Dwarf-shrub habitats and shrublands

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Abstract and Keywords

Dwarf-shrubs are vegetation types dominated by low (less than 3-4 m high), predominantly evergreen, shrubs, typically on soils with low nutrient availability. Characteristic dwarf-shrub vegetation and shrublands occur in the five regions of the world with Mediterranean-type climates of mild, wet winters and hot, dry summers: phrygana/garrigue and maquis in the Mediterranean; coastal sage scrub and chaparral in California; matorral in Chile; fynbos in South Africa; and mallee and heathland/kwongan in southern and western Australia. This chapter discusses the factors influencing the suitability of dwarf-shrub habitats for plants and animals, general principles of managing dwarf-shrub vegetation and shrublands, burning, grazing and browsing, European Atlantic lowland heathlands, and Atlantic upland heaths and moorlands.

Keywords: habitat management, grazing, browsing, lowland heathlands, upland heaths, moorlands
These are vegetation types dominated by low (less than 3–4 m high), predominantly evergreen, shrubs, typically on soils with low nutrient availability. Characteristic dwarf-shrub vegetation and shrublands occur in the five regions of the world with Mediterranean-type climates of mild, wet winters and hot, dry summers:

- phrygana/garrigue and maquis in the Mediterranean;
- coastal sage scrub and chaparral in California;
- mattrail in Chile;
- fynbos in South Africa;
- mallee and heathland/kwongan in southern and western Australia.

In the Mediterranean garrigue/phrygana refers to open, dwarf-shrub-dominated vegetation typically a metre or less high, and maquis thickets of dense shrubs and small trees up to 4 m or so high. Similarly, in southern Australia, kwongan refers to dwarf-shrub/undershrub vegetation and mallee to taller shrubland. A range of other types of dwarf-shrub vegetation occur in montane areas and in semi-arid environments where there is insufficient water for the growth of trees. An important type of semi-arid dwarf-shrub vegetation is sagebrush steppe, which covers large parts of the western USA. Shrubby vegetation in semi-arid and montane areas is rarely, if ever, actively managed for conservation. Apart from sagebrush steppe, it is not considered further in this chapter.

Another characteristic type of dwarf-shrub habitat is the European Atlantic cultural heathlands and moorlands. These are dominated by ericaceous shrubs on acidic substrates in the cool, wet conditions of north-west Europe. These can be divided into:

- lowland heathlands on nutrient-poor sands and gravels in the warmer and drier lowlands, including on acidic sand dunes;
- upland heaths and moorlands in cooler, wetter conditions, typically on peat and at higher altitude.

Management of these Atlantic heathlands differs from that of other dwarf-shrub-dominated vegetation and shrublands in that a variety of very specific management interventions is often used to maximize the conservation value,
particularly in the case of lowland heathlands. Management of
Atlantic lowland heathlands and upland heaths/moorland are
discussed separately in Sections 6.5 and 6.6.

6.1 Key factors influencing the suitability of dwarf-shrub
habitats for plants and animals
Most conservation management of dwarf-shrub vegetation and
shrublands other than Atlantic heathlands aims primarily to
maintain their intrinsic floral and faunal interest by
perpetuating their characteristic vegetation types, rather than
aiming to provide specific conditions for individual species or
groups of species. All five regions with Mediterranean climates
support characteristic and species-rich floras, containing high
degrees of plant endemism and a range of endemic fauna.
South African fynbos is especially botanically diverse (Figure
6.1). Shrubby vegetation outside of these regions is usually far
less species-rich.

Conditions for plants and animals within dwarf-shrub habitats
vary primarily in relation to the stage of re-growth following
disturbance, although the structure and species composition of
this re-growth can also be modified by grazing and browsing.
The most common form of disturbance is fire. The early stages
of re-growth following burning are open and typically support
a diverse range of largely short-lived grasses and forbs,
commonly referred to as fire ephemerals or fire-followers,
together with associated open-ground invertebrates. Over
time, this herbaceous layer is usually out-competed by dwarf
shrubs, unless their re-growth is suppressed by heavy grazing.
In some vegetation types, though, herbaceous vegetation
persists in open ground between shrubs. The shrub fauna
changes as the shrubs increase in height. For example, the
bird fauna of Mediterranean shrublands changes from that of
open, sparsely vegetated ground to species characteristic of
dense shrubs, while taller shrubby vegetation supports species
more typical of woodlands (e.g. Katsimanis et al. 2006).

6.2 General principles of managing dwarf-shrub vegetation
and shrublands
Dwarf-shrub vegetation and shrublands contain assemblages
of plants adapted to particular fire regimes. Many of these
contain small and thick-leaved, highly flammable, foliage and
also require fire for germination. Dwarf-shrub
(p.133)
vegetation and shrublands are thus prone to natural wildfires that periodically set back succession. Fires in dwarf-shrub vegetation are effectively crown fires (Section 7.4.6) in that they consume all, or the majority, of above-ground vegetation. Prescribed burning is frequently used to remove entire stands of older shrubby vegetation with the aim of reducing the risk of catastrophic wildfires (hazard-reduction burning). This approach is slightly different to the use of surface fires in woodland to reduce fuel loads within existing stands of trees (Section 7.4.6). The effectiveness of hazard-reduction burning in shrublands is probably quite variable (Figure 6.2).

Large areas of shrubby vegetation have been managed to provide grazing for livestock. Trees have also been cut and removed from it for firewood or other uses. The shrubs themselves are often relatively unpalatable, at least compared to most grasses. Consequently, shrubby vegetation has typically been periodically burnt to remove unwanted, unpalatable woody plants and to increase nutritious re-growth, especially of grasses and palatable herbs. In South African fynbos burning is also used to maximize production of flowers for harvesting, particularly species of protea, *Protea* spp. However, heavy grazing of re-growth by livestock, \( \text{(p.134)} \)
especially by very selective grazers such as sheep, and of more established shrubs by goats, has the potential to eliminate more grazing-intolerant plant species and thereby impoverish the flora. Combinations of frequent burning and heavy grazing of re-growth will eventually eliminate most, or all, dwarf shrubs to produce grassy vegetation. Frequent burning combined with heavy grazing (over-grazing) is considered to have severely degraded most sagebrush steppe and large areas of fynbos. In many areas management for grazing has involved the complete destruction and in some cases re-seeding with grasses, especially in the case of sagebrush steppe. Prescribed burning for conservation also aims to provide a mosaic of different stages of re-growth to maintain a range of conditions suitable for species associated with these different stages, while, where necessary, grazing at suitable levels to sustain commercial grazing or maintain a diversity of open-ground vegetation and its associated fauna. Long periods of fire suppression can in some cases result (p.135) in the loss of characteristic dwarf-shrub habitats through colonization by more competitive, fire-intolerant plant species.

Fig. 6.2 Hazard-reduction burning. Californian chaparral, such as this, is especially prone to wildfires. Prescribed burning is often carried out with the aim of reducing fuel loads and the likelihood of large-scale, catastrophic fires. Research suggests that although these measures may be successful in suppressing wildfires under moderate weather conditions, the length of time since areas were last burnt has little or no effect in preventing large-scale fires driven by high winds (Keeley et al. 1999; Keeley and Fotheringham 2000; Moritz et al. 2004; Mount Tamalpais State Park, California, USA).
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The presence of alien/exotic plant species is an issue in many types of dwarf-shrub vegetation. Spread of alien/exotic annual grasses, especially from the Mediterranean region, is a particular problem in chaparral and sagebrush steppe in the western USA. Trees and shrubs, especially acacias, *Acacia* spp., pines, *Pinus* spp., and *Hakea* spp., are the most important invasive alien/exotic species in South African fynbos. Interestingly, Mediterranean vegetation appears to be relatively immune to significant invasion by alien/exotic plant species. Management therefore often aims to reduce or eradicate undesirable alien/exotic plant species.

Although the overall aim of management may be to maintain dominance by dwarf shrubs, in some types of vegetation much of the floral and faunal interest is associated with the herbaceous vegetation and open ground between the shrubs. Mediterranean vegetation in particular often consists of mixtures of open herbaceous vegetation, low-growing dwarf-shrub-dominated phrygana/garrigue, and taller, shrubby maquis. Much of the botanical and invertebrate interest in these mosaics is associated with open areas. Mosaics of vegetation types have in many cases been created by periodic cultivation that sets back succession (Figure 6.3).

6.3 Burning
There are three main factors to consider when deciding a prescribed fire regime for dwarf-shrub vegetation and shrublands. These are the:

- season of burning;
- frequency of burning;
- size of area burnt at any one time.

