extensive mire type in the uplands is known as blanket bog which is really a misnomer for a wide range of unconfined peatlands. Blanket mire is a more accurate term, where a mire is any peat-forming ecosystem. It is worth noting that the NVC defines communities on the vegetation alone, so degraded blanket bog on blanket peat (> 0.5 m deep) may be inappropriately identified as heath or grassland communities.

Grasslands

The grasslands found in unenclosed moorland areas can be sub-divided into acid, calcareous and neutral grasslands. This sub-division assists the understanding and identification of the different types, which are described by the National Vegetation Classification (NVC) (Rodwell 1992, Table 6.4).

Acid grasslands are the most extensive grassland type in England, being generally derived from the heavy grazing of dwarf shrub communities. They occur from the lowlands to the montane zone and in the unenclosed uplands they may be dominated by such grass species as sheep's fescue *Festuca ovina*, common bent *Agrostis capillaris* or mat grass *Nardus stricta*, or by heath rush. These grassland types are mostly relatively species-poor, but where they are found in association with dwarf shrub and mire communities they can add to the diversity, structure and function of the habitat. Bracken over grassland, or dense stands of bracken alone, is another feature of the unenclosed (and enclosed) uplands.

More species-rich upland acid grassland communities also occur, eg NVC types U4c and U5c, but are restricted in distribution, occurring for example in the North Pennines. Another community, U3, *Agrostis curtisii*, also has a limited distribution and is confined to the south west of England. Other kinds of acid grassland present in the uplands of England are the purple moor-grass and rush pasture communities. These occur on poorly drained soils, particularly in Devon and Cornwall where the habitat is known as Culm grassland. Their vegetation consists of various species-rich types of fen meadow and rush pasture. Purple moor-grass and rushes, especially sharp-flowered rush *Juncus acutiflorus*, are usually abundant. The communities often occur in a mosaic with wet heath, dry grassland, swamp and scrub.

Purple moor-grass and rush pastures are highly susceptible to agricultural modification and reclamation. Only a small percentage of the original resource now remains in the UK and Europe, and fragmentation and isolation of stands have been common. Certain *Molinia*-dominated acid grasslands are included in Annex 1 of the Habitats Directive. Acid grasslands are also included in the Biodiversity Action Plan (UK Biodiversity Group 1998; UK Steering Group 1995).

Calcareous grasslands in the uplands are generally restricted to shallow soils that are derived from a variety of calcareous bedrocks. The majority of upland calcareous grassland is found on Carboniferous limestone in the North Pennines, Yorkshire Dales, Cumbria and Peak District, and the Corallian limestones of the North York Moors. It is inherently more species-rich than acid grassland and supports an exceptional diversity of plants, including rarities and species restricted to lime-rich soils such as blue moor-grass *Sesleria caerulea* and common rock-rose *Helianthemum nummularium*. It can be found as open or dense swards, with a tall and tussocky or short and tightly cropped structure.

Calcareous grasslands are thought to have been widespread at a European scale at the turn of the century. However, as they are particularly sensitive to changes in management, these grassland types are now rare in Europe. They are included in Annex 1 of the Habitats Directive and the Biodiversity Action Plan programme (UK Steering Group 1995; UK Biodiversity Group 1999).

Unimproved neutral grasslands are those which have not undergone agricultural improvement and are generally species-rich. They are usually enclosed and managed as traditional hay meadows or pastures and are covered in Chapter 7 Meadows and enclosed pasture.

Metalliferous communities

These are communities which have developed on metal-rich soils and are also called calaminarian grasslands. They are rare communities that should be maintained and their nature conservation importance is recognised by their inclusion in the Habitats Directive. The soil on which these communities exist can cause pollution problems, particularly by rivers, and if land owners and water companies want to remove the potential source of pollution the communities are threatened.

Examples include metalliferous grasslands in the Pennines, Yorkshire Dales, Peak District ('lead-rakes'), metalliferous mire communities with particular bryophyte interest on Bodmin Moor, and a metalliferous algae community in the River Nent in the Pennines. The communities on spoil-heaps of the Pennine lead mines, for example, have a very characteristic flora which is restricted by the presence of lead and other metals in the soil (Kelly & Perry 1990). Lead-tolerant species such as spring sandwort *Minuartia verna*, alpine penny-cress *Thlaspi caerulescens*, sheep's sorrel *Rumex acetosella* and various lichens and mosses thrive in the absence of competition from other plants. Lead-tolerant varieties of fescue *Festuca* spp. and bent grasses *Agrostis* spp. are also found, and these have proved useful in the reclamation of metalliferous spoil in industrial areas.

Metalliferous habitats are of some value for invertebrates. For example, the nationally scarce ground beetle *Notiophilus aesthuans* seems to favour lead mine spoil in the Yorkshire Dales, as well as occurring in montane areas in Scotland. In addition to their wildlife value, many old spoil-heaps are of considerable geological interest. See Chapter 4 Earth heritage features.

Further information: Antonovics *et al* 1971; Baker 1987; Sellers & Baker 1988; Stewart & Drewitt 1989; Rodwell 2000.

6.4.4 Birds

Unenclosed heaths, grasslands and mires can be important habitats for birds. British breeding birds that are positively associated with these habitats in the uplands are identified in Stillman & Brown (1998) and their definition of upland birds and list of species relevant to England are used here.


Black grouse

Heather is an important feeding and nesting habitat for red grouse *Lagopus lagopus*, and to a lesser extent black grouse *Tetrao tetrix*. Scrubby areas on heaths are also important for black grouse, as well as other birds such as whinchat *Saxicola rubetra* and stonechat *Saxicola torquata*. Ring ouzel *Turdus torquatus*, wheatear *Oenanthe oenanthe*, meadow pipit *Anthus pratensis* and skylark *Alauda arvensis* also breed in the unenclosed uplands, although the last species is more associated with lowland grasslands. Moorland areas provide hunting grounds as well as nesting sites for rare raptors such as merlin *Falco columbarius* and hen harrier *Circus cyaneus*. Peregrine *Falco peregrinus* and raven *Corvus corax* can be found nesting on cliffs within moorland. Few breeding bird species actually appear to be dependent upon heather moorlands (Fuller 1996).

Blanket bogs support breeding golden plover *Pluvialis apricaria* and dunlin *Calidris aplina* and waterlogged areas with pools and mossy hollows of *Sphagnum* are important feeding grounds for these birds. Many other birds also nest in heather and rough grazing areas while feeding in boggy patches, next to water or in agriculturally improved grassland near the moor. Redshank *Tringa totanus* and snipe *Gallinago gallinago* utilise unenclosed and enclosed damp grasslands for breeding and feeding, and twite *Carduelis flavirostris* are particularly associated with the moorland edge. The bird species associated with moorland areas in England are shown in Table 6.5.

6.4.5 Invertebrates

Northern and western British moorlands tend to have some elements of lowland heathland fauna reaching their northern limit and montane species reaching their southern limit. On the whole the diversity is fairly low when compared with lowland habitats, although spiders, ground beetles, rove beetles and craneflies can be diverse. Relatively few scarce species are restricted to moorland. The highest proportion of moorland species are among the moths, ground and rove beetles, money spiders and craneflies. The greatest biomass is in the form of cranefly larvae (leatherjackets) and click beetle larvae (wireworms), including several species of the former and three or four main species of the latter, as well as annelid worms (small white Enchytraeidae). Leatherjackets and wireworms are of particular value for upland birds. In grass moorland and bracken mosaics, the beetle *Phyllopertha horticolor* may also form a significant biomass. Nationally rare and scarce invertebrate species particularly associated with moorlands in England are listed in Table 6.7.

Particularly conspicuous and typical moorland beetles include click beetles and the common tiger beetle *Cicindela campestris*. Moths include the northern eggar moth *Lasiocampa quercus*, emperor moth *Pavonia pavonia* and common heath moth *Ematurga atomaria*. The mountain ringlet butterfly *Erebia ephiphron*,

small heath butterfly *Coenonympha pamphilius* and the large heath butterfly *Coenonympha tullia* are also typical, the last only occurring on bogs. Other typical species include the mountain bumble bee *Bombus monticola,* northern darter *Sympetrum danae,* northern aeshna *Aeshna juncea* and golden ringed *Cordulegaster boltoni* dragonflies, immature stages of the last occurring in streams while the adults range widely over moors.

Further information:
Coulson, Fielding & Goodyear 1992; Fishpool & Usher 1989; Sanderson *et al* 1995; Sutherland & Hill 1995; Usher 1992; Usher & Thompson 1988.

6.4.6 Mammals

Moorland provides the only habitat of the mountain hare *Lepus timidus* in England (Table 6.9). It lives on the *Calluna-Eriophorum* areas at higher altitudes than the brown hare *Lepus europaeus.* This species, which is native to Britain, is found only in the Peak District in England, where it has been introduced.

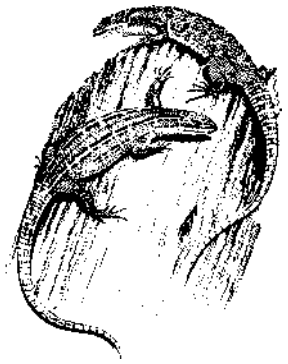
Structurally diverse moorland can provide high densities of small mammals, notably field voles *Microtus agrestis* and shrews *Sorex* spp. (Butterfield, Coulson & Wanless 1981). Voles are herbivores and feed mainly on grasses. As such, they can be found in large numbers on grass moorland and in lower numbers in heather moorland. These form an important element in the food chain, being especially important prey items for birds of prey, such as short-eared owl *Asio flammeus*, hen harrier, buzzard *Buteo buteo* and other animals such as the adder *Vipera berus* and polecat *Mustela putorius.*

Moorlands provide valuable habitats where these are adjacent to woodland blocks. For example rocky, undisturbed moorlands provide valuable habitats for pine martens *Martes martes* when adjacent to large areas of conifer or deciduous woodland. Open moorland can also be a valuable buffer for preventing incursion of grey squirrels *Sciurus carolinensis* to woodlands occupied by red squirrels *S. vulgaris.*

Open moorlands provide areas for foraging for deer. The largest population of red deer in England occurs in the 'West Country' (Langbein 1997), with the best known herds found within Exmoor and the Quantock Hills. The increase in red deer numbers in the south west of England over recent decades has led to mounting concern about deer damage. This is particularly justified in woodland habitats, where regeneration can be significantly reduced. On moorlands the contribution by deer to overall grazing can be important in relation to appropriate levels of domestic stock.

6.4.7 Amphibians and reptiles

Moorlands can provide valuable habitats for both amphibians and reptiles (Table 6.9). Frogs, toads and newts may be more restricted in the use of these areas by the occurrence of suitable breeding ponds. Sometimes moorland ponds are naturally too acidic for successful breeding owing to surrounding peat. However, such ponds are also poorly buffered and can be particularly susceptible to anthropogenic acidification.



Common lizard

Large areas of natural and semi-natural habitat, with low levels of disturbance, favour the development of good and robust reptile populations. These areas can also support a high biomass of prey species (invertebrates for lizards; small mammals, lizards and amphibians for snakes). In such systems, local losses can be replenished by immigration.

Upland habitats, notably moorland and newly planted woodland, are valuable habitats for adders. These snakes are becoming scarcer in lowland habitats in part due to disturbance, as well as habitat loss and fragmentation. The large expanses of structurally diverse habitat, rich in both lizard and mammal prey, are therefore important for this species.

Two species of lizard occur in upland habitats, the common (or viviparous) lizard *Lacerta agilis* and the slow worm *Anguis fragilis*. Both species occur in a wide range of habitats throughout England and can be common in moorland, open woodlands and grasslands.

6.5 Habitat and management requirements of moorland species

Some habitat and management requirements of key moorland species are shown in Tables 6.2 (vascular plants), 6.6 (birds), 6.8 (invertebrates) and 6.10 (mammals, amphibians and reptiles). However, there is generally a shortage of adequate knowledge on the ecological and hence the management requirements of many upland species. Recommendations presented here are based on the best available information or, where there is little or no quantitative evidence, then the opinion of experienced workers in the field concerned. Such recommendations may change as further information becomes available.

Some nationally rare and scarce vascular plant species are particularly associated with dwarf-shrub communities while others occur in grassland, mires or rocky habitats in the unenclosed uplands. Many are not exclusive to moorland areas, and may even be considered to be more typical of enclosed or lowland areas, in which case cross-references to other chapters are made. However, all species require their particular habitat type to be maintained; for example, heaths should not be lost nor mires drained. Many require particular grazing regimes, although the most appropriate intensity varies with the species concerned.

For many non-vascular plants, their ecology is poorly understood and therefore very little information is available on their habitat and management requirements. Bryophytes of mires, wet heath and dwarf-shrub heath generally require minimal intervention, except possibly control of scrub development. Burning, particularly if frequent or intense, can be damaging to some non-vascular plants in these habitats (N. Hodgetts pers comm) and so particularly rich sites or sites with rare species should be

protected from burning. Non-vascular plant diversity and abundance is likely to be greatest in unburnt areas or areas burnt on a very long rotation.

Certain rare bryophytes occurring on moorland have specialised habitat and management requirements. For example, slender green feather-moss *Hamatocaulis vernicosus* is found in base-rich lowland sedge-fens and upland flushes, where the development of scrub and coarse vegetation is prevented by management such as cutting or grazing. In this situation it is necessary to maintain the level and chemical quality of the water table and to maintain levels of grazing or cutting, as appropriate, to prevent the encroachment of tall vegetation. Another rare species, marsh earwort *Jamesoniella undulifolia* occurs in wet mineral-rich *Sphagnum* mires. To maintain this species it is necessary to prevent changes in hydrological conditions, including drainage and flooding for reservoirs. It is also necessary to prevent eutrophication of the habitat, including pollution from agricultural run-off and drift, and damage to the colonies by poaching by cattle.

Many birds typical of the unenclosed uplands rely on heather moorland and require extensive areas of this habitat in good condition to feed and breed. Blanket bog and bracken stands are also important for many bird species. Maintaining moorland habitat diversity, including mires, wet heath and grassland, scrub and trees, and freshwater habitats such as pools, rivers and lakes ensures that the maximum diversity of bird species can be supported.

Moorland areas containing habitat, floristic and structural diversity are particularly valuable for invertebrates. For example, mosaics including heath, wet flushes, grassland, scattered shrubs and trees and fresh water support a diverse invertebrate assemblage, as do areas with significant moss cover and a diversity of exposed substrates, such as bare peat, mineral soil, sand, rocks and stones. Dwarf-shrub communities containing all phases of heather growth, including young and mature heather with a build-up of litter, provide feeding, breeding and sheltering habitats for many types of invertebrates. A range and abundance of flowering plants, especially species with early flowers or a long flowering period, provide important pollen and nectar sources. Animal dung and small hydrological features such as peat pools, *Sphagnum* pools, seepages and stream headwaters, with varied margins to water bodies, are also of value.

Further information:
Birds: Dodds *et al* 1996; English Nature 1996a; Hudson & Newborn 1995; Mason & MacDonald 1999); Phillips 1997b.
Invertebrates: Coulson 1988; Coulson & Butterfield 1985; Gardner *et al* 1997; Gardner & Usher 1989; MacDonald & Haysom 1997; Usher 1992.

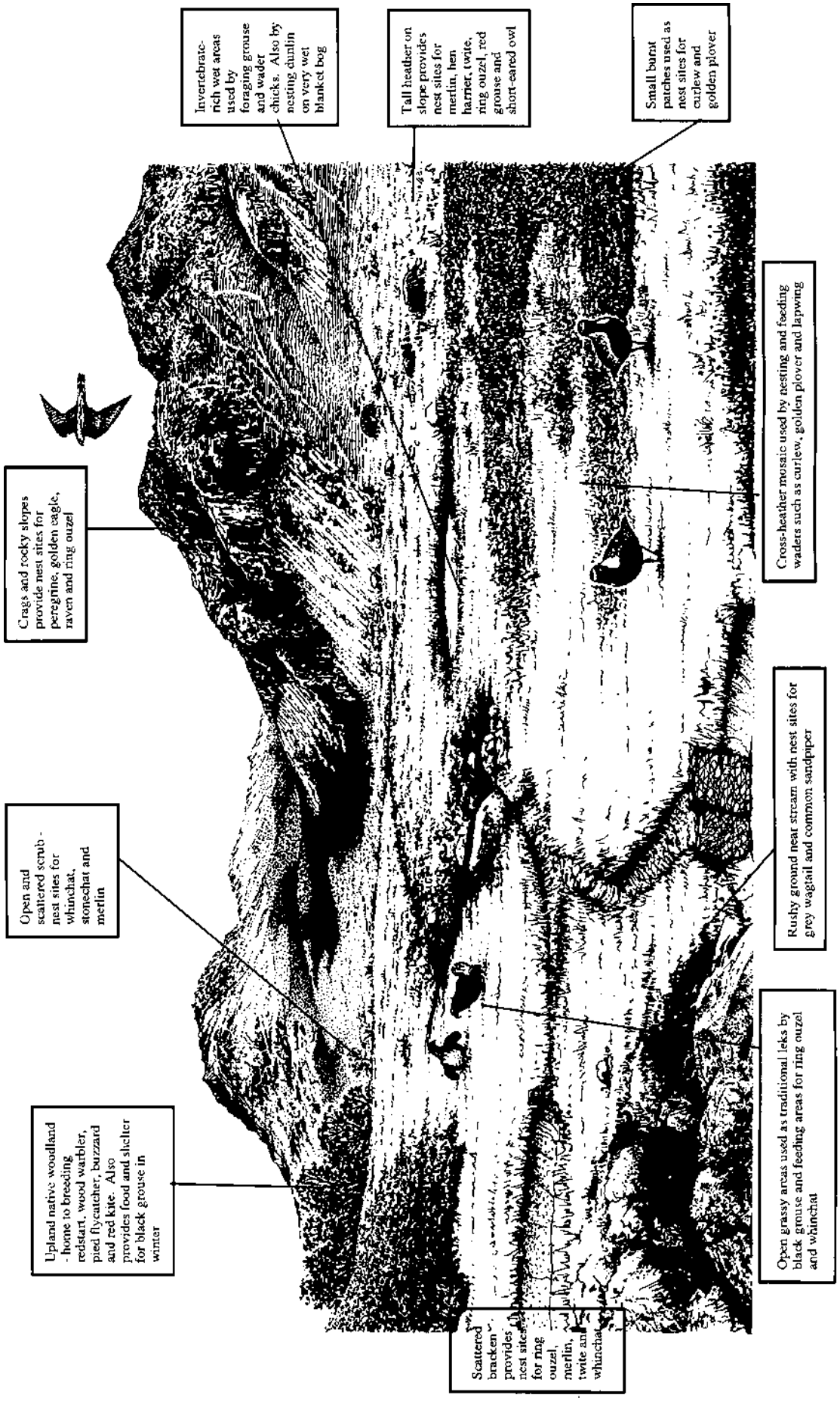


Figure 6.1. Stylised ideal moorland for birds in the English uplands

Management of moorland

6.6 Managing moorland

The main agricultural and sporting management practices conducted in moorland areas include grazing, burning and cutting of heaths, mires and grasslands, and predator control. Other activities include bracken, scrub and rhododendron management, while agricultural improvement and moorland drainage has also been practised in the past. Grazing, burning and cutting are covered in this section, while other management activities, including predator control, reversing moorland drainage, applying surface treatments, managing shrub and recreation, are covered in the following sections (see 6.7). Bracken management is discussed in Information Note 6.

A diverse approach to management in the English uplands is desirable, to assist in maintaining and enhancing biodiversity. This also recognises that different approaches may be traditional and appropriate in different parts of the country, and management objectives may differ between sites.

6.6.1 Grazing of moorlands

Retaining a varied moorland resource requires a balance between high grazing pressure, which can lead to the spread of grasses and loss of dwarf shrubs, and low-grazing pressure, which can allow invasion of some trees and shrubs (Hester 1996; Ward, Macdonald & Matthew 1995).

The three main components of the grazing process are defoliation, trampling and manuring (Crofts & Jefferson 1994). The overall effect of grazing is to reduce the quantity of more palatable plant species and increase the frequency of less palatable and more grazing and trampling resistant species (eg grasses, low and rosette-forming species and distasteful plants). The specific effects of grazing will depend on a number of factors, including the following (Ausden & Treweek 1995):

- the types of vegetation present;
- the condition of the vegetation present (including the proportion of different age classes of heather, if present);
- the timing of grazing (whether year round, seasonal or occasional);
- the intensity of grazing (numbers of animals, length of grazing period);
- the type of grazing animal (species, breed, age, sex);
- the associated practices (supplementary feeding, presence and nature of shepherding practices, use of vehicles);
- the other management practices conducted (burning, cutting, bracken management);

- the existence and location of fences and other boundaries;
- the geographical location of the area;
- the underlying geology, soil type and wetness of the area;
- the climate, topography, altitude and aspect.


Cowberry

All grazing animals are to some extent selective in the plants they eat. Favoured elements of the vegetation are eaten first while less desirable plants are left until last or not eaten at all. There is considerable variation in grazing behaviour between different types of animals, different breeds of the same animal and different age classes within breeds. The grazing preferences of the stock employed will affect the species composition and structure of the vegetation.

Sheep and cattle are the main grazing animals on moorlands, with some horses, ponies and feral goats. Grazing animals other than domestic stock include deer and rabbits. The sheep and beef enterprises encountered in the English uplands are introduced in Chapter 2, with further details in Information Notes 3 (sheep) and 5 (cattle). The grazing characteristics of large herbivores in the uplands are given in Box 2.4. The characteristics of the different breeds of sheep and cattle are described in Information Note 2 (sheep) and 4 (cattle).

Further information: Hester 1996.

Livestock management on moorlands

Shepherding, also termed 'raking', is required for good grazing management of a hill sheep flock. It spreads the sheep and hence the grazing pressure over the hill and reduces the risk of localised overgrazing. It is a practice which has severely declined in recent years, as the number of people employed on upland farms has decreased. Where uneven grazing pressure is a problem for nature conservation interests and shepherding is not currently practised, incentives for shepherding may be an option. For example, moving stock away from the 'bottom edge' of the heather at least twice a week could be beneficial. All Terrain Vehicles are sometimes used by shepherds, but this is best kept to defined routes and only if continued use of a route does not lead to damage to the vegetation.

Appropriate burning management, producing a pattern of small patch burns, also encourages stock to move across an area (see 6.6.2 on burning).

Stock proof boundaries, such as fences and walls where they already exist, also help to control stock movement and hence grazing pressures on moorlands. Repairing or erecting walls or fences in certain areas can be used to reduce or remove grazing. However, new stock proof boundaries often need careful consideration to avoid conflict with landscape and public access objectives, as well as agricultural uses. On common land, permission is required from the Secretary of State to erect new boundaries.

Small fenced areas can be used for monitoring the effects of removing or reducing grazing, although these need to be large enough to avoid shelter effects. Fencing areas around the bases of cliffs may allow

the spread of plants confined to these areas by grazing. Temporary fencing of areas will allow recovery of dwarf shrubs, flowering and seed set of moorland plants, and badly eroded areas to recover.

Fences have been known to kill birds because they can become entangled in wire netting or hit the wire in flight (particularly grouse). Fixing markers to the wire reduces the problem. For further details of fencing options and techniques, together with the associated problems, see Information Note 7 on fencing in upland areas.

Stock feeding is common in the English uplands, where livestock are provided with additional or 'supplementary' feed in winter. This may be in the form of hay, silage, pellets or solid feed blocks and licks. These are placed at various locations around the moor, some even being air lifted to more remote locations. Supplementary feeding is provided because sheep require a better nutrient source in the autumn before tupping and especially in the spring before lambing and during lactation. Alternatively, this nutrient source can be provided by grazing the ewes at these times on in-bye land, agriculturally improved hill pasture or grassland away from the farm.

Supplementary feeding is often crucial to the profitability of hill sheep, and relevant to the nature conservation issue because overgrazing and physical damage to dwarf shrubs is a recognised problem around feeding areas (Evans & Felton 1987). The resulting concentration of animals and the use of vehicles to bring feed can damage vegetation. A feed block, for example, lasts one or two weeks and heather damage adjoining a block can extend to 10 m with the heather taking up to 10 years to recover. Supplementary feeding introduces nutrients and potentially weed seeds into the system. It could also be argued to be unsustainable, because it artificially inflates the number of stock that a given area can support, and so may lead to generally higher grazing levels over the whole management unit. On the other hand, if sufficient feeding sites are used, nature conservation interests can benefit because sheep are encouraged to disperse over a wider area of land (provided stocking levels are not so high that grazing damage continues).

General recommendations concerning stock feeding and watering on moorlands are given below.

- If feed is required at times of year other than in winter, it suggests that the vegetation present is not sufficient to support the stocking levels employed.

- Do not feed stock on land with wildlife interest such as heaths and blanket mires.

- Where winter feeding is unavoidable, any feed, mineral supplements and blocks should be sited on areas with little wildlife interest, such as on acid grassland. It should not be on or ideally within 100 m of dwarf shrub heath, blanket mire or wet, flushed areas.

- Alternatively, rotate the feeding sites regularly to avoid damage. They can be used to aid the dispersal of sheep across the hill if sufficient sites are used.

- Locate water troughs in areas of low conservation interest.

Further information: Roberts *et al* 1996b.

Off-wintering of stock is another important aspect of livestock management in moorland areas. Many farmers remove their stock from unenclosed land for the winter, usually taking them off in October-November and returning them between March-June, depending on the timing of lambing and the weather conditions. Stock are either kept on in-bye land around the farm, or indoors where sufficient housing exists, or sent to other farms with spare grazing capacity for a fee (away-wintered).

Dwarf shrubs are most susceptible to grazing damage in the spring and most vulnerable to grazing in the autumn and benefit from this reduced grazing. For additional benefit, for example to allow recovery of degraded heaths and mires, stock can be removed from the management unit at the end of September and their return delayed until April, May or June. Where off-wintering is desirable for conservation purposes, incentives to increase or introduce this practice, may be an option. Similarly, where sheep housing is unavailable or inadequate, financial help may be needed for additional sheep housing to facilitate increased off-wintering. It is important that off-wintered sheep do not damage other important habitats on the farm or further afield, such as species-rich or wet grassland.

Further information: Chapter 2 , 2.8.3 and Information Notes 1-5.

The effect of grazing on moorland plant communities

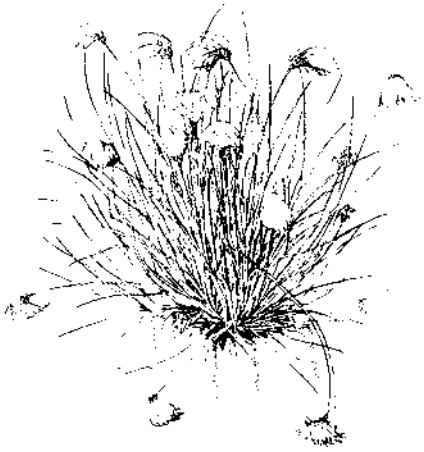
The effect of grazing on moorland plant communities is a well documented but variable process (eg Anderson & Radford 1994; Armstrong & Milne 1995; Grant *et al* 1976, 1978, 1982, 1985, 1987, 1996; Hester 1996; Rawes 1983; Shaw *et al* 1996, 1997; Shaw, Wheeler & Backshall 1997; Welch 1974, 1984a,b&c, 1985, 1986; Welch & Scott 1995). Moorlands are usually composed of a mosaic of plant communities, such as heath, grass and mire, and each is differentially grazed and affected by grazing. They each have their own rates of production and utilisation, and these in turn vary with factors such as climate, altitude and geographic location.

The potential effects of grazing on moorland habitats include both ecological effects, such as:

- changes in the vegetation structure;
- changes in the plant species composition;
- changes in the fauna;
- the introduction of alien plant species;
- the loss of plant and animal species;

and physical effects, such as:

- poaching;
- nutrient enrichment from dung and feed;
- formation of bare ground, tracks and ruts;
- erosion.



Hare's-tail cotton-grass

These effects can be both beneficial and damaging to moorland habitats, but sustainable grazing levels:

- maintain heathland communities and prevent the loss of the heathland fauna and flora;

- lengthen the burning or cutting cycle used to manage the heath;
- increase the diversity of the habitat because animals congregate and influence certain areas in particular ways;
- provide dung which is an important habitat for invertebrates and these in turn provide food for birds.

Moderate levels of grazing may lead to a change in dominance from heather to bilberry. Heavy grazing on poorer soils can bring about the replacement of heather with swards dominated by unpalatable mat-grass and heath rush. On better soils, finer grasses such as *Agrostis* and *Festuca* can replace heather under heavy grazing. Heather can be checked and bilberry encouraged by certain grazing pressures (Welch *et al* 1994).

Local variations in grazing density occur, and can be affected by environmental variations such altitude, aspect, rainfall, soil wetness and pH. These variables determine the type, productivity and hence the carrying capacity of the vegetation, and also affect the grazing behaviour of the livestock (Mowforth & Sydes 1989).

Metalliferous communities may require grazing in order to retain the characteristic metal-tolerant plants such as alpine penny-cress and spring sandwort.

The effect of grazing on moorland birds

Knowledge of the effects of grazing on moorland bird populations is extremely poor and very little is understood about how different grazing levels affect different bird species (Fuller 1996). There are various mechanisms by which grazing animals may influence breeding birds on unenclosed moorland, including effects on vegetation structure, trampling of nests and young, and dunging, which provides invertebrate food.

