Dry grasslands

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Abstract and Keywords

This chapter discusses grassland management. The common objectives of grassland management are to: provide the desired sward composition, the specific aim often being to maintain or increase plant species richness; provide the sward height and structure favoured by a desired range of animals; and prevent colonization by scrub and trees. The effects of non-intervention on grasslands; management by grazing, management by cutting or without grazing, management by burning or without grazing, rotational management, soil disturbance; and the use of fertilizers, lime, slurry, and farmyard manure are discussed.

Keywords: grassland management, grazing, cutting, burning, soil disturbance, fertilizers, lime, slurry, manure

There are a number of terms used to describe areas dominated by grasses. Prairie refers to flat and rolling grassy plains in central North America. Steppe is used to describe semi-arid grasslands on plains in mid-latitudes of Europe and Asia. Grasslands that contain widely scattered trees and/or shrubs, typically in the tropics or subtropics, are called savannah.
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Rangeland is a term used mainly in North America for areas of grazed, near-natural vegetation comprising grasslands, shrublands, woodlands, and forests.

Wet grasslands are those with a high water table and/or which hold surface water. The suitability of wet grasslands for wildlife is highly influenced by their hydrology. They are discussed with other types of wetland in Chapter 8.

Dry grasslands are usually classified according to their:

- soil pH,
- extent of agricultural improvement,
- domination by so-called warm- or cool-season grasses,
- altitude.

There is a range of similar terms used to describe grasslands in terms of their soil pH. Grasslands with a pH of between about 4 and 6 are described as acid, acidic, or calcifugous. They occur over acidic/base-poor rocks, particularly on soils heavily leached by high rainfall, and on nutrient-poor, acidic sands. Grasslands with a pH between about 6 and 7.5 are called neutral or mesotrophic. Grasslands with a pH above about 7.5 are referred to as base-rich, calcareous, calcicolous, or alkaline. They usually support a more species-rich vascular plant flora than acid grasslands. As will be discussed, however, the botanical composition of all these grasslands can be heavily influenced by management.

Most grasslands have been created by people for agricultural use from other habitats, or are highly modified remnants of natural grasslands. The degree of modification for agriculture, usually termed agricultural improvement, or just improvement, greatly influences their existing and potential value for wildlife. Agricultural improvement of dry grasslands involves addition of fertilizers, (p.88) mainly nitrogen and phosphorus, to increase plant growth and in many cases also re-seeding with a limited range of agriculturally productive grasses. The level of agricultural improvement is usually classified as improved, semi-improved, or unimproved.

Warm- and cool-season grasses differ in their carbon metabolism. Warm-season grasses have C₄ metabolism, which means they initially fix carbon dioxide into a four-carbon compound. Cool-season grasses initially fix carbon dioxide as a three-carbon compound. As their name suggests, warm-season grasses are typical of warmer climates. Where they occur
together, warm-season grasses tend to be more productive in the warmth of summer and cool-season grasses in the cooler conditions of spring and autumn.

5.1 General principles of managing grasslands
Common aims of grassland management are to:

• provide the desired sward composition, the specific aim often being to maintain or increase plant species richness;
• provide the sward height and structure favoured by a desired range of animals;
• prevent colonization by scrub and trees.

As with most other ‘dry’ habitats, the main techniques used to achieve these are grazing, cutting, burning, and soil disturbance. Also, as in other habitats, these forms of vegetation removal and disturbance have the potential to damage the fauna in the short term. Hence a major consideration is the timing and spatial pattern of this management to minimize any short-term damage.

Grasslands are often associated with a number of other types of habitat and often managed together with them. These include small wetlands, areas dominated by tall forbs, scattered scrub, and limestone pavement (Figure 5.1). Upland and montane grasslands contain a range of features that are rare or absent from other types of grassland: rock cliffs and ledges, scree, flushes (areas with lateral movement of water), and snow fields.

5.1.1 Effects of management on vegetation
The most important management-related factors influencing vegetation composition of grassland are as follows.

• The intensity and selectivity of vegetation removal and, to a lesser extent, its timing. Both will influence competition between plant species.

(p.89)
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(a)

(b)
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Fig. 5.1 Limestone pavement. These are areas of more-or-less horizontal limestone rock broken up by deep cracks known as grykes (a). They contain a relict flora of open-ground plants that has persisted since the last glaciation, because these pavements have never become completely afforested.

A very extensive and special example of limestone pavement is found in The Burren, County Clare, Ireland. The Burren contains a notable flora including relict populations of arctic-alpine plants at close to sea level, for example mountain avens, *Dryas octopetala* (b), uniquely mixed with small numbers of Lusitanian-Mediterranean species.

Traditional management in The Burren involves grazing the higher limestone pavement with cattle in winter, and moving these to lower pastures in summer. This seasonal altitudinal movement of stock is the opposite to that of most transhumance systems (see Fig. 5.9). The absence of grazing on the limestone pavement in summer allows plants to flower and set seed. In the complete absence of grazing, the limestone pavement and associated grasslands in the Burren tend to be colonized by hazel scrub, *Corylus avellana*.

The extent to which management creates suitable gaps within the sward in which plants can germinate, and provides suitable conditions for their subsequent establishment.

The method, intensity, and timing of vegetation removal will also influence seed production and hence the ability of plants to regenerate.
The effect of vegetation removal on plant species richness will vary according to the type of grassland. The basic principle is that if the grassland is dominated (p.90) by one or a limited range of large grasses or forbs in the absence of management, then removing vegetation will reduce the dominance of these larger species and allow less-competitive, smaller plants to survive. This will in most cases increase plant species richness (see review by Bakker 1998).

Most lichens in grasslands require open, sunlit conditions and bare and disturbed ground. They are generally unpalatable and hence benefit from selective grazing that reduces surrounding competition, but are damaged by heavy trampling.

The suitability of conditions for regeneration of plants will be important in influencing the grassland's long-term plant species composition. All plants need to reproduce via propagules at some stage. Propagules will only germinate and establish in patches of bare soil sufficiently free of competition from existing vegetation. These patches are called germination gaps, which are most commonly formed through trampling and other disturbance by grazing animals. A consistent supply of bare and disturbed ground will be necessary to maintain any ruderal (annual or biennial) flora within the grassland.

Increasing nutrient levels through inorganic fertilizer application will in virtually all cases damage the flora of existing, species-rich grasslands. There are, though, rare occasions when low inputs of organic fertilizer may be used to maintain high plant species richness through replacing nutrients removed as hay.

5.1.2 Effects of management on fungi

Fungi are an important component of many dry grasslands and perform an important role in nutrient recycling. A group considered to be of particularly high conservation value in Northern European grasslands are the waxcaps of the genus *Hygrocybe*. Diverse fungal assemblages are largely restricted to agriculturally unimproved and semi-improved grasslands, including some that are species-poor in vascular plants and consequently often considered of low conservation value. Increasing nutrients, particularly nitrogen through fertilizer application, is considered damaging to larger fungi. Leaving cuttings on site will also allow nutrients to accumulate.
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(Griffith et al. 2004). Fungi usually fruit most prolifically amidst short turf. It is, though, not known to what extent suitability for fruiting influences the long-term persistence of fungi. Many types of fungi grow on the dung of large herbivores and hence benefit from grazing.

5.1.3 Effects of management on the grassland fauna

In the majority of grassland the most important factor influencing its suitability for birds and small mammals is its structure and the process that create it, rather than plant species composition per se. This is usually referred to as sward structure. In practice, plant species composition will affect structure to an extent and vice versa.

Sward structure refers to variation in the density and height of the vegetation. It is useful to distinguish between fine-scale variation (over tens of centimetres), often referred to as tussockiness, and larger, coarse-scale variation (over tens of metres or more).

For birds, sward structure and the availability of bare ground and abundance of litter will influence their ability to detect predators and feed efficiently and the suitability of the grassland for nesting (Vickery et al. 2001; Whittingham and Evans 2004). Bare ground probably increases access for birds to soil invertebrates (Perkins et al. 2000) as well as surface-living arthropod prey such as beetles. A dense litter layer probably makes it more difficult for most birds to access soil invertebrates. Vegetation composition will also directly influence food supply for birds, for example by providing suitable seeds or palatable grass species. Providing variation in sward conditions will increase the likelihood of there being at least some suitable conditions for nesting or feeding in a given area.

The grassland management itself can also affect populations of grassland birds by influencing nest and chick survival. Vegetation removal and other agricultural activities can destroy a high proportion of nests and young of birds. These losses can be minimized by altering the timing of management and by using other specific management techniques.

Scattered scrub and trees will increase the numbers of bird species using a grassland by providing nest sites and song posts for additional species. However, these will tend to be
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more generalist species, rather than grassland specialists. Trees and scrub may also provide nest sites and look-out posts for predatory birds and thereby reduce the breeding success or survival of grassland specialists (e.g. Green et al. 1990b). In North America trees and scrub will also encourage brown-headed cowbirds.

Densities and species richness of small mammals, such as voles, are higher in taller, ungrazed grassland with an abundant litter layer than in heavily grazed grassland (Rosenstock 1996; Tattershall et al. 2000; Evans et al. 2006). However, there is evidence that the highest densities often occur at moderate to high grazing intensities that provide a mixture of tall grass and cover and also fresh vegetation growth stimulated by livestock grazing (Schmidt et al. 2005b). Many slightly larger mammals that dig burrows and rely on detecting predators by sight, such as rabbits, prairie dogs, ground squirrels, and sousliks, Spermophilus spp., prefer (and maintain) short, open grassland.