The season will influence fire intensity by affecting the moisture content of the fuel and the weather conditions during burning. Wildfires typically burn under hot, dry, windy conditions. Prescribed burning is virtually always carried out using back-fires (Section 5.6) under low windspeeds during the cooler, wetter periods of the year (cool-season-prescribed burning) when fires burn less intensively and are more easily managed. Precautions obviously need to be taken to minimize the risk of burns becoming out of control (Section 5.6). Thus, prescribed fires will burn both at a different season and less intensively than the majority of wildfires, to which the vegetation was originally adapted.
Burning should be avoided immediately before periods of heavy rain that might cause unwanted erosion of bare ground exposed by burning on more erodible (p.136) and steeper slopes. The frequency of burning will be determined primarily by the need to leave a long-enough interval between burns so that:

Fig. 6.3 Disturbance by periodic cultivation. Disturbance can be important in maintaining species-rich, early successional habitats within shrubby vegetation. This is especially the case in the Mediterranean region, where a large proportion of the endemic flora is associated with open and disturbed habitats.

Disturbance provided by periodic cultivation on these terraces supporting species-rich herbaceous vegetation containing a diverse (and confusing) variety of species and forms of Ophrys orchids, a highly diverse group in the Mediterranean. These include Bertoloni's orchid, Ophrys bertolonii (left), and early spider/Gargano orchid, Ophrys sphegodes/garganica (right). These orchids are absent from the often species-poor, dense stands of maquis at the top of the picture that often eventually develop in the
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• the absence of disturbance (near Mattinata, Gargano Peninsula, Puglia, Italy).

vegetation contains representative stages of the oldest desirable stages of re-growth;
• plants that recover from seed following fires (obligate seeders) have sufficient time to mature and produce seed before the area is re-burnt;

while not burning so infrequently that:
• there is an unacceptable risk of large wildfires that endanger people and property and run the risk of eliminating species within a given patch of habitat;
• the characteristic vegetation is out-competed by any potentially more vigorous, fire-intolerant plant species.

A further consideration in some cases is the likely effect that the frequency of burning has on the abundance of any unwanted, alien/exotic plant species. The ability of more palatable plants to persist will also be influenced by the grazing pressure on re-growth following burning.

Fire regimes in forests are often used to mimic what is considered to be their natural fire regime. However, unlike in forests, where fires leave scars on trees enabling past burning regimes to be re-constructed, burning usually removes entire stands of shrubs. Thus it is usually far more difficult to re-construct the frequency of natural fire regimes in shrubby vegetation.

The risk of large, catastrophic wildfires can be reduced by maintaining permanent bare or sparsely vegetated firebreaks/fuel breaks, to both help reduce the spread of wildfires and provide access for fire-fighters. These can be created by grubbing out vegetation and ploughing or bulldozing strips of ground. Firebreaks/fuel breaks are unlikely to prevent the spread of wildfires under very dry and windy conditions when they can cross even wide expanses of bare or sparsely vegetated ground. In some cases there is a danger of the open conditions along firebreaks/fuel breaks providing routes for colonization by unwanted, ruderal, or alien/exotic plant species (Merriam et al. 2006). Fuel loads can to some extent be reduced by grazing.
Different types of dwarf-shrub vegetation vary in the time they take to pass through their characteristic successional stages and thereby in the minimum length of burning rotation required to maintain the desired range of successional stages. Fynbos typically takes about 30 years for the longer-lived shrubs to attain maximum height, while following burning sagebrush steppe can take 35–120 years or more to attain a similar shrub cover to that of unburnt areas (p.138) (Baker 2006a). Mature Californian chaparral can remain relatively resilient to change in the absence of burning. Ancient, 150-year-old stands of chaparral differ in shrub species composition to younger stands, due mainly to loss of shorter-lived obligate seeder species, but can still recover almost as well as mature stands in terms of recovery of fire-followers/fire ephemerals (Keeley et al. 2005a).

The minimum desirable frequency of burning needs to be based on the length of time for the slowest-maturing, obligate seeders to mature and set sufficient seed to maintain their persistence within the vegetation. Shrubs can regenerate in two ways following canopy fires: by re-sprouting from underground rootstock (sprouters) and germinating from the seedbank. The extent to which individual species regenerate in either of these ways will to some degree depend on the temperature of the fire. However, some species are usually largely or totally dependent on regenerating from seed. These are called obligate seeders. If the area is repeatedly burnt at intervals shorter than the time it takes these plants to mature and set seed, it will denude the species’ seedbank without replenishing it. This will eventually cause its disappearance from the vegetation. For fynbos vegetation it is recommended that at least 50% of the population of the slowest-maturing shrubs, typically protea species, have flowered for at least 3 years before being burnt again. In this case burning no more frequently than once every 10–15 years is considered sufficient to maintain the persistence of these slower-growing species (see Tainton 1999). Frequent burning is likely to favour sprouters over obligate seeders (Syphard et al. 2006), although very frequent burning may even reduce the capacity for sprouters to recover following burning.

The frequency of burning also has the potential to influence the abundance of unwanted, alien/exotic plant species. In shrublands in the western USA very frequent burning can favour alien/exotic annual grasses and other ruderal plants,
while burning of ancient stands of shrub can open them up to colonization by alien/exotic plants (Keeley et al. 2005a, 2005b; Figure 6.4). Native shrubs in Californian chaparral are eliminated and replaced by alien/exotic, weedy grassland when areas are burned more frequently than once every 10–15 years. Alien/exotic trees in fynbos can be removed by combinations of felling, burning, and chemical treatment. The most successful methods vary between tree species (van Wilgen et al. 1994). A widely used method to control pines and Hakea species in fynbos is to fell them, leave them to drop their seeds and then burn the area to kill their seeds and any of their regenerating seedlings. However, there is evidence that the intense fires created by burning felled material possibly also prevents, or at least hinders, successful regeneration of native vegetation (Holmes et al. 2000).

(p.139)

As in all rotational management for conservation, it will generally be better to burn a larger number of smaller areas rather than a smaller number of large ones. This will maximize medium-scale variation in stages of re-growth and minimize the risk of local extinctions. However, this has to be set against the increased resources needed to burn many small areas compared to fewer larger ones. Hazard-

**Fig. 6.4** Alien/exotic grasses in the western USA. Invasion of native vegetation by alien/exotic annual grasses is an issue in Californian chaparral and other fire-prone habitats in the Western USA. These annual grasses not only out-compete native herbaceous plants, but can also increase the fuelload in the gaps between shrubs and allow fires to spread between shrubs even before they have grown large enough to coalesce. The increase in fire frequency further encourages growth of these alien/exotic annual grasses (Knick and Rotenberry
reduction burning should focus on strategically positioning burns to protect vulnerable areas, and minimize the proportion of land elsewhere subjected to the ecologically damaging high frequencies of fire needed for successful wildfire reduction (Keeley et al. 1999; Keeley 2002).

Overall, it will be best to maintain a variety of burning rotations (especially frequency but to some extent also season) between the desirable upper and lower limits for that particular vegetation type. This will maximize variation in vegetation composition and structure.
6.4 Grazing and browsing

Most grazing and browsing of dwarf-shrub habitats and shrublands is by sheep, cattle, and goats. The main considerations are the effects of grazing on the:

- regeneration of shrubs following burning;
- potential effects of browsing on more established shrubs;
- composition of any associated herbaceous vegetation.

The effects of livestock on re-growth of shrubs will depend primarily on the:

- stocking levels;
- type of grazing animal;
- fire regime.

Grazing animals are attracted to palatable re-growth of grasses, forbs and regenerating shrubs following burning (e.g. Van Dyke and Darragh 2006). Grazing intensities in recently burnt areas will therefore be highest when overall stocking levels are high and only a small proportion of the habitat burnt at any one time. Very heavy grazing, especially immediately following burning, can thus result in areas of shrublands becoming dominated by grazing-tolerant grasses and unpalatable or otherwise grazing-tolerant shrubs (Figure 6.5). Therefore, in situations where grazing has the potential to damage re-growth, livestock should be kept off, or only grazed at low densities on, recently burnt land. This will obviously conflict with maximizing grazing income.

Sagebrush steppe is particularly sensitive to grazing. It has probably developed in the absence of significant grazing by large herbivores (Mack and Thompson 1982). The ability of many areas of heavily grazed sagebrush steppe to recover following reduction in grazing levels is questionable (Knick et al. 2003).

The feeding characteristics of different grazing animals are described in Section 5.4.1. Sheep are more selective grazers than cattle, and therefore have a greater potential to eradicate re-growth and young plants of more grazing-sensitive species. Cattle tend to reduce re-growth of different species more equally, thus not favouring less-palatable species to the same extent. For this reason, mixtures of cattle and sheep, rather than cattle alone, are recommended for grazing fynbos.
Goats feed more on woody plants than either sheep or cattle, and can influence the composition of more established shrub by selective browsing. Goats also climb up small trees to browse their lower branches. Heavy grazing by goats therefore has the potential to reduce the species richness of established larger shrubs, rather than just influence their abundance by affecting their early growth stages.

(p.141)

The effects of livestock on open herbaceous vegetation between shrubs are similar to those in other types of grassland (Section 5.4). The highest plant species richness, and probably in many cases invertebrate species richness, tend to occur at moderate grazing levels that produce a mosaic of moderately grazed herbaceous vegetation and dwarf shrubs (Verdú et al. 2000; Vulliamy et al. 2006). Very high levels of grazing will discourage large, palatable forbs, and favour lower-growing grasses that are tolerant of grazing, and plants that have chemical or physical defences against grazers.