Certain grazing regimes may have benefits in terms of producing the appropriate vegetation structure. For example, grazing may create short or tussocky vegetation, depending on the vegetation and stock type involved, and both can be beneficial for birds. It can also lead to bare, sparsely vegetated or disturbed ground, which some birds require. However, too many grazing animals can destroy the vegetation and structure required by some birds, such as dwarf shrub heath with tall heather, and remove valuable food sources, such as cotton-grass *Eriophorum* flowers which are very nutritious and are favoured by sheep and black grouse. Grazing animals can also disturb and destroy the nests and young of ground-nesting birds, particularly waders.

A lighter summer grazing regime on flatter, unenclosed ground can provide a short sward of benefit for breeding waders such as golden plover, although different waders have different requirements (see Ausden & Treweek 1995 and Table 6.6). In general, low levels of grazing on unenclosed land are most appropriate for the conservation of moorland bird populations including most ground-nesting waders.

Enclosed upland farmland is of outstanding importance for moorland birds. Not only can it support very high densities of breeding waders, but it is used for feeding before, during and after the breeding season

by many of the birds which nest on adjacent moors. Its management is, therefore, likely to be a crucial factor in determining the health of populations of many moorland nesting birds.

Further information: Fuller 1996; Table 6.6; Chapter 7 Meadows and enclosed pasture.

The effect of grazing on moorland invertebrates

Grazing is a gradual form of vegetation removal when compared with burning or cutting, except at high densities. Its effects are therefore incremental rather than catastrophic, which is important for invertebrates. Catastrophic management, such as sudden periods of very intensive grazing, burning or cutting causes breaks in the continuity and the condition of habitats. This may lead to the loss of invertebrate species, although the scale is obviously important - how catastrophic an event may be depends on the amount of ground covered in relation to the dispersal distance of the invertebrate species.

A good diversity of vegetation structure, including tall and mature heather, tussocks and a build-up of litter, is particularly important for invertebrates. This is especially true for web-spinning spiders and grazing animals also directly destroy webs. Grazing creates or removes diversity in the structure and composition of vegetation, depending on the species and characteristics of the grazing animal and the stocking levels involved. For example, continuous grazing at high stocking densities is likely to create a uniformly short turf with few flowers, which is generally poor for invertebrates. Mammal herbivores also compete with phytophagous invertebrates for food.

For invertebrate conservation on moorland, the main management objective is to maintain or increase the habitat diversity and the structural diversity of the vegetation, which will assist in increasing the diversity of invertebrate species. The diversity of physical structure is particularly important in heathlands, including all phases of the heather cycle from young to mature and degenerate heather with its associated litter. It is also important to ensure continuity of all phases within relatively small areas. Establishing grazing levels which encourage patchiness in moorland swards, rather than even swards, is also beneficial, as is encouraging floral diversity, especially flowering nectar sources in addition to heather.

Grazing can be beneficial for invertebrates which require bare, sparsely vegetated or disturbed ground. Many invertebrates are also associated with the grazing animals themselves, in particular their dung, or with carrion. Other invertebrates are associated with undisturbed and ungrazed areas. See Table 6.8 for habitat and management requirements of moorland invertebrates.

Further information: Shaw *et al* 1996.

The effect of grazing on moorland mammals

The diverse vegetation structure required for small mammals can be maintained by light grazing by stock. In some areas it may even be maintained by 'natural grazing' by deer and voles, and also by climate. Overgrazing can remove the necessary vegetation structure and lead to the loss of small mammals (but see 6.4.6), as well as the species dependent upon them. Heavy stock grazing is likely to lead to competition for resources with deer where these are present. See Table 6.10 for habitat and management requirements of moorland vertebrates.

The effect of grazing on moorland amphibians and reptiles

Terrestrial habitats for the more widespread species of amphibians can be managed in a variety of ways with a view to maintaining structurally diverse conditions. Heavy grazing and frequent burning should be avoided as these remove the structure which benefits these animals and maintains their invertebrate food source. Light grazing can help to maintain an uneven vegetation structure. Natterjack toads *Bufo calamita*, on the other hand, which have now been found in the uplands, may benefit from localised heavier grazing pressures. This not only opens up habitats to provide bare ground and short vegetation for foraging, but also makes the area less suitable for the more widespread amphibians and the grass snake *Natrix natrix*, which is a predator on the natterjack.

Reptiles require a structurally varied ground cover, without heavy shading. The species composition is less important than structure. Management should therefore aim to maintain the latter. Often such vegetation would persist in the absence of management in nutrient poor soils or where grazing is light. Overgrazing or too frequent burning will reduce structural variation and both management techniques can kill animals (through trampling or burning).

Consideration may need to be given to reducing grazing pressure, at least at local 'hot-spots' often associated with southerly facing slopes. This can be achieved through erecting fences; these may be permanent or temporary features that may keep grazing stock off areas at all times or for only the most sensitive times of the year (ie April to September inclusive). See Table 6.10 for habitat and management requirements of moorland vertebrates.

The effect of removing or reducing grazing on moorland habitats

High grazing pressures tend to change dwarf shrub vegetation into grass, rush and sedge communities, which are of lower nature conservation value (Welch & Scott 1995). Much research work on the effects on upland vegetation of removing sheep grazing was reported in a literature review (Marrs & Welch 1991), which led to a number of conclusions.

- There was a large amount of variability in the results of such studies, with few clear trends.
- Where heather was already present in the vegetation it tended to increase in cover at a rate of between 0-5 % per year.
- Where heather was absent, its invasion and subsequent growth was difficult to predict. Grassy bog, tall grass, scrub and woodland vegetation communities developed in different places

depending on initial floristic composition, nearness of seed sources, whether the soil was disturbed and the heather seed activated, and niche availability.

! Lichens tended to increase in some sites.

! There was evidence at many sites that when sheep densities were reduced, other herbivores, including deer, rabbits *Oryctolagus cuniculus*, hares and voles, increased.

Other observations are included below (P. Welsh, pers comm).

! Where a high frequency of suppressed plants remain, rapid (two to three years) recovery of good dwarf shrub cover can occur when the grazing pressure is reduced.

! If a low frequency of dwarf shrubs remains, heather recovery can be aided by light grazing in June to August, and/or by burning after a good seeding year. However, even light summer grazing can restrict bilberry growth.

! If few or no dwarf shrubs remain, the vegetation is likely to become dominated by the tallest growing grass or cotton-grass, with thick litter layers and a reduction in other herb and grass species.

! An absence of animal dung will lead to the loss of specialised invertebrate species, such as the nationally scarce dung beetle *Aphodius fasciatus*, which is associated with sheep and cattle dung in moorland and montane areas (R. Key, pers comm).

A summary table of the impacts of sheep keeping on habitats and landscape features can be found in Milne *et al* 1998.

The MLURI Hill Grazing Management model of the effects of sheep grazing

This computer based model is a means of assessing the effects of a given grazing management regime (stock type, numbers, seasonality) on the vegetation. It does this by predicting the degree of utilisation likely on different vegetation types at different times of year at a particular site (Armstrong & Milne 1995). It is particularly sensitive to estimates of grassland cover on the area concerned, because this forms the preferred grazing of sheep.

The model has proved to be useful as an educational tool and in providing site specific predictions (Armstrong & Milne 1995). These are useful in testing field assessments and expert opinion. Predictions made by the model are likely to become more reliable as further data on plant communities, species and grazing animals are added.

Further information: Armstrong 1993.

Sustainable grazing of moorland

The most appropriate stocking level for any particular moorland area will depend upon all the factors listed in 6.6.1, as well as the purposes of management.

Options for grazing of upland dry heath are shown in Box 6.1-6.3.

Box 6.1 Management options for grazing of upland heath and blanket mire in England

To maintain vegetation in favourable condition
(See Information Note 1 to determine vegetation condition)

Maintain current grazing practices

- Provided grazing practice has not recently altered and is not causing a deterioration of the habitat.
- Remember that recent alterations may take several years to manifest themselves as a cause of habitat deterioration.
- See Boxes 6.2-6.3 for guidelines on stocking rates.
- Favourable condition may also result from a complete absence of stock grazing.

Shepherd sheep to ensure the area is grazed evenly, or as desired

- Consider incentives for shepherding where it is not currently practised.
- Consider concentrating shepherding effort at particular seasons.

Do not feed stock on habitats of nature conservation interest

- Feed may be used at lower altitudes on areas of no conservation interest, such as species-poor acid grassland, to assist in influencing grazing patterns on the management unit as a whole.

To bring vegetation into favourable condition

Where vegetation is unfavourable because of heavy grazing:

Off-winter stock

- Heather is particularly susceptible to grazing damage in the spring and autumn and would benefit from a reduced grazing pressure at these times.
- Where off-wintering is not already practised, consider its introduction.
- Seek a longer off-wintering period, from September to May-June.
- Consider additional sheep housing to facilitate increased off-wintering.
- Consider additional away-wintering to facilitate off-wintering. This involves stock leaving the farm and spending the winter on lower ground.

Reduce grazing

- See Boxes 6.2-6.3 for guidelines on stocking rates.
- Encourage low-intensity farming on the upland unit as a whole and avoid moving large numbers of stock from the moor on to potentially important enclosed land.

Where vegetation is unfavourable because of too little grazing:

- Scrub and woodland development on moorland may be desirable for wildlife in certain situations. Therefore, an increase in grazing may not be required.
- Where the heath is deemed to be threatened by under-grazing, increase grazing to sustainable levels. See Boxes 6.2-6.3 for guidelines on stocking rates.

Box 6.1 Management options for grazing of upland heath and blanket mire in England (cont)

To bring vegetation into favourable condition where the above practices do not bring sufficient improvement

Remove grazing temporarily

- Small fenced plots illustrate the effects of removing grazing and are useful for monitoring purposes.
- Larger grazing exclosures allow a return to a more natural state, increasing overall habitat and species diversity.
- A period of three to five years of no grazing would allow restoration of vigour to suppressed heather plants, or 5-10 years for more badly affected areas.
- Consider temporary fencing out of retreating heather edges.
- A range of grazing regimes across an area, from none to a variety of lightly grazed states, may provide maximum diversity.
- Only return stock to excluded areas when the vegetation has recovered, and at a lower stocking level than had previously caused the vegetation to deteriorate.

Remove grazing permanently

- Where appropriate in the context of the surrounding land and its management, consider establishing areas with no stock grazing, to allow recovery and to enhance biodiversity.

Cross-leaved heath

Box 6.2 General points relating to stocking rates on all habitats of moorland areas

- The following stocking densities are guidelines only because the appropriate rate for a particular area will depend on many factors (see 6.6.1) and the individual characteristics of the site.
- Stocking rates are expressed in terms of Livestock Units (LUs, see Glossary) or sheep / ha (where a sheep is taken to be a ewe plus its followers, ie lambs), or cows / ha (where a cow is taken to be a male or female beef animal).
- Appropriate stocking rates will also depend on the type of stock used and the timing of grazing.
- Most areas contain an intimate mixture of vegetation types, and the proportions of each will affect the number of stock the management unit can support without damaging the habitats.
- When determining grazing levels, other relevant management activities on the land, such as burning and bracken management, will need to be taken into account.
- Cattle, horse or pony grazing can help to reduce the dominance of purple moor-grass, mat grass or heath rush, eg in *Nardus-Galium* (U5) grassland (Rodwell 1992). However, heavy stocking can damage dwarf shrubs and wet ground.
- Where cattle, horse or pony grazing is practised, overall stocking rates should not exceed those identified for sheep (see livestock unit, LU, equivalents in Glossary). A higher degree of caution will be required in addressing acceptable levels and timing of grazing by cattle and horses.
- Stocking rates should not lead to excessive poaching or any indicators of overgrazing (English Nature 1995b & c; MacDonald 1993.).
- An increase in the area of bare ground is a simple indicator of extreme overgrazing.
- High numbers of deer can have a significant effect on the vegetation.
- Consider the requirements of animal and plant species of nature conservation interest, in terms of the grazing regime and vegetation types needed. Generally, a more structurally and botanically diverse habitat will be of benefit.

As heather plants grow larger and more woody their growth rate and form change (MacDonald 1996a). The changes are described classically according to four developmental phases: pioneer, building, mature and degenerate. The vigour of heather plants is greatest during the first two phases while stand productivity is greatest when all the heather plants are in the building phase, when the heather canopy attains maximum coverage and density. In dense, even-aged stands each phase typically lasts from five to 10 years.

Grazing at low densities can benefit heather growth on dry heath by slowing down the rate of heather ageing. It can maintain the plants in the building or maximum phase of growth and prevent them from passing into the later, degenerate phase of growth (Gimingham 1995; Mowforth & Sydes 1989). However, too much grazing leads to the loss of dwarf shrub cover (Hester 1996). Heather cover on upland can also be maintained by other means. This is because heather is able to regenerate by layering,

which is the development of adventitious roots and shoots on prostrate stems, particularly in damp conditions (Gimingham 1988a & b; MacDonald *et al* 1995; see 6.6.2).

Heather cover will generally decline if grazing animals utilise more than 40% of the season's growth (experimentally determined for building phase heather, Grant *et al* 1982). More recent research has indicated that even lower utilisation rates than previously thought may lead to suppression (see Table 2.7). There is generally a positive relationship between stocking rate and utilisation of heather, and a negative relationship with cover of heather (Nolan, Henderson & Merrill 1995). Just as importantly, the structural habitat features which dwarf shrubs provide are eliminated by heavy grazing and this occurs in advance of the loss of dwarf shrubs.

Heather is also grazed most in autumn, winter and spring. It is most vulnerable to grazing during the autumn, after the plants have expended energy on producing flowers and seed, and in the spring when plants are producing their first flush of growth. At these times both the carbohydrate reserves and overwintering shoots can be damaged (Mowforth & Sydes 1989). This covers the period of greatest nutritional demand for the sheep (ie prior to mating, lambing and lactation) and is also the time when grass availability and digestibility decline. Both sheep and heather will benefit if sheep are moved to more productive land during these critical periods, although this is likely to be a problem only if stocking levels are high.

To maintain dwarf shrub cover, stocking levels need to be appropriate to the type and age structure of the vegetation present, as well as the time of year. For example, heather can tolerate higher levels of grazing in the building phase of growth and in the summer months.

Levels of grazing damage to dwarf shrubs tend to be lower in the summer, because stock generally prefer to graze other herbage, which is usually plentiful at this time. Bilberry tends to be grazed most in September and October, with a secondary, lower peak in March and April (FRCA 1997). Bilberry is somewhat more tolerant of heavy grazing than heather, being rhizomatous. At moderate grazing levels heather increases at the expense of bilberry.

When determining appropriate stocking levels for upland heaths, other management practices and issues on the land in question will also need to be taken into account. These may include, for example, burning practices or the number of wild herbivores present, eg deer.

Assessment of grazing pressure on moorland was developed by English Nature using a 'Grazing Index', an easy to use and repeatable method developed for assessing the impact of grazing on heather moorland (Bullock 1997; English Nature 1995b & c). Further work has now been completed by Scottish Natural Heritage (MacDonald *et al* 1998a) and English Nature (see Information Note 1).

Appropriate grazing of upland wet heath

Heavy grazing on infertile wet soils replaces heather swards with indigestible and unpalatable highly acidic grassland dominated by mat-grass, purple moor-grass and heath rush (Hester 1996; Miles 1988). The previous history and stand structure of wet heather moorlands, such as whether and when it was burnt, can have an important effect on the response to stocking rate changes.

Options for grazing of upland wet heaths are outlined in Box 6.1, and stocking rate guidelines in Boxes 6.2 and 6.3.

Sustainable grazing of blanket mire

The sensitivity of blanket bog vegetation to grazing depends on the initial species composition of the sward and the age of the stand. Generally, the wetter the site the lower the productivity of the blanket mire plants and the greater the sensitivity to grazing (Coulson, Fielding & Goodyear 1992).

Hare's-tail cotton-grass *Eriophorum vaginatum* and heather form the majority of the sheep diet on blanket mire during the winter (Grant *et al* 1976). The former is also favoured in early spring, when the flower stems and leaf bases emerge from the dead tussocks (Mowforth & Sydes 1989). This is termed draw-moss or moss-crop in parts of England. It is also grazed in late summer in preference to heather when the productivity of the more palatable grasses falls (Rawes & Williams 1973).

Grazing can either maintain or reduce the cover of dwarf shrubs and other plants, depending on the situation and the grazing level. Light summer grazing, for example, can help to reduce heather domination, shrub invasion and cotton-grass competition in recovering situations. High levels of grazing can reduce the cover of *Sphagnum* and lichens, while *Eriophorum* species and / or purple moor-grass increase in dominance (Coulson, Fielding & Goodyear 1992; Rawes & Hobbs 1979). Light grazing by sheep, without burning, is likely to be an acceptable management for blanket bogs in the interests of conservation (Rawes & Hobbs 1979).

Sheep generally prefer the vegetation found on mineral soils to that occurring on areas of peat (Rawes & Welch 1964). Blanket bog vegetation is comparable in energy content with that on the mineral soils, but has lower digestibility and mineral content. The peat of blanket mires is incessantly leached by rain, is low in available nutrients, and is generally too deep to allow root penetration to the underlying mineral soil.

The density of sheep on blanket bog at Moor House in the northern Pennines, for example, was found to be low, in parts down to 0.02-0.2 sheep / ha (Heal & Perkins 1978). At this density they had little influence on total primary production on most of the bog, removing only a small fraction of the vegetation. Where sheep grazing intensity was increased on blanket bog either experimentally (Rawes & Williams 1973) or through long-term management (Welch & Rawes 1966), the major changes were a decline in the standing crop of heather and an increase in hare's-tail cotton-grass. The presence of heath rush in heavily grazed bogs (0.75 or more sheep / hectare) indicates that the *Juncus*-dominated sward is at least partially caused by heavy grazing pressure.

Taylor & Marks (1971) found that removal of grazing resulted in greater above-ground standing crop of cloudberry *Rubus chamaemorus* with an increased shoot density and larger shoots bearing many more flowers and fruits than grazed plots.

Options for grazing of blanket mire are outlined in Box 6.1, with stocking rate guidelines in Boxes 6.2 and 6.3. See also Box 6.4 for information on grazing of other upland mires.

Box 6.3 Stocking rates on moorland habitats

See options and general recommendations for grazing of moorland areas in Boxes 6.1 and 6.2.
See also examples of stocking rates in various environmental land management schemes (Chapter 7, Table 7.7)

Upland dry heath (NVC types H4, H8, H9, H10, H12, H15, H16, H17, H18, H21)

To maintain dry heath in favourable condition:

- year round stocking rates should not exceed 0.5-1.5 sheep / ha or 0.075-0.225 LUs / ha; (Edwards & Marsden 1991; MAFF 1998b-f); Nature Conservancy Council 1990b; Smallshire *et al* 1997);
- winter stocking rates should be reduced by 25%, with all hoggs, cattle and horses removed, and stocking should not exceed 1 sheep / ha or 0.15 LUs / ha (MAFF 1998b, d, & e);
- increasing altitude and wetness will reduce environmentally sustainable, year round grazing levels to below 1.0 sheep / ha or less than 0.15 LUs / ha.

To bring dry heath into favourable condition:

- year round stocking rates should not exceed 0.5-0.75 sheep / ha or 0.075-0.1 LUs / ha (Evans & Felton 1987; MAFF 1998c-e);
- winter stocking rates should be reduced by at least 25%, with all hoggs, cattle and horses removed, and preferably all stock should be removed in winter.

Upland wet heath (NVC types M15, M16) **and blanket mire** (NVC types M17, M18, M19, M20)

To maintain wet heath and blanket bog in favourable condition:

- undisturbed wet heaths and blanket mires require little management and should be left completely alone as far as possible (Burgess *et al* 1995), but few of these now remain in England;
- no grazing in the autumn or winter, with at most very light grazing in the summer, is the ideal grazing regime for wildlife on most wet heaths and blanket mires;
- year round stocking rates should not exceed 0.25-0.5 ewes / ha or 0.037-0.075 LUs / ha; (Mowforth & Sydes 1989; RSPB 1995);
- winter stocking rates should be reduced by at least 25%, with all hoggs, cattle and horses removed and preferably all stock should be removed in winter;
- year round stocking rates of up to 1.0 sheep / ha or 0.15 LUs / ha may be environmentally sustainable on degraded blanket bogs which lack *Sphagnum* or not do not show active *Sphagnum* growth.

To bring wet heath and blanket bog into favourable condition:

- a maximum year round stocking rate of around 0.1 sheep / ha or 0.015 LUs / ha has been recommended (Evans & Felton 1987), with winter levels again lower still;
- some recovery can be achieved with up to 0.5 sheep / ha or 0.075 LUs / ha in summer and / or complete off-wintering;
- if bare peat is exposed, it is very difficult to stabilise and any stocking will make matters worse;
- restoring high water levels may be the most important factor in reversing deterioration.

Box 6.3 Stocking rates on moorland habitats cont.

Mires other than blanket mire

! See Box 6.4

Unenclosed grassland

Stocking rates will depend on the type of grassland and the objective for the area, for example, whether restoration of heather cover or flowering of limestone grassland is being sought.

Acid grassland (NVC types U1-6)

! Unimproved upland grassland with more than 50% *Agrostis-Festuca* grassland: 5 sheep / ha or 0.75 cattle / ha or 0.5-0.75 LUs / ha all year, or equivalent during the summer only (Countryside Council for Wales 1992).
! Unimproved upland grassland with less than 50% *Agrostis-Festuca* grassland (ie *Molinia* or *Nardus* dominated): 2.5 sheep / ha or 0.5 cattle / ha all year or 0.37 LUs / ha, or equivalent during the summer only (Countryside Council for Wales 1992).
! Stocking should not normally exceed 0.25-0.6 LUs / ha on upland rough grazing pastures (MAFF 1997b, 1998d & f, 1999).

Calcareous grassland (NVC types CG2, CG3, CG6, CG7, CG9, CG10)

! Graze stock at no more than 1 sheep / ha or 0.15 LUs / ha for any continuous period of eight weeks between 1 May and 31 August (Mercer & Evans 1997).
! At any other time graze stock at no more than 2 sheep / ha or 0.3 LUs / ha. Grazing rates may be higher when gathering stock on up to five separate days per year (Mercer & Evans 1997).
! Encourage diversity of the habitat by having some areas only grazed in autumn and others ungrazed by stock.
! See also Chapter 7 Meadows and enclosed pasture.

Neutral grassland (NVC types MG2-10)

! Flower-rich pastures and hay meadows: 5 sheep / ha or 0.75 cattle / ha at any time (meadows must be closed for at least 8 weeks before mowing and the aftermath should be grazed, Countryside Council for Wales 1992).
! Damp and marshy grassland: 0.5 cattle / ha / year. (Lower stocking rates are recommended between 1 March and 30 June to reduce nest trampling, Countryside Council for Wales 1992.)
! See also Chapter 7 Meadows and enclosed pasture.

Upland habitat mosaics

! See Box 6.5

Sustainable grazing of other mires

The desirability of grazing on upland mires other than blanket mires depends on the nature of both the mire and the grazing regime. The mire types concerned (listed in Tables 6.1 & 6.4) comprise small sedge bryophyte fens, valley mires, *Molinia* and *Juncus* fens and springs. They vary in their response to grazing, and as in the grazing of the surrounding vegetation, the effect will depend on the four main variables - the timing of grazing, the duration of grazing, the type of animal conducting the grazing and the number of these animals. Many of these factors will be determined by the agricultural practices on the surrounding land, but some general principles aimed at maintaining the nature conservation interest of the different mire types are explained in Box 6.4.

Some mires, particularly certain flush communities, may benefit from light grazing which can maintain plant and invertebrate diversity by reducing the dominance of more aggressive species and creating gaps by trampling. As these community types almost always occur in mosaics with other vegetation types that are grazed, they are inevitably grazed to some extent.

There is insufficient knowledge and variety in mires to be able to recommend exact grazing levels for these communities. Even if this were possible, it would be difficult to achieve specific management for mires because they typically occur as intimate mixtures with other habitats. However, a range of grazing levels, from light to very light to none at all, would be desirable to obtain maximum habitat and species diversity.

Further discussion of management options for flushed grasslands and mires can be found in Chapter 7 (7.6.4).

Box 6.4 Recommendations concerning grazing of mires within unenclosed upland grasslands

Grazing of upland small sedge bryophyte fens
(NVC types M4, M5, M6, M9, M10, M11, M13)

Timing and length of grazing period

! Graze late in the summer and stop in autumn
The best starting date is sometime in July, to allow flowering and seed set, with finishing dates in the autumn when the mires become too wet, which is generally in October.

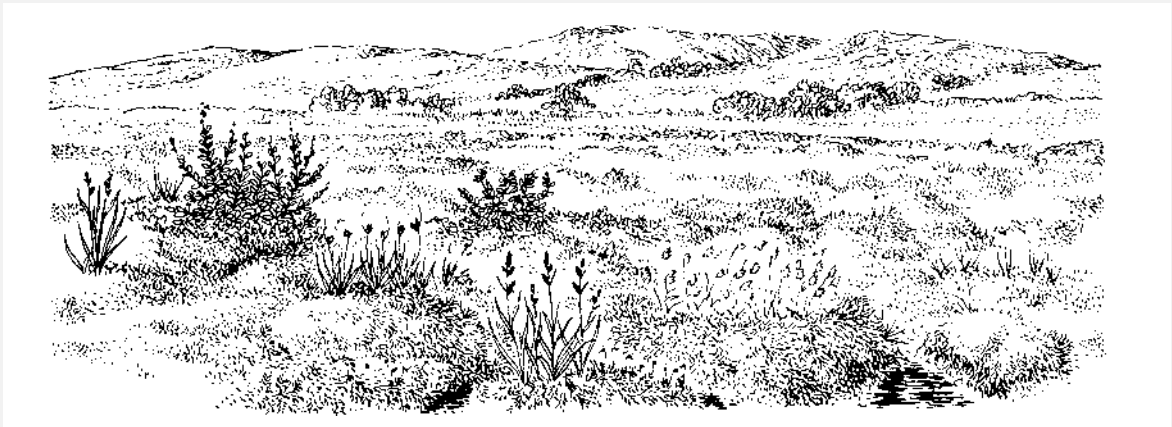
! Avoid excessive poaching by being flexible in the deployment of grazing stock.
Trampling creates an uneven surface which is pitted with holes created by hooves. At low levels this provides regeneration niches for plants, but at high levels it may result in fragmented vegetation and erosion.

Type of grazing animal

! Cattle are preferable for grazing these mire types.
Some of the lighter traditional cattle breeds are most appropriate, and single suckler beef cows are also suitable.

! Sheep are not as desirable because they tend to produce a more uniform vegetation structure.

! Horses and ponies in enclosed grassland tend to crop certain areas more closely while leaving others untouched, principally latrine areas, and this may allow rank vegetation to develop (Burgess *et al* 1995).



Box 6.4 Recommendations concerning grazing of mires within unenclosed upland grasslands cont.

Number of grazing animals

! As a guide, use up to 2 cows / ha (or equivalent) for short periods (until the vegetation is eaten down), or lighter stocking rates for longer, and ideally only on mires where grazing is not damaging (see below).

The stocking rate for the whole grazing unit may be determined by the vegetation type surrounding the mires, but if possible consider the requirements of the mire types present, as outlined below (Rodwell 1991):

M4-5 Wet, fragile habitats that are typically too wet to be grazed and would be damaged by heavy stocking.

M6 Grazing determines the composition of this mire type. If too heavy, grazing may result in a switch from sedge- to more rush- or grass-dominated communities. Grazing alone, or in combination with other management practices such as drainage, burning and applications of fertiliser and lime, can have this effect, eg grazing and drainage combined can convert the community to grassland. Exclusion of grazing may lead to the loss of small plant species and invasion by scrub, with succession to wet scrub woodland in time.

M9 Wet, fragile habitats which are typically too wet to be grazed and would be damaged by heavy stocking.

M10 Most stands are grazed and this mire type requires light grazing and trampling by large herbivores to maintain the species diversity. Too much grazing is likely to be damaging, and grazing by cattle, or sheep and cattle in combination, is preferable. It may progress through tall-herb dominated communities to shrubs or woodland in the absence of grazing.

M11 Anything other than light grazing is likely to be detrimental. Found mainly at higher altitudes in England, where climate and water movement can maintain an open structure.

M13 Grazing, particularly in combination with other treatments such as burning, drainage, mowing, peat cutting and eutrophication, may eliminate this community. However, grazing or mowing can maintain the species diversity of some of the sub-communities, and prevent succession to woodland.

Grazing of upland valley mires (NVC type M21)

! Ideally very little grazing should occur on upland valley mires, although light grazing should not cause significant adverse effects and valley mires dominated by *Molinia* may benefit.

Box 6.4 Recommendations concerning grazing of mires within unenclosed upland grasslands cont.

Grazing of *Molinia* and *Juncus* fens
(NVC types M17, M22, M23, M24, M25, M26)

! Light spring / summer grazing and higher cattle grazing in late summer / autumn allows flowering of species-rich communities (but may conflict with heathland requirements in mosaics).

! In *Molinia*-dominated areas where a reduction in dominance of this species is desired, graze the area relatively intensively (see below), preferably with cattle, during the period of maximum growth and palatability of *Molinia*, ie mid-May to mid-July.