(p.92) A wide range of factors will be important in influencing conditions for invertebrates. In general, taller swards support a larger number of individuals and species of arthropods, although many species are restricted to short, open swards (Morris 2000). In cool regions bare and disturbed ground is particularly valuable, especially on well-drained and friable soils on sunny slopes. This provides a suitable microclimate for warmth-loving species towards the edge of their climatic range and open, compacted ground for solitary bees and wasps to excavate nests in. Disturbance also creates suitable conditions for annual plants, whose seeds can be important seed sources for invertebrates. Other features of particular value for invertebrates in grasslands are:

- the presence of specific food plants of suitable growth form;
- a continuity of suitable nectar sources for adult insects;
- litter for litter-dwelling species;
- seed heads, both as a source of seed for some species and to provide over-wintering sites;
- grass tussocks to provide over-wintering sites;
- dung and carrion for dung- and carrion-feeding specialists and their predators.
Other features of particular value for invertebrates often associated with grasslands are:

- quarries, eroding cliffs and faces, disturbed edges of paths, derelict land, and other disturbed areas that provide early-successional habitats;
- wet flushes, marshy areas, and temporary pools.

As in other habitats, a key principle when managing grasslands for insects is to maintain a range of suitable conditions in close proximity to help provide the range of microhabitats required for insect species to complete their annual life cycles.

5.2 Non-intervention

In the absence of vegetation removal through grazing, cutting, burning, or soil disturbance, most grasslands will eventually become dominated by a limited range of more competitive larger perennial grasses and forbs and accumulate a layer of dead plant litter. They will lack plants that need to regenerate from seed at frequent intervals, and be largely dominated by plants that spread vegetatively. Unmanaged grassland will provide suitable conditions for a range of plants, birds, invertebrates and small mammals that prefer tall vegetation and an abundant litter layer and require freedom from disturbance to complete their life cycles.

(P.93) It is often assumed that if a grassland is left ‘unmanaged’, it will fairly quickly become colonized by scrub. This will not be the case, though, if there are no seeds of woody plants present or no gaps within the sward in which they can establish. Unmanaged grasslands can be surprisingly stable and resistant to scrub establishment (Figure 5.2). Woody plants commonly colonize grasslands where a period of heavy grazing or other disturbance that creates suitable conditions for their establishment is followed by a relaxation of management that allows the young seedlings to grow into bushes and trees. Establishment of trees and shrubs is discussed further in Sections 7.1.3 and 7.1.4.
5.3 Differences between grazing, cutting, and burning

Grazing has a quite different effect on sward composition and structure to either cutting or burning. The differences are described below. For practical reasons, cutting can obviously only be undertaken on relatively flat sites. Cutting may be the only practical method of managing small grasslands which are impractical to graze or burn, such as those in urban areas. Upland and montane grasslands are usually impractical to manage by anything other than extensive grazing.

5.3.1 Sward composition and structure

Light to moderate grazing removes vegetation gradually and selectively and, in so doing, can maintain suitable conditions for animals living within the sward while this is taking place, Fig. 5.2 Unmanaged grassland and scrub invasion. Grasslands that have been left unmanaged for a number of years, particularly those on more fertile soils, accumulate a thick layer of plant litter that smothers any gaps for scrub seedlings to establish in.

This is part of a large area of grassland that has been unmanaged for about 20 years. Despite this, the grassland contains virtually no scrub, instead comprising tall, rank grasses, common nettles, *Urtica dioica*, and tall umbellifers, *Umbelliferacea*, (Rainham Marshes, East London, England).
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so long as some of the vegetation is retained. By contrast, cutting close to ground level and burning are catastrophic events. Both suddenly remove virtually all the vegetation and make the grassland temporarily unsuitable for its inhabitants (see Morris 2000 for effects on invertebrates). They will be particularly damaging to species that are slow or unable to re-colonize as the vegetation becomes suitable for them again. These negative effects can be reduced by only cutting or burning a proportion of the grassland at any one time.

The selectivity of vegetation removal through grazing varies according to the type of grazing animal and grazing pressure. Grazing particularly benefit plants that either avoid being eaten, or recover well following defoliation. Plants avoid being eaten by:

- being unpalatable; that is, containing distasteful or poisonous substances;
- having physical defences such as spines;
- being low-growing and, in particular, forming rosettes that are difficult for animals to bite (Figure 5.3).

The group of plants best adapted to tolerate repeated defoliation are grasses and other monocotyledons. These grow from meristems situated at the base of the plant, which are out of the reach of grazing animals. Dicotyledons grow from apical meristems which, if protruding above ground, are vulnerable to being grazed. Grazing creates coarse-scale variation in sward structure and composition by accentuating existing variations in plant composition due to differences in topography and former management. Animals also create variation in sward conditions by treading down vegetation and creating patches of bare ground by poaching and other forms of disturbance. Patchy deposition of dung and urine can further increase spatial variation in plant composition.

(p.95)
The largely unselective vegetation removal by cutting and by burning tends to encourage greater uniformity in vegetation composition, height, and structure compared to grazing. Cutting and burning tend to encourage tall, bulky plant species that can outgrow smaller ones during the periods between the one-off cutting or burning events. These usually include larger, often more palatable plant species, which would otherwise be selectively removed by grazing animals (Figure 5.4).

Burning creates more bare ground than cutting, particularly with more intense fires that remove a greater proportion of litter. This favours the germination and growth of annual plants. Burning also often removes vegetation less uniformly than cutting due to variations in fire intensity. Fires often miss or only superficially burn some patches of vegetation.

Fig. 5.3 Benefiting from heavy grazing. Heavy grazing provides a competitive advantage for plants that are avoided by grazers. The poisonous large Mediterranean spurge *Euphorbia characias* (a) has been avoided by livestock that have closely cropped all the surrounding vegetation. Acanthus-leaved carline thistle, *Carlina acanthifolia* (b), is low-growing and difficult to bite, and also spiny.
flush of re-growth following burning attracts heavy grazing by livestock and wild herbivores.

Mowing and leaving the cuttings *in situ* smothers small plants and covers bare ground, including potential germination gaps, and so tends to reduce plant species richness. Management of meadows involves cutting and removing vegetation followed by a period of grazing (known as aftermath grazing). The aftermath grazing creates germination gaps.

**5.3.2 Scrub**

Grazing, cutting, and burning differ in their effects on scrub. Grazing animals prevent scrub from establishing by eating their seedlings. They can weaken or kill more established scrub through browsing and bark removal, but this ability varies with livestock type, grazing pressure, timing of grazing, and availability of more preferred vegetation. Cutting prevents seedlings from growing above the height of the cutting blade. Burning removes fire-intolerant species, but leaves fire-tolerant species to continue growing with often reduced competition.

**5.3.3 Soil nutrients**

Grazing animals re-distribute a high proportion of the nutrients removed in the vegetation via their dung and urine, unless the livestock are folded (kept in a pen) on other areas at night to deposit dung on them. Patchy deposition of dung increases variation in vegetation composition and structure by...
increasing spatial variation in nutrients. Avoidance of dunging areas by grazing animals can further accentuate this variation. Folding was used widely to deposit (p.97) nutrient-containing dung on arable land from animals grazed during the daytime on grassland or heathland.

Cutting and removal of vegetation removes nutrients from the grassland, and this can be useful when seeking to reverse the effects of artificially raised nutrient levels. Leaving cuttings in situ recycles them. Burning abruptly releases a proportion of nutrients in its ash.

5.3.4 Dung and carrion

Dung produced by grazing animals supports a diverse assemblage of invertebrates, particularly species of beetles and flies. These can provide prey for birds such as red-billed choughs, *Pyrrhocorax pyrrhocorax* (Roberts 1982), and bats. Carcasses of livestock can be important in sustaining scavenging birds and mammals, as well as supporting carrion-feeding invertebrates.

5.4 Management by grazing

The specific effects of grazing will depend primarily on:

- the type of grazing animals (and to a lesser extent their breed, age, experience, and herd structure);
- grazing pressure;
- the timing and duration of grazing.

The value of domestic animal's dung for invertebrates is reduced by the administration of anti-parasitic drugs (Section 4.4.3). A further consideration is the potential effects of domestic livestock on wild herbivores, either through reducing food for them, or by facilitating their use of the grassland by reducing sward height to within their preferred range.

5.4.1 Effects of different grazing animals

The most commonly used domestic grazing animals in habitat management are cattle, sheep, equines (horses, ponies, and donkeys), and goats. Wild herbivores can also be important grazers and beneficial creators of disturbance. Different types of livestock vary in their:

- spatial patterns and selectivity of vegetation removal;
- trampling effects;
• dung fauna;
• extent to which they browse woody vegetation.

(p.98) Differences in sward structure between cattle, equines and sheep are illustrated in Figure 5.5. Goats browse woody vegetation far more than other livestock.

Before comparing the effects of different types of livestock, it is worth noting that their effects will vary with grazing pressure. In particular, variation in sward structure and differences in the effects of grazing animals will be greatest under medium grazing pressure (Section 5.4.3).