Therefore, while grazing levels need to be relatively low to maintain dominance by shrubs, especially following burning or where the aim is to regenerate lost shrub cover, moderate-to-heavy grazing can also be important in maintaining high species-richness of associated open habitats.

6.5 European Atlantic lowland heathlands
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Lowland heathland is a highly valued cultural landscape in north-west Europe. Most lowland heathland is thought to have been created and maintained through past human land use and now requires intervention management to prevent it (p. 142) from succeeding to woodland or becoming dominated by grasses or bracken, *Pteridium aquilinum*. Some areas of lowland heathland presumably existed prior to human influence in open woodland, glades, dunes, and exposed upland and coastal areas. Heathland on many coasts is maintained as climax vegetation through salt spray and exposure.

Lowland heathlands vary in wetness, ranging from dry heaths on free-draining acidic sands and gravels to humid heaths, wet heaths, and bogs on increasingly wetter and deeper, acidic peat. Management of bogs is discussed in Section 8.9. Heathland often also forms transitions and mosaics with these peatlands, acid grasslands, scrub, and woodland, and is usually managed in association with them.

This management has generally involved the following, with the specific details varying between regions:

- grazing;
- cutting of vegetation for fuel, fodder, and animal bedding;
- cutting of peat turfs from mires for animal bedding and fuel;
- periodic cultivation;
- periodic burning to promote lush re-growth for grazing and clear areas for cultivation.
Most of these types of management were used to transfer nutrients from the heathland to fertilize adjacent arable land. In continental north-west Europe livestock were grazed on the heathland during the day and brought inside at night. The dung and urine deposited at night was soaked up by vegetation and dried peat used for bedding. This, together with the remains of uneaten fodder and ash from burnt turfs, was spread on arable land. These practices created so-called plaggen soils. These contain a layer of dark, peaty material lying over the existing mineral soil. Burning and removal of vegetation also depleted nutrients. It is unclear the extent to which heathlands were used to fertilize arable land in the UK, although there is evidence that in at least some areas livestock were grazed on heathland during the day and folded (Section 5.3.3) on arable land at night to deposit nutrient-containing dung on them. More southerly heathlands in Brittany, Spain, and Portugal were also grazed, burnt, and periodically cultivated (Webb 1998).

6.5.1 Key factors influencing the suitability of Atlantic lowland heathlands for plants and animals

Dry heathland is invariably extremely species-poor for vascular plants, comprising mainly a small number of dwarf-shrub species. Heather, Calluna vulgaris, is (p.143) the dominant structural component of virtually all types of drier lowland heath. More open areas can support a wider variety of mosses and lichens. The main vascular plant interest is associated with disturbed conditions, wet heath and associated mires, and seepage areas. Wetter areas can support a number of plants rare in the otherwise nutrient-rich lowlands.

An important concept when managing lowland (and upland) heathlands is that of heather structure. Heather has four recognized growth phases (Gimmingham 1972), which differ in their structure and associated fauna. These are described below. The time taken to reach these different phases will vary between sites according to growth rates.

- **pioneer**: young (0–5 years old) plants colonizing from seed or the early re-growth following burning or cutting of older plants;
- **building**: vigorously growing and dome-shaped plants (5–15 years old);
- **mature**: slower-growing plants with a more open canopy (15–25 years old);
- **degenerate**: plants that are starting to open out, collapse, and eventually die (25–> 40 years old).
Lowland heathlands are of particular value for a variety of southern bird, reptile, and especially invertebrate species that are largely confined to this and other similarly structured warm, sandy habitat towards the cooler and wetter edges of their climatic range. Lowland heathlands support low densities of breeding birds of only a limited range of species, but containing several species considered of high conservation value in north-west Europe. These include Dartford warbler, *Sylvia undata*, Eurasian nightjar, *Caprimulgus europaeus*, wood lark, *Lullula arborea*, and tawny pipit, *Anthus campestris*. Few bird species remain on heathlands in winter. The value of lowland heathlands for birds is mainly influenced by structure. Dartford warblers favour areas with mature gorse, *Ulex europaeus*, scrub, Eurasian nightjars require small patches of dry, bare or sparsely vegetated ground among vegetation in which to nest, whereas wood larks need disturbed ground, short grassland and scattered trees and tawny pipits sandy heathland and active dunes (Bibby 1979; Sitters *et al*. 1996; van den Berg *et al*. 2001). Extensive areas dominated by dwarf shrubs without trees and scrub are extremely poor for birds. The primary bird interest of wet heaths and associated mires is breeding waders/shorebirds.

Dry heathland supports virtually the entire, albeit small, reptile fauna of north-west Europe, including two highly-valued species, the sand lizard, *Lacerta agilis*, and smooth snake, *Coronella austrica* (Figure 6.6). The acidic water bodies associated with heathlands provide breeding habitat for several species of amphibians. Heathland is generally poor for mammals, only supporting low densities and lacking any characteristic species. Lowland dry heathland supports a particularly rich variety of warmth-loving invertebrates.

*Fig. 6.6* Smooth snake. This is one of many southern, warmth-loving species that in the north west of its range in Europe is confined to the warm conditions provided by the free-draining soils of Atlantic lowland heathland. It is
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It is especially rich in solitary bees and wasps, spiders, and true bugs. The main features of importance for invertebrates are listed below.

- There is a mosaic of growth phases/structures of the dwarf shrubs, since different growth phases support different invertebrate assemblages.
- There are areas of bare, consolidated and disturbed sand intermixed with sparse and dense vegetation. These provide warm microclimates, open areas for hunting and a suitable substrate for invertebrates to burrow in. Areas of other bare ground are valuable, but probably less so than bare sand.
- There are steep slopes and banks, especially south-facing, bare or sparsely vegetated ones, that provide nesting habitat for solitary bees and wasps.
- There is a continuity of suitable nectar sources, including early-flowering shrubs and nectaring plants associated with disturbed and more nutrient-rich vegetation. Nectar sources can be otherwise scarce outside of the main (p.145) flowering periods of the dominant dwarf shrubs. Vegetation along verges and various composites and umbellifers are especially valuable.
- The scattered trees, especially birch *Betula* spp., are in a range of different growth stages, and there are blocks of structurally diverse gorse scrub, which each support different invertebrate assemblages.
- There are mires and pools.

As can be surmised from the above, large areas covered solely by dwarf shrubs are not very rich in invertebrate species. Different successional stages of wet heaths and mires also support different assemblages of invertebrates. Acidic pools and mires associated with heathland can support important assemblages of invertebrates, probably due in part to the lack of fish. These pools and associated heathlands can be rich in dragonfly and damselfly species.

6.5.2 Overview of management
Agricultural use of heathland has become largely uneconomic. In the absence of vegetation removal through agriculture, many heathlands are susceptible to loss of dwarf-shrub vegetation through succession to woodland and grassland and expansion of bracken. Although bracken is a native component of many heathlands, dense stands of it support a very limited fauna. The main tree species that colonize lowland dry heathland are silver birch, *Betula pendula*, Scots pine, *Pinus sylvestris*, maritime pine, *Pinus pinaster*, lodgepole pine, *Pinus contorta*, and dwarf mountain-pine, *Pinus mugo*. Tree and scrub species commonly colonizing wet heath are alien/exotic rhododendron, *Rhododendron ponticum*, and native downy birch, *Betula pubescens*, and willows, *Salix* spp. Unmanaged heathland usually also lacks disturbed, early successional conditions (Figure 6.7).

Management often also aims to reduce nutrient levels. Not only does nutrient removal no longer take place through agricultural use, but heathlands are nowadays subject to deposition of anthropogenic atmospheric nitrogen as well as acidification from anthropogenic atmospheric sulphur. Increases in nitrogen levels encourage the growth of competitive grasses at the expense of dwarf shrubs (Heil and Diemont 1983). The main species involved are wavy hair-grass, *Deschampsia flexuosa*, and to a lesser extent sheep's-fescue, *Festuca ovina*, on dry heath and purple moor-grass, *Molinia caerulea*, on wet heath. Increases in nitrogen levels also encourage the growth of pleurocarpus (creeping, stringy) mosses. Replacement by grasses can also be initiated following killing of heather plants by heather beetles, *Lochmaea suturalis* (Heil and Diemont 1983; Berdowski and Zeilinga 1987; Bokdam 2001). The susceptibility to severe heather beetle  (p.146)
defoliation is also thought to increase with nitrogen levels (Brunsting and Heil 1985; Power et al. 1998). Acidification from sulphur deposition can decrease overall plant species richness in wet heaths and mires (Roem et al. 2002). Thus, the over-riding aims of managing dry heathland for conservation usually involve:

• maintaining dominance by dwarf shrubs and providing the desired mixes of growth phases by combinations of burning, cutting and removing vegetation and by grazing (Figure 6.8);
• preventing dominance by trees and shrubs by removing individual trees and areas of scrub, while retaining suitable densities and distribution of scattered pines, birches, and blocks of dense and structurally diverse gorse scrub for their value for birds and invertebrates;
• eradicating other alien/exotic, invasive plant species such as rhododendron and the dwarf shrub shallon, Gaultheria shallon;
• preventing expansion, and in some cases decreasing the area, of dense bracken;

Fig. 6.7 Non-intervention and succession on Atlantic lowland heathlands. In the absence of management dwarf-shrub heath can be out-competed by other vegetation, such as this alien/exotic dwarf mountain-pine. This unmanaged dune heath also contains relatively uniformly structured heather with little or no bare ground: see Fig. 6.8 for a comparison (west coast of Jutland, south of Hanstholm, Denmark).
Fig. 6.8 Good heather structure. A key management aim in most Atlantic lowland heathlands is to provide good (i.e. varied) heather structure comprising mixtures of structure interspersed with bare and disturbed ground to maximize the range of suitable conditions for invertebrates and reptiles. Compare these photographs with the more uniform heather structure in Fig. 6.7 (Kalmthoutse Heide, Flanders, Belgium).
• preventing expansion, and in some cases decreasing the area, of purple moor-grass and wavy hair-grass by grazing, cutting, and sod cutting/turf stripping;
• providing the desired structure of any associated grassland, primarily by grazing;
(p.148)
• maintaining suitable bare and disturbed ground, especially on southerly facing slopes for invertebrates, ruderal plants, and reptiles.

The key for most groups, especially invertebrates, is to provide a mixture of conditions. For example, sand lizards prefer areas of varied topography supporting structurally diverse vegetation and bare ground (House and Spellerberg 1983). It is important to recognize the value of mixtures of habitats when re-creating habitat. Whereas it may be tempting to convert an entire area of former arable land to heathland, there may be greater benefits in providing some areas of flower-rich neutral grassland as well to provide nectar sources for heathland insects.

Management of wet heaths and mires usually also aims to maintain a:

• near-natural hydrology by blocking any artificial drainage;
• variety of successional stages and vegetation structures from open pools to Sphagnum-dominated areas, wet dwarf shrubs, sedge, and grass-dominated areas to scrub, by arresting or reversing succession to rank, grass-dominated vegetation and scrub.

(a) Young, pioneer-phase heather interspersed with bare ground and grassland.
(b) Patches of bare and disturbed ground and grassland scattered among building and mature heather.
(c) Degenerate heather containing some regenerating, pioneer-phase heather and grasses among it.
Succession in wet heaths and mires can be set back or retarded by sod cutting/turf stripping, removal of scrub and trees and by grazing. Cutting of dwarf shrubs and sedge and grass-dominated areas can be impractical in very wet areas and burning these areas is often contentious. Grazing is usually considered the best form of management. Raising water levels too rapidly runs the risk of flooding out existing important wet heath fauna and flora (WallisDeVries 2002).

There is evidence that anthropogenic acidification reduces the plant species-richness and abundance of characteristic wet heath species, and may reduce potential beneficial effects of sod cutting (e.g. Sansen and Koedam 1996). This has prompted attempts to increase the pH of acidified wet heaths by spreading lime to restore their characteristic plant assemblages, in some cases in combination with sod cutting (Beltman et al. 2001; Dorland et al. 2005). Liming has only so far only been used on a small scale in restorative management.

6.5.3 Cutting and burning lowland heathland vegetation

Cutting and burning dry heathland vegetation can both be used to:

- maintain dominance by dwarf shrubs, by preventing heather from reaching its degenerate phase, whose open conditions can be vulnerable to colonization by other potentially dominant plants;
- prevent shrubs and trees from becoming dominant;
- remove patches of above-ground growth of dwarf shrubs and thereby diversify the structure of uniform stands;
- remove nutrients.

Burning can remove more of the accumulated litter and expose more bare ground than cutting, although the specific effects will depend on the intensity of the burn. Prescribed burning and mowing typically remove similar quantities of nutrients. The quantities removed during typical cutting or burning rotations are, though, low compared to those removed by sod cutting/turf stripping. For example, on heathland in north-west Germany prescribed winter-burning and mowing and removal of vegetation both only removed the equivalent of 5 years of atmospheric nitrogen deposition, compared to 89 years’ worth for sod cutting/turf stripping (Härdtle et al. 2006).
Both cutting and burning return heather to its pioneer phase, but differ in the origins of this re-growth. Burning stimulates germination of heather seed. Regeneration following prescribed burning is usually from both the underground rootstock of burnt plants and from seed. In some cases regeneration is virtually entirely from seed (Sedlakova and Chytry 1999; Nilsen et al. 2005). Most regeneration following cutting is by re-sprouting from underground rootstock. Cutting only retards growth of small seedlings among the dwarf shrubs. Burning has the potential to kill more established trees and scrub. Again, the specific effects vary according to the intensity of the fire.

The major practical difference is that fires have the potential to get out of control, with obvious risks to people, property, and of burning unacceptably large areas of habitat. This should not be a problem, though, providing it is undertaken at appropriate times of year and with suitable precautions. It will obviously be unacceptable to burn heathland close to habitation. Cutting is impractical on steep slopes, in rocky or otherwise bumpy terrain, and in very wet areas.

The need to manage dwarf-shrub vegetation to maintain its dominance will vary according to the potential for colonization by grasses. This will be higher in areas with high nitrogen levels and a nearby source of grass seed (Britton et al. 2000a; Barker et al. 2004). Conversely, the open conditions produced by burning in particular can themselves provide opportunities for tree seedlings and bracken to establish (Bullock and Webb 1995). Re-growth of heather following both burning and cutting can be suppressed and vegetation composition altered by grazing (Vandvik et al. 2005).

Although both cutting and burning can be used to increase vegetation structure at a large scale through providing areas of differently aged re-growth, it is important to realize that the growth phase and vegetation structure within any area cut or burnt at the same time will itself be relatively uniform. More small-scale variation in heather structure can often be produced by allowing heather to pass through its growth phases and regenerate naturally, providing it does not become out-competed by other plants, and by judicious use of grazing.

**Burning**
The effects of fire will also vary according to its time of year and weather conditions immediately before and during burning. As in other habitats, wildfires will occur more often during hot, dry conditions in summer and burn at high temperatures. In contrast, prescribed burning is carried out in late winter, when the vegetation is dry enough to burn but the soil wet enough to prevent the fire from becoming too intense and difficult to control. Wildfires are thus, compared to prescribed burns, more likely to kill larger trees and scrub, remove a greater proportion of organic matter in the soil, create more bare ground, kill dwarf shrubs by burning their rootstock as well as above-ground vegetation, and kill seeds near the soil surface. Most regeneration following intense fires is from seed. However, if fires burn deeply and hot enough to destroy most of the seedbank, then regeneration of dwarf shrubs may be poor and burnt areas instead colonized mainly by widely dispersing mosses and birch (Clément and Touffet 1990; Gloaguen 1993; Bullock and Webb 1995). Regeneration following prescribed burning typically results in an increase in plant diversity between 2 and 4 years afterwards, typically comprising grasses, forbs, and bryophytes (Vandvik et al. 2005).

Prescribed fires should be carried out by back-burning (Section 5.6), since back-fires are easier to control than head-fires and more effective at removing above-ground vegetation and litter. The same precautions need to be taken as when burning other types of vegetation (see also Section 5.6). Firebreaks/fuel breaks on heathland consist of bare or only sparsely vegetated ground that can be created by cutting and removing vegetation and rotovating strips. These can provide a valuable source of bare and disturbed ground. Firebreaks/fuel breaks need to be 5 m or more wide (Symes and Day 2003), be consolidated enough to prevent fire appliances from becoming stuck and include turning circles for them. Ponds are sometimes excavated in heaths to provide water for firefighting as well as open water habitat. This destroys potentially highly valuable existing habitat, and should only be undertaken after very thorough consideration.

Burning of humid, wet heath and mires is contentious, since it can damage the moss layer if carried out in dry conditions and also encourage dominance by species-poor stands of purple moor-grass (Brys et al. 2005). However, Bullock and Webb (1995) found that humid and wet heath had returned to close
to its assumed pre-burn condition by 11 years after intense summer fires during (p.151) drought conditions. Burning purple moor-grass-dominated wet heaths and mires when the moss layer and peat is too wet to burn is, though, considered by some to be an acceptable method of opening up and removing rank vegetation to encourage less competitive plant species (Symes and Day 2003).

Burning should not be carried out in areas known to support important concentrations of reptiles and lichen-rich heath.

**Cutting**
The best method for cutting and removing heathland vegetation is by using a double-chop forage-harvester. This cuts the vegetation with knives, resulting in better regeneration than when stems are shattered using a flail cutter. Older, degenerate heather, though, may not regenerate from rootstock. Cutting is usually undertaken in autumn and winter, to minimize any damaging effects on nesting birds and active reptiles and invertebrates. Cut material can be used to provide a source of heather seed for heathland restoration. Where this is the case, the heather should be cut between about mid-October and early December to maximize the quantity of ripe seed harvested before it is shed.