Suggested grazing regimes for *Molinia* 'grass' moor are as follows:

Mid-May - Mid-September:	@ 1.0 cow / ha for M25 / M15 @ 0.3 cows / ha for M17
Equivalent overall annual grazing level:	@ 0.33 cows / ha for M25 / M15 @ 0.1 cow / ha for M17

The overall grazing level could be achieved by grazing for a longer period with fewer stock, but the levels shown should be maintained from mid-May to mid-July.

See also management of *Molinia* in Chapter 7 Meadows and enclosed pasture, and Boxes 6.11 and 6.12 for options concerning burning of *Molinia* grassland.

Sustainable grazing of upland unenclosed grassland

Virtually all sub-montane grasslands in England require some mechanism to prevent succession to shrubs and woodland if they are to remain as grassland. Where the grassland is of value for wildlife, halting this succession is obviously desirable although the presence of some trees and scrub can increase biodiversity. Many upland, unenclosed grasslands are species-poor but some species-rich grasslands also occur, particularly in limestone areas, and these are of value for the plants and invertebrates they support. All upland unenclosed grasslands represent an important agricultural resource.

Grazing is the most common means of maintaining grassland and the nature of the grazing will determine the form of the vegetation. At low stocking densities it will tend to produce a mosaic of tall and short vegetation, especially on larger areas. High stocking rates are more likely to create a uniformly short turf with few flowers (Ausden & Treweek 1995). However, this depends on the grazing animal involved and the timing of grazing. Grazing during the growing season (early spring to late summer) favours those plant species able to survive and reproduce under repeated defoliation. This usually means the more common and competitive grass species. The abundance of palatable tall herbs and species, whose populations rely on plants setting seed, can be considerably reduced.

Winter grazing is preferable for maintaining more grazing sensitive species. If carried out in October to March it can prevent the build-up of vegetation and arrest succession, but still allow plants to flower and set seed. However, grasses are at their least productive and palatable at this time and determining

appropriate stocking rates can be difficult. In moorland mosaics, other vegetation types such as heaths may also be damaged by grazing at this time. Options concerning grazing on upland unenclosed grasslands are shown in Boxes 6.2 and 6.3 and discussed for different grassland types below. See also Chapter 7 Meadows and enclosed pasture.

Many areas of species-poor grassland have been derived from heavy grazing of dwarf-shrub communities. Conservation objectives for some upland areas may, therefore, focus on the restoration of an upland heath resource rather than the maintenance of a species-poor grassland community.

Acid grassland

Acid grasslands can be characterised by the dominant species present. On drier soils, bent *Agrostis* and fescue *Festuca* species can become dominant while on wetter soils rush *Juncus* species and purple moor-grass are more abundant. Mat-grass can also dominate, generally as a result of heavy grazing on the more species-rich types.

Grassland dominated by *Agrostis* (not *A. curtisii* - see below) and *Festuca* species is the most palatable and digestible acid grassland type when there is a high proportion of green material present (Armstrong 1996; Mowforth & Sydes 1989). Although growth of these grasses occurs in all seasons, most is in summer. This dies off in the autumn, resulting in a build up of dead material unless summer grazing is heavy. Dead material is of low digestibility and will build up in the sward if it is grazed lightly or not at all.

Mat-grass is one of the most widespread but least palatable grasses found in the upland grasslands of England. It is grazed by sheep, cattle and horses in late winter and early spring when other vegetation is scarce (Welch 1986), but its leaves are high in silicates and this makes it tough to eat (Armstrong 1996). New growth in spring, which has low silicate levels, can be quite digestible if the new growth can be separated from the previous year's dead material. Intensive grazing will increase the proportion of this grass in the vegetation because other grasses are favoured and grazed more intensively. However, removing grazing can also lead to an increase in *Nardus*-domination, at least in the short term, and will become tall and rank and overshadow other species. This is influenced by the previous grazing regime and soil type involved.

Wavy hair-grass *Deschampsia flexuosa* is less palatable than *Agrostis* and *Festuca* species and is mostly grazed during May to July. However, in grassland dominated by this species it may also be eaten in winter because it is evergreen (Mowforth & Sydes 1989). Grazing of wavy hair-grass generally tends to reduce its abundance.

Heath rush is less palatable and digestible to sheep than grasses but is grazed more readily by cattle and horses (Mowforth & Sydes 1989). It is only grazed in late autumn, winter and early spring when more palatable vegetation is scarce. The *Juncus-Festuca* grassland (U6) is strongly encouraged by particular kinds of burning and grazing treatments on blanket bog (eg in the South Pennines). Once established, *Juncus squarrosus* can be persistent and invasive, but it can decline due to competition from *Sphagnum* or taller vegetation if grazing is reduced or removed.

Purple moor-grass *Molinia caerulea* dominates large areas of poorly drained land in the uplands of Britain, particularly in the south west (Torvell, Common & Grant 1988). In traditional sheep production *Molinia* is usually little grazed, although it can provide a useful resource for the summer grazing of hill cattle.

Ungrazed *Molinia* can develop very tall tussocks which are difficult to reduce or remove. Under continued heavy grazing pressure *Molinia* grasslands can spread (Welch 1984a), particularly on wetter soils and where burning is practised.

Molinia is deciduous and has a short but highly productive growing season. It is quite digestible between May and July when the new growth is available and it is readily grazed at that time (Welch 1984). Fresh growth of *Molinia* has the feeding value of cultivated grasses but a lower calcium content (Mowforth & Sydes 1989). However, the digestibility quickly declines and the swards generally contain a high proportion of dead matter which has negligible nutritional value (Armstrong 1996). As a consequence, these grasslands do not provide grazing in the winter (Grant *et al* 1963). See section on grazing and *Molinia* in Boxes 6.2 and 6.3 above, Grant *et al* 1996 and burning of *Molinia* in Boxes 6.11 and 6.12.

Bristle bent *Agrostis curtisii* dominates large areas of grassland on moors in the south west of England. On Dartmoor, for example, it is more abundant than *Nardus*, and governs the carrying capacity of the land for grazing stock. It is relatively unpalatable, of low agricultural value and particularly prevalent after burning.

Calcareous grassland

Calcareous grasslands are mostly found on shallow soils over limestone and are often species-rich and of considerable nature conservation interest. The various calcareous grassland communities found in the uplands are dependent on a certain balance of grazing for their maintenance (Rodwell 1992). In agricultural terms they are important for grazing of cattle and sheep, because they tend to be very palatable and the nature of the substrate or topography often renders cultivation impractical. Stock will graze them in preference to heaths or more acid grasslands where a choice is available, leading to the greatest grazing pressure and dung deposition occurring in these areas. See also Chapter 7 Meadows and enclosed pasture.

Further information: Roberts, MacDonald & Wood-Gee 1996b.

Grazing of habitat mosaics

Moorlands are generally very varied and rarely consist of just one habitat type. Vegetation mosaics of heath, grassland and mires are widespread and very valuable for wildlife interests. Hill grazing systems are usually made up of such mosaics, over which herbivores are able to range freely. Grazing animals have seasonal preferences for different types, typically preferring the more palatable grasses in spring and summer and switching to heather only in the winter when the growth of grass has declined. The utilisation of heather will vary for each management unit, depending on the area of palatable grass present and the grazing pressure exerted on it. The latter is determined by the seasonal stocking rate and the type, breed and size of the animals involved. Management units with a higher proportion of more palatable grass can generally support more stock.

Heather occurs in mixtures with other species and in mosaics with other vegetation types. The palatability of these other species, which may vary through the year, may affect grazing on the heather (Armstrong 1996; Hester & Baillie 1999; Mowforth & Sydes 1989). For example, local concentrations of heather grazing will occur near grassy areas and patches of palatable or reseeded grassland. Heather

which is mixed with *Agrostis-Festuca* or *Deschampsia flexuosa* grassland is more likely to be eaten than heather which is mixed with grasses of poor forage value such as *Molinia caerulea* and *Nardus stricta*. Flushes are also preferentially grazed.

Apart from calcareous grassland where it occurs, *Agrostis-Festuca* grassland is the most preferred upland moorland vegetation of sheep. The presence of this grassland type increases the number of sheep that an upland grazing unit can support. However, it also attracts grazing animals, sometimes leading to localised damage to the vegetation when they have a free range and can congregate.

Vegetation mosaics may lead to conflicting management requirements. For example, cattle grazing may be desirable for flushes but less so for areas of dwarf shrub heath. In some cases, fencing may be an option, to allow different management regimes to be implemented on adjoining areas of land. In other situations, compromise regimes, or seasonal or annual variations in grazing, may be all that is practical. In reality, the vast majority of the English uplands comprise mosaics grazed under one regime. The Macaulay Land Use Research Institute model (MLURI, see) has the potential to help when determining appropriate grazing levels for upland habitat mosaics. See Box 6.5 for options for grazing upland habitat mosaics.

Box 6.5 Options for grazing of upland habitat mosaics

Grazing of *Agrostis-Festuca* grassland - heather mosaics

! Use the two pasture systems recommended by the Macaulay Land Use Research Institute (MLURI, Mowforth & Sydes 1989).

  If reseeded pastures or *Agrostis-Festuca* grasslands are available in upland areas, these are most usefully integrated into the moorland grazing programme by using them only when herbage quality is most important to the sheep, ie in the autumn prior to tupping and in the spring immediately before lambing and during lactation. In this way, lamb production can be maintained while damage to heather may be reduced.

! Adopt appropriate and different stocking levels for the *Agrostis-Festuca* grass and heather areas where it is possible to maintain them (see boxes above).

Grazing of poor grass - heather mixtures

! In areas of acid grassland dominated by mat-grass or purple moor-grass, measure or estimate the area of heath and calculate stocking rates on the area of heath alone (see stocking rates for wet and dry heaths above).

! Graze so as to allow scattered mosaics of shrubs and woodland to establish in poor grass areas, to increase the diversity of habitats and wildlife present (Usher & Thompson 1993).

6.6.2 Burning

The principles of moorland burning

Burning has been used to manage vegetation in Britain for centuries, principally for stimulating new growth of grasses or heather. Careful, periodic burning of upland vegetation can have advantages for agriculture, game rearing, wildlife conservation and intrinsic landscape appeal. However, inappropriate and careless fires in the uplands can be more damaging than a complete lack of burning management.

If vegetation is to be managed by burning then a range of burning regimes, from more intensive, to less intensive and no burning at all are best for biodiversity. This desirable range of regimes applies across an individual site as well as across the country. It will create a mosaic of habitat types with vegetation of different ages, composition and structure. These in turn will support a diversity of animal and plant species.

The most commonly burnt upland vegetation type is dwarf shrub heath, although some burning of blanket bog, enclosed and unenclosed grassland, bracken and shrubs is also undertaken. Burning alters the vegetation composition, pattern, physical and age structure, nutrient status and carrying capacity for herbivores, as well as the associated fauna. A summary of the advantages and disadvantages of burning for different land uses is given in Table 6.11.

Natural regeneration of heather

Heather moorland is the most commonly burnt habitat in the uplands and burning is particularly associated with grouse moors. Heather regenerates after burning by re-sprouting from the bases of the stems (if these survive and are not too old and woody), or by the exposure and germination of seeds which have lain dormant in the upper few centimetres of the soil. In both cases the new shoots produced grow more vigorously than on the bushes prior to burning, ie the plants are rejuvenated. Re-sprouting heather plants can grow much more quickly than heather seedlings. But re-sprouting from dormant buds on the stem bases declines as bushes become larger and more woody. Re-sprouting tends to occur best when stems are less than pencil thickness. So when older stands are burnt germination of seed can be the principal means of regeneration.

It is a common misconception that heather will disappear if it is not burnt (Macdonald 1996a). This is only likely to occur in old, even-aged heather stands, those which are heavily grazed, or in situations where prolonged, regular burning has reduced the capacity of stands to maintain themselves vegetatively. However, heather is able to regenerate vegetatively by layering under the right conditions without the need for burning (Gimingham 1988b).

Heather stems buried by the growth of *Sphagnum* and other mosses produce adventitious roots and these continue the growth of the heather stems. This process, known as layering, promotes natural regeneration without the necessity to burn. Layering tends to be associated more with deep peat and more sheltered conditions (MacDonald *et al* 1995), although it also occurs in dry heaths. It rejuvenates heather plants and stands in which vigorous layering is maintained will not become degenerate. High levels of productivity can be maintained for many decades and it can lead to a diverse age structure and mixture of species.

Hence heather cover can be maintained for many decades in the uplands by layering, without burning, even in drier eastern areas. However, regular burning (or cutting) is likely to reduce the capacity of stands to maintain themselves by layering should burning (or cutting) cease. In the absence of burning such stands may undergo successive degenerate phases while conditions conducive to layering slowly become established. In the absence of succession to woodland, heather cover is likely to stabilise eventually, with the formation of an uneven-aged and unevenly structured stand.

To burn or not to burn?

Whether burning is or is not appropriate for a piece of land will depend on the objectives for that particular area. These objectives may be for nature conservation, game, agriculture or landscape, although these land uses are not mutually exclusive. Achieving these objectives may or may not require burning. The advantages and disadvantages of burning various habitats for different land uses are shown in Table 6.11.

If it is decided that burning is necessary to achieve the desired objectives, the actual effects of burning on any particular area will depend on the following:

- the vegetation composition and condition, including the proportions of different communities, species distributions, age and structure;
- the previous management history, particularly whether the site has been burnt, drained or grazed;
- the current management regime, particularly the grazing intensity and whether shepherding is carried out;
- the method of burning, including frequency, patch sizes and pattern, and the time of year;
- the likely intensity of the fire, which is particularly influenced by the weather conditions;
- the nature of the substrate, such as mineral soil or peat, its depth, water content and organic content;
- the surrounding vegetation, such as bracken or woodland;
- the local physical conditions, such as climate, altitude, aspect, exposure and topography.

The decision to undertake burning should also consider the following points:

- the availability of appropriate labour, equipment and expertise to burn, because without these burning may be uncontrolled and damaging;
- the likelihood of a planned, appropriate burning programme being continued into the future, because sporadic burning may be worse than none at all.

Burning should not be carried out in areas where it would be the introduction of a new management practice. Additionally, it should be stopped in areas where its original introduction extended the practice into inappropriate locations and habitats (see Boxes 6.8, 6.11 & 6.12).

The creation of fire breaks may be necessary to prevent more extensive uncontrolled fires. These wildfires can lead to the loss of valuable wildlife habitats, threaten public safety and property, tie up the emergency services, cause erosion and scar the landscape for considerable periods of time. Large stands of woody heather or extensive areas of dense grass litter may develop in the absence of burning, and these can sometimes pose a fire hazard. In these situations, burning may be appropriate to reduce the fuel available to burn, to create fire breaks and generally reduce the likelihood of uncontrolled fires.

Maintaining some areas unburnt or burnt on a long rotation can be of great benefit for wildlife. Recommendations concerning burning of dry heath, wet heath, blanket bog and grassland for nature conservation purposes are given in the following sections.

Post-fire succession on dwarf shrub heath

After a fire on dry heath, heather and other dwarf shrub stands show a fairly regular pattern of succession, although this can be influenced by the grazing pressure. A typical pattern would start with a predominance of grass species and sometimes bilberry *Vaccinium myrtillus*, because they are able to grow and spread faster than heather after a fire. Eventually these are overtopped by heather and become only minor components of the sward. However, this pattern is affected by the frequency of burning. Heather itself may be lost if moorland is burnt too frequently, because this prevents it from out competing other species which are quicker to establish, particularly grasses (Mowforth & Sydes 1989). When an area has been left unburnt for a long time, the old heather bushes may not regenerate vegetatively when burning is reintroduced, but the presence of a seed source may allow successful seedling establishment if ground disturbance occurs.

Regular burning of peatland communities can cause a shift from *Sphagnum*-richness to a distinctly heathy vegetation (Rowell 1988). This depends on the nature of the fire and is most likely with particularly hot fires which can lead to drying of the peat and changes in its nature and structure. Light fires at longer return intervals may have little effect.

The effect of burning on moorland plants

Heather

Burning can maintain heather in the building stage of growth and prevent it from reaching the degenerative phase. The capacity of heather to recover from burning depends on:

- the age of the heather stand being burnt;
- the presence and age of a bank of dormant seed in the upper few centimetres;
- the presence of dormant buds at the base of the stem;
- the temperature of the burn;

! the intensity of grazing pressure.

Other plants

The balance of vascular plant species can be altered by burning. Some plants have adaptations which render them relatively resistant to fire, eg growing points at or below ground level. Purple moor-grass, deer grass *Trichophorum cespitosum* and hare's-tail cotton-grass are examples of such species (Rowell 1988). Other species are more adversely affected by burning and changes in the competitive balance are as important as the effects on the vigour of particular plants.

Non-vascular plants can be harmed by burning, although there has been little research on this subject (Shaw *et al* 1996). The intensity and frequency of the fire is critical. For example, damage to bryophytes can be avoided if a quick fire occurs when the ground is frozen (Rowell 1988). Some species, including certain, but not all, *Sphagnum* species, are also capable of rapid recolonisation following burning (Daniels 1991). Low intensity fires on blanket bogs at more than 20-year intervals may have little long-term effect on *Sphagnum* species, but moderate to high intensity fires at return intervals of less than 20 years can eradicate them.

Where the climate is appropriate, stable, layering stands which have experienced prolonged periods without any form of major disturbance provide a favourable habitat for certain liverworts (and invertebrates) which need high humidity and shelter (MacDonald 1996a). Many of these species are uncommon and/or have poor powers of dispersal and recolonisation, and may be lost if burning is introduced.

The effect of burning on moorland birds

Red grouse

Regular burning is undertaken on grouse moors to provide the mosaic of heather types required by red grouse. These birds require a mosaic of stands of heather of different ages for feeding, sheltering, nesting and rearing their young, and these conditions are provided by regular moorland burning. For example, young heather is utilised as food while older, taller heather provides good cover in which nesting grouse can avoid predation and find shelter in bad weather.

The purpose of burning on grouse moors is principally to restructure the vegetation so that feeding sites and nesting sites of appropriate height are provided for grouse or sheep (MacDonald 1996a). Red grouse need an intimate mixture of short heather (10 cm to 20 cm tall) for feeding and taller heather (20 cm to 30 cm) for nesting. They tend to avoid heather which is taller than 35 cm. For sheep, on the other hand, the principal management aim is to maintain most of the heather less than 20 cm tall, with some limited taller areas to provide accessible food during snow.

Heather can comprise 90% of the diet of grouse, although other plants are also utilised. Cotton-grass is of great value for grouse, particularly the flowers in the spring when food is a limiting factor. This food source is also eaten by sheep. Invertebrates also form an important part of the diet of grouse, especially the chicks, and are particularly numerous in wetter areas.

Further information: Hudson & Newborn 1995.

Other birds

Moorland management for grouse has an important role to play in maintaining the extent of open heather (RSPB 1998). Grouse moors provide extensive areas of heath and have the potential to support breeding populations of characteristic species, such as hen harrier, merlin, golden plover, black grouse and twite.

However, moorlands managed for grouse are not necessarily of high nature conservation interest for bird species other than red grouse (Brown & Bainbridge 1995). No other birds appear to share the same habitat preferences and aversions as do red grouse, and other moorland may be of equal or even higher value. Moorland bird species show a range of habitat associations and a higher species diversity would be expected in areas with a mosaic of different habitat types than in areas of pure heather moorland (Stillman 1995).

The distribution of breeding birds suggest that they are particularly affected by changes in the vegetation structure and composition, which affect the breeding, roosting and feeding potential. See the habitat and management requirements for moorland birds in Table 6.6.

The effect of burning on other moorland animals

A fire sweeping through the vegetation will kill all of the less mobile animals living above ground, and depending on the severity, many of those inhabiting the surface layers of the soil (Rowell 1988). Well controlled, winter burning is least damaging and burning small patches of habitat in rotation, as in management for grouse, will help to prevent whole populations from being destroyed.

Invertebrates

Different groups of invertebrate species are affected differently by burning, some increasing in burnt areas while others decline (Shaw *et al* 1996). Burning affects invertebrates both directly, by destroying individuals and their prey, and indirectly through changing the physical habitat characteristics and plant species composition. The latter affects both the vegetation structure and food sources for invertebrates.

The type and scale of burn determines the severity of the impact. Rapid, light winter burning allows many invertebrates to survive in the surface layer of soil, in damp litter, mosses and tussocks, and some species are in resting stages at this time. Hotter fires kill many more invertebrates. Large burns may prevent recolonisation.

The maintenance of a mosaic of different aged *Calluna* stands, including some areas which are never burnt, is the best conservation strategy, for example, for lepidoptera on northern heaths, because it maintains species diversity. The mobility of most invertebrates and the relatively small plots which are burned at any one time enable recolonisation by many invertebrate species. Individual species, however, may benefit or be harmed by burning, and where rarities are known to be present on a moor, their particular habitat requirements should be considered.

As with some plant species, stable, layering stands of heather which have had prolonged periods with no major disturbance can support certain invertebrates which need high humidity and shelter (MacDonald 1996a). Many of these species are uncommon and / or have poor powers of dispersal and recolonisation.

Burning of grassland can be detrimental to invertebrates. If virtually all the above ground vegetation is destroyed, entire populations at a site may be eliminated. It is particularly damaging to relatively immobile groups such as molluscs, which can be very slow to recolonise even small burnt sites (Kirby 1992).

Mammals

For mountain hares, traditional grouse moor management can be beneficial. Regular (eg 12-year rotation) burning will ensure a continued flush of young heather, which provides the primary food of this species. However, burning should be in a mosaic, so that hares have mature vegetation for cover and young heather for feeding within their home ranges. They also like large patches of short vegetation so that they can see predators and easily escape. Typically these habitats need to be provided within the 1-km range. Highest densities are found in heather moors overlying base-rich rocks, with fewer being found in areas over poor acidic rocks.

Amphibians and reptiles

Burning is not necessary to maintain amphibian and reptile populations. Where burning is conducted, to minimise the effects on these groups it should only be done during the winter and on as small an area as possible. It should be no more intense than to produce a light impact on the vegetation. Large burns are particularly detrimental to these animals, although mosaics of smaller burns and mature heather should be less problematic to reptiles.

Moorland burning and the law

Burning is restricted by law to a certain period of the year and all burning must follow the legal requirements and management guidelines detailed in the MAFF (1992a) Heather and Grass Burning Code and Scottish Natural Heritage Muirburn booklet (Scottish Natural Heritage 1993). See Box 6.6 for the legal requirements concerning burning and the following boxes for recommendations concerning burning of different habitat types.

Box 6.6 Legal requirements for moorland burning

Legal requirements for burning

Burning of heather, grass, gorse, bracken and bilberry is governed in England and Wales by The Heather and Grass etc. (Burning) Regulations 1986 (SI 1986 No. 428), as amended by The Heather and Grass etc. (Burning) (Amendment) Regulations 1987 (SI 1987 No. 1208).

See the MAFF leaflet *The heather and grass burning code* (1992a) and the Scottish Natural Heritage leaflet *A muirburn code* (1993).

By law, burning is only allowed between:

- 1 October-15 April in the uplands (ie Severely Disadvantaged Less Favoured Areas).
- 1 November-31 March in the lowlands.
- At other times under a licence which can be obtained only in very specific circumstances.

Licence applications must be made to the local office of the Ministry of Agriculture, Fisheries and Food (MAFF) 28 days in advance and no more than 56 days before burning is to finish.

Those undertaking burning must:

- Give not less than 1 day nor more than 7 days written notice of intent to burn to neighbours and owners and occupiers of the land, with details of dates, time, place and extent of the burn.
- Ensure that sufficient people and equipment are on hand to control the burn.
- Take all reasonable precautions to prevent injury or damage to people and animals.
- Follow special arrangements and plan well in advance if burning on a Site of Special Scientific Interest (SSSI). Burn according to a burning plan agreed and consented by English Nature.

Those undertaking burning must NOT:

- Start burning between sunset and sunrise.
- Cause a nuisance through the creation of smoke.
- Create dark smoke.
- Start a fire which is likely to injure, interrupt or endanger road users.
- Damage scheduled ancient monuments.

Burning dry heath for nature conservation

If not carried out appropriately, burning dwarf shrub heaths can be counter productive for grouse moors, agriculture and nature conservation alike, altering or destroying plant communities along with their associated invertebrate and bird populations. Developing burning programmes, utilising existing expertise and acquiring the necessary labour are all important in establishing appropriate burning management of moorland areas. A variety of burning management regimes, across one area of land as well as across the country, from more regular burning management to a total absence of burning in some areas, will best serve the needs of nature conservation.

In the absence of burning and the presence of nearby seed sources, heather-dominated areas may be colonised by shrubs and trees. These can regenerate in heather stands in gaps that are formed when plants age and begin to die back, opening up the bushes from the centre. Where the main objective is to maintain the dwarf shrub heath, control of some scrub invasion by burning may be appropriate. However, where the heath is sufficiently large for some loss of habitat to be acceptable, establishing scattered mosaics of native scrub and woodland, for example of hawthorn *Crataegus monogyna*, rowan *Sorbus aucuparia* and birch *Betula* spp, may be desirable.

Timing

Where burning is desirable for the objectives of the area, it should allow sufficient time for heather to regain dominance but prevent it from accumulating too much woody material. Heather is best burnt when it has reached the end of its building stage or the early mature phase. The time taken to reach this stage will depend on the climatic and edaphic conditions prevailing locally, but usual rotations are around 10-15 years (Coulson, Fielding & Goodyear 1992). A practical way to adjust the burning regime to take account of local productivity is to burn when the heather is 20-30 cm tall.

Generally, the older the heather stand at the time of burning, the longer the time taken for regeneration. From a wildlife point of view, this is not necessarily a disadvantage, because slower regeneration tends to encourage a more unevenly structured sward and a wider range of plant species to establish. For conservation purposes, some longer burning regimes will be desirable to favour certain plant and animal species, eg merlin *Falco columbarius* (to provide taller nesting cover), lichens (intolerant of frequent burns).

In practice moors are usually burnt in spring, often because this is the only time when the weather conditions are favourable. Some research suggests that heather regenerates more successfully after autumn fires (Mowforth & Sydes 1989). However, frost-heaving of seedlings over the winter may reduce successful regeneration, even if more seedlings appear. Spring burning can be preferable if it is conducted on cold, frosty days when the fire travels swiftly across the vegetation because it is less likely to damage species such as *Sphagnum* mosses.

Temperature

The temperature of the burn is very important if regeneration of heather is to be successful. A good burn clears away all the above-ground parts of the plants but leaves the stem bases from which, beneath the soil surface, new shoots are produced that can draw on the fully developed root system. A second means of regeneration is from the germination of seed and establishment of seedlings, which usually requires

hotter, more intense fires to clear the litter and produce a good, consolidated seed bed. The actual temperature produced is determined by a number of factors including:

- wind speed;
- rate of passage;
- the amount of moisture in the vegetation;
- the amount and nature of the combustible material.

Old heather consists of a greater proportion of woody stems and can burn hotter and for longer than younger heather (Mowforth & Sydes 1989). However, old, degenerate stands tend to burn very irregularly and are not necessarily hotter. The most important factors are the amount of foliage and other combustible material, and the height of this above the ground, because of the effects of wind and air supply. Tall heather with a large amount of canopy material forming a continuous, finely divided, well aerated fuel source can be very intense and almost impossible or dangerous to control.

Some of the highest temperatures and longest durations of high temperatures have been found in building and mature heather stands (Hobbs & Gimingham 1984). As with older heather, the structure and especially the height of these stands is the important factor. Particularly severe burns can alter the physical structure, the chemical composition and even the hydrology of the soil, which influences the resulting vegetation and the appearance and character of the landscape.

Traditional grouse moor management does not favour low intensity fires because they leave large amounts of debris on the surface, which can retard regeneration (Whittaker & Gimingham 1962). However, this type of burn may favour a range of species other than grouse and be most appropriate for certain sites, eg those with reptile interest. If heather stems are thin and young (eg 1-4 mm diameter), they will resprout quite readily and the remaining litter is less of a problem.

Frequency

Bell heather, bilberry and cowberry may be temporarily abundant or dominant after fire, but are gradually suppressed by the regrowth of heather (Gimingham 1972). Where frequent burning suppresses heather regrowth these species can attain lasting dominance. Where burning is relaxed, the heather stands can become degenerate and less suitable for grouse and sheep grazing. They may also be open to invasion by grasses or bracken or, if seed parents are present, shrubs and trees (although this may be desirable for the nature conservation objectives of an area of heath).

Burning *Calluna*-dominated stands on mineral soils at about 3-6 year intervals shifts the dominance to grasses, especially wavy hair-grass on well drained soils and purple moor-grass on poorly drained soils (Miles 1988). This is because dwarf shrubs need sufficient time to grow tall enough to begin to shade out the graminoids, which regrow much more rapidly after disturbance.

Recommendations concerning burning of dry heath are contained in the following boxes.