Cattle

Cattle have a different method of feeding to equines or sheep and this produces quite different effects on vegetation composition and structure. Cattle feed by wrapping their large, rasping tongue around the sward and cutting it between their lower teeth and upper dental pad as they swing their head. This makes their feeding unselective at a very fine scale, since they cannot differentiate between different plant species within the tuft of vegetation they grab.

Cattle also differ from sheep and equines in the distribution and nature of their dung. They deposit most of their dung in a scattered manner, throughout the grassland, although it is sometimes concentrated in favoured lying-up areas. Cattle dung supports an especially diverse invertebrate fauna (Figure 4.8). Cattle avoid grazing within 10–20 cm of their pats, leaving scattered patches of fertilized taller vegetation (called avoidance mosaics). At medium grazing intensities, the combination of the removal of tufts of vegetation and avoidance of pats produces more tussocky vegetation than grazing by equines or sheep. Tussocky, cattle-grazed grassland is generally considered better for most ground-nesting birds than more homogenous swards maintained by sheep grazing. This is probably because the greater variation in cattle-grazed swards provides greater opportunities for concealment and camouflage of nests and young. European hares, *Lepus europaeus*, also prefer cattle-grazed swards to those produced by sheep (Smith et al. 2004b).

The hooves of cattle exert a greater trampling pressure than those of equines and a far higher pressure than those of sheep. Cattle are therefore better at squashing down and
breaking up rank vegetation and litter and at creating bare ground by poaching. Adult cattle trample a lower proportion of birds’ nests than sheep per quantity of vegetation removed, although frisky, young cattle trample a similar proportion (Figure 8.29). There is little information comparing nest-trampling rates of cattle and equines.

Cattle can reduce the vigour of woody plants by tearing off leaves and twigs. Horned cattle can inflict further stress on woody plants by breaking twigs and rubbing off bark with their horns.

(p.99)
An important consideration when deciding which type of cattle to use is whether they will need to survive on nutrient-poor vegetation and in hostile weather conditions. This varies with age and breed (Section 4.4.2).

Grasslands supporting relatively nutritious grasses can be grazed in summer by most modern, commercial breeds, including young cattle. Older breeds of more slowly maturing beef cattle are considered best for feeding on coarse, less nutritious vegetation. Cattle are better able to digest coarser vegetation once their rumen has fully developed at 18–24 months old. Milk production generally requires more

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**Fig. 5.5.** Grazing animals and sward structure. Cattle, equines, and sheep produce quite different sward structures at medium grazing pressures, as shown here. At high grazing pressures all create a short and uniform sward.

(a) Cattle usually produce the most tussocky vegetation. They also create more trampling and disturbance than either equines or sheep.
nutritious forage and hence dairy cattle are generally unsuitable for grazing coarser vegetation. There is little suggestion of significant differences in grazing behaviour between cows and bulls.

If an aim of grazing is to reduce the abundance of more unpalatable vegetation, by forcing livestock to eat it through lack of alternative, more palatable forage, then more hardy or primitive breeds might be needed. This will especially be the case if it requires year-round grazing under severe weather conditions.

(b) Equines typically create a mosaic of short, heavily grazed lawns interspersed with patches of taller, lightly grazed or ungrazed vegetation.
(c) Sheep nibble the vegetation close to the ground. They tend to produce a less tussocky sward than cattle, although still avoid particular unpalatable plants, in this case small tussocks of mat-grass, *Nardus stricta*. 
Equines and sheep

Equines and sheep feed by nibbling vegetation using their incisors. They are both highly selective grazers, being able to differentiate between different plants as they nibble. Sheep will preferentially feed on the flowers and buds of preferred forbs. They therefore have the potential to seriously deplete nectar sources for insects. Equines usually concentrate on eating palatable grasses and generally avoid forbs. The small size and nibbling behaviour of sheep make them ineffective at grazing down and breaking up tall swards. Cattle are much better at doing this (see above). Conversely, the selective nibbling and only limited trampling of sheep is better for lichens.

At medium stocking densities equines will accentuate existing large-scale variation in vegetation structure and composition, by heavily grazing some areas and avoiding others. This larger-scale variation in sward structure and composition can be further enhanced by equines’ habit of concentrating dung in discrete areas. This results in localized nutrient-enrichment and often colonization by taller, more nutrient-demanding plants. At moderate grazing intensities grazing by equines produces a mixture of closely cropped lawns and patches of ranker, ungrazed vegetation. The amount of bare ground produced by equines is intermediate between that produced by cattle and sheep.

Sheep have a bad reputation for creating extremely uniform, closely cropped swards. They do tend to produce more uniform swards than equines and especially cattle, although this uniformity of composition and structure is to some extent due to the often high stocking densities at which they are kept. Sheep do (p.101) not have specific dunging areas. They create less bare ground through poaching than either cattle or equines and cannot break up tall, rank vegetation.

Equines and sheep will both feed on coarser vegetation, including sedges and rushes, when there is little grass available, especially in winter. In these conditions equines will dig up rhizomes, browse woody plants and tear off and eat bark, often killing shrubs and saplings. Conventional sheep are poor at browsing scrub, even when there is little else to eat. However, primitive breeds of sheep browse woody vegetation far more than conventional breeds, and are useful at controlling young scrub (Section 4.4.2). Equines form strong
social groups, including sub-groups of colts and fillies. In extensive and naturalistic grazing regimes the territorial nature of these different social groups can result in large-scale variations in grazing pressure and hence in vegetation composition and structure.

Virtually all equines used for conservation grazing of grasslands are ponies. Donkeys are rarely considered. They can, though, be useful for controlling thistles, *Cirsium* spp., rushes, and other coarse vegetation where these are a problem, such as on former arable land. Donkeys will preferentially graze thistles down to their basal rosettes and nibble down rushes, despite there being plenty of apparently more palatable grasses present. Donkeys are similar to sheep in being best suited to drier conditions and, unlike ponies, will not graze in shallow water.

As with cattle, a major consideration when deciding the type of sheep or equine to use is the level of hardiness required. Also, as with other livestock types, this will vary largely with age, and to some extent breed. Both very young and very old sheep and equines are less able to graze coarser vegetation. Hill breeds of sheep are generally better able to survive in more hostile weather conditions on poor-quality forage than upland breeds, which are in turn more hardy than lowland ones. Primitive sheep are extremely hardy. There is a suggestion that, in the case of at least some breeds, rams and wethers (castrated males) browse more and feed on coarser vegetation than ewes. There is no evidence in any marked difference in feeding behaviour between sexes in equines.

**Goats**

Goats are well-known for consuming a wide variety of vegetation. They will typically spend 50–75% of their time browsing the leaves of trees and shrubs, far more than cattle, sheep, or equines. Goats also strip the bark of woody plants, particularly in winter. This makes them very effective at controlling even established scrub. Goats also graze grass and forbs, but do not usually crop them as short as sheep do. The other important feature of goats is their agility. This allows them to exploit food sources out of the reach of other grazers. They can rear up on their back legs to reach vegetation, and climb bushes, small trees, and precipitous slopes. The disadvantage of this is they can destroy patches of
grazing-sensitive vegetation that have previously survived on ledges and cliffs out of the reach of other grazing animals.

Goats form groups of females (nannies) and young. These can also include yearling males. Male goats (billies) may be solitary or form all-male groups. Billies and nannies are thought to have slightly different feeding preferences. In particular, billies strip bark more (Bullock and Oates 1998). The main problem with goats, though, is preventing them from escaping.

Other grazing animals
A number of wild grazing animals are especially important in influencing habitat conditions in semi-natural grasslands. Prairie dogs, pocket gophers, and American bison, Bison bison, are important grazers and creators of soil disturbance in North American prairies. European rabbits are important grazers and create valuable soil disturbance in many grasslands in Europe, especially those on loose, dry, especially sandy soils.

Prairie dogs, pocket gophers, and rabbits all cause soil disturbance by burrowing, and, in the case of rabbits, also by scraping the ground along the boundaries between warrens. Prairie dogs play a key role in providing suitable conditions for a wide range of other animals in short-grass prairie (Figure 5.6). Heavy rabbit grazing provides short vegetation and bare ground that, on suitable soils, can support vegetation characterized by lichens, cushion-forming mosses and winter annuals (Dolman and Sutherland 1992), and support warmth-loving invertebrates towards the edges of their climatic range. Very short, open, stony and disturbed ground produced by heavy rabbit grazing is favoured by Eurasian thick-knees, Burhinus oedicnemus, a rare and declining bird in much of Europe (Green and Taylor 1995; Beasley et al. 1999). The close, selective nibbling of rabbits and lack of heavy trampling by them favours lichens on grass heaths and grassy sand dunes. Lichens are otherwise easily trampled and destroyed by large grazing animals. Soil disturbance and local concentrations of dung produced by rabbits can provide suitable conditions for a range of plant species otherwise rare or absent within the grassland, including valuable nectaring plants. Rabbits are also important prey for a wide range of
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carnivores. They are the primary prey of 29 species of predators in their native Spain (Delibes and Hiraldo 1981).

Rabbits prefer short swards. They can be encouraged by using other livestock to keep the sward suitably short (Section 5.4.2) and by providing suitable cover and areas for them to establish warrens in (Figure 5.7).

American bison have similar feeding characteristics to cattle, but tend to concentrate on grasses rather than forbs to a greater extent and to browse slightly (p.103).

less (Plumb and Dodd 1993).

Wallowing (dust-bathing) by American bison can create temporary pools. Deer will graze grasslands heavily close to the safety of woodlands. Wild boar and pigs can create valuable soil disturbance by rooting.