It can be difficult to cut wet and humid heaths without causing unacceptable soil damage, although some rutting will create beneficial disturbance. The best option is to use low-ground-pressure tyres and cut during the drier conditions of early autumn or when the ground is frozen.

**Frequency of cutting and burning**
The frequency of cutting and burning will depend on the desired proportions of different growth phases, more frequent rotations being required where the aim is to maintain a high proportion of early growth phases. Species that prefer short, recently cut or burnt (or heavily grazed) areas include silver-studded blue butterflies, *Plebejus argus*, especially towards the edge of their climatic range and wood larks and red-billed choughs (on maritime heath). Dartford warblers prefer taller, older heather. Prescribed burning of heathland for conservation is typically carried out on a rotation of 15–30 years. It is, though, also important to leave some areas unmanaged to also provide older and degenerate Heather for
its associated species and, if regeneration is successful, provide areas with greater small-scale vegetation structure than can be achieved by burning or cutting.

**Sizes of areas cut and burnt**

Cutting or burning only small patches of heathland at any one time increases spatial diversity in vegetation structure, and decreases the likelihood of (p.152) inadvertently damaging localized populations. However, this has to be set against the greater time needed to cut or burn many small areas. Burning patches between 0.25 and 1.0 ha is a good compromise. A commonly used technique when cutting is to mow long, sinuous, one cut-wide strips.

6.5.4 Grazing and browsing
The effects of grazing on heathland are difficult to predict, and vary widely between sites and grazing regimes (Bullock and Pakeman 1996). Its main potential benefits are to:

- provide structural variation within areas of dwarf shrubs by arresting or delaying their aging process, including providing areas of short, heavily grazed heather that is structurally similar to its pioneer phase;
- prevent taller grasses, especially purple moor-grass and wavy hair-grass, from out-competing heather;
- prevent or reduce establishment of scrub;
- maintain open, trampled, and grazed conditions on wet heath, especially to benefit less-competitive plant species found on damp, bare acidic ground;
- maintain areas of associated short and open grassland;
- increase overall plant species richness (Bullock and Pakeman 1996; Bokdam and Gleichman 2000).

Grazing is generally considered better for invertebrates on heathland than cutting or burning, because it can create more small-scale variation in vegetation structure, and provides more soil disturbance and a source of dung (Kirby 1992b). The value of different types of dung for invertebrates and information on the use of anti-parasitic drugs in livestock are given in Section 4.4.3. Nowadays, conservation grazing of heathland invariably involves allowing livestock to roam and graze within relatively large grazing units, instead of being shepherded and removed indoors at night or on to adjacent land. This type of grazing regime will not deplete nutrients from the heathland as a whole, but can re-distribute nutrients within it by selective deposition of dung.

As in other habitats, livestock require access to shade and water. The distribution of these will affect grazing patterns. Supplementary feeding should be avoided because it will increase nutrient levels. The availability of nearby alternative (sacrificial) grazing to and from which livestock can be moved can be important in enabling suitable grazing levels to be achieved on the heathland itself.
The basic grazing characteristics of herbivores used in conservation grazing have been described in Section 5.4.1. Additional information regarding their use on heathlands is given below.

**Cattle**
Cattle create more tussocky vegetation than either sheep or ponies. They also produce far more poaching and trampling per quantity of vegetation removed than sheep, and slightly more than ponies. Cattle can concentrate their dung at habitual resting sites, but do not have specific latrines like ponies. Cattle are similar to ponies in preferring feeding on grasslands, particularly more nutrient-rich ones, and wet heath/mire to dry heathland. As with both ponies and sheep, cattle only take significant quantities of dwarf shrubs in winter when there is little grass available. They can, though, differ slightly from ponies in their seasonal use of habitats as described above.

Cattle have the potential to achieve all the potential benefits of grazing listed at the beginning of this section, with the exception of controlling established scrub. They are, though, less suitable for grazing areas dominated by short, acid grassland than ponies and especially sheep, because they do not nibble vegetation close to the ground. Cattle graze back and create variation in structure of taller grasses, especially purple moor-grass, although often less so than ponies, and graze and trample wet areas. Cattle do not browse scrub as much as ponies and primitive sheep breeds but can still reduce establishment of seedlings of trees and shrubs by removing them among mouthfuls of other vegetation.

The most favoured hardy cattle for conservation grazing of heathlands and purple moor-grass dominated grasslands in continental north-west Europe are Galloways.

**Ponies**
Ponies have a similar nibbling action to sheep, are highly selective and can create short, closely cropped grass swards and carpets of ericaceous shrubs. Their level of poaching and other disturbance is intermediate between that of sheep and cattle. Ponies prefer grassland, especially more nutrient-rich types, to dry heathland, and again only feed to a significant extent on dwarf shrubs in winter when there is little grass available. They differ from sheep in grazing wet heath and
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...mire, and from conventional sheep in browsing trees and shrubs, especially the wintergreen gorse. Browsing is greatest in winter when other forage is scarce. In the New Forest in England (Figure 4.5) the diet of ponies varies seasonally more than that of cattle, feeding more on the deciduous purple moor-grass in (p.154)

...wet areas in summer, and making increased use of browse in winter (Pratt et al. 1986; Putman et al. 1987).

Ponies can concentrate their dung in limited latrine areas, resulting in localized soil enrichment and more nutrient-rich vegetation.

**Sheep**

Many areas of heathland, particularly areas of dry heath and acid grassland, have traditionally been grazed by sheep, often by specialist heathland breeds. Conventional, as opposed to primitive, sheep prefer grasses to dwarf shrubs, and only take significant quantities of the latter in winter when there is little or no grass available (Bakker et al. 1983). Heavy grazing by sheep can create short carpets of closely cropped heather. Sheep do not concentrate their dung in limited areas, as cattle and particularly ponies do. Conventional breeds of sheep are (p. 155) rather poor at achieving the potential benefits of grazing...
described above. They nibble down shorter acid grassland to produce a tight, often relatively species-rich but uniform sward. They nibble off flowers, which can be important nectar sources for heathland invertebrates at critical times of year. Grazing down the sward short using sheep can be used to encourage rabbits (Section 5.4.2). Sheep also have the disadvantages, especially compared to cattle, of:

- being less good at breaking down tall grasses where these are competing with dwarf shrubs, and producing less variation in structure of these tall grasses;
- producing less poaching and consequently less bare ground;
- generally avoiding grazing wet heath and mires.

Many heathlands are open to public access where sheep are vulnerable to attack from dogs, thus requiring restrictions on dog walking. Conventional sheep browse the leaves of scrub very little, but primitive sheep breeds are excellent at browsing (Figure 6.9). They are particularly valuable at controlling birch regeneration.

**Goats**

As in other habitats, goats spend a greater proportion of their time browsing and feeding on other woody vegetation than other livestock. They can therefore be effective at controlling young scrub and small trees and grazing dwarf shrubs. They are similar to sheep in avoiding wet areas and being vulnerable to attacks by dogs. As in all other habitats, though, the main issue with using goats is the difficulty of containing them.

**Rabbits**

European rabbits can be important grazers and creators of disturbance on heathlands and associated acid grasslands. They can maintain short, open heather, bare and disturbed ground, and provide valuable dung and carrion. Methods for encouraging European rabbits are described in Section 5.4.2.

**Deer**

Browsing by red deer can be effective at controlling pine saplings. Browsing by deer is most intense close to woodland, where most tree regeneration is likely to take place, and in areas less heavily disturbed by people.

*(p.156) Grazing pressure and timing of grazing*
There are just two main options for the timing of grazing on heathlands and its associated habitats: summer grazing (i.e. spring to autumn) and year-round. Introducing, or re-introducing, livestock to formerly ungrazed heathland has the potential to damage existing valuable features. As when introducing grazing to other habitats, it is therefore prudent to begin at a low grazing pressure and, if necessary, increase livestock numbers over time in response to the results of monitoring and the experience gained. Fencing can be used to exclude grazing from sensitive areas, for example taller, mature heather containing localized populations of sand lizards. In mixtures of heathland and other habitats, grazing pressure within different habitats will be a product of:

- overall grazing pressure;
- the relative proportions of these different habitats;
- the relative preferences of livestock for these different habitats.

Preferences of livestock vary during the year. The effects of grazing on the composition and structure of dwarf shrubs will therefore be greater where overall grazing pressure is high and there is little or no alternative forage. Thus, sheep only eat significant quantities of dwarf shrubs if there is little alternative dry grass to eat, and ponies and cattle only eat significant quantities of dwarf shrubs if there is little or no dry grassland, wet heath or mire to feed on. In particular, all types of livestock usually eat more dry dwarf shrubs in winter when they have eaten all or most of the remaining grass and any deciduous purple moor-grass has died down (Pratt et al. 1986; Putnam et al. 1987).