Box 6.7 General recommendations concerning burning of dry heath

- Follow the legal requirements contained in Box 6.6.
- Plan a long-term programme of burning for the area concerned.
- Identify areas where burning would be harmful (see Box 6.8), mark them on a map and exclude these from the burning programme.
- Identify areas where burning is not necessary, because the heather is already regenerating vegetatively by layering, and exclude them from the burning programme.
- Identify areas where burning is desirable to promote diversity and mark them in a map for inclusion in the burning programme.
- Where burning is appropriate, it should be continued on a regular rotation basis, because this keeps stock moving around the moor and prevents recently burnt areas suffering excessive grazing.
- Use a variety of burning cycles and patch sizes across an area, to improve habitat complexity (see Boxes 6.9 and 6.10). Aim for patches as small as possible but occasional larger fires may suit some species.
- Burn some heathland areas and margins less intensively to encourage habitat diversity, particularly abutting onto other habitats.
- Consider cutting some areas instead of burning them (see section on cutting below).
- Ensure herbivore levels are appropriate to retain heather (see section on grazing above), and preferably stock should be shepherded to spread grazing evenly across the hill.
- Ensure that a sufficient total area is burnt at any one time to prevent concentration of livestock on recently burnt patches, to the extent that they severely poach the ground or retard or obliterate dwarf shrub regeneration.
- Follow the recommendations in the following boxes, including the safe burning guidelines in Box 6.10.

Box 6.8 Areas to be avoided when burning dry heath

To benefit wildlife, do not burn in the following situations:

Vegetation types:

- Dwarf shrub stands which have not been burnt for long periods (more than 40 years), where known, and which have well developed layering.
- Flushes and valley mires, because these important habitats can be damaged.
- Grass-heath mosaics, because the grassland may spread at the expense of the heathland, although this depends on the frequency of fire and the grazing pressure.
- Areas of bracken, and dwarf shrubs into areas of bracken. It may be advisable to leave or cut a strip of 5 m from the bracken edge, or burn narrow strips '30 m wide' at right angles to the bracken edge. Vigorous heather regeneration may be able to hold its own against bracken.
- Areas where the grazing pressure exceeds 1.5 ewes per hectare (or equivalents for other animals), because the regrowth is likely to be eaten out by stock, although this depends on the total area burnt.
- Areas where stock tend to congregate, as again the regrowth is likely to be eaten out.
- Large blocks of vegetation, because burning in smaller patches benefits all land uses (see Box 6.10), although the total area burnt is again important in preventing livestock from accumulating on burnt areas and grazing off the regeneration.

Physical conditions:

- Wet, shaded or humid situations (eg steep northerly slopes, bogs) where layering is likely and species sensitive to burning are likely to be found.
- Steep, rocky or scree slopes, rocky outcrops, gills and cloughs, because of the risk of erosion and the wildlife value of these habitats.
- Exposed summits, ridges, areas above the natural tree line (about 600 m), and where heather is already prostrate through natural causes, because vegetation cover here is often patchy and growth very slow.

For birds:

- Known merlin and hen harrier nesting sites, and also leave some areas of long heather elsewhere for new breeding birds.
- Wet flushes and small areas of cotton-grass, because cotton-grass flowers are an important food source in their own right and these areas are important sources of invertebrate food for birds.

For woodland and scrub:

- Some heathland margins, particularly adjacent to native shrubs and trees such as hawthorn, rowan and birch, so that mature dwarf shrub and scrubby vegetation can develop and diversify the habitat.
- Next to forests, woodlands, scrub and hedges, because of the danger to these features. Cutting here may be useful to create fire breaks.
- Juniper scrub, because of its wildlife value and slow regeneration (but see 6.7.4)

Box 6.9 Length of burning rotation for dry heath

- Take account of local productivity; grouse moor managers burn when the heather is 20-30 cm tall.
- For nature conservation objectives heather may be allowed to grow taller than 20-30 cm before burning, although the possible affects of this on the regeneration of dwarf shrubs and plant species diversity must be considered.
- Burning rotations can be from 6-10 years on Exmoor in southern England to 10-15 years in Scotland (Hester & Sydes 1992; Mowforth & Sydes 1989). In reality, particularly in the north of England and in Scotland, they are often much longer. They tend to be shortest towards the south and east and at lower altitudes.
- A longer rotation of 12-20 years may be preferable for nature conservation interests, because stands of dry heath in favourable condition (see Information note 1) can be 15-20 years old.
- Lengthen the burning rotation to say 20 years in the south west of England and 15 years in the Pennines, at least in some areas, and have other areas which are never burnt.
- Long burning rotations are particularly relevant on slopes, above gullies and cloughs, and at the moorland edge. This allows the heather to grow taller to provide nest sites for birds such as merlin, hen harrier, twite and ring ouzel.
- Use a shorter burning rotation on some flat or gently sloping (<15^{o}C) ground to keep a short sward for nesting waders.
- A variety of burning rotations across a moor may be desirable.
- Once it is determined how many years it takes for the heather to reach the desired height, divide the total area in the burning programme by this number to obtain an average figure for the area to be burnt each year.
- Where heather is the dominant species but grows in mixtures with grasses, lengthen the burning cycle until the plants are taller than the height recommended above, and at least taller than the grasses (excluding flowering stems of grasses).

Box 6.10 Guidelines for safe moorland burning

Public safety

! Plan and be prepared well in advance.

! Inform the fire service when burning commences and when it is finished for the day.

! Have a mobile telephone or radio system available for calling up extra assistance or the fire service.

! Erect warning signs.

! Ensure fires do not put neighbouring areas at risk.

Weather conditions

! Burn when the weather is dry enough to allow a controlled burn but not so dry that the burn will be too hot.

! Choose a day with a steady but gentle breeze (Force 3, 7-10 knots or 8-12 miles per hour), which would move leaves and small twigs constantly but not blow dust about or move small branches of trees.

! Burning after frost or when the ground is wet helps to avoid damaging fires.

Equipment and people

! Use sufficient people who understand the work and know the ground well.

! Wear appropriate protective clothing; use fire resistant clothes and helmets with tinted, heat resistant visors, and avoid gloves because this allows the temperature of the fire to be assessed.

! Have sufficient, appropriate equipment on hand; the following can help:

- ❏ knapsack sprayers with diesel are effective for initiating fire fronts;
- ❏ water-sprayers should be used to control the fire, either knapsack ones for putting out small fires and hot spots, or vehicle mounted sprayers for larger areas, preferably on vehicles with a low ground pressure;
- ❏ plenty of beaters and scrapers should be available;
- ❏ foam additives increase the volume of water and are simple and easy to use;
- ❏ fire-retardant foam is another option.

! Be realistic about the area of heather you intend to burn; estimates vary, but a guide for England is about 2 ha per person per day, which is calculated using a speed of fire advance of about 2 m per minute, a fire width restricted to 30 m and 6 hours of actual burning time in a day.

Box 6.10 Guidelines for safe moorland burning (cont.)

Fire breaks

! Choose natural boundaries for the burn wherever possible, or create fire breaks as soon as possible in the season.

! Fire breaks need to be at least 6 m wide and preferably more than 10 m long.

! Break up large areas of tall heather initially with a lattice pattern of long fire-breaks (Phillips & Watson 1995). These can be created by careful, small scale burning or cutting (see section on cutting below).

Direction of burns

! Always burn away from woodland, forests, scrub, mires, steep slopes, ancient monuments, and other areas of conservation value.

! Burn with the wind, preferably downhill and towards a fire break. Burning against the wind, or 'back burning', can be used to create fire breaks. It produces a hotter fire than burning with the wind, and is more difficult and will require greater expertise and man power.

! Control both flanks of the fire at a desired width, leaving the fire front to move in the predetermined direction, or have at least one flank defined by a natural or prepared fire break.

Size of burns

! Burn a patchwork of widely scattered, small areas across the moor, for example, long narrow strips up to 30 m wide and covering about 0.5-1.0 ha. Smaller burns are less likely to produce intense fires and are easier to control. They also provide structural diversity for birds and other animals, and help to spread the grazing pressure of sheep across the moor.

! On slopes, relatively shorter burns should be used down hill and longer burns along the contour of the slope

Severity of burns

! Burn so as to leave the bases of the stems, from which heather will regenerate vegetatively.

Burning of blanket mire and wet heath for nature conservation

The question often raised in relation to blanket mire and wet heath is whether or not it should be burnt. Fire cycles on mires are not fully understood (Lindsay 1995), but burning these habitats in the same manner as dry heaths is thought to reduce their conservation value (Usher & Thompson 1993). Burning on blanket mire and wet heath is not required to maintain their nature conservation interest (Mowforth & Sydes 1989; Rawes & Hobbs 1979) and for this reason it should be minimised and where possible eliminated.

Burning has a marked effect both on the floristic composition and production of blanket mire and wet heath vegetation (Heal & Perkins 1978). For example:

- unburnt bog can have greater species diversity than burned bog (Hobbs 1984);
- some plants, notably *Sphagnum* mosses, can be eliminated by burning;
- hare's-tail cotton-grass recovers quickly after burning and can become dominant;
- hare's-tail cotton-grass above ground standing crop after five years can be about 65% of the total vascular plant community (Gore & Olson 1967), and can assume permanent dominance if the community is burnt frequently (Rawes & Hobbs 1979);
- a short burning rotation (every 10 years) can result in increased dominance by *Eriophorum* spp, while a long burning rotation can lead to greater abundance of heather after fire;
- crowberry, bilberry and grasses can be encouraged if burning rotations are short;
- heather regenerates more slowly, taking about 20 years to regain its full dominance, when it can contribute 70% to the above-ground standing crop (Forrest 1971);
- heather on blanket bog may eventually be eliminated by a 10-year burning cycle;
- cloudberry and cross-leaved heath may dominate initially after fire, but are likely to be succeeded by heather during long intervals between fires (Mowforth & Sydes 1989).

The actual effects of burning on any particular area will depend on a number of factors, as discussed earlier. Recommendations concerning burning of blanket mire and wet heaths are contained in Box 6.11.

Box 6.11 Recommendations concerning burning of blanket mire and wet heath

- As a general rule when managing mires for nature conservation, if in doubt, do not burn (Brooks & Stoneman 1997).
- Where blanket bog and wet heath is in favourable condition (see Information Note 1), the ideal option for nature conservation purposes is not to burn at all.
- A 20-year burning regime is the recommended minimum rotation for blanket mires (Mowforth & Sydes 1989) and a burning rotation of 20-30 years may be preferable.
- Where burning is conducted, for conservation purposes it is desirable to convert some areas (wetter, steeper, higher altitude locations) to no burning areas.
- When conducting any burning on blanket mire or wet heath, follow all the legal requirements, areas to be avoided and other recommendations contained in the previous boxes.
- Large areas of old, tall heather on wet substrates are ideally left unburnt, because of the risk of very hot fires and little regeneration.
- Large areas dominated by cotton-grass *Eriophorum* spp. are best avoided because this will encourage these species, unless accompanied by stock reduction as part of a restoration phase.
- Areas which contain pools or peat hagging, and close to eroding runnels, should also not be burnt.
- Where accidental fires are likely and extensive areas of old, woody heather exist, burn fire breaks as a precaution (Mowforth & Sydes 1989) or consider cutting fire breaks (see below), but consider the possibly damaging effects of the use of machinery.
- Areas where *Molinia* is present at more than 20-30% cover, are best not burnt, because this will encourage this grass, but see Box 6.12 on burning of grassland.

Burning of upland unenclosed grassland for nature conservation

Burning of grassland favours plant species best able to withstand the effects of the burn, notably those with perennating structures protected at or below the surface of the ground (eg purple moor-grass and mat-grass). On wetter upland soils purple moor-grass and rushes *Juncus* spp. are sometimes burnt to prevent tussock formation and promote succulent new herbage for livestock (Crofts & Jefferson 1994).

As a rule, burning alone should not be used to manage grasslands. It can encourage purple moor-grass to dominate, and the nutrients released during burning can also encourage other undesirable plant species to invade. The aftermath needs to be grazed, and in conjunction with grazing, burning can be an effective reclamation technique.

Recommendations concerning burning of grassland are contained in Box 6.12 (and see 7.7.6).

Molinia *grassland*

Burning has traditionally been used in upland areas to burn off dead and unpalatable parts of purple moor-grass to provide an earlier, more nutritious and more accessible flush of young, palatable grass for grazing. Summer grazing on *Molinia* grasslands is only readily available if the leaf litter is burnt every year (Miles 1971), or if the tussocks are grazed intensively in the spring, usually with cattle (Grant, Hunter & Cross 1963).

Yearly burning perpetuates *Molinia* and debilitates heather (Miles 1971). *Molinia* is liable to dominate after burning on suitable damp substrates because most of its buds are protected from the fire by its dense tussocks (Mowforth & Sydes 1989). If it is not burned or grazed regularly, *Molinia* litter builds up, quickly smothering other vegetation and increasing its dominance. It can form large tussocks which may be very difficult to use or remove.

In certain areas, burning *Molinia* is beneficial for birds. In the South Peninnes, for example, burning removes the *Molinia* litter and exposes a rich source of seeds for twite and other finches in early spring. It also encourages flowering and seed production in grasses.

The major aims in management of *Molinia*-dominated areas for wildlife are to reduce the dominance of this species to allow more diverse communities to develop, and to produce habitats which are suitable for invertebrates and birds such as breeding waders. Recommendations for burning *Molinia* grassland are contained in Box 6.12. See also Boxes 6.2 and 6.3 on grazing of grasslands.

Lesser clubmoss

Box 6.12 Recommendations for burning upland unenclosed grassland
(For information on burning of meadows and enclosed pasture, see Chapter 7)

Do:

- Follow the legal requirements and general recommendations contained in the previous boxes.
- Burn in January, February or March to reduce the adverse effects of fire on flora and fauna.
- Burn small portions of the site on rotation, to decrease the likelihood of eliminating entire populations of plants or animals, and to increase the rate of recolonisation from the surrounding unburnt areas.
- Burn in small patches to provide a variety of conditions for wildlife.
- Burn on dry winter days when the ground is cold or wet, and there is a steady, gentle breeze (about 7-10 knots or 8-12 miles per hour).
- Burn with the wind, because it is less damaging to invertebrates as the fire travels faster and is cooler.
- Leave areas of tall, dense or tussocky vegetation to provide cover for small mammals and invertebrates.
- Identify natural fire breaks, or create them by rotovating or 'backburning' strips of land at least 5 m wide.
- Graze the aftermath.
- Leave some areas out of the burning cycle for a couple of cycles, to mature and develop a tussocky structure with a build up of litter, for invertebrates which require these conditions.
- Ensure there are always some areas in the mature, tussocky state, and that when they are eventually burnt there has been a period of overlap in condition with other areas that are allowed to retain this condition.

Do not:

- Introduce burning on un-burnt sites until the implications for the communities and species present are understood.
- Burn unless some sort of management regime, such as grazing, mowing or increasing the stocking density, is to be introduced after the burn (unless grazing at appropriate levels and times is not possible).
- Burn an entire site.
- Burn the same area every year.
- Burn where *Molinia* is present as part of a mixed plant community because it will increase rapidly at the expense of other species.

6.6.3 Burning and grazing combined

Burning and grazing of dry heath

To maintain dwarf shrub cover on dry heaths where grazing and burning occur together, the right balance needs to be attained. Limited grazing with appropriate burning can be compatible with maintaining dry heath. Heavy grazing causes the loss of heather whatever the burning practice.

Carefully burnt areas may be better able to withstand grazing than unburnt areas, because it promotes vigorous heather growth, which is more able to tolerate grazing. The mosaic of heather stands that results from patchwork burning also helps to spread the grazing pressure across an area. On a moor well managed by burning, moderate levels of sheep grazing can benefit both sheep and grouse, by maintaining the heather in the pioneer and building phases. This has the added benefit of increasing the interval needed between fires, with a concomitant reduction in the adverse impacts of burning (Shaw *et al* 1996).

The effect of grazing depends on the area burnt at any one time, as well as the relative attractiveness of recently burnt and less recently burnt areas. For example, small patch burning can lead to overgrazing of regeneration if labour is too limited to burn a sufficiently large number of patches to spread out the grazing impact. A large number of small burns or a few larger burns can actually reduce the tendency for regenerating heather to be overgrazed, provided the stocking rate is sufficiently low.

Burning and grazing of blanket mire and wet heath

In many upland areas of Britain, unfavourable burning and grazing regimes on wet moorlands can lead to a decline in the cover of heather, and its replacement by grass, sedge and moss species (Birse 1980).

Grazing of blanket bog at an intensity of less than 0.1 sheep per hectare can have a detectable effect on *Calluna* production during development after burning. The shoot weight can be reduced by 30-40% compared with growth in exclosures (Rawes & Williams 1973). Cloudberry can also be significantly affected by burning and grazing (Taylor & Marks 1971). A sheep density as low as one individual per 40 ha affects this plant because sheep preferentially graze its leaves and shoots. Burning increases the number and size of shoots produced and the period of peak grazing intensity on blanket bog corresponds with the time of maximum vegetative growth and flowering of cloudberry. Hence burning and grazing combined lead to virtually no flowers or fruits developing on this species.

After burning, grazing can allow hare's tail cotton-grass to gain dominance at the expense of dwarf shrubs, and considerably reduce the lichen cover (Rawes & Hobbs 1979).

Burning and grazing of *Molinia* grassland

Burning of *Molinia* has traditionally been used, particularly in the south west of England, to burn off dead and unpalatable plant matter and so provide a flush of young, palatable grass for grazing. Heavy grazing on infertile wet soils replaces heather swards with indigestible and unpalatable highly acidic grassland dominated by purple moor-grass or other species (Hester 1996; Miles 1988). Burning alone also encourages this species. However, burning and then grazing relatively intensively during the period

of maximum growth and palatability of *Molinia*, ie mid-May to mid-July, can help to reduce the dominance of this species. See Box 6.4 regarding grazing of *Molinia*, Box 6.11 on burning of *Molinia* and also management of *Molinia* grasslands in Chapter 7 Meadows and enclosed pasture.

Further information: Todd 1997.

6.6.4 Cutting

In some circumstances moor burning may not be an appropriate management practice to use to encourage the regeneration of heather and introduce structural diversity in the vegetation. For example, burning may not be possible or desirable owing to:

- unsuitable weather conditions during the legally permitted time period;
- the proximity of other land uses, which would be damaged if fires ran out of control (eg forestry);
- high recreational use of an area;
- the presence of important, fire-sensitive animal or plant species, such as certain bryophytes and lichens;
- the lack of appropriate expertise or manpower.

In such situations, cutting can offer a potential solution (Ward, MacDonald & Matthew 1995) and has become increasingly important as a substitute for burning. It is also used as an additional tool to assist moorland burning practices, for example:

- in the cutting of fire breaks;
- in breaking up large areas of old, leggy heather and allowing the re-establishment of a burning programme;
- in providing a practical alternative to burning where this is not possible or desirable (see above);
- in cutting of drain sides to maintain visibility for safety;
- in fitting into the other demands of the farm when convenient and when labour is least in demand elsewhere, eg in January or February;
- in helping to control purple moor-grass where burning would be unsafe.

On the negative side, cutting, like burning, is a drastic and catastrophic event for the vegetation and its associated fauna (unlike the incremental effects of grazing, for example). The machinery used in cutting can damage fragile peaty ground and is restricted to areas with suitable topography. Cutting is also

more expensive than burning, although the sale of cut heather for commercial purposes can reduce the cost (North York Moors National Park 1991).

Cutting appears to promote shoot regeneration, and for young heather stands on drier substrates little difference may be found in the rate of regeneration after burning or cutting (Gardner, Liepert & Rees 1993). However, in old stands of heather, cut areas may take longer to regenerate than burnt areas, and sometimes may not regenerate at all. The pulse of high temperature experienced during burning is thought to stimulate seed germination and vegetative growth of heather and a number of other species (Whittaker & Gimingham 1962). In addition burning removes the old stems and accumulated litter, which may prevent or slow down seedling germination and growth if the litter is not removed after cutting.

Cutting is probably best regarded as a complementary method to burning, being used where and when burning is not possible or desirable, and for creating fire breaks to improve fire control (Ward, MacDonald & Matthew 1995). It may also be an effective alternative to burning in vegetation containing a high proportion of purple moor-grass. Here mowing, removing the litter and grazing the aftermath can lead to increased species-richness. Recommendations concerning cutting of heather are contained in Box 6.13.

Further information: MacDonald 1996b; North York Moors National Park 1996; Snow & Marrs 1997.

The effect of cutting on moorland birds

Following the recommendations in Box 6.13 regarding cutting times should avoid any problems this method may cause to moorland birds.

The effect of cutting on moorland invertebrates

As with burning, the sudden and uniform effects of cutting can have an adverse impact on invertebrate populations, particularly those of specialist, monophagous species feeding on the aerial parts of plants. However, cutting may be less harmful to invertebrates than burning because it allows mobile and litter species to escape or avoid destruction. If an area is cut once a year, then it will be least damaging to invertebrate populations if this is done in late autumn or early spring.

Box 6.13 Recommendations concerning heather cutting

Time of heather cutting

Unlike heather burning, cutting is not restricted by law to any particular time. However, it is important to consider the following points:

! Avoid cutting during the main bird-nesting season from mid-April to the end of July.

! If possible, cut during the burning season, from 1 October to 15 April.
Regeneration is generally better after spring rather than autumn cutting.

! Avoid cutting near popular areas if it is carried out during the flowering season because complaints from the public are likely to result.

! Avoid cutting when the ground is saturated, as this can damage the peat surface.

! Cut when appropriate for the vegetation concerned, eg every 10-20 years for heather growing alone or in mixtures with grass, but more frequently for fire breaks alongside forestry.

Areas to avoid when cutting heather

! Avoid wet areas and bogs, which are sensitive to disturbance and important for wildlife.

! Avoid cutting large areas of old heather because regeneration is unlikely to be very successful.

! Retain some areas of old heather for the benefit of nesting birds.

! Avoid archaeological sites, which can be easily damaged by cutting and vehicles.
Records of known sites are held by Local Authorities and National Parks.

! Avoid steep and rocky ground, and check the area for large stones as these can damage cutting equipment.

! Leave a bank of old heather adjacent to roads because this will reduce the visual impact of the cut areas.

Box 6.13 Recommendations concerning heather cutting (cont.)

Method of heather cutting

! Plan a programme of cutting.

! Plan the size of the cuts.
- ❑ Short cuts should be no more than 1 ha in size and preferably smaller if habitat diversity is to be increased.
- ❑ If long cuts are made, the edges should be wavy to blend in with the landscape and contours.
- ❑ The cut should not exceed 30 m in width.

! Leave a 10 cm heather stem above the ground.

! Use a 4-wheel drive tractor and on softer ground fit double wheels, to reduce compaction of the peat and the risk of bogging down.
A Turner flail is extremely effective on both young and old heather (North York Moors National Park 1986).

What to do with the cut heather

! Do not leave material on the cut area as this prevents regeneration.
- ❑ However, this depends on the density and nature of the cut material and the prevailing climate. Brash will break down more rapidly in western locations which experience frequent wetting and drying, and if the cut material is finely divided and thinly spread.
- ❑ The brash can be rowed up on one side of the cut using equipment such as a helipede rotary win rower or a Vicon aerobat.
- ❑ The rows can then be gathered and removed.
- ❑ Alternatively, a double-chop forage harvester can be used, which chops the material finely and allows it to be incorporated into the soil quite rapidly.

! Do not store bales or heaps of cut heather on the moorland, as this kills the underlying vegetation and looks unsightly.

Uses of cut heather

! If the heather is cut after the flowering season it can be used as a seed source for restoration work on eroding or fire-damaged moorland. Alternatively, there are a number of commercial uses for cut heather.

Source: North York Moors National Park 1993a.

6.7 Other techniques for managing moorland

6.7.1 Controlling predators

Predator control is practised over substantial parts of the English uplands and has many potential effects on bird and mammal populations. As a result, common generalist predators such as crows and foxes are scarce over large areas of the uplands.

Foxes, stoats, weasels and carrion crows are the main predators of grouse on moorland and may be controlled by legal means. Legal predator control may also benefit other upland breeding birds (Brown & Bainbridge 1995), because it reduces predation on eggs and chicks. Such predation has been found to be a major direct cause of breeding failure in curlews, for example (Grant 1997). Nest predation is widely believed to be the most important cause of reproductive failure in birds in general (Cote & Sutherland 1995).

Predation may contribute to bird population declines by exacerbating problems caused by other factors such as cold weather, changing agricultural practices and the use of pesticides (Cote & Sutherland 1995). However, the role of predation in causing long-term declines of bird populations is far from clear. Some studies of predator removal programmes have resulted in increased breeding success or increased brood size of the target species, but evidence for longer-term benefits is more limited. Predator control may also allow higher densities of red grouse and other ground-nesting birds to exist than would otherwise be the case, although this has not been proven.

Where predator control is conducted it is particularly important in the late winter and early spring, although controls are needed all year, because if a hen bird is lost early in the season the chicks which she may have produced are also lost. Good farming hygiene is also important, because sheep carcasses and other edible waste encourages predators, particularly crows and foxes (although carrion is a useful food source for other birds such as buzzards). Crow numbers can be controlled using Larsen traps, and foxes are controlled by a variety of legal methods. The number of game keepers employed in grouse moor management has declined over the years. Therefore, where predator control is no longer practised, the breeding success of birds such as golden plover may decline (Parr 1992, 1993).

Certain birds of prey, hen harriers in particular, are considered by some moorland managers to be significant predators of grouse. Their persecution has led to conflict between conservation and grouse shooting interests (Redpath & Thirgood 1997). Illegal persecution on moors with a grouse shooting interest is suspected as a major factor in the serious decline of the hen harrier population in Britain (Clarke & Watson 1997). The number and distribution of hen harriers in England is believed to be limited by persecution (Etheridge, Summers & Green 1997). The distribution of grouse moors strongly limits that of buzzards and ravens, although it has not been proven whether this is because of persecution or several other factors such as moor management, and food and nest-site availability (Gibbons *et al* 1994). The killing of such birds is strictly illegal.

Further information: Hudson & Newborn 1995; Redpath & Thirgood 1997.

6.7.2 Managing the hydrology of moorland areas

The effects of moorland drainage

Artificial drainage damages moorland communities. It can lead to changes in the hydrology, morphology and ecology of blanket and other mires. It produces very few benefits and can lead to a variety of adverse effects (Burt, Heathwaite & Labadz 1990; Coulson, Butterfield & Henderson 1990; Heathwaite & Gottlich 1993; Hobbs 1986; Lindsay *et al* 1988; Stewart & Lance 1983, 1991; Thompson, MacDonald & Hudson 1995). These effects include:

- a lowering of the water table, especially in summer;
- a change in the pattern of water retention and movement in the peat body, the effect varying from a metre or so either side of the drainage ditch to far wider impacts and being influenced by the hydraulic conductivity (density) of the peat;
- drying the peat, resulting in a decrease in the permeability and bulk of the peat, and the processes of primary consolidation, shrinkage, secondary compression and wastage or subsidence of the mire surface;
- aeration of the peat, leading to chemical and biological changes which result in solute release;
- an accelerated rate of decomposition and erosion of the peat;
- changes in the water quality of the run-off and receiving water bodies, because of changes in the chemical characteristics and sediment loading;
- changes in both the magnitude and spatial distribution of run-off;
- an increased incidence of flooding;
- an increase in the silting-up of streams;
- a loss of wetland plants;
- a reduced number of invertebrates, which are used by grouse and other upland birds as a protein-rich food source for their chicks;
- a reduced invertebrate diversity, particularly of the scarcer species which tend to be associated with wetter areas;
- young birds, sheep and lambs becoming trapped in the open drains or ‘grips’;

Moorland drainage used to be subsidised and widely practised, with the intention of improving the vegetation for grouse or grazing stock. Now the grants are no longer available and it is generally discouraged and has declined.

Hydrological management of upland mires

Water supply is the key environmental factor that underpins the existence of all peat-forming systems or mires. Management of the hydrology of mires is of prime importance; management of the vegetation is a secondary factor, only possible once the water balance is under control (Rowell 1988).

Mire characteristics vary according to the mean position of the water table and its seasonal and climatic fluctuations, but the decisive prerequisite for mire growth is a water table that reaches almost to its surface. Peat in its natural state contains by volume 88-97% water, 2-10% dry matter and 1-7% gas (Ivanov 1981).

It is important to understand the following factors when attempting to conserve and restore mires:

- water status;
- water source;
- nutrient status;
- water chemistry.

Restoration work is possible in some areas, where ditches can be blocked with impermeable barriers (dams), sluices and weirs, to raise the water levels back to the surface. Much can be learnt from the experience gained on restoring lowland raised mires. See Box 6.14 for further details.

Further information: Brooks & Stoneman 1997; Rowell 1998; Information Note 9 Moorland grip blocking.

Box 6.14 Recommendations concerning hydrological management of moorland habitats

! No new drainage should be undertaken on any upland mires or heaths, especially around bog pools and wet flushed areas.

❑ Drainage achieves little in terms of heather or grouse production and any drying is detrimental to feeding waders and grouse chicks (Brown & Bainbridge 1995).

! Leave undisturbed blanket and raised mires completely alone as far as possible.

❑ However, disturbed sites may require considerable management effort to restore their hydrology and vegetation type (Burgess *et al* 1995).

! Maintain the complete hydrological unit of special mire sites.

! Prevent further physical disturbance to upland heaths and mires as far as possible.

! Seek to maintain the water table at or just above the surface of mires during the winter, and not more than 10 cm below the surface during the summer and preferably close to the surface.

! Avoid nutrient enrichment via water courses on upland heaths and mires.

❑ Any water inputs should be acidic and nutrient poor.

! Block existing drains and seal any cracks in the peat to prevent further drainage.

❑ See Information Note 9 for grip blocking specifications.

! Remove trees and shrubs from mires where they are considered to be threatening the interest of the habitat, while minimising disturbance and perhaps allowing some to develop into native scrub and woodland where appropriate (see Brooks & Stoneman 1997).