Fig. 5.6 Prairie dog towns. Colonies of prairie dogs, known as towns, are important in sustaining a range of other species in the short-grass prairies of North America. Their grazing provides short, open areas favoured by mountain plovers, *Charadrius montanus*, and their vacant burrows habitat for burrowing owls, *Athene cunicularia*, rabbits, hares, lizards, and rattlesnakes. The prairie dogs themselves are important prey for ferruginous hawks, *Buteo regalis*, swift foxes, *Vulpes velox*, and the endangered black-footed ferret, *Mustela nigripes*.
5.4.2 Using mixtures of grazing animals

Grasslands can be grazed using combinations of different livestock. The effects can be difficult to predict. Adding small numbers of cattle to otherwise sheep-grazed grassland, particularly in winter, can be used to add valuable bare and disturbed ground for invertebrates and regeneration gaps for plants. Combinations of cattle and sheep can be used to open up tall and rank swards. Cattle are first used to graze down and break up the tall sward. Sheep are unable to do this. Sheep are then introduced to nibble and pull out the remaining dense thatch from the short sward that cattle are unable to reach.

Combinations of livestock also have the potential to reduce the overall selectivity of vegetation removal, through one type of animals feeding on the plants  \( \text{(p.104)} \)

**Fig. 5.7** Encouraging rabbits. European rabbits can be important grazers and agents of soil disturbance in grasslands, but are reluctant to establish new warrens in areas far from cover.
the other has avoided. This can reduce overall structural diversity, but increase plant species richness at the small to medium scale, by reducing the dominance of more competitive species that the other livestock type has selectively avoided. For example, horses avoid grazing their latrine areas, and this allows more competitive plant species to become dominant in these areas. Adding cattle reduces the dominance of these more competitive plant species in the horse latrines, and increases plant species richness in them (Loucougaray et al. 2004).

Grazing by one species can be used to facilitate use of the grassland by other grazers. Sheep can be used to graze down the sward to a suitable height for rabbits.

(p.105) 5.4.3 Grazing pressure

Grazing pressure will influence the structure and composition of the sward and thereby its associated fauna. At medium stocking levels animals will tend to increase variation in sward structure by selectively removing a greater proportion of the vegetation in some areas compared to others. The extent and pattern of this will vary with livestock type. Very high or very low levels of grazing will remove, respectively, virtually all or none of the vegetation. Neither will increase variation in structure. Higher levels of grazing will obviously create a shorter sward and tend to create more bare and disturbed ground, although the extent of this will again be influenced by livestock type, the timing of grazing, and soil wetness in the case of bare and disturbed ground. The short, open conditions and bare ground produced by heavy sheep, and especially rabbit, grazing are important in maintaining the characteristic

Rabbits can be encouraged on to fields by depositing piles of brash (a). These provide safe cover for the rabbits while they excavate warrens in the soil beneath them. The brash piles can be removed once a new warren has been established (b; Minsmere, Suffolk, England).

A different approach is required on soils where rabbits have difficulty excavating burrows, such as on thin, calcareous soils overlying relatively hard chalk or limestone. In these areas mounds and banks of soil can be provided for them to excavate warrens in.
species-rich assemblages of lichens that can occur on skeletal, especially calcareous soils (Lambley 2001).

Grazing pressure influences sward composition by selectively disadvantaging some plants more than others. At very low stocking levels animals will concentrate on the most palatable plants. As stocking levels increase, animals will remove an increasing proportion of bulky and palatable species, and thus increasingly benefit those plant species that avoid being eaten or recover well from it. It is only at very high stocking levels, where there is little else left to eat, that livestock will be forced to eat the least palatable plants. Plant species often become dominant on grasslands because they are relatively unpalatable and thereby gain an advantage over the rest of the vegetation. In many cases, though, increasing grazing intensities to levels high enough to reduce these less-palatable species may be damaging to the other grassland flora and fauna. It may also be unacceptable to commercial graziers.

Methods of estimating the approximate numbers of livestock to use are described in Table 5.1 and Figure 5.8. The effects of grazing on sward conditions will vary between years due to weather-related differences in plant growth. Although it is useful to set out desired stocking levels, these still have to be adjusted to achieve the desired sward conditions. In particular, the suitability of the sward for birds in spring can change rapidly in response to rapid grass growth, while periods of drought may mean that livestock numbers have to be reduced because there is insufficient food for them. Good conservation grazing management relies largely on the adjustment of stocking levels in a particular area through skill and judgement: knowing when to move them, and which areas to exclude livestock from at particular times of year. These may include areas with high densities of nesting birds or important food plants or nectar sources for (p.106)

<table>
<thead>
<tr>
<th>Table 5.1 Livestock units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal</td>
</tr>
<tr>
<td>Sheep</td>
</tr>
</tbody>
</table>
Dry grasslands

<table>
<thead>
<tr>
<th>Animal</th>
<th>Livestock unit for medium-sized animal</th>
<th>Range of livestock units for small to large animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ewes (including their lambs) and rams</td>
<td>0.10</td>
<td>0.08–0.15</td>
</tr>
<tr>
<td>Ewe followers and store lambs</td>
<td>0.08</td>
<td>0.06–0.10</td>
</tr>
<tr>
<td><strong>Cattle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy cows</td>
<td>1.0</td>
<td>0.8–1.1</td>
</tr>
<tr>
<td>Suckler cows (including their calves)</td>
<td>0.9</td>
<td>0.7–1.1</td>
</tr>
<tr>
<td>Beef and other cattle older than 2 years</td>
<td>0.7</td>
<td>0.6–1.0</td>
</tr>
<tr>
<td>Weaned beef and other cattle younger</td>
<td>0.6</td>
<td>0.5–0.7</td>
</tr>
<tr>
<td>Equines</td>
<td>1.0</td>
<td>0.8–1.2</td>
</tr>
</tbody>
</table>

These are the standard measure for describing grazing pressure. They show the relative quantity of vegetation removed by different grazing animals. From the figures shown here, it can be seen that one medium-sized dairy cow removes the same quantity of vegetation as 10 medium-sized ewes (including their lambs). Values of livestock units for other ruminants can be calculated by dividing their live weight (in kg) by 650.

Source: UK's Rural Development Service Technical Advice Note 33.

Invertebrates. Livestock can be excluded temporarily from sensitive areas using electric fencing.

When introducing grazing to a formerly unmanaged sward it is prudent to only introduce it to a proportion of the area and only begin grazing at a low stocking level. Heavy grazing, as with burning and cutting, has the potential to cause the local extinction of existing populations of invertebrates. In
particular, it might remove important larval foodplants, nectar sources, or over-wintering sites and thereby prevent populations of insects from completing their annual life cycle. Examples of where this has occurred are given by Waring (2001). Grazing pressure can, if need be, be increased later on based on the results of monitoring and any other experience gained. If the sward has been left unmanaged for a long time, there is unlikely to be any urgency in restoring it to a heavily grazed condition.

The practicality of achieving desired sward conditions depend to some extent on the size of the grazing units. Greater control can be achieved using smaller grazing units. Each of these can then be grazed at an optimum level. The ability to achieve desired stocking levels may also depend on the availability of alternative land of minimal conservation interest, on which livestock can be placed (p.107)

when not required on areas of high conservation value. This is often referred to as sacrificial grazing. Within very large grazing units the distribution of livestock, and hence variation in grazing intensities, was formerly commonly controlled by shepherding. This practice is rarely, if ever, economically

Fig. 5.8  Estimating how many stock to use. The standard measure of grazing pressure is the number of livestock unit days/ha per year. This provides an index of the approximate quantity of vegetation removed by grazing animals per hectare of land over 1 year. Grazing pressure can be calculated using the following formula.

| Livestock unit days/ha per year = number of stock livestock unit of stock type number of days spent grazing per |
Dry grasslands

practical in temperate areas nowadays.

In the uplands where flocks of sheep and herds of cows have been continually grazed in an area over a number of generations, they often form their own, defined home-ranges. These flocks and herds are known as hefted. Specific considerations when grazing upland and montane grasslands are highlighted in Figure 5.9. (p.108)

For example, six medium-sized beef cattle older than 2 years (=0.7 livestock units per animal; see Table 5.1) that graze for 180 days during the year on 5 ha of land will exert a grazing pressure of

\[6 \times 0.7 \text{ livestock units} \times 180 \text{ days/5 ha} = 151 \text{ livestock unit days/ha per year.}\]

These figures do, though, have to be treated with caution. In particular, the timing of grazing also influences the extent of vegetation re-growth and hence the grazing pressure required to remove it. They are, however, useful in estimating the approximate number of stock of a given type that are required at a site, although these numbers have to be adjusted depending on seasonal and between-year variation in vegetation growth. Ranges of grazing pressure used to manage different types of grassland are shown below.

<table>
<thead>
<tr>
<th>Type of grassland</th>
<th>Grazing pressure (livestock unit days/ha per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry, unimproved, acid and base-rich</td>
<td>40–100</td>
</tr>
<tr>
<td>Neutral semi-improved and improved</td>
<td>100–400</td>
</tr>
</tbody>
</table>

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Fig. 5.9 Upland and montane grasslands. In upland areas livestock, like these sheep in the Spanish Picos de Europa (a), are traditionally moved to high pastures in summer and wintered in sheltered lowlands. This system of seasonal
5.4.4 Timing and duration of grazing

The timing and duration of grazing will influence:

- the suitability of the sward for its inhabitants, especially birds and invertebrates, at different times of year;
- the effect grazing has on individual plant species and hence the long-term sward composition;
- the damage caused to the fauna by the vegetation removal itself and trampling of livestock.