Grazing animals influence the structure of dry heathland by grazing shoots and trampling plants. Moderate levels of grazing can benefit dwarf shrubs by reducing competition from more vigorous grasses, although the effects of grazing in benefiting dwarf shrubs will vary. Grasses are more competitive relative to heather on more nutrient-rich soils (Bokdam and Gleichman 2000). Heather is usually grazed preferentially to cross-leaved heath, Erica tetralix, often the dominant species in humid and wet heath, and slightly more than bell heather, Erica cinerea. Hence grazing will tend to decrease the abundance of heather relative to these species. On wet heath and mires grazing and trampling can provide open conditions for a range of scarce plants (Figure 6.10).
Higher grazing pressure, especially from sheep, ponies, and European rabbits, produces short lawns of dwarf shrubs. Very heavy grazing leads to replacement of the grazing-intolerant heather with grazing-tolerant grasses and forbs. Heather is particularly susceptible to damage by grazing in autumn. Very heavy grazing and churning up of large areas of wet peat by livestock or deer will be damaging. In particular this can be the case where there is a small area of wet heath/mire on which animals concentrate their activities, set within a larger area of dry heathland and grassland. Grazing mixtures of dry heathland and grassland in winter will be a balance between reducing the abundance of unwanted wintergreen plants that can out-compete dwarf shrubs, without reducing the abundance of the dwarf shrubs themselves. Winter grazing can be useful in

\[\text{(p.157)}\]

Fig. 6.10 Heavy grazing and trampling. Heavy grazing produces pioneer-type heather structure (a), and can eventually result in its replacement by grazing-tolerant grasses.

Heavy trampling on wet heath, such as along this track created by ponies and people (b), provides suitable open conditions for a range of less-competitive plants. The margins of this track support abundant marsh clubmoss, Lycopodiella inundata, which is rare and declining throughout most of its European range, and the scarce brown beaksedge, Rhynchospora fusca. Both are absent
reducing the vigour of wavy hair-grass in areas where it produces a flush of growth in late autumn following autumn rains, and begins re-growing early the following year. Winter grazing by cattle can also be used to reduce the vigour of the tall grasses wood small-reed, *Calamagrostis epigejos*, and Yorkshire-fog, *Holcus lanatus*.

Grazing densities of heathlands are typically between 20 and 70 livestock unit days/ha per year (see Table 5.1 and Fig. 5.8 for an explanation of how to estimate (p.158) grazing pressure). As a rule of thumb, stocking levels need in winter to be about a third of those used in summer.

Livestock can affect regeneration of trees and shrubs by eating their seedlings when feeding on grass and other low vegetation, and by specifically browsing the leaves of trees and in some cases stripping their bark. Most livestock only browse trees and shrubs to any extent when there is little other food, especially in winter and under high stocking levels. Often, though, grazing levels need to be so high to suppress tree and scrub regeneration that this conflicts with other objectives. Hence even though grazing can reduce encroachment by trees and shrubs, additional cutting and removal is often required (Bokdam and Gleichman 2000; Piessens et al. 2006).

Periodic grazing can be also be used to graze down areas over a short period, and temporary or permanent fencing can be used to exclude grazing from specific areas. For example, grazing is often temporarily excluded to prevent livestock from eating the flowers of marsh gentian, *Gentiana pneumonanthe*, on wet heath used by the larvae of the Alcon blue butterfly, *Maculinea alcon*. Grazing is typically excluded from these key areas between the end of June and mid-September. This allows sufficient time for the adult butterfly to lay their eggs at the base of the gentian's flowers, the eggs to hatch, the caterpillar to eat the gentians seeds, and finally fall to the ground and be adopted by ants.
Burning, by producing a flush of palatable re-growth, can also be used in combination with grazing. Livestock preferentially graze the re-growth and keep previously burnt areas short.

6.5.5 Removing individual trees and patches of scrub
Removing individual trees and patches of scrub can present a dilemma. Removing all of them will make the area less interesting for most birds and many invertebrates, whereas leaving them will provide a source of seeds for further establishment of trees and shrubs (Manning et al. 2004). A compromise is to leave scattered single and clumps of trees (Figure 6.11).

The value of heathland for birds and invertebrates can also be enhanced by maximizing the length and structural variation of its interface with woodland. Sheltered hollows facing towards the sun can be created to benefit warmth-loving invertebrates and woodland edge diversified to provide feeding edge for Eurasian nightjars. Principles are similar to those described for enhancing the edges of rides and margins of woodlands in general (Section 7.4.1).

The method used to remove trees and patches of scrub will depend on their size. Saplings can be pulled up by hand but is a laborious process. Larger trees can be cut using chainsaws. Dense stands of trees and scrub can be removed using forestry mulchers. Subsequent treatment with herbicide is usually necessary to prevent re-growth of deciduous trees where this is not controlled by browsing. As with scrub removal in general (Section 7.3.1), it is best to concentrate on areas most recently colonized by trees, since these will be easier to restore to heathland vegetation. Older, leggy, gorse can be cut to ground level (coppiced) and allowed to re-grow or regenerate from seed to provide denser stands favoured by Dartford warblers.
Disturbance of the ground layer during tree removal will probably be sufficient to expose any buried heathland seed and provide suitable conditions for its germination. Removal of accumulated tree litter and humic material to just above the mineral layer helps in re-establishing heathland vegetation beneath dense stands of trees by maximizing removal of nutrients, while still retaining a smear of organic matter above the mineral soil containing buried seeds (Allison and Ausden 2006). Heathland invaded by Scots pine is usually easier to return (p.160) to heathland than area colonized by birch and bracken, although there is much variation in the success of management between sites (e.g. Mitchell et al. 1999). Birch is more invasive on phosphorus-rich soils (Manning et al. 2004).

Fig. 6.11 Scattered trees and scrub. Trees and scrub can out-compete lowland heathland vegetation, but their presence also enhances the value of heathland for birds and many invertebrates. A compromise is to remove the majority of the trees and scrub, but retain scattered individuals and patches. Densities of three or four trees per hectare are generally recommended (Symes and Day 2003), with their locations and distribution also taking account of aesthetic considerations (Grange Heath, Dorset, England).
6.5.6 Controlling bracken

Bracken often forms large, monospecific stands of minimal conservation value, although it can be beneficial in providing nest sites for Eurasian nightjars and wood larks. There is often a desire to eradicate large areas of dense bracken. However, as with controlling other invasive plants (Section 4.5), any decision should take account of whether it is expanding and the likelihood of successfully reducing it and establishing more valuable habitat in its place.

There are four methods of controlling bracken: spraying with the herbicide Asulam, cutting, rolling, and bulldozing. The most effective method is spaying with Asulam. This can be applied to dense stands using a boom-sprayer or weed-wiper, or by spraying from a helicopter. Scattered bracken can be treated by spot-spraying. Follow-up spraying is always necessary to prevent surviving bracken from re-expanding. Other techniques can only be used on large expanses of bracken with little other conservation interest. Cutting reduces the abundance of fronds but will not kill bracken. However, 2 years of cutting mature fronds in mid-summer and replacement fronds as they reach maturity in late summer should significantly reduce its density, although annual cutting will subsequently be needed to prevent it from re-expanding. Squashing bracken using a roller with crimping edges has a similar effect to cutting and needs to be undertaken at the same frequency to achieve similar results. Bulldozing the fronds, rhizomes, and litter is also very effective (Mitchell et al. 1999).

Bracken produces a dense litter that inhibits the growth of most other plants. Thick layers of litter beneath long-established stands need to be removed, or at least scarified so that most breaks up and blows away, to allow other vegetation to establish following control.

6.5.7 Sod cutting/turf stripping to reduce nutrient levels and other methods of creating bare and disturbed ground

Sod cutting/turf stripping is the most effective method for reducing nutrients, especially nitrogen levels, within the vegetation, litter, and organic layer to favour dwarf shrubs at the expense of competitive grasses (Diemont and Linthorst Homan 1989; Britton et al. 2000b; Härdtle et al. 2006). Sod cutting/turf stripping will also create bare ground. Stripping
down to as far as the mineral layer removes a higher proportion of nutrients, but delays the re-establishment of (p. 161)

(p.162) dwarf-shrub vegetation, because it removes any existing seedbank and probably provide less favourable conditions for germination of dwarf shrubs (Diemont and Linthorst Homan 1989; Allison and Ausden 2006). The best option is to remove material to just above the mineral layer as described in Section 6.5.5. It can be difficult to dispose of topsoil removed by sod cutting/turf stripping, making it impractical to undertake over very large areas. There has been some success in marketing the material as acidic garden mulch, but in some areas it contains levels of heavy metals that are too high for this. Stripping of

Fig. 6.12  Sod-cutting/turf-stripping. Anthropogenic atmospheric nitrogen deposition increases nitrogen levels in the vegetation and soil. This favours grasses at the expense of heather. (a) Sod-cutting/turfstripping can be used to remove this accumulated nitrogen, thus favouring heather, which can be
large areas has been used to expose sand to create mobile sand dunes (Figure 6.12). Sod cutting/turf stripping can also be used to set back succession in wet heath and mires, by lowering the surface of the peat relative to water level and exposing the buried seedbank.