❑ Note that birch, willow and bog myrtle scrub on upland mires can provide valuable invertebrate habitats, especially the younger trees and shrubs.

❑ Several years of follow-up work such as hand-pulling of seedlings to control trees and shrubs may be necessary where removal is considered appropriate.

! Dig pools into the peat on already disturbed sites to provide a location where *Sphagnum* species can colonise and start to reclaim drier areas of peat.

6.7.3 Applying surface treatments to moorland areas

Applications include artificial fertilisers, animal slurry, farm yard manure (FYM), lime, pesticides and herbicides. There have also been instances of industrial waste being spread on moorland areas (eg paper pulp, sludge). These substances alter the nutrient status of the area and in addition can smother the vegetation. Ideally, none of these substances should be added to any moorland areas (but there are some exceptions, as discussed below).

Heaths and blanket mires have a low nutrient status. Grazing and burning tend to prevent the accumulation of nutrients in the system and so inhibit the natural trend towards replacement of dwarf-shrubs by grasses, trees or bracken (Gimingham 1995). Adding fertilisers alters the pH and nutrient status of the system, which gives grasses a competitive advantage over dwarf shrubs because they are better able to capitalise on the increased nutrients. This in turn may encourage a greater intensity of sheep grazing on the grass and dwarf shrubs alike. In this way, additions of nutrients may lead to a change in moorland habitats, such as the replacement of dwarf shrubs by grasses.

Grasslands that are unenclosed should not receive fertilisers. This is because adjacent habitats such as dwarf shrub heath can be adversely affected by increased nutrient levels, as well as increased sheep dunging where animals are attracted by the greater grass growth.

Botanically rich grasslands, in particular, should never have fertilisers applied if the nature conservation interest is to remain. Most species-rich swards of high botanical interest have developed in nutrient-poor conditions which have reduced growth rates and have allowed a rich variety of slow-growing stress-tolerant plants to coexist. Increasing nutrient levels by the addition of fertilisers, particularly nitrogenous ones, will favour more vigorous species, especially certain grasses, to the detriment of other plants. It is also likely to result in greater litter production, which smothers smaller plants and reduces the availability of gaps in the sward for germination. Corresponding changes in the composition and structure of the sward will also adversely affect the existing invertebrate fauna (Ausden & Treweek 1995).

The addition of lime or marl to acidic soils will affect the availability of nutrients by changing the exchange balance of soils. They should never be added to areas of botanical interest, or to areas from where they may wash into water courses and affect their fauna and flora, unless lime or marl have traditionally been applied to a site over a long period and no adverse aquatic effects will occur.

Herbicides may be acceptable applications for nature conservation purposes where, for example, physical or mechanical control methods are impractical. For example, weed-wiping to control creeping thistle and ragwort may be desirable on unenclosed limestone grassland, and asulam control of bracken may form part of moorland restoration programmes. Fertilisers and lime may also be appropriate on grassland areas as part of restoration programmes, for example after bracken control or severe erosion.

6.7.4 Managing moorland shrubs

Moorlands commonly contain areas of native shrubs and scattered trees, including hawthorn, rowan, birch, gorse and juniper *Juniperus communis*. These provide a valuable habitat for wildlife, particularly where they occur as a mosaic with other habitats, as well as being landscape features. Some areas of scrub may be of value for the woody species present, such as juniper and western gorse which have a limited distribution. Even where common species make up the scrub, the habitat is likely to be important for breeding, feeding and sheltering birds, mammals and invertebrates. Rare or local animal and plant species also occur in the vegetation of woodland-scrub-grassland margins, particularly where this is associated with ancient woodland and grassland.

In many situations it is desirable to protect and increase the scrub habitat, for example on extensive areas of moorland where shrub and woodland cover has declined. In other circumstances, control or removal may be more appropriate, such as where shrubs are regenerating into heathlands of limited extent or species-rich grassland.

Retaining and developing the cover of shrubs, scattered trees and light woodland on moorland is particularly beneficial for upland breeding birds and invertebrates. Light cover provides nest sites, song posts, foraging areas and sheltered roosts for birds such as black grouse, whinchat, stonechat, tree pipit *Anthus trivialis*, ring ouzel and, where old crow nests are available, nest sites for merlin. The gradation of grassland through scrub to woodland is also rich in invertebrate life. Upland woodland supports breeding birds including pied flycatcher *Ficedula hypoleuca*, redstart *Phoenicurus phoenicurus*, wood warbler *Phylloscopus sibilatrix*, siskin *Carduelis spinus* and redpoll *Acanthus flammea*, as well as a diversity of invertebrates.

Appropriate areas could be fenced in some situations to encourage natural regeneration by excluding grazing sheep and deer. Examples may include steep slopes, gullies, narrow cloughs and areas at the moorland edge. Other suitable areas are bracken beds or botanically poor grasslands such as those dominated by mat-grass *Nardus stricta* and rushes *Juncus* species. Areas of existing or developing shrubs are another obvious location for protection from grazing.

On less steep areas, the shrubs could be grazed or cut in rotation in order to retain a mosaic of age classes. Cutting could be carried out when the shrubs are about 5-15 years old, on about 10 % in any one year. Below old stands of shrubs where regeneration is poor the ground could be scarified to encouraged seedling establishment, but only if the stocking levels are suitably low to allow seedlings to survive.

The total area of shrubs and scattered trees could be increased by targeted planting of native species in areas of low existing wildlife interest, provided only species typical to the location and of local provenance are used (Rodwell & Patterson 1994). Such species might include hawthorn, rowan , birch and oak *Quercus* spp, with willow and alder *Alnus glutinosa* along water courses. Normally fencing would be needed to protect planted shrubs, but where this is not possible tubes and stakes could be considered without fencing. A disadvantage of this method is that tubes and stakes are likely to be damaged by wind and snow and may also be used as rubbing posts by stock.

Further information: Hopkins 1996; Rodwell & Patterson 1994; Chapter 8 Woodland and scrub.

Juniper

Juniper scrub is of considerable nature conservation importance because of its limited distribution and extent, and this is recognised by its inclusion in the Habitats Directive. It is particularly valuable for invertebrates. It was once widespread in the English upland fringes but is now thought to be declining at numerous locations and many populations show few signs of regenerating naturally (Barrett 1997). Remaining stands tend to be even-aged and dominated by mature and old bushes.

Disturbance of some kind, including burning, may be beneficial to juniper, because it encourages seedling establishment. However, adult plants are likely to be killed by burning, and where grazing animals are present their grazing and browsing is likely to destroy any successful seedling establishment. If it is possible to exclude grazing animals, including rabbits, then burning adjacent to fruiting, mature stands may be beneficial and encourage regeneration (A. MacDonald, pers comm). If burning is used as a tool then the rotation should be very long, eg 40 - 50 years at least, and mature bushes themselves should not be burnt, because the control of the spread of the fire would be very difficult. If restructuring of stands of mature juniper is felt desirable to diversify the ages present then cutting would be preferable to burning.

Juniper plants may establish where heather is tall, unburnt and only lightly grazed, because the heather tends to become more open in these circumstances and the juniper plants are partially protected from browsing, at least by sheep.

Further information: Barrett 1997; Clifton, Ranner & Ward 1995.

Gorse

European gorse *Ulex europeus* provides a wildlife habitat in itself, particularly for invertebrates and birds. However, it can invade areas of heath or grassland, thereby reducing the amount of valuable wildlife habitat or grazing land. It also poses problems for farmers because stock can become tangled in it.

Gorse scrub is often burnt or cut to control it. Burning gorse alone is of little benefit for long-term control of this species (MAFF 1992a). Its effect is to bring about a break in seed dormancy, resulting in the appearance of young seedlings as a carpet to re-invade the burned area. These may be controlled by light grazing, but this is unlikely to reduce the area of gorse in the long term, unless the stumps and regrowth are treated with herbicides, which is rarely acceptable in semi-natural habitats. Rotational burning can be useful for breaking up stands of gorse, allowing stock to move around the area, promoting a flush of grass for grazing and diversifying the age structure of the scrub.

The effect of cutting is similar to burning because it can increase the vigour and stimulate growth of gorse. As with burning, rotational cutting can be useful to agricultural and wildlife interests.

Western gorse can form part of the heathland community, especially in south west England, and is an important species in its own right because of its limited distribution. For wildlife interests, it is not appropriate to target control at this species, but it may be perceived as a problem by farmers because such heaths are relatively unproductive.

Rhododendron

Rhododendron *Rhododendron ponticum* is a problem on some moorlands, particularly in south west England and locally elsewhere. Preventing invasion should be the top priority where it is a threat, because this is better than trying to cure the problem once it has taken hold. However, it can be successfully removed by spraying the plants with glyphosate and a suitable wetting agent, although very thorough spraying is needed, and usually more than one application is required. This should be followed by treating the cut stumps with triclopyr and hand-pulling of seedlings in subsequent years. Rhododendron has a short-lived seed bank and the important factor is to remove the seed source.

Controlling tree and shrub invasion on mires

Active peat-forming *Sphagnum* vegetation is not generally invaded by trees, but a reduction in the water balance of a bog can lead to tree invasion (Burgess *et al* 1995). The main tree and shrub species which invade mires are birch, willow, rhododendron and Scots pine *Pinus sylvestris* (RSPB 1995). Some potential actions are given below.

- Assess whether the mire and its hydrology can be restored, or whether the area is too dry for restoration to be feasible.
- If the mire can be restored, identify a hydrological management programme to restore the hydrological integrity and make the area wetter.
- Remove seedlings and saplings by hand pulling.
- Remove older specimens by bow saws, brush cutters, or chain saws.
- Dispose of the material by various means dependent on the situation and conditions (see below).
- Some species, particularly birch and rhododendron, will coppice if cut and require secondary treatment. This may involve chemical applications (spray or weed wipe new growth or treat cut stumps), grinding or careful extraction of cut stumps, annual cutting of regrowth, grazing or flooding.

However, if a site is still relatively wet, disturbance resulting from trampling or the use of vehicles can cause long-term damage. Chemical applications also have the potential to harm bryophytes and aquatic systems.

There are various means of disposing of cut material on larger mires.

- Leaving on site stacked, unstacked or in ditches.
- Dragging or carrying off site, with or without the use of low ground pressure vehicles, with or without the use of brash or other temporary roads which are subsequently removed.
- Burning on site on sheets of corrugated iron raised above the bog surface by bricks, and removing the ash to prevent nutrient enrichment.
- Chipping on site, and leaving the remains in ditches or removing them.
- Winching off site.
- Removing material by sky-line logging systems.
- Removing material by helicopter.

6.7.5 Moorland management and the archaeological and historical interest

The moorlands of England contain a legacy of structures and systems related to over 6,000 years of agricultural and industrial activity (Wood-Gee 1996). Together with the geology, land form and vegetation, these remains reveal the history of the English uplands.

Management sympathetic to wildlife, as outlined in this chapter, is usually beneficial to archaeological interests. However, many aspects of farm work inadvertently result in damage. The implications for archaeology should be carefully considered before starting any work near archaeological sites and features. The following guidance for their protection should be adhered to (Wood-Gee 1996).

- Remember that sites can extend beyond visible remains. For example, complex prehistoric and medieval agricultural systems, extending to several hectares, may lie around a fort or homestead.
- A minimum 10 m margin should be allowed around identified sites or areas (more if the site is scheduled), and 20 m if planting trees or encouraging woodland regeneration.
- Adequate stocking of archaeological sites should be included in a grazing plan, to keep sites free of scrub and bracken, but without stocking so heavily that erosion or other physical damage results. Sheep may be preferable to cattle.
- Archaeological sites or features should never be used as stances for feed rings or shelter for stock. Supplementary feed should never be offered on or in the immediate vicinity of archaeological features.
- When re-seeding, ploughing or other soil disturbance should be avoided as it can destroy features in and around archaeological sites. Deeper ploughing of sites which are already cultivated should be avoided.

- Archaeological sites such as burial cairns or deserted settlements should not be used as dumping grounds. Consideration should be given to removing earlier dumped material.

- Use of metal detectors should not be allowed on ancient monuments, nor should any archaeological finds be removed.

- Any finds or new features should be reported to English Heritage, the Regional Archaeologist or local museum.

- Where sites have suffered erosion and the protective cover of turf or soil has been broken, sheep often congregate using the bare patches as social gathering areas. The initial erosion problems can soon worsen, leading to disappearance of earthen monuments or archaeological deposits. Prompt filling-in of scrapes or natural erosion hollows will protect such sites for the future. Stock proof (and where necessary rabbit proof) fencing may be necessary to reduce damage but details of measures to allow for continued grazing within the fenced areas should be included in a grazing plan.

- Consideration should be given to removing trees, scrub, gorse, bracken and woody plants to protect sites from damage. Disturbance of the ground surface should be minimised by cutting trees at ground level and spot treating stumps to prevent regrowth. If possible, the trunks of wind-thrown trees should be cut and the root plate replaced.

- New drainage should not be carried out on or near an ancient monument. Particular care is required when maintaining existing drains. Consideration should be given to resiting drains directly affecting archaeological sites.

- Ground disturbance should be avoided where rabbit control is carried out.

- Peat cutting or quarrying on the site of ancient monuments should not be permitted.

Further advice on protecting archaeological features, eg when burning or grazing land, is contained within the preceding sections.

Further information: Historic Scotland 1996.

6.8 Techniques to re-create moorland habitats

The term re-creation is generally used when the vegetation concerned is no longer present. Restoring or improving the condition of moorland habitats has already been covered in earlier sections of this chapter. Information has recently been published particularly about upland and lowland heathland and peatland re-creation and restoration, and much research is currently under way. It is not intended to reproduce the re-creation information here, but some general principles are included below.

6.8.1 Re-creation of heathland areas

Generally, it is most cost-effective and a higher nature conservation priority to concentrate effort on restoration by improving the condition of heavily grazed heathland, rather than trying to re-create it where it has completely disappeared (Thompson, MacDonald & Hudson 1995b). The problems of restoring heather and other dwarf shrubs to former heaths and moorland which have lost all such cover are naturally greater than repairing damage to existing heathland areas and preventing their loss in the first place (Ward, MacDonald & Matthew 1995).

The important factor in heathland re-creation is to reduce or remove the grazing pressure. It is best to target areas where heather and other dwarf shrubs are already frequent, if suppressed, to prevent further decline. Alternatively, target areas where dwarf shrubs are less abundant but have not yet disappeared, to enhance their status (Marrs & Welch 1991). If heather plants occur at more than four plants per square metre then a dramatic increase in heather cover can occur within five years when grazing is substantially or completely removed. Even at dwarf shrub frequencies lower than this, the approach is valuable and can provide good dwarf shrub cover over the longer term.

Survey data suggest that recovery from grassland is occurring on some sites, albeit at a slower rate than the loss (Hester 1996). The soil under heather contains a large seed bank which can remain viable for many years, even after heather has disappeared above ground. However, it needs exposure to light and, therefore, disturbance to germinate (Thompson, MacDonald & Hudson 1995b). Hence successful growth to adult plants is difficult to achieve in swards heavily dominated by grasses. Where no seed bank remains import of dwarf shrub seed will be necessary to re-create heathland. Techniques of scarifying, seeding and grazing control have been developed and widely employed now, to re-create heather and grass mixtures on areas of highly acidic grassland, and on bare peat created by bad burns or erosion (Anderson 1997; North York Moors National Park 1986, 1991; Philips 1993). Further development of seed collection, seed treatment, site preparation and application techniques is currently underway.

Heather and other dwarf shrub seed can be obtained by cutting seed-bearing plants from October to January. A forage harvester or flail mower and baler can be used where conditions are suitable (eg. flat, no boulders) and this material is normally applied at about 600 g per m^2. An alternative source of seed can be obtained by collecting the remaining litter and soil surface from recently burnt areas of vigorous heather, either by hand or an industrial vacuum cleaner run from a portable generator. This material is usually spread at the lower rate of about 200 g per m^2. If storage of either type of material is required, it should be dried first.

To prevent loss of the seed-bearing material from the application site, the application of an open covering of forestry brashings is employed. Alternatively, and particularly to avoid soil erosion, an acid soil tolerant, short-lived, nurse grass can be sown, such as rye-grass *Lolium perenne* or red fescue *Festuca rubra.*

Common bent, wavy hair-grass or sheep's fescue have also been used, but these species may not necessarily be short-lived and so should be used with caution. Seed can be sown at a rate of about 2 g per m². On very infertile mineral or peat substrates, a light fertiliser dressing of NPK fertiliser at 50-100 kg / ha may be considered to assist heather and nurse grass establishment. For heather to establish under any of these techniques, there must be initial protection from grazing animals in some cases for up to five years.

Attempts have also been made to revegetate eroded peat surfaces, although this is very difficult to achieve, particularly over large areas. In the northern Pennines, as long as adequate NPK fertiliser was provided and sheep grazing prevented, a continuous cover of *Deschampsia flexuosa* could be achieved as a primary cover (Gore & Godfrey 1981).

Heather restoration on *Molinia*-dominated areas is unlikely to succeed unless *Molinia* is first controlled by herbicide or removed by turf stripping, and heather seed introduced into the denuded areas created. Grazing would then have to be excluded to enable establishment of heather plants. Attempts to establish heathland or even increase heather abundance in areas dominated by *Molinia* by simply excluding grazing are unlikely to be successful, although this will depend on the initial percentage of heather present. Ungrazed *Molinia* is likely to form a dense litter layer which prevents heather or other dwarf shrub seedlings developing. For further information on this subject see Todd 1997.

The slow attainment of mature bush size and the difficulties of transplanting make bilberry unsuitable for use as a main species in schemes to recreate moorland. Heather is easier to establish, either from transplants or seeding (Welch *et al* 1994).

Further information: Anderson, Tallis & Yalden 1997; Anderson & Gilbert 1998; Andrews & MacDonald 1996a; Bacon 1996; Dryden, Horton & Hall 1997; Gimingham 1992; Hudson & Newborn 1995; North York Moors National Park 1986, 1991; Parker 1995; Phillips 1997a; Pywell, Webb & Putwain 1996.

6.8.2 Re-creation of blanket mire after afforestation

If restoration of the blanket mire is the desired objective, the actions to be undertaken include damming ditches and felling trees where these are present. Cut trees can be either removed, left on the surface whole or chipped, or packed into ditches. If the mire has previously been fertilised, the area should be left for one to two years for nutrient levels to fall before the water levels are raised by ditch damming work (RSPB 1995).

Further information: Bacon & Lord 1996; Brooks & Stoneman 1997.

6.9 Pests and diseases affecting moorland

6.9.1 Fungal attack

Heather shoots may be damaged by snow mould *Fusarium* spp. or heather rhizomorph fungus *Marasmius androsaceus*, but these do not usually affect extensive areas of heather (Thompson, MacDonald & Hudson 1995b). These types of damage can be distinguished quite easily from the effects of heavy grazing because the heather shoots and leaves remain intact. Management can do little to alleviate the effects of fungal attack, but burning and reducing grazing pressure may encourage better heather growth.

6.9.2 Invertebrate pests

Heather beetle *Lochmaea suturalis* is a brown beetle about 6 mm in length. Both adults and larvae feed principally on heather, although, rarely, *Erica* spp. are also eaten. Heather beetle has caused extensive damage to heather moors across England between 1998 and 2000, and this current outbreak is thought to be one of the most serious in recent times. The impacts of this damage can last for many years, and there is, not surprisingly, a strong temptation to undertake dramatic control measures to counter any future outbreaks. However, no additional specific management is to be recommended or likely to be successful. Traditional heather management practices should continue to be followed (English Nature 1994e; Joint Nature Conservation Committee 2000).

Magpie moth *Abraxus grossulariata* larvae can damage heather and bilberry, and occasionally cause defoliation over fairly large areas, most often in Scotland.

Winter moth *Operophtera brumata* larvae can also damage heather and bilberry, but are usually a relatively minor problem.

Vapourer moth *Orygia antiqua* larvae, like those of the winter moth, feed on heather and bilberry but are a relatively minor problem.

Willow beetle *Lochmaea caprea* can cause extensive defoliation of crowberry *Empetrum nigrum* moorland.

Parasitic worms and **ticks** are pests of grouse, and both require control if populations of grouse are to thrive. The control of ticks, usually by treating the other main carrier, the sheep, help to reduce tick burdens on a moor and the incidence of 'louping ill', a disease carried by ticks which affects both sheep and grouse. Bracken harbours ticks and it is often controlled to reduce tick populations. Studies on moorland are being carried out by the Heather Trust, centred around reducing host potentials for ticks by manipulating wild mammal numbers, particularly in summer (Guthrie 1997).

Further information: English Nature 1994e; Hudson & Newborn 1995; MacDonald 1993; Thompson, MacDonald & Hudson 1995b.

Table 6.1 Mire types in the English uplands

Soligenous mires
! Associated with moving water, flushes or springs. ! Slow rates of peat formation, as a result of an oxygenated, moving water supply. ! Plant communities containing *Sphagnum recurvum, Molinia*, sedges, rushes and pleurocarpus mosses. ! NVC communities include the small sedge and bryophtye fens M6 *Carex echinata-Sphagnum recurvum/auriculatum* mire, M10 *Carex dioica-Pinguicula vulgaris* mire and M11 *Carex demissa-Saxifraga aizoides* mire (Rodwell 1991b).
Basin mires
! Often associated with glacially deepened hollows. ! Deep peat formation is possible, and the vegetation surface may be floating. ! Generally no outflow of water and minimal ground water oscillation. ! Encompass a wide range of NVC communities including small sedge and bryophyte fens, *Molinia* and *Juncus* fens, swamp and carr (Rodwell 1991b).
Valley mires
! Occur along the direction of the water flow, which is usually along the valley axis. ! Exhibit a wide base-status range. ! Encompass a wide range of NVC communities, including small sedge and bryophyte fens, *Molinia* and *Juncus* fens, swamp and carr (Rodwell 1991b).
Floodplain mires
! Develop on alluvium which is susceptible to flooding. ! Common in base-rich areas and often follow the sequence: open water to swamp to carr. ! Vegetation communities include *Sphagnum* where the nutrient status is low, and extend to reed and sedge communities where the nutrient supply is high. ! Typical NVC types include various swamp communities.
Raised mires or bogs
! Usually confined and limited in extent, having a recognisable boundary called the rand. ! Mire surface is isolated from the surrounding ground water table, resulting in an ombrotrophic plant community dependent on water and nutrients derived from atmospheric precipitation. ! May have a characteristic domed shape, although this may be obscured by past peat cutting. ! The typical NVC community is M18 *Erica tetralix-Sphagnum papillosum* raised and blanket mire (Rodwell 1991b).

Table 6.1 Mire types in the English uplands (continued)

Blanket bogs or mires

- Generally require high rainfall, high atmospheric humidity, a low temperature range and mean temperature, a low slope angle, low substrate permeability and low water aeration for formation.
- Usually develop over impermeable soils or bedrock, although podsolisation, and the resultant formation of impermeable horizons within the mineral soil, may result in blanket mire development.
- Depending on their location, they are known as plateau or saddle mires.
- Often form on the watershed between water catchments.
- Generally have frequent or abundant *Sphagnum*, although this is not always the case in English blanket mires (despite stratigraphic records indicating they once were), because of past management such as burning, draining and grazing.
- NVC communities include M17 *Scirpus cespitosus-Eriophorum vaginatum*, M19 *Calluna vulgaris-Eriophorum vaginatum* and M20 *Eriophoroum vaginatum* blanket mires (Rodwell 1991b).

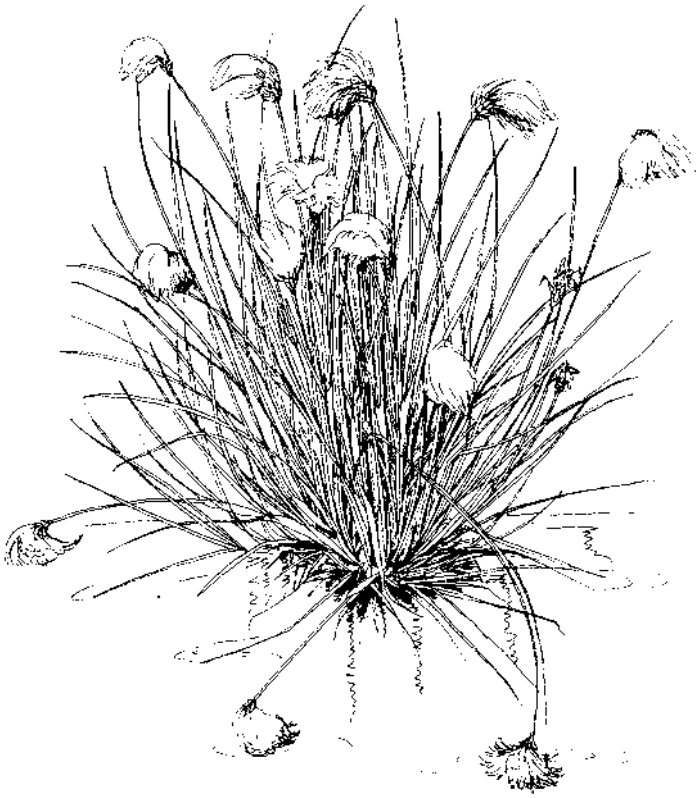


Table 6.2 Nationally rare and scarce vascular plants associated with moorland in England

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Ajuga pyramidalis pyramidal bugle	LR-ns	Dry heathland or grassland on free-draining, steep, sunny slopes with incomplete vegetation cover, usually on soils with medium base-status.	! Protect sites from destruction.	Cumbria Fells & Dales
Alchemilla glaucescens	LR-nt	Limestone grassland, usually on Carboniferous limestone, maintained by sheep-grazing.	! Protect sites from the application of fertilisers or pesticides. ! Maintain moderate levels of sheep-grazing.	Cumbria Fells & Dales Forest of Bowland Pennine Dales Fringe Yorkshire Dales
Alchemilla minima	VU, EE Priority	Very short turf of base-rich *Festuca ovina* grassland. Generally in moist places at lower altitudes near flushed areas; at higher altitudes amongst limestone boulders and debris. It is well adapted to sheep-grazing. Its requirements are poorly understood.	! Maintain moderate grazing. ! Protect sites from habitat destruction and the application of fertilisers or pesticides. ! See Species Action Plan (UK Biodiversity Group 1998).	North Pennines Yorkshire Dales
Alchemilla wichurae	LR-ns	On damp basic soils. On herb-rich ledges and in upland grassland where grazing or mowing keep the vegetation short. Common by waterfalls or seepages on cliffs. Sometimes on bare rocks and scree and also track sides in the Yorkshire Dales.	! Where it grows on track sides, it needs protection from trampling by walkers and off-road vehicles. ! Roadside populations need to be protected from agricultural enrichment which promotes the growth of coarse grasses.	Cumbria Fells & Dales North Pennines Yorkshire Dales

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Arenaria norvegica ssp. anglica English sandwort	Sched. 8 of WCA VU, EE	A stress-tolerant species of bare substrates, either on shallow, dry soils near to or amongst Carboniferous limestone pavement or on frequently flushed slopes around the edges of flushes and mires. Always on sparsely vegetated ground. Two colonies are in wet bryophyte-rich tufaceous flushes.	! Where necessary, protect the sites from recreational damage by walkers and off-road vehicles. ! Control grazing at the sites to moderate levels. Levels of less than 1.5 ewes per hectare during the growing season have allowed populations to thrive. Moderate grazing is preferable to no grazing.	Yorkshire Dales
Asplenium septentrionale forked spleenwort	LR-ns	Steep or vertical faces of hard, base-poor, dark-coloured volcanic and metamorphic rocks, on dry, south-facing, unshaded slopes. Also occasionally on spoil heaps of metalliferous mines and old earthy, unmortared walls. It is intolerant of shade, waterlogging and competition from gorse and other shrubs.	! Landscaping or reclamation should avoid damage to the habitat. ! Where necessary, shrubs should be cleared away.	Cumbria Fells & Dales Dartmoor North Pennines
Calamagrostis stricta narrow small-reed	LR-nt	Near-neutral bogs and marshes.	! Prevent drainage of sites.	Southern Pennines Yorkshire Dales
Carex ericetorum rare spring-sedge	LR-ns	Short limestone grassland.	! Protect sites from habitat destruction and the application of fertilisers or pesticides. ! Maintain light or moderate levels of grazing.	Cumbria Fells & Dales North Pennines
Carex magellanica tall bog-sedge	LR-ns	Upland blanket bogs and valley mires, in *Sphagnum* lawns and in-filled hollows in wet, level moorlands and clearings in swampy woods.	! Prevent drainage of sites.	Border Uplands Cumbria Fells & Dales North Pennines

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Carex ornithopoda bird's-foot sedge	LR-nt	Open, calcareous grassland on Carboniferous limestone, often on thin, parched soils, which require light grazing to maintain the open character of the vegetation. Also close to exposed rocks on south-facing slopes, in full sun, and in shattered limestone pavement.	! Maintain light or moderate levels of grazing.	Cumbria Fells & Dales North Pennines White Peak Yorkshire Dales
Dactylorhiza traunsteineri narrow-leaved marsh-orchid	LR-ns	Wet, base rich habitats such as fens and flushes.	! Prevent drainage of sites and general lowering of the water table. ! Maintain light or moderate levels of grazing.	Forest of Bowland North York Moors and Hills Yorkshire Dales
Dianthus deltoides maiden pink	LR-ns	In sandy grassland or heath, usually growing where the sward is broken by bare rock or soil. See Table 10.1.	! Control levels of grazing and other disturbance to moderate levels. ! See Species Action Plan (UK Biodiversity Group 1998).	Border Uplands Clun & North West Herefordshire Hills Dark Peak North Pennines North York Moors and Hills White Peak Shropshire Hills
Equisetum pratense shade horsetail	LR-ns	Typically on river banks, on damp, base-flushed soils. Thriving best on deep, moist, freely-draining banks of essentially sandy soils or alluvial silt, flushed with base-rich water where there is light shade.	! Where sites are developing denser shade as woodland develops, it may be necessary to thin the canopy to provide the light shade which is most beneficial to this species.	North Pennines