There are two main approaches to grazing: either maintaining a similar grazing regime each year or grazing different areas each year on rotation. Grazing can be carried out at any time of year, but in temperate areas grazing is typically carried out:

- from spring to autumn (i.e. during the growing season), often referred to as summer grazing;
- from autumn to spring (i.e. during the dormant season), often referred to as winter grazing;
- year-round.

**Summer grazing**

Most pastures are grazed in summer to maximize their agricultural output. The main aims of conservation grazing in summer are to maintain high plant species richness by preventing more competitive plant species from out-competing less competitive ones, and to provide a suitably short and open sward required by desired groups of breeding birds, wintering

...
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birds arriving after the growing season, and invertebrates. The disadvantages of grazing during the growing season are that it can:

- remove nectar sources for adult insects;
- prevent the development of seeds for seed-feeding invertebrates and birds, seed heads used by over-wintering invertebrates, and make conditions less suitable for larger and longer-lived invertebrates;
- trample birds’ nests (Beintema and Müskens 1987; Green 1988).

Hence the optimal grazing regime will seek to provide the desired sward conditions while minimizing these negative effects. In less productive grasslands, especially those on thin soils where vegetation growth is limited by summer drought, it may be possible to achieve the desired open and varied sward conditions by grazing during winter and avoid these disadvantages of summer grazing. (p.110) Summer grazing will prevent larger, more vigorous plant species from out-competing smaller, less competitive ones. The specific timing of grazing during the growing season will also have subtle effects on plant species composition. Plant species will vary in their ability to withstand defoliation during different periods of growth, and this will alter their relative competitive ability. In practice, though, the subtle effects of differences in the specific timing of grazing during summer are rarely an important consideration when deciding on grazing regimes. Instead, the timing of summer grazing is more often determined by agricultural objectives and the requirements of nesting birds.

Methods for minimizing trampling of bird’s nest by livestock have been developed mainly specifically to benefit breeding waders/meadow birds on wet grasslands and are described in Section 8.12.3. These techniques can, though, also be applied to drier grasslands.

Grazing levels during summer and autumn will be important in creating short swards for birds to feed on larger soil invertebrates in winter (e.g. Buckingham et al. 2006), and where there is little or no vegetation growth in winter; sward conditions at the beginning of the following breeding season.
Grassland fungi possibly benefit from relatively heavy grazing in summer. Most species are thought to fruit best when the sward is short (less than about 10 cm) in late summer and autumn.

**Winter grazing**

Winter grazing has traditionally taken place on grasslands on more free-draining soils in the lowlands that are less subject to poaching. Livestock grazed in upland areas in summer are often out-wintered in sheltered, lowland grasslands. Winter grazing has declined in many areas, with less hardy, modern commercial breeds usually now wintered indoors.

The presumption against grazing most types of grasslands in winter is based largely on its potential damage to the agricultural productivity of the sward. It is interesting to note that in original-natural grasslands there would undoubtedly have been a higher grazing pressure in winter *relative* to the quantity of food available. This is the opposite to most conventional agricultural systems. The higher grazing pressure in winter in natural systems might explain the large array of ruderal plants that require bare ground (created by poaching in winter), and the large number of forbs that are intolerant of heavy grazing during the growing season.

The main uses of conservation grazing in winter, or outside the main growing season, are to:

- provide suitable conditions for invertebrates in summer, without the deleterious effects of removing vegetation during summer (Figure 5.10);
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• **Fig. 5.10** Grazing outside the main growing season. This provides the benefits of reducing accumulation of litter and creating bare ground, but without removing nectar sources and food plants for insects during their main active periods. This forest-edge grassland is grazed for a period in early spring, but is left ungrazed during the middle of summer when the cattle are moved to higher ground. The mixture of bare ground and abundant flowers support a wealth of insects, including this superb cardinal butterfly *Argynnis pandora* (Arguébanes, Asturias, Spain).

- maintain specialized plant communities created and maintained by winter grazing.

Winter grazing may also supplement summer grazing in order to:
- help maintain a suitably short sward in spring in areas where vegetation continues to grow during winter;
- reduce the dominance of less palatable wintergreen plants that are largely ungrazed in summer.

Winter grazing can be used to provide suitable conditions for warmth-loving invertebrates on agriculturally unimproved grasslands on light, free-draining soils, especially over chalk and limestone. On these generally unproductive swards summer grazing is not necessarily needed to maintain the short, open conditions required by many invertebrates and less competitive plant species. (p.112) Winter grazing will maintain relatively open conditions by preventing the accumulation of litter and create bare and disturbed ground by poaching, but without the potentially damaging effects of summer grazing. Grazing pressure should be high enough to remove accumulated litter and create bare ground, but light enough to retain seed heads and tussocks, both of which can provide important over-wintering sites for invertebrates.

Where sward continues to grow during winter, additional light winter grazing may be beneficial in maintaining a short and open sward for wintering birds that feed on soil invertebrates, and for open-sward-loving species the following spring.
Several species of birds that feed on soil invertebrates prefer fields with livestock in them during the winter (Perkins et al. 2000).

A common use of winter grazing is to reduce the vigour of unwanted, less palatable, wintergreen plants, such as rushes and some coarse grasses. These tend to be avoided by grazing animals in summer when more palatable herbage is available. However, wintergreen plants become the best forage available in winter once deciduous plants have transferred their food reserves below ground and any other more palatable vegetation has been consumed.

Although a degree of poaching caused by winter grazing is beneficial in grasslands, excessive poaching can damage species-rich grassland and result in colonization by some unwanted plants, such as thistles, ragwort Senecio spp., and rushes. Winter grazing needs constant attention to be successful. In winter a sward can rapidly change from being lightly poached and moderately vegetated to heavily poached and largely denuded of vegetation. This is particularly the case on wetter soils.

**Year-round grazing**

Year-round grazing using similar stocking levels is a feature of most extensive and naturalistic grazing regimes (Section 4.4.1). In original-natural conditions food supply is likely to have often limited large herbivore numbers in winter. Starvation of livestock is unacceptable under animal welfare legislation. This means that stocking levels for year-round grazing have to be based on the maximum winter carrying capacity of the area, which will be considerably lower than that in summer. Maximum stocking levels for year-round grazing are typically only a third, or even less, of those that a site is capable of supporting in summer.

Hence grazing with similar numbers of livestock throughout the year will usually make it difficult to maintain suitable conditions for species that require short, open conditions in late spring and summer. This will particularly be the case where vegetation growth has been artificially raised through previous fertilizer application.
Supplementary feeding can be used to maintain livestock in winter, but is generally disadvantageous because it will increase nutrient levels. However, supplementary feeding of livestock can be important in providing seed for some bird species in the late winter and early spring. Supplementary grazing should only be carried out on land of low conservation value.

5.5 Management by cutting with or without grazing
There are two types of cutting used on grasslands. These are mowing close to ground level to remove the bulk of the sward or cutting to remove specific patches of unwanted, taller vegetation. This is often referred to as topping. The main conservation benefits of mowing are its use in combination with grazing to maintain the conservation value of agriculturally unimproved hay meadows, and using it to provide a patchwork of different stages of re-growth on grasslands where vegetation removal by grazing is impractical. Agriculturally improved grasslands cut for silage have little wildlife interest, and have received little interest from conservationists.

5.5.1 Meadows, and silage and haylage fields
Meadows can be managed to produce hay (dried grass and forbs), silage (grass cut while still green and then fermented), or haylage (dry silage). Cutting is carried out close to ground level to maximize the off-take of herbage. Increasing the height of the cut can, though, in some cases increase overall grass yield. For example, in silage fields cut twice or more during the season, increasing the height of the first cut from 3 to 8 cm can increase the total annual grass yield (Binnie et al. 1980). The re-growth following cutting is then grazed.

Common aims in conservation management of agriculturally unimproved hay meadows are to maintain their high plant species richness and high ratio of forbs to grasses while minimizing the loss of nests and chicks of ground-nesting birds during cutting. The main management-related factors that will influence the flora of grasslands managed by cutting are the timing of and number of annual cuts and the timing and pressure of subsequent grazing.

Hay meadows are traditionally cut once a year between June and August. The general timing of cutting varies between regions while its precise date in a given area will vary from year to year depending on weather conditions. The timing of
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cutting will affect at what stage of a plant’s growth it is defoliated and, importantly, whether or not it is able to set seed before it is cut. Cutting earlier in the summer will reduce the number of plant species able to flower and set seed and, if carried out over many years, ultimately reduce the number of plant species persisting in the sward. Cutting very early in late spring or early summer will prevent more or less all plant species from setting seed. It will result in the sward becoming dominated by perennial grasses, which are able to spread vegetatively and persist without regularly setting seed. Cutting in late spring or early summer will also destroy bird’s nests. Methods for minimizing losses of nests and chicks are discussed in Section 5.5.4.