(b, c) An extreme form of sod-cutting/turf-stripping has been carried out in the National Park de Hoge Veluwe, Gelderland, in the Netherlands. Here, 65 ha of drifting, wind-blown sand has been re-created by felling pine woodland and removing the topsoil. The sparsely vegetated sand supports a number of species that are rare in the Netherlands, including the spectacular ladybird spider, *Eresus cinnaberinus*, blue-winged grasshopper, *Oedipoda caerulescens*, and sand lizard. The mobility of the dune can be appreciated from the bottom photograph which shows a cut stump now left standing high above the sand.

Small-scale sod cutting/turf stripping can be used to provide suitable conditions for a range of scare plants (e.g. Jacquemart *et al.* 2003; Jansen *et al.* 2004), using the same methods and principles as described for fens (Section 8.8.4).

Other methods for exposing bare ground, other than through trampling by livestock and the activities of European rabbits, include:

- cutting and removing the vegetation and then rotovating the soil;
- scraping away the vegetation and topsoil using a bulldozer or angled blade attached to a tractor;
- creating vertical faces and eroding slopes;
- disturbance and compaction caused by human trampling, horse-riding, cycling, motorbikes, and other vehicles.
Where a thick layer of organic matter is present, sod cutting/turf stripping will be better than rotovation at exposing more bare sand and any buried seedbank. Rotovating partially re-buries the organic matter within the upper layer soil. Rotovating, or even ploughing, can be used at less frequent intervals on formerly cultivated heathland soils to set back succession (Degn 2001). When creating bare sand using a bulldozer or tractor-mounted blade, the scraped soil and vegetation should be mounded on its northern side to prevent it shading the bare ground created.

A continuity of disturbed conditions can be created by constructing vertical sand faces and erodable slopes (Figure 6.13). These can provide important nesting sites for solitary bees and wasps, and basking and warm, dry, over-wintering sites for reptiles. They should ideally face towards the sun to provide the warm conditions favoured by the majority of species associated with bare and disturbed ground. The area of suitable face and bank can be maximized by excavating a sand face and using the material removed to build an additional bank. These areas may require periodic small-scale vegetation clearance to keep them open, although they are often kept open by trampling and rubbing by livestock. Trampling along paths and disturbance by vehicles is sometimes considered a nuisance on heaths as in other habitats. However, as in free-draining grasslands, it can produce a variety of valuable microhabitats for invertebrates,
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particularly consolidated and sparsely vegetated sand on the path edges. Areas *continually* churned up by vehicles and horses will be less valuable.

As with all forms of disturbance, it is important to carry it out on rotation. Disturbance should ideally be created successively in adjoining plots to increase the chances of species colonizing newly created plots from those that are becoming unsuitable. As a rule of thumb, only create disturbance over a proportion, for example between a tenth and a third, of the habitat at any one time, to minimize the risk of destroying all the suitable habitat for a species at once. It is common practice to periodically rotovate entire areas, especially firebreaks/fuel breaks. A better option is to maintain a far wider firebreak/fuel break, but only rotovate a (p.164) proportion, for example a third to a half its width each year. This will maintain a variety of successional stages in close proximity to one another, while still maintaining its function (Kirby 1992b).

6.6 Atlantic upland heaths and moorlands

Dry and wet dwarf-shrub upland heaths and moorlands dominated by heather are restricted to upland areas of north-west Europe, mainly in the British Isles. Most areas have been created by deforestation and been subsequently maintained by grazing and burning. Trees are usually absent. Burning (known as muirburning in Scotland) has been used to maintain dominance by heather and encourage a flush of palatable grasses and heather re-growth for grazing by sheep and red deer, or to provide a small-scale mosaic of young and old heather for red grouse, *Lagopus lagopus scoticus*, to maximize numbers for shooting. Areas of open upland managed for sheep are known as sheep-walk and for deer known as deer forest. Peat cutting for fuel has also been undertaken in wetter areas.

Upland moorlands invariably occur, and are managed, together with areas of blanket bog, wet flushes, acid grassland, and bracken. Upland heath and moorland is also farmed in association with a fringe of enclosed upland grassland at lower altitude known as in-bye.
The dwarf-shrub vegetation of drier upland heath and moorland differs from those on lowland heaths in the presence of several montane dwarf shrubs. Upland heaths and moorland also lack many of the rarer plants associated with disturbed ground that are found on lowland heath. Wetter areas are, as on lowland wet heath, typically dominated by mixtures of heather, cross-leaved heath, and purple moor-grass. These grade into waterlogged blanket bog and bog pools dominated by mixtures of heather, hare's-tail cottongrass, *Eriophorum vaginatum*, and *Sphagnum* mosses. Wet flushes, particularly base-rich ones, can be botanically rich and contain many plant species with localized distributions.

Despite the similarities in dominant plant species, the fauna of upland heaths and moorland is quite different to that of lowland heaths, although there is some overlap of species, especially at lower elevations. Whereas lowland heaths support a range of mainly southerly species, the cool, wet, and cloudy upland heaths and moorlands and associated habitats support a range of mainly arctic-alpine, alpine, and boreal invertebrates, and a number of arctic and boreal bird species.

Areas consisting largely or entirely of dry upland heath and moorland support only a very limited avifauna, with only one species, red grouse, confined to this habitat. However, a wider range of birds are associated with mixtures of (p.165)
upland heath and moorland and other upland habitats. These include northern harrier, *Circus cyaneus*, merlin, *Falco columbarius*, black grouse, *Tetrao tetrix* (Figure 6.14), Eurasian golden-plover, *Pluvialis apricaria*, short-eared owl, *Asio flammeus*, ring ouzel, *Turdus torquatus*, common stonechat, *Saxicola torquata*, and twite, *Carduelis flavirostris*. Vegetation structure is important in influencing habitat use by many of these upland birds, with heterogenously structured vegetation probably supporting the widest range of species (Pearce-Higgins and Grant 2006). Scattered trees and woodland will increase bird species richness and favour species such as black grouse and scrub-associated songbirds, but decrease suitability for most species typical of open habitats, particularly breeding waders/shorebirds.

The invertebrate fauna varies with the growth phase of heather following cutting or burning (Usher 1992), as on lowland heaths, but lacks the suites of species of high conservation value associated with early successional habitat. (p.166) The invertebrate fauna of upland heaths and moorland is rarely, if ever, specifically taken into consideration during management.

6.6.1 Overview of management

Most upland dry heath and moorland is managed by periodic burning to provide grazing for sheep and red deer and maximize red grouse numbers. Judicious burning also maintains dominance by heather by setting back its growth stage, thereby encouraging the vigorous, building, and mature phases of heather, which are less vulnerable to colonization by grasses. Management for red grouse also involves control of its predators and parasites.

Fig. 6.14 Black grouse. Like many birds found on Atlantic upland heaths and moorlands, black grouse actually require a mixture of habitats. They often nest in tall heather, but the hens require protein-rich food prior to laying, such as flowers of cottongrass in bogs and buds of other plants. In summer chicks feed on invertebrates, especially in wet flushes. In winter black grouse feed on dwarf shrubs and, especially when these are covered in snow, on the twigs and needles of various trees (photograph by RSPB IMAGES).
A large proportion of upland heath and moorland and associated blanket bog, wet flushes, and acid grassland is considered to be in an unfavourable conservation condition due to the effects of heavy grazing (over-grazing) by sheep (Fuller and Gough 1999) and too frequent burning. High levels of grazing favour grasses over heather-dominated vegetation, and frequent burning, especially in wetter areas, can result in the replacement of heather-dominated vegetation by purple moor-grass. Replacement of heather by grasses is exacerbated by anthropogenic atmospheric nitrogen deposition (Hartley and Mitchell 2005). Heavy grazing by sheep has been encouraged by agricultural subsidies. Large areas of dense bracken are often controlled to increase the area available for grazing. Frequent burning of associated bogs (Section 8.9) is considered to have damaged its flora and, together with heavy grazing, can cause unwanted erosion. Wetter areas have been damaged by drainage.

Thus, although upland heaths and moors are again relatively similar to lowland heaths in terms of their dominant plant species, the conservation value of upland heath and moorland has usually been damaged by over-exploitation, and that of lowland heathland usually by lack of recent management that has resulted in its loss through succession.

Conservation management of upland heaths and moorland and associated habitats invariably has to take account of its commercial management for livestock, red deer or red grouse, and therefore usually aims to:

- provide a mosaic of heather growth phases by periodic burning and in some cases cutting to benefit red grouse or provide sufficient re-growth for livestock and red deer, and to maintain heather mainly in its building phase and thereby minimize the risk of its replacement by grasses;
- maintain, or restore, wet heath, blanket bog, and wet flush vegetation by leaving it ungrazed or only grazing at low levels, preventing burning and blocking any artificial drainage (grip-blocking; Section 8.9);

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- provide an overall mosaic of suitably lightly or moderately grazed wet habitats — blanket bog, species-rich flushes, and wet grassland and heterogenous dry upland heath and moorland — to maintain a diverse range, and high densities of the previously mentioned bird species.