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Equisetum variegatum variegated horsetail	LR-ns	A wide variety of open habitats. See Table 7.10.	! Maintain the site's hydrology, including water quality and patterns of water levels and flow.	Border Uplands Cumbria Fells & Dales Exmoor and the Quantocks North Pennines Yorkshire Dales
Euphrasia rivularis	LR-nt, E Priority	In bryophyte-rich flushes by streams, on wet, flushed slopes and on wet ledges and seepage areas on cliffs in montane areas.	! The conservation needs of this and other eyebrights are under review. Meanwhile, sites should be protected from habitat destruction. ! See Species Action Plan (UK Steering Group 1995).	Cumbria Fells & Dales
Euphrasia vigursii	VU, EE Priority	Damp, grassy heathland. There has been a substantial and continuing loss of inland populations through habitat dereliction, especially the abandonment of grazing	! Many sites are likely to require grazing to maintain open vegetation, for example light grazing by ponies. ! The conservation needs of this and other eyebrights are under review. ! See Species Action Plan (UK Steering Group 1995).	Bodmin Moor Dartmoor
Gentiana pneumonanthe marsh gentian	LR-ns	Damp acid grassland or heathland. It is vulnerable to agricultural improvements such as ploughing and draining but also to agricultural neglect when grazing is reduced or stopped, and to excessive, uncontrolled burning. However, there is evidence from lowland heathland sites that burning can encourage regeneration and population increase.	! Protect sites from agricultural improvement. ! Maintain moderate levels of grazing.	Cumbria Fells & Dales Forest of Bowland Shropshire Hills

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Hammarbya paludosa bog orchid	LR-ns	In boggy areas where the drainage water is moderately acid, frequently in *Sphagnum* and also on peaty mud and among grasses on the edge of runnels. Usually associated with some movement of water. Occurs on lightly grazed open mires.	! Protect sites from drainage and destruction.	Border Uplands Cumbria Fells & Dales Dartmoor Bodmin Moor North Pennines Yorkshire Dales
Illecebrum verticillatum coral-necklace	LR-ns	Neutral to acid soil in seasonally wet sandy or gravelly tracks and on shallow stream edges and flooded ditches. It requires open ground and some trampling is likely to be beneficial.	! Prevent interference with the water regime. ! Some sites may require management to keep the vegetation open.	Bodmin Moor
Juncus alpino-articulatus alpine rush	LR-ns	Open, base-rich flushes, lake margins and mossy marshes on shallow soils. See Table 9.2.	! Protect sites from drainage and destruction.	North Pennines Yorkshire Dales
Juncus filiformis thread rush	LR-ns	Edges of lakes and reservoirs. See Table 7.10.	! Protect sites from changes in water regime which would prevent fluctuation levels. ! Maintain the marshy or open, disturbed character of lake shores.	Cumbria Fells & Dales Forest of Bowland North Pennines Pennine Dales Fringe Yorkshire Dales
Limosella aquatica mudwort	LR-ns	On exposed mud at the edges of rivers, lakes, reservoirs, pools, ditches and winter-flooded ruts. Often on acidic soil and possibly favoured by nutrient enrichment by droppings. Many sites have been lost to drainage or to ponds becoming overgrown. See Table 9.2.	! Prevent drainage of sites. ! Prevent the encroachment of scrub or other coarse vegetation.	Pennine Dales Fringe South West Peak Yorkshire Dales

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Linum perenne perennial flax	LR-ns	Base-rich grassland over limestone. See Table 7.10.	! Mow late in the year to 10-15 cm height, or light grazing by cattle or sheep all year or, preferably, during the winter only leaving a reasonably long sward. ! It can persist for a number of years without management or, at least for a few years, moderate grazing throughout the year.	Cumbria Fells & Dales Yorkshire Dales
Lotus angustissimus slender bird's-foot trefoil	LR-ns	In grassland amongst scrub, around rocky outcrops and on grassy banks, usually by the sea. See Table 7.10.	! Protect sites from destruction.	Dartmoor Exmoor and the Quantocks
Lycopodium annotinum interrupted clubmoss	LR-ns	Upland heaths, flushes, grassland and open woods. Typically found in hollows and on steep slopes with late snow-lie in various sorts of heaths. On base-poor substrates, usually well drained.	! Protect sites from frequent moor burning and other forms of destruction.	Cumbria Fells & Dales
Lycopodiella inundata marsh clubmoss	LR-ns Priority	Bare, moist peaty, silty, sandy or sometimes muddy sites which are almost free of competition from other plants. On mires, heaths, lake margins and sand and clay pits, normally submerged in winter and spring and wet in summer. Most sites are highly acidic and deficient in bases and minerals. It may be particularly sensitive to pollution of rain and surface waters. At some sites to provide bare substrate, disturbance is required, for example poaching by livestock, peat-cutting or disturbance by vehicles.	! Protect the site from air- or water-borne pollution, and drainage. ! Ensure that levels of disturbance are sufficient to provide bare substrate without damaging existing colonies. ! Prevent the site becoming overgrown by coarse vegetation. ! See Species Action Plan (UK Biodiversity Group 1998).	Cumbria Fells & Dales Dartmoor

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Lysimachia thyrsiflora tufted loosestrife	LR-ns	Fens and swamps among open, tall vegetation.	! All sites should be protected from drainage and lowering of ground waters.	North York Moors and Hills
Minuartia verna spring sandwort	LR-ns	Open or semi-open short grassland over calcareous rocks, among limestone rocks and scree or on old lead and zinc mine spoil, often associated with sites liable to soil erosion. Also on base-rich rock ledges and gullies, often at high altitude. The distribution is mainly restricted to sites with an annual rainfall of at least 100 cm and the species is susceptible to summer drought. It is threatened by insufficient grazing, which allows the sward to become too closed for the species.	! Protect sites from destruction. ! Where possible, sites should be heavily grazed. Other forms of disturbance may be required where heavy grazing cannot be arranged.	Cumbria Fells & Dales Dark Peak North Pennines Pennine Dales Fringe South West Peak White Peak Yorkshire Dales
Myosotis stolonifera pale forget-me-not	LR-ns	Somewhat base-poor springs and seepage areas, soakways and flushes on hillsides and in valleys by pools, in ditches and in the backwaters of streams.	! Protect sites from destruction and drainage.	Border Uplands Cumbria Fells & Dales Dark Peak Forest of Bowland North York Moors and Hills Southern Pennines Yorkshire Dales
Persicaria mitis tasteless water-pepper	LR-ns	On wet or damp mud or peat banks, left exposed in summer. See Tables 7.10 and 9.2.	! Protect sites from drying out, filling in of ponds and fencing of ditches.	Border Uplands Shropshire Hills Yorkshire Dales

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Pilularia globulifera pillwort	LR-ns Priority	Bare wet substrates at the edges of slightly acid to neutral water bodies, usually on soft clays and silts. Unable to compete with larger plants such as reeds or other fen species nor survive under the shade of overhanging trees, it relies on fluctuations in the water level to control the spread of larger plants. In some sites the species relies on disturbance by cattle or horses to uncover bare substrate which it can colonise; at such sites it seems to disappear if grazing ceases. In Scotland it is also known to grow in water up to 2 m deep or as floating mats; it may be found in similar sites in England. See Tables 7.10 and 9.2.	! In sites where the species relies on a fluctuating water level, the pattern of fluctuating levels should be maintained. ! In sites where the species relies on disturbance, then the site should be kept accessible to large livestock. In small sites, care should be taken that poaching is not accompanied by excessive manuring. In the absence of grazing animals, mechanical or manual means could be used to control the spread of swamp and fen and provide bare substrate for pillwort. ! All sites should be protected from drainage or habitat destruction. ! Protect the sites from water pollution, especially by agricultural fertilisers. ! See Species Action Plan (UK Biodiversity Group 1998).	Black Mountains and Golden Valley Cumbria Fells & Dales Dartmoor Pennine Dales Fringe
Polygala amarella dwarf milkwort	VU	Open sites in short turf over calcareous rocks in well-drained sites. See Table 5.1.	! Protect sites from habitat destruction. ! Where heavy grazing is thought to be restricting the populations, this should be controlled.	North Pennines Yorkshire Dales Cumbria Fells & Dales
Potentilla neumanniana spring cinquefoil	LR-ns	Open ground and seasonally parched, skeletal soils on limestone crags and screes. See Table 10.1.	! Some sites may require control of rank grasses or scrub, by cutting or grazing.	Cumbria Fells & Dales Oswestry Uplands White Peak Yorkshire Dales

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Primula farinosa bird's-eye primrose	LR-ns	Calcareous mires. See Table 7.10.	! Control grazing to moderate levels wherever possible. ! Protect sites from agricultural intensification.	Cumbria Fells & Dales Forest of Bowland North Pennines North York Moors and Hills Pennine Dales Fringe White Peak Yorkshire Dales
Pyrola media intermediate wintergreen	LR-ns	Damp mossy habitats in woods and heaths. See Table 8.1.	! Sites which are grazed should be grazed only lightly. ! Sites should not be planted with non-native trees.	North Pennines North York Moors and Hills
Sibthorpia europaea Cornish moneywort	LR-ns	In humid microclimates in sheltered sites on acidic soils and rocks. See Table 10.1.	! Protect sites from changes in hydrology and water regime.	Bodmin Moor Dartmoor Exmoor and the Quantocks
Silene nutans Nottingham catchfly	LR-ns	Open grassland on limestone, usually rough ungrazed grassland on shallow, well drained soils on steep slopes, ledges, etc. Populations can be lost where scrub is allowed to succeed the rough grassland.	! Sites should not be grazed. ! Where necessary, occasional removal of woody species may be necessary.	White Peak
Spiranthes romanzoffiana Irish lady's-tresses	LR-ns Priority	In a carpet of *Molinia caerulea* on damp soil grazed by cattle, seasonally inundated or flushed.	! Ideally, it should be grazed when the plants are dormant.	Dartmoor

Plant species	Status	Habitat requirements	Management requirements	Distribution by upland Natural Area
Thlaspi caerulescens Alpine penny-cress	LR-ns	A pioneer colonist of metalliferous mine wastes and river gravels contaminated with lead, zinc and cadmium, often in limestone areas but also on shales. Usually in open vegetation but able to persist in a more closed turf. It is threatened by insufficient grazing, which allows the sward to become too closed for the species. See Table 5.1 & 10.1.	! Protect sites from destruction. ! Where possible, sites should be heavily grazed. Other forms of disturbance may be required where heavy grazing cannot be arranged.	Border Uplands North Pennines White Peak Yorkshire Dales
Vaccinium microcarpum small cranberry	LR-ns	*Sphagnum* mires, often on small hummocks of glacial origin within blanket mires, also on *Sphagnum* hummocks.	! Protect sites from destruction.	Border Uplands
Viola lactea pale dog-violet	LR-ns	Patchy or open heaths or moors on level to gently sloping sites, with soil which is dry or water-logged in winter and where soil pH varies from 4.7-6.5. It cannot compete with taller vegetation and is vulnerable to agricultural neglect as well as modernisation.	! Tactics which control tall vegetation and create open soil will favour this plant. These could include grazing, general disturbance of soil along roads and paths, regular mowing and short winter burning rotations.	Bodmin Moor
Viola rupestris Teesdale violet	LR-nt	In open turf on base-rich sites, which are likely to have remained relatively open and treeless through out history. On the cold high limestone areas in heavily grazed swards. One site is at lower altitude on a warm south facing slope. At light levels of grazing the sward, typically dominated by *Sesleria caerulea*, can become overgrown, leading to a decline in the violet.	! Ensure sufficient grazing to keep a short, open turf.	Cumbria Fells & Dales North Pennines Yorkshire Dales

Key to Table 6.2

Status

Annex IIb	- listed on Annex IIb of the EC Habitats and Species Directive
Sched. 8 of WCA	- listed on schedule 8 of the Wildlife & Countryside Act.

Red list categories

CR	- critically endangered
EN	- endangered
VU	- vulnerable
DD	- data deficient
LR -nt	- Lower risk - near threatened
LR-ns	- Lower risk - nationally scarce
E	- endemic to Great Britain
EE	- endemic to England.

Biodiversity Action Plan (BAP)

Priority	- Priority species from UK Steering Group 1995 and UK Biodiversity Group 1998.
SCC	- Species of conservation concern from UK Steering Group 1995 and UK Biodiversity Group 1998.

Sources

Most information from Foley 1987; Grime, Hodgson & Hunt 1990; Hodgetts, Palmer & Wigginton 1996; I. Taylor pers comm; Page 1982; Porley & McDonnell 1997; R. Cooke pers comm; Rich 1997; Stewart, Pearman & Preston 1994; Wigginton 1999.

Table 6.3 Nationally rare and scarce bryophytes associated with moorland in England

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Aloina ambigua	LR-ns	Rocks, banks, soil and walls. See Table 10.2	Bodmin Moor Cumbria Fells & Dales
Amblyodon dealbatus	LR-ns	A calcicole of wet, open ground such as tussocks in tufa-springs and on stream banks, cliffs and gravel where flushed by calcareous water.	Border Uplands Cumbria Fells & Dales North Pennines Yorkshire Dales
Barbilophozia kunzeana	LR-nt	Most habitats are damp or waterlogged, including mountain stream sides, basin mires, wet moorland hollows and valley bogs, in acidic to mildly basic conditions.	Border Uplands Yorkshire Dales
Brachythecium mildeanum	LR-ns	Wet, open grassland and stony ground overlying calcareous rocks.	Yorkshire Dales
Bryum intermedium	LR-ns	A calcicole on bare damp soil. See Table 10.2.	Border Uplands Cumbria Fells & Dales This species is widely overlooked and probably occurs in other upland natural areas.
Bryum riparium	LR-ns	In a range of intermittently wet non-calcareous habitats, including crevices in rocks in stream-beds and beside streams where kept moist by seepage from *Sphagnum*, on bare peat, on the sides of ditches and in arable fields within the flood zone of streams. It appears to be a poor competitor with other plants, but takes advantage of any open acid habitat to which the rhizoidal tubers happen to be washed.	Cumbria Fells & Dales Forest of Bowland
Bryum tenuisetum	LR-ns	On acid sandy or peaty soils, often on heathland or at the margin of upland reservoirs, very rarely in acid arable fields.	Pennine Dales Fringe

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Calypogeia azurea	LR-ns	A calcifuge plant of peat, peaty or sandy soil, in blanket bog, on heaths, moorland and rocky banks. Rarely and possibly as an adventive, in woodland.	Cumbria Fells & Dales Yorkshire Dales
Campylopus schwarzii	LR-ns	Flushes or steep, acid, humus-rich banks among rocks, especially where there is some seepage of water, also on flushed rock-slabs, often in exposed moorland sites. Other habitats are dripping vertical rock-faces in open ravines, mountain cliffs, in bogs, on the edge of peaty pools and in turf in areas of late snow.	Cumbria Fells & Dales
Campylopus setifolius	LR-ns Priority	An oceanic species found in a variety of acid habitats, always with a humid microclimate. Often amongst tall *Calluna* on north to easterly aspects in steeply sloping turf; also on rock ledges with water dripping from above, in the spray zone of waterfalls, in block-screes and at the edge of streams and flushes. It is sometimes found in bogs.	Cumbria Fells & Dales
Campylopus subulatus	LR-ns	Unshaded, acid, gravelly and sandy places, including tracks, paths, lay-bys, old tarmac on roadsides and stony or gravelly river-margins.	Forest of Bowland Cumbria Fells & Dales Bodmin Moor
Catoscopium nigritum	LR-ns	Semi-open, rocky ground, in calcareous springs and flushes	North Pennines
Cephalozia catenulata	LR-ns	In woods and on peaty soil and banks. See Table 8.2.	Border Uplands Cumbria Fells & Dales Dartmoor North Yorkshire Moors & Hills Southern Pennines Yorkshire Dales Bodmin Moor
Cephalozia loitlesbergeri	LR-ns	On raised bogs, blanket mires, valley bogs and wet moors and also occasionally in damp heathland.	Cumbria Fells & Dales

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Cephalozia macrostachya var. *macrostachya*	LR-ns	Largely confined to saturated micro-habitats on ombrogenous mires, valley bogs, acid basin-mires and very wet heaths. It generally grows amongst *Sphagnum*.	Exmoor and the Quantocks
Cephalozia pleniceps	LR-ns	In peat bogs, acid flushes and wet heathland as well as by streams, typically growing amongst *Sphagnum*.	Bodmin Moor
Cephaloziella elachista	LR-ns	Generally amongst larger bryophytes, especially *Sphagnum*, in raised and valley bogs. On wet heathland it has been found on the sides of decaying *Molinia* tussocks.	Cumbria Fells & Dales Shropshire Hills
Cephaloziella integerrima	EN	In lowland *Calluna* heath on damp clay soil or sand, especially where compacted by rabbits; also on mine waste and slatey soil in a quarry.	Bodmin Moor
Cephaloziella stellulifera	LR-ns	Mine-waste, coastal sites and on heathy tracks or sandy ditch-banks inland. See Table 10.2.	Bodmin Moor Exmoor and the Quantocks North Pennines Pennine Dales Fringe
Cinclidium stygium	LR-ns	Forming green or reddish tufts or patches in calcareous fens and marshes and in basic springs and flushes.	Cumbria Fells & Dales Yorkshire Dales
Cladopodiella francisci	LR-ns	Damp lowland heaths in southern England. Further north also in bogs, moorland and on lake sides, banks and ditch-edges.	Bodmin Moor Dartmoor
Dicranella crispa	LR-ns	In a wide variety of habitats but apparently absent from markedly acid or basic substrates. Most typical on disturbed open soil on banks of gravel, clay, loam or sand by roads, rivers and streams. Also on rocks, especially vertical sandstone.	Yorkshire Dales
Dicranum bergeri	VU	Raised bogs.	Border Uplands
Diplophyllum obtusifolium	LR-ns	A calcifuge pioneer of disturbed soil.	Bodmin Moor Cumbria Fells & Dales Exmoor and the Quantocks

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Fossombronia fimbriata	LR-nt	Damp gravelly, sandy or schistose soil on stream sides, lake margins, roadsides and paths.	Border Uplands
Funaria muhlenbergii	LR-ns	A calcicole on bare soil among rocks, in turf, on anthills or on thinly earth-covered rocks. See Table 10.2.	Cumbria Fells & Dales Oswestry Uplands White Peak Yorkshire Dales
Hamatocaulis vernicosus slender green feather-moss	Annex IIb DD	Somewhat base-rich springs in upland districts. In the lowlands it is rare and generally occurs in spring-influenced sites in mildly basic small-sedge fens.	Cumbria Fells & Dales Shropshire Hills
Hennediella stanfordensis	LR-ns	On shaded, trampled ground by footpaths and under trees.	Shropshire Hills
Hypnum imponens	LR-ns	Wet heaths and raised valley- and blanket-bogs.	
Jamesoniella undulifolia marsh earwort	Sched. 8 of WCA EN Priority	In small quantity in wet minerotrophic *Sphagnum* mires.	Bodmin Moor Cumbria Fells & Dales
Jungermannia caespiticia	LR-nt	A pioneer species of moist base-poor soils in a variety of habitats including moorland edges, stream banks, reservoir margins and mine workings. In the Pennines it favours clay soil overlying Millstone Grit and more rarely, decaying shale. It occurs in pure patches or in association with other bryophytes and is somewhat erratic and seasonal in occurrence. The main growing season is in the autumn.	Dark Peak Southern Pennines Yorkshire Dales
Kurzia sylvatica	LR-ns	Steep peat-banks and moist organic soil in moorland and damp heaths, less often in bogs and occasionally in woodland. Sometimes also on damp, sheltered rock outcrops.	Cumbria Fells & Dales Border Uplands South West Peak
Lophozia obtusa	LR-ns	At higher altitudes it grows in mossy, often basic turf on sheltered north- or east-facing slopes or basic flushes. On lower ground it grows in woodland of birch and under *Calluna*.	North Pennines

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Meesia uliginosa	LR-ns	Calcicole of wet, open ground on seeping rocks, tufa and gravel.	Cumbria Fells & Dales Border Uplands North Pennines
Moerckia hibernica	LR-ns	Damp, base-rich ground. See Table 7.11.	Cumbria Fells & Dales Yorkshire Dales
Nardia geoscyphus	LR-ns	On moist basic soil and rocks. See Table 10.2.	Border Uplands Dark Peak Dartmoor Forest of Bowland North Pennines Oswestry Uplands Southern Pennines South West Peak
Oncophorus virens	LR-ns	In damp calcareous turf. See Table 7.11.	Cumbria Fells & Dales North Pennines
Philonotis caespitosa	LR-ns	On moist or wet non-calcareous soil and rocks, where flushed or flooded by slightly basic mineral-rich water. See Table 10.2.	Bodmin Moor Border Uplands Cumbria Fells & Dales Dark Peak Exmoor and the Quantocks Forest of Bowland Pennine Dales Fringe Southern Pennines Yorkshire Dales
Physcomitrium sphaericum	LR-nt	As green patches or scattered shoots on mud exposed on the margins of lakes and reservoirs and on the beds of dried-up ponds.	Dark Peak Forest of Bowland South West Peak Pennine Dales Fringe

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Pohlia andalusica	LR-nt	Damp sandy acidic soils, on heathy gravelly tracks, and on china clay and metalliferous mine-waste.	Bodmin Moor
Pohlia lescuriana	LR-ns	Preferring moisture-retentive soils, usually clay, although not those that are strongly basic. See Table 7.11.	Dark Peak Dartmoor Forest of Bowland Shropshire Hills Southern Pennines
Pseudobryum cinclidioides	LR-ns	In marshes and wet woodland. See Table 8.2.	North Pennines
Racomitrium elongatum	LR-ns	On sandy or gritty soils from near sea-level to high altitudes.	Cumbria Fells & Dales Border Uplands
Rhytidium rugosum	LR-ns	A calcicolous species of dry, short and often rather open grassland and turf on well drained shallow rendzina soils developed over a range of substrates including limestone. Also on dry south- to southwest-facing rock-ledges of inland cliffs and in limestone quarries.	Cumbria Fells & Dales North Pennines White Peak Yorkshire Dales
Scapania paludicola	EN	Lowland and subalpine bogs, acid mires and wet heaths, growing among *Sphagnum*.	Bodmin Moor Pennine Dales Fringe
Sphagnum affine	LR-ns	In a variety of weakly minerotrophic mires, including slightly basic flush-bogs, as well as on more swampy ground, in ditches and on flushed stream-banks.	Cumbria Fells & Dales
Sphagnum austinii	LR-ns	Raised and blanket bogs where the peat is deep and wet, frequently forming large hummocks among *Calluna vulgaris*, *Eriophorum vaginatum*, *Trichophorum cespitosum* and other bog species of *Sphagnum*.	Cumbria Fells & Dales Border Uplands Dartmoor
Sphagnum balticum Baltic bog-moss	Sched. 8 of WCA EN Priority	In wet hollows of raised and valley bogs.	Border Uplands

Plant species	Status	Typical habitat	Distribution by upland Natural Area
Sphagnum flexuosum	LR-ns	In marshes, woodland and on flushed rock-ledges. This species is thought to be under-recorded.	Cumbria Fells & Dales
Sphagnum majus	LR-nt	With *S. balticum* and *S. recurvum* in wet depressions in the marginal zone of a large valley bog.	Border Uplands
Sphagnum pulchrum	LR-ns	Forming carpets in depressions (including old peat-diggings) on ombrotrophic bogs, normally in very acid water.	Border Uplands
Tomentypnum nitens	LR-ns	Open, calcareous mires and flushes with gently flowing water, often on gentle slopes flushed by water from steeper ones.	Border Uplands North Pennines Yorkshire Dales Cumbria Fells & Dales South West Peak
Tortella densa	LR-ns	On limestone rocks and in grassy flushes. See Table 10.2.	Cumbria Fells & Dales North Pennines Yorkshire Dales
Tortula subulata var. *subinermis*	LR-ns	On soil and about tree-bases by streams and rivers.	Forest of Bowland White Peak
Trichostomopsis umbrosa	LR-ns	Damp, shady, calcareous places. See Table 10.2.	White Peak
Weissia microstoma var. *brachycarpa*	LR-ns	On wet non-calcareous clay, loam or marl. See Table 7.11.	Dark Peak Forest of Bowland
Weissia rostellata	LR-nt Priority	An ephemeral species colonising moist bare ground. Most frequent on gravelly ground and mud exposed in late summer and autumn on the margins of reservoirs and occasionally rivers, but also in a number of other situations including the banks of ditches, woodland rides and bare patches and turfy hollows in fields and pastures. Usually on clay or rich organic soil which is water-retentive or kept moist by its physical situation.	Border Uplands Forest of Bowland Southern Pennines

Key to Table 6.3

Status

Annex IIb	- listed on Annex IIb of the EC Habitats and Species Directive
Sched. 8 of WCA	- listed on schedule 8 of the Wildlife & Countryside Act.

Red list categories

CR	- critically endangered
EN	- endangered
VU	- vulnerable
DD	- data deficient
LR -nt	- Lower risk - near threatened
LR-ns	- Lower risk - nationally scarce
E	- endemic to Great Britain
EE	- endemic to England.

Biodiversity Action Plan (BAP)

Priority	- Priority species from UK Steering Group 1995 and UK Biodiversity Group 1998.
SCC	- Species of conservation concern from UK Steering Group 1995 and UK Biodiversity Group 1998.

Sources

Most information from Hill, Evans & Bell 1992; Hill, Preston & Smith 1992, 1994; Hodgetts, Palmer & Wigginton 1996 and Porley & McDonnell 1997.

Table 6.4 Plant communities associated with moorland areas in England

NVC code	NVC name	Inclusion in Annex 1 of Habitats Directive[1]	Significance in England[2]	Upland Natural Areas of England where community occurs[2] (see Figure 1.1)
HEATHS				
Dry heath				
H4	*Ulex gallii-Agrostis curtisii* heath.	Dry heaths	I	87, 92, 94
H8	*Calluna vulgaris-Ulex gallii* heath.	Dry heaths	I	4, 10, 25, 29, 30, 42, 58, 60, 87, 92, 94
H9	*Calluna vulgaris-Deschampsia flexuosa* heath.	Dry heaths	UK	2, 4, 8/15, 10, 12, 14, 17, 25, 29, 30, 42, 58
H10	*Calluna vulgaris-Erica cinerea* heath.	Alpine and sub-alpine heaths Dry heaths	UK	2, 4, 10, 12, 17, 42, 87, 92
H12	*Calluna vulgaris-Vaccinium myrtillus* heath.	Alpine and sub-alpine heaths Dry heaths	UK	2, 4, 8/15, 10, 12, 14, 17, 25, 29, 30, 42, 58, 60, 87, 92, 94
H13	See Chapter 5 Montane areas.			
H16	*Calluna vulgaris-Arctostaphylos uva-ursi* heath.	Alpine and sub-alpine heaths Dry heaths	L	10
H18	*Vaccinium myrtillus-Deschampsia flexuosa* moss-heath. See also Chapter 5 Montane areas.	Alpine and sub-alpine heaths Dry heaths	L	2, 4, 8/15, 10, 12, 14, 17, 25, 29, 42, 58, 60, 87, 92, 94
H19	See Chapter 5 Montane areas.			
H21	*Calluna vulgaris-Vaccinium myrtillus-Sphagnum capillifolium* heath	Alpine and sub-alpine heaths Dry heaths	I	2, 4, 10, 12, 17, 42, 87
H22	See Chapter 5 Montane areas.			