Following cutting, hay is left on the field to dry, and turned to help expose it all to the drying sun. This management has the inadvertent effect of allowing ripened seed to fall back on to the field. The re-growth following cutting (the aftermath) is grazed in autumn, usually by cattle. Light grazing typically continues during winter, in some cases with the cattle replaced by sheep, until late winter or spring when the livestock are removed and the meadow ‘shut up’ to grow on for hay. This aftermath grazing is important in maintaining the high plant species richness of agriculturally unimproved meadows. Its poaching creates germination gaps and animal’s hooves press seeds into contact with the soil, so helping them germinate. Grazing of the re-growth of more competitive plant species reduces their vigour and ability to out-compete smaller plants. Cattle produce more poaching and therefore more regeneration gaps than sheep, per quantity of vegetation removed. Too much poaching, though, can result in the establishment of some more competitive annuals and biennials such as docks, *Rumex* spp. Grazing animals also disperse seed between fields, either attached to their fur or deposited in their dung.

Cessation of aftermath grazing, or changes in its timing, will result in slow, but important, changes in plant species composition. For example, in hay meadows in northern England Smith and Rushton (1994) found that the high species richness of existing meadows was maintained by both autumn and spring grazing. Autumn grazing favoured autumn-germinating ruderals. Spring grazing disadvantaged plants...
that grow early in the season, and benefited a range of forbs over grasses that otherwise dominated in the absence of spring grazing.

Silage fields are heavily fertilized to increase their yield, and this enables them to be cut for silage two to three times in late spring and summer. The combination of fertilizer application and repeated cutting greatly impoverishes the flora. Most silage fields are in any cases re-seeded with a small number of agriculturally productive grasses, especially perennial rye-grass, *Lolium perenne*. This early and repeated cutting destroys many nests of birds that are attracted to nest in tall grass. Aftermath-grazed silage fields can, though, support a range birds in winter that feed on larger soil invertebrates. There is also potential for silage fields to provide food for seed-eating birds in winter (Figure 5.11). (p.115)
5.5.2 Other grasslands
Where grass is not being cut and removed for agricultural reasons, the main considerations are whether the cuttings are removed and the:

- timing of cutting;
- height of cutting;
- frequency of cutting;
- size and spatial arrangement of cut blocks.

The effects of patch size and frequency of cutting are discussed in Section 5.7. There is unlikely to be any reason for cutting more than once a year on grasslands managed for conservation, because of the damaging effects of multiple cutting already described for silage fields.

It is important to remove dense cuttings to prevent them from smothering smaller plants and potential germination gaps. Leaving thick layers of cuttings is also thought to be damaging to waxcap and other larger fungi (Griffith et al. 2004). Removing cuttings will help deplete nutrients, which will invariably be beneficial in maintaining high plant species richness. Leaving cuttings on botanically uninteresting grasslands, though, might be beneficial in providing temporary

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**Fig. 5.11** Managing silage fields for wintering, seed-eating birds. Heavily fertilized silage fields are extremely species poor in both plants and animals, but comprise a high proportion of the grassland in some lowland areas. Research has recently found that they can at least be managed to benefit wintering seed-eating birds, especially buntings such as yellowhammers, *Emberiza citrinella* (shown here). This management involves not taking the final silage cut, to allow grasses to set seed, and leaving this standing grass crop over the winter to provide seeds for birds. This management regime slightly reduces the agricultural productivity of the sward the following year, but the grass seed can be used to restore the sward if managed correctly (Buckingham and Peach 2006; photograph by RSPB IMAGES).
cover for small mammals and some invertebrates until the vegetation has grown again.

The timing of cutting will influence plant species composition and the proportion of birds’ nests destroyed during cutting, as described for meadows and silage and haylage fields. Even though grasslands managed by cutting are poor for invertebrates, flowers in them can still provide useful nectar sources for mobile, winged insects. Cutting small-scale patches can be used to add heterogeneity of vegetation structure and plant species composition. It can also be used to set back the flowering period of patches of flowers. This can be used to prolong their overall flowering season in a given area and the length of time that they are available as nectar sources for insects.

Increasing the height of cutting will probably benefit some sward-inhabiting invertebrates and small mammals, by at least retaining some cover. It will reduce direct damage to birds’ nests. However, gathering of cut grass will destroy a large proportion of remaining nests and young. Any nests and young that do survive will usually be conspicuous and vulnerable to predators. Cutting to a higher level can, though, be used to reduce the height of the sward to within the range favoured by different groups of wintering birds, for example for wintering geese (Vickery *et al.* 1994). Regular cutting at a height of 15 cm is used to maintain a dense sward of 15–20 cm high to actually *discourage* feeding birds, such as flocks of common starlings, *Sturnus vulgaris*, gulls, corvids, and plovers, from grassland at airports to reduce bird strikes (Civil Aviation Authority 1998).

5.5.3 Topping
Cutting of specific patches of vegetation (topping) can be used to:

• reduce the vigour and prevent seeding of specific patches of tall, unwanted plants, which have been avoided by grazing animals;
• remove dead stems and seed heads to maintain very open conditions favoured by some open-ground bird species.
In both cases the benefits of removing this taller vegetation have to be carefully balanced against those of retaining it. Plants such as thistles are often the target of topping, but can be very valuable for insects, especially for nectar. Seed heads are valuable over-wintering sites for invertebrates. Topping prevents the development of seed for birds in winter and decimates populations of larger invertebrates.

In most cases, topping only produces small quantities of poor-quality vegetation that dry up and blow away, without smothering lower-growing plants. Even though annual topping reduces these plants’ vigour, it is rarely effective at eradicating them.

5.5.4 Minimizing losses of birds’ nests and chicks during cutting

A range of methods can be used to minimize losses of birds’ nests and chicks. The most widespread technique, though, is delaying cutting until after birds have finished breeding. In temperate areas delaying cutting until early August will prevent loss of any nests. However, leaving hay cut until this late reduces its nutritional value and can thereby make management uneconomic. It can be difficult to dispose of poor-quality hay. Most hay fields managed for conservation in Atlantic temperate areas are cut between mid-July and early August.

An additional method used on drier grassland is to mow from the centre of the field outwards to reduce chick loss (Figure 5.12). Further techniques have been used specifically to reduce loss of nests and chicks of breeding waders/meadow birds. These are described in Section 8.12.3 on wet grasslands, but could equally be used on drier grasslands.

5.6 Managing by burning with or without grazing

Prescribed burning, with or without grazing, can be used to:

- maintain the characteristic species assemblages of fire-prone grasslands by removing fire-intolerant plants, including woody vegetation;
- provide a mosaic of different stages of re-growth (Figure 5.13).
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Burning is also used agriculturally to increase re-growth of palatable grasses and remove woody species to maximize grazing. Herbivores are attracted to the lush re-growth following burning. This patchy grazing can enhance the heterogeneity of sward conditions created by burning different patches of grassland: the grassland consisting of areas of largely ungrazed, unburnt grassland, heavily grazed, recently burnt grassland, and areas intermediate between these. One-off burns are also used to remove litter when seeking to restore open conditions to rank grassland. (p. 118)

The main considerations when burning are its method, season, and frequency, and the size of area burnt at any one time. The method, season, and frequency of burning will all influence the intensity of the fire. There are two main methods of burning. Fires can burn against the wind (back-fires) or in the same direction as the wind (head-fires). Burning against the wind

Fig. 5.12  Corncrake-friendly mowing. Fields are conventionally mown from the outside of the field inwards (a). This concentrates any chicks in an everdecreasing island of un-mown grassland until this is itself cut, killing the chicks.

Mowing from the centre of the field outwards (b) allows chicks to escape to surrounding fields, and has been used to increase productivity of corncrakes, Crex crex, in the UK (Tyler et al. 1998). Mowing from the inside outwards is more difficult, though.
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means that the fire moves more slowly and burns with smaller flames than head-fires, and burns hotter at the ground surface. Back-burns are therefore safer and easier control and are the recommended method. Burning upslope is similar to burning with the wind, because in both types of burning the fire pre-heats the fuel in front of it, thereby increasing the rate of spread of the fire.

Season will influence fuel load by affecting the quantity and moisture content of the vegetation and conditions during burning. In practice, burning is usually carried out using at times of year when the vegetation will burn sufficiently, but the fire easy to control; that is, at cool times of year. It is rarely, if ever, carried out during hot, dry periods when natural wildfires occur. This difference in season and fire intensity means that prescribed burning will have different effects to the natural wildfires that have maintained the grassland. As with other forms of vegetation removal, the timing of burns influences which plant species are most heavily negatively impacted by its defoliation, and this will influence subsequent species composition. For example, on North America prairies prescribed spring fires favour large, late-flowering warm-season grasses, while summer fires (similar to natural wildfires) favour a range of early-season grasses and forbs (Howe 1995; Copeland et al. 2002). Burning should be avoided immediately before periods of heavy rain that might cause unwanted erosion of recently exposed ground, especially on more erodible slopes.

Fig. 5.13 Fire. Bare and litter-free ground produced by recent burning provides ideal conditions for some open-country birds, such as this blackwinged lapwing, *Vanellus melanopterus* (Masai Mara National Reserve, Rift Valley Province, Kenya).
Burning at less frequent intervals will allow a greater quantity of combustible material to accumulate and hence increase fire intensity, and also reduce the proportion of early stages of regrowth. The intensity of burns also affects conditions for germination. More intense burns remove a greater proportion of the litter and kill seeds close to the soil surface. It can either reduce invasion of alien/exotic species (e.g. Gillespie and Allen 2004) or increase it. Annual burning of large areas can result in dominance by a usually small number of fire-tolerant and ruderal plant species, sometimes including prolific, alien/exotic species (e.g. Trager et al. 2004).