Whereas there is a general consensus that heavy grazing has in most cases been damaging the conservation value of these upland habitats, there is less certainty that these damaging effects can be reversed simply by reducing grazing levels, at least in the short term.

Management may also aim to encourage re-afforestation by native woodland by reducing levels of grazing and browsing by livestock and, in Scotland, by red deer (Figure 7.2).
6.6.2 Burning and cutting

The basic principles of burning and cutting are similar to those on lowland heathland. They differ in that heather in wetter areas of upland can perpetuate itself by rooting from prostrate stems. Layering prevents the heather from reaching its degenerate phase, and thus does not require periodic cutting of burning to maintain its vigour. The bird nesting season is later in the uplands, so burning can take place slightly later into spring than on lowland heaths. In the wetter climate of the uplands there are usually even fewer days suitable for burning in winter and early spring.

The large size and remote nature of most areas of upland heath and moorland means there is less of an issue of fires getting out of control and threatening people and property, than on most areas of lowland heathland. Burning is therefore used far more widely. Cutting is in any case often difficult in the more remote terrain.

Management for sheep and red deer usually involves burning relatively large areas to provide re-growth of grasses and heather for them to feed on. Management for red grouse involves burning narrow strips (muirburning in Scotland; Figure 6.15). Densities of breeding northern lapwings, Eurasian golden-plovers and Eurasian curlews *Numenius arquata* tend to be higher on moors managed for red grouse compared to on other heather-dominated moorland with similar vegetation, but it is difficult to differentiate between differences due to vegetation management and those caused by control of predators. Densities of most songbirds tend to be lower on managed grouse moors (Tharme *et al*. 2001). Eurasian golden-plovers, though, benefit from heather burning because they favour the short re-growth for nesting and chick-rearing, providing this is close to earthworm-rich grassland for adults to feed on (Whittingham *et al*. (p.168))
2000). Areas that should not be included within the heather-burning rotation include:

- exposed ridges, summits, and slopes where dwarf-shrub heath is maintained by exposure and where burning only results in slow regeneration and has the potential to initiate erosion;
- wet heath and blanket bog, which can be damaged by burning, and where there is a risk of severe damage to the underlying peat;
- wet flushes, whose vegetation will be damaged by burning;
- damp slopes and gullies supporting important assemblages of bryophytes that can be damaged by burning;
- grass/heather mosaics subject to high grazing pressure are therefore vulnerable to replacement of the heather by grasses;
- scattered trees and scrubs, which are important in their own right and which would be damaged by burning;

**Fig. 6.15** Muirburning. Management to increase numbers of red grouse for shooting involves burning narrow (typically less than 30 m wide) strips. This provides a small-scale mosaic of nutritious heather re-growth for feeding intermixed with taller heather for cover and nesting. The management aims to prevent heather from becoming more than about 30 cm high, with burning rotations typically in the range of 10–25 years (near Kingussie, Highland, Scotland).
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(p.169)

- areas of taller, older heather important for nesting northern harriers and merlins (Redpath et al. 1998) and those that have well-developed layering.

As with lowland heaths, grazing animals concentrate on the nutritious re-growth following burning. Therefore, burning a small proportion of areas supporting high stocking levels, can greatly suppress or even prevent successful regeneration of dwarf shrubs. Bracken can expand following burning, as on lowland heathlands. Blanket bog should not be burnt, since frequent burning, particularly in combination with heavy grazing and increased atmospheric nitrogen deposition, can lead to loss of peat-building *Sphagnum* and virtually complete dominance by hare's-tail cottongrass. As in lowland areas, burning upland wet heath can encourage species-poor stands of purple moorgrass at the expense of heather (Ross et al. 2003).

6.6.3 Grazing

The large size and remote nature of most areas of upland moorland means that grazing units are invariably large and encompass a range of habitats. Grazing pressure therefore has to be set at appropriate levels to maintain the whole suite of habitats within the grazing units within the desired state. Virtually all commercial grazing on upland heath and moorland is by sheep. However, cattle are generally preferred to sheep for conservation grazing for similar reasons to those described for heathlands and grasslands. Flocks of sheep and herds of cattle in upland areas are often hefted (Section 5.4.3). Ponies and goats are rarely used.

Heather can tolerate 40% of its current season's shoots being removed by grazing for a few years, but removal of 80% or more of shoots results causes it to die back, leaving it vulnerable to being out-competed and replaced by grasses. Heather is most vulnerable to defoliation in autumn (Grant et al. 1978, 1982). As on lowland heathlands, autumn grazing is most damaging. Modelling suggests that levels of utilization need to be less than 21–27% of potential maximum shoot production over the longer term to maintain dominance by heather (Read et al. 2002). The precise effect will depend on the age and vigour of heather and whether or not grass is already in the area. Tell-tale signs of grazing beginning to reduce the dominance of heather are when its pioneer-phase forms a low carpet and more mature heather begins to
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resemble topiary, and eventually a drumstick-like form, comprising woody stems with shoots reduced to heavily-grazed tufts at their tops.

As on lowland heaths, sheep, cattle, ponies, and also red deer prefer feeding on grasses and most other monocotyledons to heather and most other dwarf shrubs. (p.170) Goats take a larger proportion of dwarf shrubs and other woody plants (Bullock 1985; Grant et al. 1987; Gordon 1989; Jewell et al. 2005). Therefore, as on lowland heath, heavy grazing of dwarf shrubs will only occur at high stocking levels, and when there is little or no alternative forage, especially in winter when there is little grass left.

To maintain dominance by existing young and vigorous heather, overall stocking levels (including those of wild red deer) need to be kept below approximately 70 livestock unit days/ha per year. Stocking levels need to be less than half these to maintain heather dominance on poor soils and at high altitude, and no higher than 20 livestock units days/ha per year is recommended to maintain dominance by old heather and where it is in competition with purple moor-grass or hare’s-tail cottongrass (Thompson et al. 1995). Supplementary feeding will influence the distribution of sheep, with high grazing pressures and die-back of heather often occurring close to feeding blocks.

Recovery of previously over-grazed heather on upland dry and wet heath has been found to occur under year-round grazing at, respectively, 40 and 24–27 livestock unit days/ha per year (see Table 5.1 and Figure 5.8 for an explanation of how to calculate grazing pressure). In both cases removing grazing completely resulted in an even more rapid recovery of heather (Hulme et al. 2002; Pakeman et al. 2003).

Heather can re-grow well from small, heavily grazed plants following a relaxation of grazing pressure, but can be difficult to re-establish once lost. The main effect of reducing grazing levels on grass-dominated former upland heath and moorland can therefore be to increase grass height and cause of the decline of lower growing plants, but with little or no (re-)establishment of other plant species (Hill et al. 1992; Hope et al. 1996). Disturbance to create germination gaps and expose
any existing seed, or spreading of seed, will probably be necessary to re-establish it.

The effects of changes in grazing levels to benefit upland birds are poorly understood. Creation of a mosaic of vegetation heights and structures by reducing stocking levels over only a proportion of sites has resulted in increases in numbers of black grouse (Calladine *et al.* 2002). Conversely, heavy grazing that results in partial replacement of heather by grassland will increase numbers of field voles, *Microtus agrestis*, and meadow pipits, *Anthus pratensis*, thereby increasing prey for breeding short-eared owls (field voles) and northern harriers (both field voles and meadow pipits). High densities of breeding northern harriers can reduce the harvestable surplus of red grouse, thereby causing potential conflicts on commercially managed grouse moors. The best option for maximizing numbers of red grouse will be to restore suitably managed heather (p.171) moorland lost through over-grazing. This will increase the area of suitable habitat for red grouse, while reducing numbers of nesting harriers in these areas by reducing densities of their main prey, field voles and meadow pipits (Redpath and Thirgood 1997, 1999; Thirgood *et al.* 1999; Smith *et al.* 2000a). Within the grassland itself, densities of field voles will be highest in ungrazed or only lightly grazed grassland (Evans *et al.* 2006). Heavily grazed, degraded hare's-tail cottongrass-dominated blanket bog can, though, provide suitably short and open conditions for breeding of Eurasian golden-plovers (Whittingham *et al.* 2000; Pearce-Higgins and Yalden 2004).

6.6.4 Controlling bracken
Principles of controlling bracken are similar to those on lowland heathland. However, the larger and more remote nature of most upland heath and moorland mean than bracken control is usually carried out on a far larger scale, often involving spraying from helicopter. As on lowland heathland, while extensive areas of dense bracken are of extremely limited value for wildlife, bracken-dominated areas containing scattered trees and shrubs can support a diverse range of breeding songbirds (Fuller *et al.* 2006). Open bracken is important for the larvae of the pearl-bordered fritillary butterfly, *Boloria euphrosyne* (Feber *et al.* 2001). (p.172)