NVC code	NVC name	Inclusion in Annex 1 of Habitats Directive[1]	Significance in England[2]	Upland Natural Areas of England where community occurs[2] (see Figure 1.1)
MIRES				
Bog pools				
M1	*Sphagnum auriculatum* bog pool community	-	L	10, 87, 92
M2	*Sphagnum cuspidatum/recurvum* bog pool community	-	L	2, 4, 10, 12, 14, 25, 29, 87, 92
M3	*Eriophorum angustifolium* bog pool community	-	L	2, 4, 8/15, 10, 14, 25, 29, 87, 92
Small sedge bryophyte fens				
M4	*Carex rostrata-Sphagnum recurvum* mire.	Transition mires and quaking bogs	L	2, 4, 8/15, 10, 12, 25, 29, 58, 87, 92, 94
M5	*Carex rostrata-Sphagnum squarrosum* mire.	Transition mires and quaking bogs	L	10
M6	*Carex echinata-Sphagnum auriculatum/recurvum* mire.	-	I	2, 4, 8/15, 10, 12, 14, 17, 25, 29, 42, 58, 60, 87, 92, 94
M7, M8	See Ch 5 Montane areas.			
M9	*Carex rostrata-Calliergon cuspidatum* mire.	Transition mires and quaking bogs Alkaline fens	L	2, 4, 8/15, 10, 29, 41, 87
M10	*Carex dioica-Pinguicula vulgaris* mire.	Alpine pioneer formations of *Caricion bicoloris-atrofuscae** Alkaline fens	UK	2, 4, 8/15, 10, 12, 14, 17, 25, 29, 42, 60, 87
M11	*Carex demissa-Saxifraga aizoides* mire.	Alpine pioneer formations of *Caricion bicoloris-atrofuscae**	UK	4, 10, 42
M13	*Schoenus nigricans-Juncus subnodulosus* mire.	Alkaline fens	Not specified	17

NVC code	NVC name	Inclusion in Annex 1 of Habitats Directive[1]	Significance in England[2]	Upland Natural Areas of England where community occurs[2] (see Figure 1.1)
Wet heath				
M15	*Scirpus cespitosus-Erica tetralix* wet heath.	-	UK	2, 4, 10, 12, 17, 29, 60, 87, 92, 94
M16	*Erica tetralix-Sphagnum compactum* wet heath.	-	I	2, 4, 10, 17, 25, 29, 87, 92, 94
Blanket mires				
M17	*Scirpus cespitosus-Eriophorum vaginatum* blanket mire.	Blanket bog (active only*)	I	2, 4, 8 / 15, 10, 87, 92
M18	*Erica tetralix-Sphagnum papillosum* raised and blanket mire.	Blanket bog (active only*)	UK	2, 4, 8 / 15, 10, 12
M19	*Calluna vulgaris-Eriophorum vaginatum* blanket mire.	Blanket bog (active only*)	UK	2, 4, 8 / 15, 10, 12, 14, 25, 29, 42, 58, 60
M20	*Eriophorum vaginatum* blanket and raised mire.	-	UK	2, 4, 8 / 15, 10, 12, 14, 25, 29, 42, 60
Valley mires				
M21	*Narthecium ossifragum-Sphagnum papillosum* valley mire. See also Chapter 7 Meadows and enclosed pasture.	-	L	10, 17, 25, 29, 58, 92, 94
***Molinia* and *Juncus* fens**				
M22 - M24	See Chapter 7 Meadows and enclosed pasture.			
M25	*Molinia caerulea-Potentilla erecta* mire. See also Chapter 7 Meadows and enclosed pasture.	-	I	2, 4, 8 / 15, 10, 12, 14, 17, 25, 29, 42, 58, 87, 92, 94
M26	See Chapter 7 Meadows and enclosed pasture.			
Tall-herb fen				

NVC code	NVC name	Inclusion in Annex 1 of Habitats Directive[1]	Significance in England[2]	Upland Natural Areas of England where community occurs[2] (see Figure 1.1)
M27	See Chapter 9 Freshwater habitats.			
Springs				
M29 - M38	See Chapter 7 Meadows and enclosed pasture (M29, M35, M36, M37, M38) and Chapter 5 Montane areas (M31, M32).			
GRASSLAND				
Neutral (mesotrophic) grasslands				
MG2 - MG13	See Chapter 7 Meadows and enclosed pasture.			
Calcareous grasslands				
CG2	*Festuca ovina - Avenula pratensis* grassland. (See also Chapter 7 Meadows and enclosed pasture)	Semi-natural dry grasslands and scrubland facies on calcareous substrate (*Festuco brometalia*) (important orchid sites*)	Not specified	30, 41
CG3, CG6, CG7	See Chapter 7 Meadows and enclosed pasture.			
CG9	*Sesleria albicans-Galium sterneri* grassland. (See also Chapter 7 Meadows and enclosed pasture)	Semi-natural dry grasslands and scrubland facies on calcareous substrate (*Festuco brometalia*) (important orchid sites*)	I	2, 4, 8/15, 10, 14
CG10	*Festuca ovina-Agrostis capillaris - Thymus praecox* grassland. (See also Chapter 7 Meadows and enclosed pasture)	Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and sub-mountain areas in continental Europe)*	UK	2, 4, 8/15, 10, 30, 42, 60
CG11	See Chapter 5 Montane areas.			

NVC code	NVC name	Inclusion in Annex 1 of Habitats Directive[1]	Significance in England[2]	Upland Natural Areas of England where community occurs[2] (see Figure 1.1)
Acid (calcifugous) grasslands				
U1	*Festuca ovina-Agrostis capillaris-Rumex acetosella* grassland.	-	L	4, 10, 42
U2	*Deschampsia flexuosa* grassland.	-	L	2, 4, 8 / 15, 10, 12, 14, 25, 29, 92
U3	*Agrostis curtisii* grassland.	-	I	87, 92, 94
U4	*Festuca ovina-Agrostis capillaris-Galium saxatile* grassland.	-	L	2, 4, 8 / 15, 10, 12, 14, 17, 25, 29, 30, 42, 58, 60, 87, 92, 94
U5	*Nardus stricta-Galium saxatile* grassland.	-	L	2, 4, 8 / 15, 10, 12, 14, 17, 25, 29, 30, 42, 58, 60, 87, 92, 94
U6	*Juncus squarrosus-Festuca ovina* grassland.	-	I	2, 4, 8 / 15, 10, 12, 14, 17, 25, 29, 42, 58, 60, 92, 94
U7, U10, U13	See Chapter 5 Montane areas.			
Tall-herb communities				
U15, U16, U17	See Chapter 10 Crags, scree and limestone pavement.			
Fern communities				
U19	See Chapter 10 Crags, scree and limestone pavement.			
U20	*Pteridium aquilinum-Galium saxatile* community.	-	-	2, 4, 8 / 15, 10, 12, 14, 17, 25, 29, 42, 58, 60, 87, 92, 94
U21	See Chapter 10 Crags, scree and limestone pavement.			

NVC code	NVC name	Inclusion in Annex 1 of Habitats Directive[1]	Significance in England[2]	Upland Natural Areas of England where community occurs[2] (see Figure 1.1)
Open vegetation				
OV37	*Festuca ovina-Minuartia verna* metalliferous grassland.	-	Not specified	4, 8 / 15, 30
OV38 - OV40	See Chapter 10 Crags, scree and limestone pavement.			
Woodland and scrub				
Various	See Chapter 8 Woodland and scrub.			

Key to Table 6.4

1 From Brown *et al* 1997.
- * Priority habitat

2 From Drewitt & Manley 1997:
- I Internationally scarce with UK representation;
- UK Well developed in the UK but represented elsewhere;
- L Widely developed in Europe.

NVC - National Vegetation Classification (Rodwell 1991, 1992 & 2000)

Table 6.5 Breeding birds associated with moorland in England

Bird species[1]	Birds of conservation concern in the UK[2]	Listed on Schedule 1 of the 1981 Wildlife & Countryside Act	Listed on Annex 1 of the EC Birds Directive	No. of British 10 km squares with breeding records 1988-90	% of breeding records in upland ITE squares[3]	Main upland habitat association	Principal Natural Areas supporting the species * = major/important areas[4]
Wigeon *Anas penelope*	Amber list	-	-	128	74.2	Moorland and fresh waters	2, 4*, 8*, 14
Teal *Anas crecca*	Amber list	-	-	571	52.5	Moorland and fresh waters	2*, 4*, 8*, 12*, 14, 25
Hen harrier *Circus cyaneus*	Red list	!	!	286	82.5	Moorland	2, 4, 8, 12* Extinct elsewhere / continuous persecution
Golden eagle *Aquila chrysaetos*	Amber list	!	!	216	88.9	Moorland and montane areas	10*, extinct elsewhere
Merlin *Falco columbarius*	Red list	!	!	386	87.3	Moorland and enclosed land	2, 4*, 8*, 10*, 12*, 14*, 15, 17*, 25*, 29, 42, 58, 87
Peregrine *Falco peregrinus*	Amber list	!	!	719	61.6	Moorland and montane areas	4, 8, 10*, 12, 14, 15, 25, 87*, 94
Red grouse *Lagopus lagopus scoticus*	-	-	-	749	78.6	Moorland	2*, 4*, 8*, 10, 12*, 14*, 15*, 17*, 25*, 29, 41, 42, 58(?), 87, 92
Black grouse *Tetra tetrix*	Red list Priority BAP species	-	-	278	86	Moorland and enclosed land	2, 4*, 8, 29, extinct elsewhere
Golden plover *Pluvialis apricaria*	Amber list	-	!	630	84.1	Moorland and enclosed land	2*, 4*, 8*, 10, 12*, 14*, 15, 17*, 25*, 29, 92
Dunlin *Calidris alpina*	Amber list	-	-	353	78.8	Moorland	2, 4*, 8*, 12, 14*, 25*

Bird species[1]	Birds of conservation concern in the UK[2]	Listed on Schedule 1 of the 1981 Wildlife & Countryside Act	Listed on Annex 1 of the EC Birds Directive	No. of British 10 km squares with breeding records 1988-90	% of breeding records in upland ITE squares[3]	Main upland habitat association	Principal Natural Areas supporting the species * = major/important areas[4]
Snipe *Gallinago gallinago*	Amber list	-	-	1,307	49.8	Enclosed land and moorland	All upland Natural Areas but 87, but note in particular 2*, 4*, 8*, 12*, 14*, 15*, 25*,29*
Curlew *Numenius arquata*	Amber list	-	-	1,354	48.1	Moorland and enclosed land	2*, 4*, 8*, 10, 12*, 14*, 15*, 17*, 25*, 29*, 30, 41, 42, 58, 60, 87, 92, 94
Redshank *Tringa totanus*	Amber list	-	-	1,046	36.8	Enclosed land and moorland	2*, 4*, 8*, 12*, 14*, 15, 25
Black-headed gull *Larus ridibundus*	-	-	-	671	46.2	Moorland and fresh waters	2*, 4*, 8*, 10*, 12*, 14, 17
Common gull *Larus canus*	Amber list	-	-	575	62.6	Moorland and fresh waters	2*, 4
Short-eared owl *Asio flammeus*	Amber list	-	!	381	70.9	Moorland	2*, 4*, 8*, 12*, 14*, 15, 17*, 25*, 29
Meadow pipit *Anthus pratensis*	-	-	-	2,257	38.1	Moorland and enclosed land	All areas
Whinchat *Saxicola rubetra*	-	-	-	1,062	59.9	Moorland and scrub	2*, 4*, 8*, 10*, 12*, 14*, 15*, 17*, 25, 29*, 30, 41, 42, 60, 87*, 92*, 94*
Stonechat *Saxicola torquata*	Amber list	-	-	847	47.7	Moorland and scrub	10*, 42, 58, 87*, 92*, 94
Wheatear *Oenanthe oenanthe*	-	-	-	1,339	60.6	Montane areas, moorland and enclosed land	2*, 4*, 8*, 10*, 12, 14, 15, 17, 25, 29, 30*, 41, 42, 58, 60, 87, 92*, 94

Bird species[1]	Birds of conservation concern in the UK[2]	Listed on Schedule 1 of the 1981 Wildlife & Countryside Act	Listed on Annex 1 of the EC Birds Directive	No. of British 10 km squares with breeding records 1988-90	% of breeding records in upland ITE squares[3]	Main upland habitat association	Principal Natural Areas supporting the species * = major/important areas[4]
Ring ouzel *Turdus torquatus*	Amber list	-	-	401	93.5	Moorland and scrub	2, 4*, 8*, 10*, 12, 14*, 15(?), 17, 25, 29, 30, 42, 87, 92*
Raven *Corvus corax*	-	-	-	783	52	Moorland and montane areas	4*, 10*, 41*, 42*, 58*, 60*, 87*, 92*, 94*, extinct elsewhere but recolonising
Twite *Carduelis flavirostris*	Red list	-	-	420	70.2	Moorland and enclosed land	4, 8, 14*, 25*, 29*

Key to Table 6.5

1. Upland breeding bird species as identified in Stillman & Brown 1994.
2. Birds of conservation concern from RSPB 1996.
   BAP relates to the UK Biodiversity Action Plan and those species which are considered to be priority species (UK Biodiversity Group 1998; UK Steering Group 1995).
3. From Bunce & Barr 1988, using the 13 ITE land classes which were regarded as upland (information not available on an English basis).
4. The following 18 Natural Areas are classed as upland by English Nature:

No.	Natural Area name
2	Border Uplands
4	North Pennines
8	Yorkshire Dales
10	Cumbria Fells & Dales
12	Forest of Bowland
14	Southern Pennines
15	Pennine Dales Fringe
17	North York Moors and Hills
25	Dark Peak
29	South West Peak
30	White Peak
41	Oswestry Uplands
42	Shropshire Hills
58	Clun & North West Herefordshire Hills
60	Black Mountains and Golden Valley
87	Exmoor and the Quantocks
92	Dartmoor
94	Bodmin Moor

Table 6.6 Habitat and management requirements of birds associated with moorland in England

Moorland birds	Habitat requirements	Moorland habitat management
Wigeon	! Weak association with open moorland. ! Nest on ground in amongst heather or bracken on bank or on wet moors and along stream sides. ! Adult feeding areas likely to be nearby improved grasslands, perhaps adjacent to fresh waters - riparian grassland. ! Chicks taken to feed on pools or in very wet areas. ! Present April to July.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips.
Teal	! Weak association with moorland fringe, and diversity of damp to wet upland habitats. ! Nest placed beneath tussocks or clumps of heather or grass adjacent to water or on wet bogs. ! Adults and young forage in pools, bogs, wet heath, waterlogged grassland and nearby rivers and lakes. ! Present March-July.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Do not burn wet heath or blanket bog as these areas are rich in plant and insect food and very sensitive to drying out.
Hen harrier	! Strong association with heather moors. ! Heather moors with a high grass component may be the most suitable for hen harriers: prey such as meadow pipits and voles are more abundant on such moors. ! Nest placed on ground in areas of tall heather, on slope with good visibility. ! Adults forage for small birds such as meadow pipits and red grouse (mainly chicks) and small mammals such as field voles, on heather and grass moors and over enclosed fields. ! Food brought to dependent young in nest by adults. ! Present all year, but most leave for lowland coastal areas outside breeding season April-end July.	! Retain existing scrub such as gorse and juniper and scattered trees such as hawthorn and rowan. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Do not burn areas of taller heather which have been used for nesting in the recent past.

Moorland birds	Habitat requirements	Moorland habitat management
Golden eagle	! Associated with remote, open country with cliffs or widely scattered woodland. ! Nest placed on rock ledge on tall cliff or in large forest tree. ! Adults forage on grouse, rabbits, mountain hares and carrion found mainly on moorland but also over enclosed land, particularly in winter. ! Adults bring food to dependent young in nest. ! Birds present throughout the year, nesting February to July.	! Manage to encourage grouse, rabbit abundance, and to increase the amount of carrion available. ! Maintain large areas of open ground.
Merlin	! Strong association with heather moorlands. ! Nest placed on ground in tall heather, or occasionally in bracken, on moderate to steep slopes. ! Also nest occasionally in trees on moorland and at the edge of plantations. ! Adults forage for a wide diversity of small bird prey (especially meadow pipit) over both moorland and enclosed grassland. ! Food brought to nest for dependent young by adults. ! Some birds present throughout the year, but many more present in breeding season, April-July, and most leave for lowland coastal areas in winter.	! Manage grazing to maintain or enhance the heath and mire communities. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Do not burn areas of taller heather which have been used for nesting in the recent past. ! Leave some areas unburnt to allow scrub and scattered trees to grow as in some areas, eg Exmoor, merlins nest in such habitats. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is still intact and likely to recover, and target the invading edge for control.
Peregrine	! Nest placed on undisturbed steep crags, cliff ledge, chimney or ledge on tall building. ! Adults forage on waders, grouse and pigeons caught over moorland, enclosed grasslands and urban areas. ! Adults bring food to dependent young in nest. ! Present throughout the year.	! Limit recreational disturbance during February-June to nest sites and potential nest sites.

Moorland birds	Habitat requirements	Moorland habitat management
Red grouse	! Nests on ground on heather moorland. ! Strongly associated with heather moorland managed for grouse. ! Adults feed particularly on young heather shoots, also bilberry shoots, cotton-grass flowers and invertebrates. ! Chicks forage for invertebrates in wet and grassy patches on heather moors. ! Present throughout the year.	! Manage grazing to maintain or enhance the heath and mire communities. ! Shepherd stock to avoid localised heavy grazing. ! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Burn heather on rotation on flatter ground to provide a mosaic of different aged stands and burn patches of about a half to one hectare at a time. ! Do not burn in areas where the heather is already prostrate through natural causes as regrowth will be slow. ! Keep stock feeding to a minimum and away from heather or rotate feeding sites to reduce damage. ! Avoid the use of fertilisers on moorland as this leads to the replacement of heather with grasses.

Moorland birds	Habitat requirements	Moorland habitat management
Black grouse	! Nests on ground in tall heather moorland or in rushy pastures. ! Adults associate strongly with mixed moorland areas, with heather moors, *Vaccinium* heaths, *Eriophorum* bog and scrub and light woodland. ! Chicks forage in wet flushes for invertebrates, particularly moth and sawfly larvae. ! In winter, birds forage on heather moorland and amongst birch, rowan, hawthorn, alder and willow scrub. ! Present in uplands throughout the year.	! Manage grazing to maintain or enhance the heath and mire communities. ! Shepherd stock to avoid localised heavy grazing. ! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Do not control rushes where bog mosses are also abundant. ! Create small, wet areas by blocking existing drains and grips. ! Retain existing scrub such as gorse and juniper and scattered trees such as hawthorn and rowan. ! On gentler slopes graze or cut existing scrub on a rotation. Provide a range of habitats by clearing about 10% of scrub each year when it is about 10 years old. ! Fence off areas of existing scrub to allow natural regeneration. Only fence off areas where grazing makes this essential by preventing natural regeneration. Ensure fencing is clearly marked to reduce the possibility of birds striking the fence. ! Scarify the ground around old stands of scrub where regeneration is poor to encourage its spread. ! Plant additional native trees and shrubs typical of the location on areas of low wildlife interest, targeting sheltered ghylls and cloughs. Suitable species may include native birch, alder, willow, rowan and hawthorn. Some aspen *Populus tremula*, juniper and Scots pine may be acceptable where locally present. ! Do not burn wet heath or blanket bog as these areas are rich in plant and insect food and very sensitive to drying out. ! Leave some areas unburnt to allow scrub and scattered trees to grow. ! Avoid the use of fertilisers on moorland as this leads to the replacement of heather and grasses. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is still intact and likely to recover and target the invading edge for control.

Moorland birds	Habitat requirements	Moorland habitat management
Golden plover	! Strong association with flat or gently sloping ground, on unenclosed blanket bog and heather moors managed for grouse or sheep for nesting and enclosed pastures for feeding. ! Nests on ground in short vegetation, created by burning, grazing or stunting on bogs or on ridge summits. ! Chicks feed on grass patches on heather moor or in wet flushes - chicks may be led over a kilometre to feed in invertebrate rich areas by their parents. ! When not incubating and before and following the breeding season, adults forage in enclosed, earthworm-rich, improved and semi-improved grassland up to at least 7 km away from nests. ! Presence in uplands very weather dependent: in mild years or areas, birds may be present throughout the year, but more usually present between late February and end June.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drain and grips. ! Use a shorter heather burning rotation on flatter ground. ! Do not burn in areas where the heather is already prostrate through natural causes as regrowth will be slow. ! Do not burn areas of undamaged blanket mire. ! Graze so as to create areas of short turf on flat or gently sloping ground.
Dunlin	! Strong association with flat to gently sloping, waterlogged plateaux, particularly with wet blanket bog and pool complexes, although exact requirements poorly understood. ! Nest in grass or *Eriophorum* tussock on blanket bog. ! Chick and adult feeding areas not well known but include the edge of wet pools, and gullies on bog. ! Present during breeding season only, late April-end June.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips.

Moorland birds	Habitat requirements	Moorland habitat management
Snipe	! Strong association with damp to wet unenclosed and enclosed land. ! Nest placed on ground concealed in tussock in tall vegetation especially rushes in enclosed fields, wet moorland, grassland and wet flushes. ! Adults forage for invertebrates in soft soil where water table near (< 20 cm) surface, in damp rushy flushes, pools, stream sides on moors and on enclosed land. ! Chicks forage for invertebrates in damp, rushy flushes, pools on moor or in enclosed fields. ! Present mainly late February-end June.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Do not burn wet heath or blanket bog as these areas provide cover and are rich in plant and insect food. ! Do not control rushes where bog mosses are also abundant.
Curlew	! Broad habitat association with flat or gently sloping ground, on low to moderate altitude moorlands and enclosed grasslands. ! Nest in a wide range of sites, on the ground in both enclosed fields and on open moorland, in rough and wet grassland and in tall and short vegetation. For example, in *Eriophorum* and large grass tussocks, in tall rushes and amongst the dead stems of sharp-flowered rush, in short or prostrate heather, in fresh burnt patches, and amongst bracken litter. ! On heavily grazed moors with short grassland, nesting birds undertake much feeding on these moors. Occasionally breeding adults will also feed in enclosed fields some distance (3-4 km) from nest sites, rather than using fields immediately adjacent to the moor. Prior to laying and during incubating, adults feed on improved and semi-improved pastures rich in invertebrates because they are feeding mainly on earthworms and leatherjackets. After hatching, adults feed in the same areas as the chicks. ! Chicks feed particularly in areas of wet rushy grassland and flushes, and moorland nesting birds will often take chicks into neighbouring enclosed fields. Also feed on the ground beneath tall heather and on short burnt heather. ! Present late February-end June.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Use a shorter heather burning rotation on flatter ground and burn patches of about a half to one hectare at a time. ! Do not burn wet heath or blanket bog as these areas are rich in plant and insect food and very sensitive to drying out.

Moorland birds	Habitat requirements	Moorland habitat management
Redshank	! Associated with riparian grasslands, unimproved and semi-improved pastures and, much less frequently, with damp moorland. ! Nest is placed on ground in tussock in unimproved and semi-improved fields and allotments, in wet hollows or riparian grasslands. ! Adults and chicks forage for invertebrates in wet riparian grasslands, stream sides and lake sides, enclosed improved land and wet, rushy patches in fields. ! Present mid-April - end June.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips.
Black-headed gull	! Nest on ground in colonies on heather moors, blanket bogs or in riparian grasslands in river valleys, around reservoirs or on islands. ! Adults forage widely for multitude of food items (invertebrates, carrion, waste) from fresh waters, improved, earthworm-rich pastures, tilled farmland, roadsides, etc. May take eggs and young of ground-nesting birds. ! Food brought to dependent young by adults. ! Present during April to June breeding season.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Do not burn wet heath or blanket bog as these areas are rich in plant and insect food and very sensitive to drying out.
Common gull	! Nest on ground in colonies on heather moors, blanket bogs or riparian grasslands in river valleys, around reservoirs or on islands. ! Adults forage widely for multitude of food items (invertebrates, carrion, waste) from fresh waters, improved, earthworm-rich pastures, tilled farmland, roadsides, etc. May also take the eggs and chicks of ground-nesting birds. ! Food brought to dependent young by adults. ! Present during April to June breeding season.	! Do not burn wet heath or blanket bog as these areas are rich in plant and insect food and very sensitive to drying out.

Moorland birds	Habitat requirements	Moorland habitat management
Short-eared owl	! Strong association with unenclosed moorland, particularly on moderate to steep slopes towards moorland edge, and with young forestry. ! Nest on ground within patches of tall heather, amongst bracken litter or in tall grassland, usually with good visibility. ! Adults forage over all open moorland and enclosed unimproved grasslands for small mammals. ! Food brought to nest by adults. ! Small numbers present throughout year but most present during breeding season April-August.	! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall.
Meadow pipit	! Found in association with nearly all types of upland habitat . ! Nest placed on ground in tussock or depression in heath, grass or bracken. ! Birds forage for invertebrates in short or moderately tall vegetation. Densities appear to be greatest on heather moors with a higher grass component. ! Food brought by adults to dependent young in nest . ! Present mainly March-late July. Not usually present outside breeding season.	! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Use a shorter heather burning rotation on flatter ground and burn patches of about a half to one hectare at a time.

Moorland birds	Habitat requirements	Moorland habitat management
Whinchat	! Strong association with tall vegetation, notably scrub, bracken and very tall grass and heather. ! Adults sally for invertebrates from tall vegetation, fence posts and fencing wire or feed off ground on grassy patches amongst heather adjacent to bracken or on improved / semi-improved pastures. ! Adults bring food to dependent young in nest. ! Birds present end April-July.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Retain existing scrub such as gorse and juniper and scattered trees such as hawthorn and rowan. ! On gentler slopes graze or cut scrub on a rotation. Provide a range of habitats by clearing about 10% of scrub each year when it is about 10 years old. ! Scarify the ground around old stands of scrub where regeneration is poor to encourage its spread. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Do not burn wet heath or blanket bog as these areas are rich in plant and insect food and very sensitive to drying out. ! Leave some areas unburnt to allow scrub and scattered trees to grow. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is still intact and likely to recover and target the invading edge for control. ! Do not control rushes where bog mosses are also abundant.

Moorland birds	Habitat requirements	Moorland habitat management
Stonechat	! Strong association with scrub, tall heather or bracken. ! Nest placed low in bracken, gorse and other tall, thick scrub, trees or heather. ! Adults feed on open grassy areas, within otherwise shrub-dominated habitat or amongst patches of bracken, so long as perches are available on tall vegetation. ! Adults bring food to dependent young in nest. ! Found throughout year on scrub areas on enclosed farmland and on open moorland.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips. ! Retain existing scrub such as gorse and juniper and scattered trees such as hawthorn and rowan. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Leave some areas unburnt to allow scrub and scattered trees to grow. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is till intact and likely to recover and target the invading edge for control. ! Do not control rushes where bog mosses are also abundant.
Wheatear	! Nest in hole in ground or wall, in bracken clump, beneath stones, on enclosed farmland, moorland or scree. ! Adults forage for invertebrates over bare ground or short swards on heather and grass moors, stream sides, lake shores and enclosed farmland. ! Adults bring food to dependent young in nest. ! Birds usually present during extended breeding season, March-September.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is still intact and likely to recover and target the invading edge for control.

Moorland birds	Habitat requirements	Moorland habitat management
Ring ouzel	! Preference for nesting in areas of sloping land, particularly ghylls and stream sides and, rarely, trees. ! Nest on ground in tall heather or bracken litter or in hole in wall or rock crevice. ! Adults forage in short swards in enclosed fields, unenclosed moors, especially *Vaccinium* when fruiting. ! Adults bring mainly invertebrate food to the nest for the chicks. ! Relatively heavily grazed areas near to nest sites, with damp, short, earthworm-rich swards for feeding, may be important but key feeding habitats and foods require further study. ! Birds present early April-end Sept. Absent from uplands in non-breeding season.	! Retain existing scrub such as gorse and juniper and scattered trees such as hawthorn and rowan. ! Fence off areas where there is some scrub to allow natural regeneration. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Leave some areas unburnt to allow scrub and scattered trees to grow. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is still intact and likely to recovery and target the invading edge for control.
Raven	! In the uplands, nest on ledges on cliff or quarry faces, and less frequently in trees (preferably conifers) which are isolated, in small woods or at the edges of plantations (not deep in large forests), and on buildings. ! Adults forage over open country for a variety of food, particularly carrion but also living animals, on moorland, enclosed and cultivated land, and roadsides. ! Opportunist feeders, scavenging carrion such as sheep, rabbit, hare, other small mammals and birds. Also take live animal prey such as small rabbits and other small mammals, reptiles, amphibians and invertebrates. Can be major predators of eggs and chicks of other birds. Some vegetable material, such as seeds, buds, berries and cereal grains, is also eaten. ! Food brought to dependent young in nest by adults. ! Early nesters and disturbance to nests when young present can affect growth. ! Present throughout the year.	! Maintain moorland trees and undisturbed cliffs for nesting. ! Manage to encourage rabbit and carrion availability.

Moorland birds	Habitat requirements	Moorland habitat management
Twite	! Strong association with tall vegetation at moorland edge, often in close proximity to water and to flower-rich meadows. ! Nest placed on ground or low down in tall heather, bracken litter or, more rarely, in grass, *Eriophorum* or small crevice, always on unenclosed land. ! Adults forage for flower seeds collected in burnt *Molinia* patches and from farmyards, haystacks, etc in April and early May, from flower-rich meadows and pastures in May and June and from roadside verges and any remaining uncut meadows thereafter. Birds will forage up to at least 2 km from moorland nest site. ! Food brought to dependent young in nest by adults. ! Birds usually present during extended breeding season, April-September.	! Maintain natural drainage and all wetland features such as pools, flushes and boggy areas. ! Create small, wet areas by blocking existing drains and grips to provide drinking areas. ! Retain existing scrub such as gorse and juniper and scattered trees such as hawthorn and rowan. ! Where burning is desirable use a rotation of at least 20 years in some areas, for example on steep slopes and in gullies and cloughs, so that the heather can grow tall. ! Leave some areas unburnt to allow scrub and scattered trees to grow. ! Where purple moor-grass is present as a uniform stand burn patches (ie not the whole area) annually. ! Where bracken is controlled, cut or spray after the breeding season in late July / early August and leave a buffer zone near streams and gullies. ! Leave areas of bracken on steep slopes or gullies. Only spray areas where the underlying sward is still intact and likely to recover and target the invading edge for control.