Burning is subject to regulations and these should obviously be checked. Suitable precautions also obviously need to be taken. These include only burning when windspeeds are low, using trained personnel, creating firebreaks/fuel breaks, having water bowsers and a pressure hose or fogging machine present, and informing the local fire service. Burnt areas should be re-visited before nightfall to check for and extinguish any areas still smouldering.

Like other forms of catastrophic management, burning has short-term, damaging effects through removing most or all of the habitat. Hence, burning needs to be carried out on rotation, to provide refuges of un-burnt grassland for animals to survive in, as discussed in the following section.

5.7 Rotational management and the size of areas managed at any one time
In some situations management is necessary to maintain the desired conditions within the grassland in the long-term, through grazing, cutting, or burning, but the key interest of the grassland is associated with grassland that has not been recently managed. Examples include where the key interests are:

- small mammals associated with rank grassland containing abundant litter;
- invertebrates that require litter; tussocks for nesting (e.g. some bumblebees) or over-wintering in, or nectar sources;
- birds that require a deep layer of litter for nesting.
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The best option is to only manage a proportion of the grassland at any one time (i.e. on rotation), to ensure there is always at least some of the grassland in the desired state for these groups at any one time. Rotational management is particularly important when undertaking catastrophic management (cutting, burning, and heavy grazing) that temporarily makes the grassland unsuitable for most of its fauna. Key decisions will be the:

- length of the management rotation;
- size and spatial arrangement of the blocks managed at different times.

The frequency at which individual areas are cut, burnt, or grazed heavily will depend on the specific requirements of the key interest of the grassland. For example, in dry prairies in Missouri, USA, cutting on a rotation of 1–2 years is considered best for grasshopper sparrows, *Ammodramus savannarum*, that require a light litter layer, whereas a rotation of 2 years or more is considered better for Henslow's sparrows, *Ammodramus henslowii*, that prefer deeper litter (Swengel and Swengel 2001). Light-to-moderate cattle grazing every 3 years or so is considered beneficial for maintaining high densities of small mammals by encouraging the growth of more succulent grasses among otherwise tall, dense grasses, while retaining the largely tall structure and dense litter layer also required by them. Cutting or burning on a rotation of more than 1 year can also be used to create coarse-scale variation in sward structure, by creating a mosaic of patches at different stages of re-growth. The best option for maintaining a diverse invertebrate fauna will be to cut different patches at varying times of year (i.e. on different rotations; Morris 2000). This will more closely mimic the effects of patchy grazing.

The optimal size and arrangement of areas managed at any one time is difficult to assess. While some bird species will require relatively large, continuous areas of suitable habitat, most invertebrates are likely to benefit from a small-scale patchwork, particularly for species with poor powers of dispersal. For a given area it will cost more to manage many separate small areas than fewer larger ones. Therefore, in practice the size of patches will be a compromise between a theoretical ideal and what is practical. For less mobile groups such as some invertebrates and small mammals, it will be best to arrange patches to ensure that they are always close to potential sources of re-colonists.

5.8 Soil disturbance

Valuable bare and disturbed ground can be created by:
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- mechanical disturbance;
- human trampling, horse-riding, cycling, motorbikes, and other vehicles;
- creating erodable banks (Figures 6.13 and 11.8);
- the activities of herbivores (Section 5.4).

Disturbance of the soil below its surface (sub-soiling) is used to reduce soil compaction caused by heavy stocking levels and agricultural vehicles, including that created during former arable use at grassland reversion sites. The potential conservation benefits of improving soil structure by sub-soiling are poorly understood.

On flat areas and gentle slopes ploughing or rotovation can provide soil disturbance and reduce the organic content of the upper soil, thereby benefiting less-competitive (p.122) ruderal plants and their associated fauna. On sandy soils periodic rotovation, typically once every 3–5 years, provides better conditions for usually scarcer, less competitive plants, especially lichens, than periodic or annual ploughing or annual rotovation. These beneficial effects of rotovation can still be apparent up to 17–20 years later (Dolman and Sutherland 1992, 1994). The effects of this periodic rotovation are similar to those of heavy rabbit grazing.

Soil disturbance by ploughing or rotovating can be undertaken at any time of year, but is most commonly carried out in late winter to:

- maximize the area of disturbed ground for invertebrates in the following spring and summer;
- provide suitable nesting conditions for birds requiring bare ground for nesting, such as Eurasian thick-knees and northern lapwings, *Vanellus vanellus*.

A novel use of soil disturbance is to diversify the structure of structurally uniform grassland using a chisel plough (Figure 5.14). A similar effect can be produced
Dry grasslands

(p.123) by sub-soiling with a conventional sub-soiler, but removing the packing roller that normally flattens the soil after it has been broken and lifted by the sub-soiler. On the heavier soils on which this technique has been used, the gaps created are sometimes colonized by unwanted agricultural weeds, especially thistles. The variation in topography produced using these methods can also make it slightly more difficult to carry out mechanical operations such as cutting.

Repeated trampling or the action of vehicles causes greater soil compaction than rotovation or ploughing. Compacted ground can remain unvegetated for a long period, especially if subject to continual trampling or vehicle action, and provide valuable habitat burrowing solitary bees and wasps (Figure 5.15). Land managers sometimes consider meandering, braided paths created by people as unsightly, and seek to confine people to more tightly defined pathways. While the centres of paths may in many cases be too regularly trampled to be of high value to invertebrates, reptiles, and ruderal plants, their intermediately trampled edges can be especially valuable for these groups. The ideal is to maximize the area of habitat disturbed through different levels of trampling and of different ages since the last regular disturbance event. This can be done by periodically

Fig. 5.14 Chisel ploughing. This can be used to break up compacted and structurally uniform, heavily sheep-grazed grassland to create small divots and hummocks for northern lapwings to nest among. The variation in sward structure created is similar to that of areas grazed and poached by cattle over a long period (Ynys-Hir, Powys, Wales; photograph by Ross Willis).
moving paths, so that heavily tramped areas gradually become more vegetated, while new, early successional habitat is created elsewhere.

*Fig. 5.15* Soil disturbance and compaction. The compaction caused by vehicles in this overflow car park suppresses vegetation and provides a suitable level of soil compaction for nesting solitary bees and wasps. Their numerous excavations can be seen on the photograph to the right. These include burrows of the European bee wolf, *Philanthus triangulum* (shown here), a fascinating solitary wasp which provisions its nest chambers almost
5.9 Use of fertilizers, lime, slurry, and farmyard manure

Application of inorganic fertilizers and slurry to grasslands to increase their agricultural productivity has greatly impoverished the value of grasslands for wildlife. The most commonly applied inorganic fertilizers are nitrogen (N), phosphorus (P), and potassium (K). High levels of plant-available phosphorus are generally associated with low plant species richness. In at least some types of grassland, the lowest plant species richness is associated with combinations of high levels of plant-available phosphorus, nitrogen, and potassium (Janssens et al. 1998; Critchley et al. 2002; Crawley et al. 2005). Typical levels of these nutrients in agriculturally improved and unimproved neutral grassland are shown in Table 5.2.

A number of specific mechanisms are thought to be involved in the reduction of the value of grasslands for birds caused by fertilizer application (Vickery et al. 2001):

- the rapid and uniform growth of grass in heavily fertilized swards in spring makes the vegetation too tall and dense for many nesting and foraging birds;
- increased fertilizer use and associated management probably decrease the abundance of large arthropod prey in the sward;

Table 5.2 Differences in key soil nutrients between agriculturally improved and unimproved grasslands

<table>
<thead>
<tr>
<th></th>
<th>Agriculturally improved perennial rye-grass-dominated grasslands</th>
<th>Agriculturally unimproved neutral, lowland hay meadows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extractable phosphorus (mg/l; Olsen)</td>
<td>18.5 ± 13.5</td>
<td>9.6 ± 4.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Agriculturally unimproved neutral, lowland hay meadows</th>
<th>Agriculturally improved perennial rye-grass-dominated grasslands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extractable phosphorus (mg/l; resin extraction method)</td>
<td>18.2 ± 8.9</td>
<td>31.8 ± 21.7</td>
</tr>
<tr>
<td>Extractable potassium (mg/l)</td>
<td>135 ± 39</td>
<td>213 ± 120</td>
</tr>
<tr>
<td>Total nitrogen (percentage of dry weight)</td>
<td>0.67 ± 0.30</td>
<td>0.90 ± 0.44</td>
</tr>
</tbody>
</table>

This table shows the higher levels of phosphorus, potassium, and nitrogen found in the soils of agriculturally improved compared to agriculturally unimproved grassland. All three nutrients are commonly applied as fertilizer. Values are means one standard deviation. From Critchley et al. (2002).

(p.125)

- increased fertilizer use allows higher stocking densities and earlier mowing of fields, both of which can reduce nest survival of grassland birds;
- fertilizer-induced replacement of floristically diverse swards with uniform grassy ones reduces the quantity of suitable seed available for birds.

Lime has commonly been applied to neutralize unimproved or semi-improved acidic soils to increase nutrient availability to plants. This will obviously damage their characteristic acid grassland flora and its associated fauna.
Application of inorganic fertilizers can also have wider detrimental effects. Nitrate is water soluble and readily leached from grassland into watercourses, where it can cause problems of eutrophication of water bodies and wetlands (Section 8.2). Phosphorus is slow to be leached out of the soil, and residual high levels of phosphorus are a major constraint when seeking to recreate species-rich grassland.