Table 6.7 Nationally rare and scarce invertebrates associated with moorland in England

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of Natural Areas)
Scientific Name	**English Name**			
Moths				
Anarta melanopa	Broad-bordered white underwing	RDB3 SCC	Moorland. Larvae feed on bilberry *Vaccinium myrtilus* and crowberry *Empetrum nigrum*. In mainland Britain this species is restricted to altitudes above 650 m.	Cheviot and West Cumbria only locations in England.
Aphelia unitana	—	RDB2	Moorland and limestone dales. Wide range of larval food plants.	Known locations at Malham Tarn, Yorkshire, Dovedale, Derbyshire, Mainfold Valley, Staffordshire and Heddon's Mouth, Exmoor.
Crambus ericella	Heath grass veneer	Nationally Scarce B	Ecology unknown - caterpillar likely to be on moorland grasses.	Cumbria and Yorks Dales. Widespread in Scotland
Carsia sororiata	Manchester treble bar	Nationally Scarce B	Caterpillar on bilberry, cowberry *Vaccinium vitis-idaea* and crowberry.	Northern and western moorland.
Dyscia fagaria	Grey scalloped bar	Nationally Scarce B	Caterpillar on heather *Calluna vulgaris*, bell-heather *Erica cinerea* and cross-leaved heath *Erica tetralix*.	Northern and western moorlands.
Epione paralellaria	Dark bordered beauty	RDB2/3 Priority	Lightly wooded upland heaths and lowland bogs. Feeds on willow *Salix* spp. and aspen *Populus tremula*.	Northumberland, Yorkshire.
Epirrita filigrammaria	Small autumnal moth	Nationally Scarce B	Caterpillar on heather and bilberry.	Northern and western moorlands.
Hypenodes humidalis	Marsh oblique-barred	Nationally Scarce B	Larva probably on cross-leaved heath.	Western moorlands - Somerset, Shropshire and Cumbria. Also southern lowland heaths.
Hyppa rectilinea	The saxon	Nationally Scarce A	Moorland and northern woods. Larva polyphagous.	Northumberland and Cumbria only in England.

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of Natural Areas)
Scientific Name	**English Name**			
Lithomoia solidaginis	Golden-rod brindle	Nationally Scarce B	Moorland and open woodland. Larva on goldenrod *Solidago virgaurea.*	Northern moorlands, south to Staffordshire. Regular migrant and turns up south of this as non-resident.
Perizoma minorata	Heath rivulet	Nationally Scarce B	On flowers / seeds of eyebrights *Euphrasia* spp in upland pasture / moorland.	Cumbria and Yorkshire in England.
Perizoma blandiata	Pretty pinion	Nationally Scarce B	On flowers / seeds of eyebrights in upland pasture / moorland.	Cumbria and Yorkshire in England.
Syngrapha interrogationis	Scarce silver Y	Nationally Scarce B	Moorland. Larvae on heather and bilberry.	Northern England, south to Staffordshire. Regular migrant elsewhere.
Xestia alpicola alpina	Northern dart	Nationally Scarce A. Priority	Moorland and high mountain tops. Larvae feed on crowberry and probably other dwarf shrubs.	Moorhouse, Pennines, Cumbria and the Cheviot.
Xestia ashworthii	Ashworth's rustic moth	Nationally Scarce A Priority	On heather and other upland plants (including foxglove *Digitalis purpurea*) in montane and moorland areas.	Northumberland.
Xylena exsoleta	Sword grass	Nationally Scarce B Priority	Moorland and open woodland. Larva polyphagous.	Northern England.
Butterflies				
Coenonympha tullia	Large heath	SCC	Fringes of blanket bogs and lowland raised mires. Larval food plant is hare's-tail cotton-grass *Eriophorum vaginatum*, adult nectar plant is cross-leaved heath.	In England, confined to the north.
Erebia aethiops	Scotch argus	England priority species	In England on sheltered calcareous / neutral grassland (*Sesleria* and *Molinia*) rather than moorland.	A few English colonies occur in Cumbria, mainly in carboniferous limestone regions north of Morecambe Bay, and the Cumbria / Yorkshire border on the Craven limestone.

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of Natural Areas)
Scientific Name	**English Name**			
Erebia epiphron	Small mountain ringlet	Nationally scarce B SCC	*Nardus* grassland, from around 400 m upwards.	In England it is restricted to the Lake District only occurring at high altitudes.
Mellicta athalia	Heath fritillary	RDB2 Priority	Moorland fringes between the open moor and usually, but not always, woodland. Larval food plant is primarily common cow-wheat *Melampyrum pratense*, although larger larvae can also use foxglove.	Exmoor.
Bugs				
Cixius cambricus	A lacehopper	Nationally Scarce B	Lacehopper feeding on roots of sedges, sometimes under stones. Upland grassland.	Largely Scotland and Wales but also Yorkshire Dales and Vale of York heaths.
Macrosteles alpinus	A planthopper	Nationally Scarce B	Planthopper on heath rush *Juncus squarrosus*. Moorland blanket bog and upland moist grassland.	Cumbria and Durham in England. More widespread in Scotland.
Flies				
Limonia stylifera	Cranefly	RDB2	Base-rich flushes in association with calcareous outcrops.	Moorhouse NNR, Cumbria and several Scottish sites.
Melanostoma dubium	Hoverfly	Nationally Scarce B	Hoverfly of upland boggy ground. Needs an abundance of nectar flowers, especially tormentil *Potentilla erecta*.	Craven Pennines and Lake District. More widespread in Scotland and Wales.
Tipula limbata	Cranefly	RDB3	Waterlogged soil on high moorland in England (and boggy woodland flushes in Scotland).	North Yorks Moors, Cumbrian and Durham Pennines.
Tipula serrulifera	Cranefly	RDB1	Waterlogged soil on high moorland in England.	Only recent site is high heather moorland in North Yorks Moors.
Beetles				
Aphodius fasciatus	Dung beetle	Nationally Scarce B	Moorland and montane dung beetle. Sheep and cattle dung.	North York Moors, Lake District and Pennines

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of Natural Areas)
Scientific Name	**English Name**			
Byrrhus arietinus.	Northern pill beetle	Nationally Scarce B	Feeds on moss - especially *Racomitrium* - on moors and mountain tops.	Pennines, Derbyshire Peaks, North York Moors and Lake District
Carabus nitens	Ground beetle	Nationally Scarce B	Moorland and wet heathland, boggy areas on moorland.	Not Scotland or Wales. Southern heathland species, getting onto high moorland in Pennines and North York Moors.
Geotrupes vernalis	Spring dor beetle	Nationally Scarce B	Moorland and heathland dor beetle. Sheep and cattle dung, usually early in the year.	Cumbria. Old records from Exmoor and North York Moors, also from lowland heaths in the Midlands and SE England. Possibly extinct in lowlands.
Miscodera arctica.	Ground beetle	Nationally Scarce B	Under stones and among moss and heather litter. Also mountain tops among *Racomitrium* and under stones.	Northern and western moorland, south to Exmoor. Also Vale of York heaths.
Olophrum consimile	Rove beetle	Nationally scarce A	Stream sides, wet moss and litter in fens at high altitude.	North York Moors only in England.
Patrobus sepentrionis	Ground beetle	Nationally Scarce B.	Under stones and among moss, usually where wet. Moorland and beside mountain streams.	Mainly Scotland but also Cumbria, Yorkshire Pennines and Humberhead Mires.
Pterostichus aethiops	Ground beetle.	Nationally Scarce B	Moorland species that may migrate to woodland in winter.	Northern upland moorland and bog.
Trechus rivularis	Ground beetle	RDB3 (over-rated)	Blanket bog and moorland.	North Yorkshire Moors, Northumberland and Wales (probably elsewhere but mistaken identity). Declining relict populations in eastern England fens.
Bees, wasps and ants				

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of Natural Areas)
Scientific Name	**English Name**			
Bombus distinguendus	Great yellow bumble-bee	Nationally Scarce B	Formerly fairly widespread bumble bee of various habitats. Has declined in most areas other than extreme northern and western parts of range.	North Yorks Moors.
Spiders				
Clubiona norvegica	A foliage spider	Nationally Scarce B	Spider among moss (especially *Sphagnum*) on high moorland.	Northern and western England - Cumbria, Yorkshire and Cheshire.
Diplocephalus protuberans	A money spider	Nationally Scarce B	Small spider living among moss , grass or rushes. Wet places in upland grassland and moorland, often by streams.	Northumberland, Cumbrian Pennines and North York Moors.
Hilaira nubigena	A money spider	Nationally Scarce A	Small spider of wet areas on moorland, usually in *Sphagnum* or at base of rushes.	Apart from single record in Sutherland, all records are from Yorks, Durham, Northumbrian / Cumbrian Pennines.
Hilaira pervicax	A money spider	Nationally Scarce B	Small spider of wet areas on moorland, usually in *Sphagnum* or at base of rushes. Adult mainly in winter.	Northern and western moorland. Yorks / Cumbria / Northumberland in England.
Macrargus carpenteri	A money spider	Nationally Scarce A	Small spider of short heather or grass on high moorland.	Northern. Small areas of Scotland and Cumbria / Northumberland.
Semiljicola caliginosa	A money spider	Nationally Scarce B	Small spider of wet places on moorland. Among *Sphagnum* and other mosses and among rushes.	Northern species, south to Yorkshire Pennines.
Snails				
Vertigo genesii	Round-mouthed whorl snail	Annex II, RDB1 Priority	In moss and sedges in spring-fed alkaline flush at 495 m.	Widdybank Fell, Co Durham. Only known site in Britain.
Vertigo geyeri	A whorl snail	Annex II, RDB1 Priority	Tufa-depositing springs and calcareous upland fens and flushes.	Cumbria.

Key to Table 6.7

Status

Annex II	Listed on Annex II of the Habitats Directive
RDB1	Red Data Book category 1 Endangered
RDB2	Red Data Book category 2 Vulnerable
RDB3	Red Data Book category 3 Rare
RDB4	Red Data Book category 4 Out of danger
RDB5	Red Data Book category 5 Endemic
Nationally Scarce A	15-30 10 km squares of national grid
Nationally Scarce B	30-100 10 km squares of national grid
Priority	Priority species in the UK Biodiversity Action Plan (UK Biodiversity Group 1998; UK Steering Group 1995).
SCC	Species of conservation concern in the UK Biodiversity Action Plan (UK Biodiversity Group 1998; UK Steering Group 1995).

Table 6.8 Habitat and management requirements of moorland invertebrates

Moorland invertebrates	Habitat requirements	Management requirements
Ground-dwelling species	A variety of bare substrates, including bare peat, mineral soil, sand and rock. They are used by carnivorous species to hunt over and burrowing species to burrow in. Wet and dry bare substrates have different faunas but both are of value. Firm, rather than churned substrates are of most value. Moss, plant litter (including heather) and stones provide cover and over-wintering sites.	! Maintain a varied vegetation structure and succession including bare ground. ! Value and retain eroded but firm substrate along paths and tracks, although this may be difficult on peaty soils and easier on mineral soil. (Peat hags can also be valuable and persist for long periods of time.) ! Prevent substrate churning by too heavy use, especially by horses / motorbikes. ! Allow some vegetation to escape the burning cycle and go into post maturity. ! Do not be too fastidious in tidying up stones and rubble, collapsed stone walls, etc.
Pollen and nectar feeding species	A range and abundance of flowering plants throughout the year, especially species with early flowers or a long flowering period, are valuable to invertebrates as pollen and nectar sources. Heather flowers can be very abundant and are used particularly by bees, as well as some moth caterpillars which eat the flowers. Bilberry, tormentil and heath bedstraw are particularly valuable, as are common daisy, yarrow, ragwort, various thistle species and any umbellifers growing on marginal grassland, at the base of walls and along road verges. The extra-floral nectaries of bracken may be a useful nectar source for some small species early in the year.	! Adjust grazing levels to achieve maximum flowering. ! Include ruderal / verge habitats in management regimes.
Ants	Tussocks, stones, stones and boulders, pieces of semi-decayed timber (including old fence-posts, etc.). The yellow meadow ant sometimes makes its domed nests on mineral soils on moorland grassland and supports a range of other species. The warm south-facing slopes of such nests may be important basking sites.	Retain such features for cover / nesting sites. ! Avoid ploughing or cutting where there are large meadow ant nests.

Moorland invertebrates	Habitat requirements	Management requirements
Solitary bees and wasps	A variety of bare substrates to burrow into, in particular with southern / SE / SW orientation. Pollen and nectar sources.	! Varied vegetation structure and succession including bare ground. ! See above re: nectar sources.
Web spinning spiders	Varied vegetation structure, including grasses, dwarf shrub heath (including mature heather) and scrub. Specialised upland spiders make their webs in screes and other accumulations of stones, especially in limestone districts.	! Adjust grazing and burning to maintain optimum mosaic, including allowing some areas to escape management into post maturity. ! No management necessary. Do not disturb.
Molluscs	Moist, sheltered places such as amongst moss or rock crevices. Limestone substrates are important for molluscs and provide a source of calcium (see Chapter 10).	! Maintain light or no grazing. ! Prevent disturbance or removal of rock habitats.
Phytophagous species	Taller, older heather supports the greatest abundance and number of species of phytophagous lepidoptera caterpillars. A diversity of appropriate moorland species, growing in a diversity of structural conditions and aspects, and with a range of young to mature growth phases, is desirable for phytophagous species on herbs. Limestone areas usually support a greater diversity of forbs for phytophagous species, including plants protected from grazing and calcicole food plant species.	! Adjust grazing to achieve maximum appropriate diversity of moorland herbs. ! Restrict / prevent access of grazing stock to rock outcrops and wet seepages with richer floras.
Dung feeders	A supply of pesticide free sheep, cow, horse and / or deer dung.	! Consider using alternatives to avermectin helminthicides.
Species that live under stones (lapidicolous)	Rock outcrops, scree, dry stone walls and buildings, their remains, old mineral spoil heaps as well as naturally occurring rocks and stones. These are frequently used as cover for ground-dwelling species, as well as basking sites and territorial perches (see also Chapter 10).	! Prevent disturbance or removal of rock habitats. ! Maintain light or no grazing. ! Encourage non-intervention areas.
Moss-inhabiting species	Areas with significant moss cover, other than post-burn moss species such as *Funaria* spp. Moss cover may occur, for example, under heather, between stones, at the base of and on walls, shrubs and trees, around flushes and beside streams. This provides cover for a diversity of ground-dwelling species, and food and habitat for pill beetles and snow fleas.	! Maintain light or no grazing. ! Encourage non-intervention areas.

Moorland invertebrates	Habitat requirements	Management requirements
Semi-aquatic species	Small hydrological features, such as peat pools, *Sphagnum* pools, flushes, seepages and trickles, and stream headwaters. Calcareous flushing adds considerably to species richness and also supports rarities among the Diptera. Varied margins of water bodies, including waterlogged moss, bare wet peat and bare mineral substrates are also of value. Often a need for nectar sources as adults.	! Prevent drainage and heavy grazing. Unlikely to benefit from other management unless scrubbing over. ! Access by grazing animals may keep bare ground open. ! See above re nectar sources.

Table 6.9 Mammals, amphibians and reptiles associated with moorland in England

Scientific name	Common name	Nature conservation status	Typical habitat	Distribution by upland Natural Area
Mammals				
Cervidae, eg *Capreolus capreolus*, *Cervus elaphus*	Deer, eg roe deer, red deer	Common and widespread; increasing. Important effects on vegetation structure.	Woodlands with open rides; open moorland, grassland adjacent to woodlands.	All have one or more species
Lepus timidus	Mountain hare	Introduced to the Peak District in the nineteenth century. Native to Britain. Locally common.	Open heathland and mountain grasslands.	Peak District
Martes martes	Pine marten	Very rare, vulnerable. Fully protected by Schedule 5 of the Wildlife and Countryside Act 1981 (as amended 1988).	Extensive conifer and deciduous woodland, often near open moorland.	Extremely rare
Microtus agrestis	Field vole	Widespread and common; important component in food chain.	Rough grass pasture, grass moorland, open woodland and rides and young 'pre-thicket' plantations.	All
Sciurus vulgaris	Red squirrel	Local, vulnerable. Fully protected by Schedule 5 of the Wildlife and Countryside Act 1991. Biodiversity Action Plan Priority species (UK Steering Group 1995).	Broadleaved and coniferous woodland.	Border Uplands North Pennines Cumbria Fells and Dales
Sorex spp	Shrews	Widespread; most species common.	Grass pasture, grass and heather moorland, open woodland and rides.	All

Scientific name	Common name	Nature conservation status	Typical habitat	Distribution by upland Natural Area
Amphibians				
Bufo bufo	Common toad	Widespread, locally common, but probably declining.	Uneven structured vegetation, eg grassland, woodland margins, near or connected to ponds or other water bodies with roughly neutral pH. Ponds may be deeper and presence of fish less a problem than for other amphibians. Will travel long distances to breeding ponds.	All
Rana temporaria	Common frog	Widespread, locally common.	Uneven structured vegetation, eg grassland, woodland margins, near or connected to ponds (can be small, must have shallow areas) or other water bodies with roughly neutral pH.	All
T. cristatus	Great crested newt	Widespread, declining but may be locally abundant and more often found in lowland habitats. Fully protected by Schedule 5 of the Wildlife and Countryside Act 1981. Biodiversity Action Plan Priority species (UK Steering Group 1995).	Breeding ponds of approximately neutral pH and free of fish with contiguous terrestrial habitat (usually in excess of 0.4 ha to sustain a viable population). Terrestrial habitat needs to contain a diversity of vegetation or physical structure. Tend to use larger ponds or rely more on clusters of nearby ponds than other newt species.	All except Exmoor and the Quantocks, Dartmoor and Bodmin Moor.
Triturus vulgaris *T. helveticus*	Smooth newt Palmate newt	Widespread, locally common. Palmate generally more tolerant of upland or more acid waters while smooth newts common and more abundant in lowland habitats.	Structurally varied habitats, eg grasslands, woodland edges, quarries, with nearby or integral ponds. Ponds can be small to fairly large.	All

Scientific name	Common name	Nature conservation status	Typical habitat	Distribution by upland Natural Area
Reptiles				
Lacerta vivipara *Anguis fragilis*	Common lizard Slow-worm	Widespread, can be locally common, but nationally probably declining. Partially protected by Schedule 5 of the Wildlife and Countryside Act 1981.	Structurally varied, open habitats; often providing basking areas. Banks, woodland margins, open moorland, tussocky grasslands and bogs. Areas should not be too wet. Limited dispersion potential means adults fairly sedentary and reflects importance of connected habitats for long-term survival of populations. Slow-worms tend to be found more in grassland habitats, especially where slugs and snails are present (major food item).	All
Natrix natrix	Grass snake	Widespread, locally common, but more associated with lowland habitats. Partially protected by Schedule 5 of the Wildlife and Countryside Act 1981.	Structurally varied habitats. Very mobile species; often associated with water (amphibians and fish are major prey items) and needs rotting vegetation for egg laying. Therefore more often associated with farmed areas than other snake species.	Most Natural Areas although records sparse in northern England
Vipera berus	Adder	Widespread, locally common, but declining. Partially protected by Schedule 5 of the Wildlife and Countryside Act 1981.	Structurally varied habitats, such as moors, woodland edges, ungrazed (or low intensity grazed) grassland. Especially in areas with low levels of disturbance, and in areas with several habitat types (eg woodland and moorland) in close proximity.	All

Source

Mitchell-Jones 1996.
Mitchell-Jones & Gent 1997.

Table 6.10 Habitat and management requirements of moorland mammals, amphibians and reptiles

Species	Habitat requirements	Management requirements
Mountain hare	Feed predominantly on heather, preferring younger shoots, and almost exclusively on it during the winter. Also eat cotton-grass species and grasses.	! Manage, via burning or cutting, to provide a good supply of young heather stems, in a mosaic with areas of cover, particularly mature heather, within the typical 1 km range.
Pine marten	Feed on small mammals, birds, berries and fruits in well-wooded habitats.	! Retain extensive woodland where the species may still be present.
Red squirrel	As a specialist pine-seed feeder they are best adapted to coniferous woodland. In broadleaved woodland they are at a serious disadvantage to the grey squirrel.	! Retain large areas of conifers (more than 2,000 ha) where populations persist. ! Retain, and expand where possible, islands of conifers where populations remain. ! Actively manage grey squirrel populations.
Small mammals	Require a structurally varied and botanically diverse vegetation, with a deep litter layer. This provides a good range of food plants (especially grasses and seed bearing plants) for the herbivorous species. It also supports the invertebrate prey of insectivores and provides suitable cover.	! Manage to promote a good ground cover and structural diversity of vegetation, with a litter understorey. ! Retain stones and stable scree slopes as cover for the common shrew.
Deer	Use open moorlands for foraging. A mixed and diverse structure to the moor, especially with different vegetation types in close proximity, provides a variety of grazing and browsing. Woodlands are also valuable for shelter and feeding.	! Manage deer populations to ensure they remain healthy, of an appropriate age and sex structure. ! Ensure they are not causing damage to important habitats through grazing and browsing.

Species	Habitat requirements	Management requirements
Reptiles	Favour large areas of natural and semi-natural vegetation with low levels of disturbance. Optimal habitats are warm, southerly aspects with a diverse vegetation. Require open areas for basking, with adjacent vegetation to provide cover from predators and over-heating. Thick tussocks of grasses, eg purple moor-grass *Molinia caerulea*, provide excellent habitats; each tussock can offer good basking sites as well as thick cover. Require areas for retreating from cold weather; hibernation occurs in vegetation (eg in a *Molinia* tussock or inside a dense bush of *Calluna)*, underground (eg small mammal or rabbit burrows), next to tree or bush roots, below stones or in thick vegetation litter. Often a continuum from wet to dry vegetation is valuable, and snakes in particular move into wetter habitats during the summer months and drier areas for winter. A varied structure also provides habitats for the food species taken, including invertebrates, small mammals, amphibians and other reptiles.	! Manage to provide a mosaic of open areas and low vegetation amongst taller, bushier vegetation, particularly on southerly slopes. For example, uneven aged heather, tall grasses or other low shrub species. ! Ensure suitable egg laying areas remain.
Amphibians	Require suitable breeding pools. Generally water of approximately neutral pH is preferred, although there are varying degrees of acid tolerance. Increasing acidity (ie decreasing pH) affects embryo development and survival and therefore breeding water with a pH of 4 or higher is required. Presence of other species can affect breeding success. For example, large numbers of predatory invertebrates, such as dragonfly larvae and water beetles, predate tadpoles. Fish also prey on frog and newt tadpoles. Require extensive areas of appropriate terrestrial habitat for feeding and hibernating. Terrestrial habitats need to offer structural variation, to provide the invertebrate foods eaten, to offer cover from extremes of temperature and to provide hibernation sites. Examples include hedgerows, the margins of deciduous woodland, dry stone walls, rocky ground and even man-made rubbish.	! Manage to ensure a mosaic of uneven vegetation structure, typically ranging from open ground to 1 m in height. ! Ensure continuous habitats that take account of the needs for foraging and over-wintering (hibernation) sites. Large expanses of habitat are preferable. ! Ensure suitable ponds, usually of approximately neutral, or only slightly acidic, pH, remain for breeding. ! Seek to minimise disturbance; especially in sensitive areas.

Table 6.11 Advantages and disadvantages of burning moorland habitats for various land uses

This is a generalised summary of potential impacts, and actual effects will vary according to the characteristics of the area being considered. Further details, particularly of species-specific reactions, should be sought in the appropriate references (Gimingham 1972; MacDonald *et al* 1998; Miles 1987; Mowforth & Sydes 1989; Rowell 1988; RSPB 1995; Shaw *et al* 1996; Thompson *et al* 1995). Note that the land uses described regularly occur together on the same area of land.

Land use	Habitat	Potential advantages	Potential disadvantages
Nature conservation	Dwarf-shrub heath and blanket bog	Direct benefits (most apply to dwarf shrub heath): ! Stimulates young heather growth and seedling regeneration, which is beneficial where the heath is in danger of being lost. ! Encourages certain important animal and plant species, eg red grouse, golden plover, bog rosemary and cloudberry. ! Creates a mosaic of stands of different ages and vegetation heights, so enhancing the structural variation of the vegetation and the diversity of invertebrates. ! Creates bare ground which is required by some invertebrates. ! May prevent trees and shrubs establishing, which is desirable is some situations, eg where birch is encroaching into south-western heaths (although burnt areas may provide effective seedbeds for tree species). ! May rejuvenate heather so that it out competes bracken, although this is likely to be dependent on various factors, eg. grazing pressure, soil depth, heather age.	! May encourage the predominance of heather to the exclusion of other species. ! Impoverishes the bryophyte and lichen flora. ! May encourage the predominance of hare's-tail cotton-grass on some blanket bogs if inappropriate rotations used. ! Encourages purple moor-grass on blanket bog and wet heath where it occurs, to the exclusion of other species. ! May change vegetation communities from ones of wildlife interest to those of less interest (particularly in combination with other management practices such as heavy grazing or drainage), eg blanket mire to wet heath, wet or dry heath to grassland. ! Reduces the likelihood of layering by dwarf-shrubs. ! May discourage certain animal and plant species, such as less mobile animals (eg molluscs), some insects (eg springtails and mites) and plants which cannot tolerate fire (eg lesser twayblade, some mosses), although many survive in damp litter, mosses and tussocks with properly controlled winter burning.

Land use	Habitat	Potential advantages	Potential disadvantages
	Dwarf-shrub heath and blanket bog (cont.)	Indirect benefits: ! Increases the tolerance of dwarf-shrubs to grazing. ! Patch burning helps to spread the grazing pressure across an area. ! Reduces the risk of uncontrolled and uncontrollable fires, which can destroy large areas of wildlife habitat.	! May prevent the establishment of native trees and shrubs, which are often desirable because they diversify the habitat and enhance the biodiversity. ! May lead to erosion and loss of habitat when burns do not regenerate well, especially if the peat itself catches fire. ! May remove habitats, damage populations and create even-aged stands when large areas are burnt instead of a mosaic of small patch burns, although if the fire burns unevenly this is not necessarily the case. ! May encourage the spread of bracken in some circumstances.
	Purple moor-grass dominated areas	! Reduces the dominance of purple moor-grass, when conducted in combination with the appropriate grazing regime. ! Reduces the risk of uncontrolled fires, which can destroy large areas of wildlife habitat. ! Removes *Molinia* litter and exposes seed which is a vital food source for twite and other finches in early spring.	! Encourages purple moor-grass to the exclusion of other species, if not conducted in combination with the appropriate grazing regime. ! May remove habitats, damage populations and create even-aged stands when large areas are burnt instead of a mosaic of small patch burns, although if the fire burns unevenly this is not necessarily the case.
	Enclosed grassland	! See Chapter 7 Meadows and enclosed pasture.	

Land use	Habitat	Potential advantages	Potential disadvantages
Grouse moors	Dwarf-shrub heath and blanket bog	! Encourages the growth of young heather, which increases the carrying capacity for red grouse. ! Improves the nutritional quality of heather and other moorland plants, although the enhanced nutrient content of shoots falls off rapidly over the first five years after fire. ! Leads to the predominance of dwarf-shrub vegetation (where grazing levels are appropriate). ! Creates a mosaic of stands of different ages and heights, which is required by nesting and feeding grouse.	! May lead to homogenous stands of even-aged heather which reduces the diversity of plant and animal life. ! Leads to erosion and reduced carrying capacity for grouse when burns do not regenerate well, especially if the peat itself catches fire. ! May prevent the establishment of trees and shrubs, which are important for black grouse. ! Prevents development of older heather important for some species of conservation interest. ! Removes areas of taller heather used as nesting sites for merlin and hen harrier.
Agriculture	Dwarf-shrub heath and blanket bog	! Encourages the growth of young heather, which increases the carrying capacity of the area for stock. ! Improves the nutritional quality of heather and other moorland plants, although the enhanced nutrient content of shoots falls off rapidly over the first five years after fire. ! Enables and encourages stock to move around the land, thereby spreading the grazing pressure.	! May cause livestock to concentrate their grazing on burnt areas and prevent the regeneration of dwarf shrubs if the total area burnt is very small. ! May lead to erosion and reduced carrying capacity for stock when burns do not regenerate well, especially if the peat itself catches fire. ! May encourage the predominance of purple moor-grass and hare's-tail cotton-grass, where these occur and inappropriate burning rotations are used, thus reducing the stocking capacity when they replace heather.
	Purple moor-grass dominated areas	! Promotes the growth of young grass in spring which is then available earlier and more accessible and nutritious for stock grazing. ! Prevents the accumulation of dead leaves and surface litter.	! Encourages the spread of purple moor-grass to the exclusion of all other species.
	Enclosed grassland	! See Chapter 7 Meadows and enclosed pasture.	

Land use	Habitat	Potential advantages	Potential disadvantages
Agriculture (cont)	Gorse	! Helps stock to move around the land and encourages an initial flush of grass growth. ! Regenerating gorse will be more readily browsed.	! Regenerates and encourages the spread of gorse.
Other	Any habitat	! Reduces the likelihood of undesirable, uncontrolled fires by: ❑ reducing the amount of material available to burn; ❑ creating fire breaks. ! Is a form of disturbance which can be important for maintaining some aspects of biological diversity and for some characteristic species.	! May destroy areas of valuable wildlife habitat, threaten public safety and property, tie up the emergencies services, cause erosion and scar the landscape when not adequately controlled. ! May burn into the peat itself, if the peat surface is dry and the burning is not undertaken responsibly, leading to drying, oxidation, bare areas and erosion, which adversely affect all land uses, as well as water quality, flow rates and water courses.