For the reasons described, there will rarely be any justification for increasing nutrient levels in grasslands managed for conservation. The two main exceptions are:

- addition of small quantities of well-rotted farmyard manure to agriculturally unimproved meadows;
- increasing the productivity of already agriculturally improved swards to encourage use by feeding geese.

Small quantities of well-rotted farmyard manure (<12.5 t/ha per year) have traditionally been added to agriculturally unimproved hay meadows in spring, to offset the loss of nutrients removed in the hay. Replacing these nutrients is thought to help maintain the high plant species richness of such meadows. Addition of higher levels of fertilizer, particularly inorganic fertilizers, will be highly damaging.

Nitrogenous fertilizer can be applied to already agriculturally improved grassland to increase their use by feeding geese (Owen 1975, Vickery et al. 1994, Percival 1993). Management also needs to ensure that the sward is within their preferred height range (Vickery and Gill 1999).

Addition of low levels of farmyard manure has been found to increase use of grasslands in winter by birds that feed on soil invertebrates, probably because it increases the numbers of earthworms close to the soil surface (Tucker 1992). Any such benefit would have to be set against the previously mentioned damaging effects of increasing nutrient levels.

5.10 Diversifying botanically dull grasslands
Botanically rich swards are associated with relatively low nutrient levels (Section 5.9). Cessation of fertilizer application to already impoverished, agriculturally improved grasslands will result in a decline in nutrient levels, although it
may be some time before they are low enough to support a species-rich sward.

The soil variable considered to most commonly limit plant species richness of grasslands is phosphorus, apart from where plant growth is limited by drought or water-logging. Where phosphorus limits plant growth, species rich swards are unlikely to develop on soils with a phosphorus content of much higher than 15 (Olsen extraction method) or 30 mg/l (resin extraction method). Successful diversification of swards can probably take place on soils with initially higher levels of phosphorus, if future management involves cutting and removal of vegetation, which will reduce nutrient levels over time.

The first option when seeking to diversify a sward is to see whether this can be achieved through a change in sward management. Reducing grazing levels in summer may allow formerly heavily grazed plants to flower and set seed, whereas creation of suitable germination gaps may allow seeds of desirable species to germinate. However, many plant species are unlikely to re-appear because their seeds are no longer present. Re-colonization by lost plants species may be more rapid if the grassland is adjacent to a more species-rich sward, especially if animals are allowed to graze both and disperse seeds attached to their fur and in their dung. Where this is not the case, the only realistic methods to restore the botanical interest of the sward are to encourage germination of any buried seedbank or to add seeds or young plants from elsewhere.

In all cases long-term sward management involving appropriate cutting dates and aftermath grazing to create germination gaps is necessary to increase and maintain high plant species richness (e.g. Smith et al. 2000b).

Methods of introducing seeds or plants into botanically dull swards have been the subject of a number of experimental studies, but the long-term effectiveness of these techniques has not yet been demonstrated. There are four possible techniques:

- over-sowing;
- addition of green hay;
Dry grasslands

- slot seeding;
- planting young pot-grown plants or seedling plugs.

An additional technique for diversifying swards, which can be used in combination with these methods, is by introducing yellow rattle, *Rhinanthus* spp., to reduce the sward's productivity (Figure 5.16). When using any of these techniques it is important to first reduce the height of the existing sward to minimize competition with the introduced plants. This can be done by cutting and removing vegetation or by grazing. Seeding and planting (p.127) is best undertaken in early autumn. The moist soil conditions during winter help plants to survive during the period when they have not yet established a deep root network. Spring-sowing or planting runs the risk of recently germinated or newly established plants dying from late spring or summer drought. Addition of green hay will be the most practical method of diversifying the sward at many sites. It does not require specialized harvesting equipment and, providing there is a suitable source

![Fig. 5.16 Using yellow rattle to increase plant diversity. Yellow rattle species are found throughout much of Europe and in North America and Asia. They are root hemi-parasites on a variety of plants, including a wide range of grasses and legumes. Addition of yellow rattle](image-url)
of green hay nearby, should be cheaper than other seeding or planting methods. Green hay will in most cases contain a wider range of suitable seed species of local provenance than commercially grown seed. However, it will not be suitable for establishing swards containing low-growing plants typical of heavily grazed grasslands, because it is difficult to harvest significant quantities of green hay from these. Planting young pot-grown plants or seedling plugs is far more expensive than other techniques per plant established. It can, though, be a useful supplementary method for introducing small numbers of plants of species that are difficult to establish from seed.

5.10.1 Obtaining suitable seed

Seed can be bought from commercial suppliers or harvested from a nearby donor site. It is important to check the provenance of commercially grown seed, to ensure it contains similar strains of plants to those found in the area. Introduction of seed from further away has the potential to swamp local strains, or it may be less suited to local conditions. Donor sites should have similar soil conditions to receptor sites, especially with regard to their pH and wetness, and be subject to similar management to provide a suitable range of plant species. Obviously, commercially grown seed should contain a suitable selection of plant species native to the area of the restoration site.

The best method of collecting seeds from donor sites is using a brush harvester. This uses a rotating brush to dislodge seeds from standing plants. There are a variety of models, including towed and hand-held ones. Seeds of different plant species ripen at different times of year. Harvesting on a range of dates will increase the number species of seeds collected. Grazing reduces dominance by grasses and enables less competitive plants to survive, at least in the short term (Davies et al. 1997; Pywell et al. 2004).

Yellow rattle is unusual among hay meadow plants, in being an annual and not surviving long in the seedbank. Therefore, for yellow rattle to persist, there must be suitable conditions for it to both set seed and germinate virtually every year.
needs to be temporarily excluded from regularly grazed donor sites to allow plants to set seed prior to harvesting.

5.10.2 Oversowing and addition of green hay

Over-sowing involves spreading seed over the existing sward. Sowing rates of 5–10 kg/ha are recommended. Heavier seed can settle out and result in uneven sowing of different species. Seed can be spread more evenly by adding an insert material to bulk it up. Silver sand or fine sawdust are suitable.

Green hay should be cut just before the vegetation has dried, browned, and the majority of its seed ripened and fallen. Green hay contains a higher proportion of seeds of desirable forb species than grasses, compared to conventional dry hay (Pywell 2006). It needs to be collected and spread on the receptor site the same day as it is cut. This prevents it from shedding its seed back on to the donor site, and from heating up and possibly damaging the seeds within it. It is recommended to spread 1 ha’s worth of green hay from the donor site over 3 ha of the receptor site.

Before over-sowing or adding green hay it is necessary to create germination gaps in addition to reducing the height of the sward. Germination gaps of about 10 cm diameter are recommended. These are best created using cattle. Where this is not practical, gaps can be created using a power-harrow or by light disking.

Livestock, ideally cattle, should be introduced following over-sowing or addition of green hay, to tread seed into the ground and help germination. Light rolling can be used if there are no livestock. Green hay should be left for between (p.129) 1 and 3 weeks to allow it to shed its seed before any grazing is introduced. Some seeds may take time to germinate, so it is worth waiting several years before concluding whether the management has been successful.

5.10.3 Slot seeding

Slot seeding is a standard agricultural method for introducing seed into an existing sward. As with other techniques for diversifying grassland, it is important to cut or graze the sward short prior to sowing. The slot seeder cuts a shallow (approximately 15 mm) groove in the grass and drills seed into it. It is recommended to fit the slot seeder with a band sprayer. This applies a narrow strip of herbicide to kill the vegetation
beside the grooves to reduce competition with establishing seedlings. If using a band sprayer, then the sward needs to be left a short while to green up following cutting, for any systemic/translocated herbicide (Section 4.5) to be effective. An advantage of slot seeding is that it results in a higher number of plants established per quantity of seed used compared to over-sowing. For slot seeding a sowing rate of 1–2 kg/ha is recommended. A disadvantage is that the introduced plants grow in lines. These lines may persist for a number of years.

Following slot seeding, the sward should be kept short to provide suitably open conditions for the establishment of seedlings. This can be done by mowing and removing the cuttings or by short periods of heavy grazing.

5.10.4 Planting young pot-grown plants or seedling plugs
Small pot-grown plants or seedling plugs are planted directly into gaps in the sward. As with other techniques, it is important to reduce the height of the sward prior to slot seeding or planting, to reduce competition from established vegetation.

5.10.5 Providing suitable aftercare
When using any method to introduce plants into the sward, it is important to provide suitable aftercare to help the introduced species establish. This should involve cutting and removing vegetation, or periods of heavy grazing, during the following spring and summer, to prevent existing grasses, and unwanted, competitive ruderal species, from out-competing the introduced plants. The timing of this management should take into account its potential damaging effects on breeding birds (Section 5.5.4). Continual, heavy grazing should be avoided, though, since this can prevent the fragile, small plants from establishing.

(p.130) It may also be adding additional seed on successive occasions in different years to increase the chance of at least some individuals of different plant species becoming established. The benefits of successive seeding, though, have to be set against the potential damage that repeated soil disturbance might cause to establishing plants. Once a suitable range of species have been established, then ongoing
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maintenance management should be introduced, as described elsewhere in this chapter.

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