Forests, woodlands, and scrub

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Abstract and Keywords

Forest and woodlands are terms that describe land dominated by trees. Scrub consists of small trees and bushes. This chapter discusses the important features of forests and woodlands for wildlife, types of forest and woodland, and managing scrub, managing woodlands, and forests for conservation.

**Keywords:** forest conservation, woodland management, wildlife, scrub management

Forest and woodlands are used to describe land dominated by trees. Scrub consists of small trees and bushes. Management of areas of dense, medium-sized, predominantly evergreen shrubs found in Mediterranean climates is discussed in Chapter 6. Management of forest, woodland, and scrub on land with a high water level is described in Sections 8.10 and 8.11.

The dominant structural components of forests and woodlands, their trees, are longer-lived than the dominant structural components of other habitats. This means that any management that takes place in woodlands and forests has to
be viewed over a far longer timescale. Changes in the
dominant tree species will take tens or even hundreds of
years. The dominant tree species present now may have
established under quite different conditions to those currently.
Because of climate change, any trees that are currently
establishing are likely to reach maturity under quite different
conditions to those at present.

Because of the length of time for seedlings to grow into
mature trees, there is a far greater presumption for
maintaining the existing dominant structural components of
the habitat—its trees—rather than seeking to radically change
their composition, as may sometimes be the case in other
habitats. Because of this, the approach taken when managing
forests and woodlands will vary greatly depending on their
existing tree-species composition, structure, and history.

7.1 Important features of forests and woodlands for
wildlife
The main features of forests and woodlands that will influence
their value for wildlife are the:

- dominant tree-species composition;
- continuity of forest or woodland on the site;
- age and structure of stands (a stand is a term for
  a growth of similar plants in a particular area; it is
  commonly used to describe a group of trees of
  similar age and species composition);
  (p.174)
- quantity and types of dead wood;
- presence of forest edge and other associated
  habitats;
- variation in soils, topography, and drainage.

7.1.1 Tree-species composition
Tree-species composition, in particular whether the dominant
tree species are broad-leaved or coniferous, is important in
influencing the biodiversity of a forest or woodland. Areas
dominated by broad-leaved trees support a distinctly different
avifauna from those dominated by conifers, while mixtures of
the two support one containing species from both. Different
tree species vary in their fauna of plant-eating insects.
Individual tree species also differ in their suitability for
foraging birds (Peck 1989) and nest sites (Hågvar et al. 1990).
The presence of different tree species will strongly influence the mycorrhizal fauna.

7.1.2 Growth stage and structure of stands

The growth stage and structure of different areas will particularly influence their bird, invertebrate, and amphibian fauna and assemblage of herbaceous plants. There are a number of terms used to describe aspects of the structure of forests and woodlands. The canopy comprises the crowns of the largest trees. The understory describes the shrubs and herbaceous vegetation beneath the canopy. Field layer refers to just the herbaceous vegetation.

The structure of a given stand changes in relation to its stage of growth since establishment or catastrophic disturbance, although this structure can be significantly modified by management. There are two main theories of woodland establishment or regeneration following catastrophic disturbance. These are described in the following two sections.

7.1.3 Theory of woodland regeneration

The theory of woodland regeneration (Oliver and Larsen 1990; Peterken 1996) proposes the following four phases of development (Figure 7.1).

Stand initiation or regeneration

Where woodland is establishing, then stand initiation will involve the establishment of tree and shrub species from seed, mainly dispersed by wind or birds (Figures 7.1a and 7.2). Establishment may be slow, because of lack of seed. The shrubs and trees that establish will be of light-demanding species. These are often called intolerant species (intolerant of shade), as opposed to tolerant species (p.175)
Fig. 7.1 The theory of woodland regeneration (from Oliver and Larsen 1990; Peterken 1996). Tree species intolerant of shade are shown in light grey and those tolerant of shade are in dark grey. See Section 7.1.3 for details.
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(tolerant of shade). In practice, these terms represent the extremes of behaviour, with tree species exhibiting a range of responses to different light intensities. **Thicket, or stem-exclusion, phase**

Following stand initiation or regeneration, the canopies of the more vigorous saplings and shrubs eventually coalesce and shade out weaker shrubs and saplings (Figures 7.1a and 7.1b). This closing of the canopy creates a simple, uniform structure, reduces levels of light reaching the ground, and creates relatively uniform levels of light and humidity at ground level. This has a profound effect on the field layer, invertebrate fauna, and avifauna.

During the thicket or stem-exclusion phase seed is produced by the maturing trees, but any seedlings that do establish have little opportunity to develop into saplings because of the low light levels beneath the closed canopy (Figure 7.1c).

**Fig. 7.2** Deer and woodland regeneration. Red deer are important grazers and browsers in parts of temperate Europe, Asia, and North America. They can profoundly influence regeneration of woodland and scrub. In this area of Atlantic moorland numbers of red deer have been reduced to encourage woodland regeneration. Note the patchy distribution of establishing trees. Alders, *Alnus glutinosa*, are restricted to areas beside streams and downy birch to those close to the seed source of mature trees. Only the bird-dispersed, berry-producing rowan, *Sorbus aucuparia*, is at all widespread in more open areas (Creagh Meagaidh, Inverness-shire, Scotland).
Eventually the canopy starts to open up, as trees fall, enabling a new cohort of saplings to grow up and (re)-initiate an understorey beneath it (Figure 7.1d). There is still, though, relatively little light beneath the canopy. These saplings will therefore generally be of tolerant tree species. The development of this understorey starts to increase structural complexity.

**Canopy break-up**

As the stand continues to age, more gaps are created in the canopy as trees fall over (Figure 7.1e). The regeneration that takes place within these gaps will depend largely on the size of the gap, the extent of any re-growth from fallen trees, and whether saplings of tolerant tree species are already present in the gap. Any grazing and browsing also influences regeneration. If the gap is very small, then it will probably be filled by expansion of the crowns of surrounding canopy trees. If the gap is larger, then it will eventually be filled by newly establishing trees, unless filled by re-growth from fallen ones or if browsing prevents re-growth. Tolerant tree species are likely to compete best and eventually form new canopy trees in smaller and more shady gaps, such as those created by a single falling tree. Intolerant tree species, and other light-demanding forbs and grasses, are only likely to establish in larger, more open and sunny gaps formed, for example, by large-scale windthrow or widespread death of trees caused by insect herbivory.

Canopy break-up greatly increases structural complexity by increasing small-scale variation in age structure. If the succession is allowed to continue unhindered, then trees will age, eventually achieving the characteristics of old-growth (Section 7.2.1).

**7.1.4 Cyclical succession of woodland, scrub, and grassland mediated through grazing (from Olff et al. 1999; Vera 2000)**

Starting with open grassland (Figure 7.3a), the proponents of this controversial theory suggest that grazing and browsing by high densities of large herbivores prevent the establishment of trees and shrubs. During periods when densities of herbivores are low, for example following disease of severe winters, thorny shrubs establish, particularly within the protection of other unpalatable forbs, such as thistles, (Figure 7.3b). These unpalatable forbs are themselves encouraged by soil disturbance by animals and deposition of dung. As the thorny
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scrub grows, it provides protection from grazing and browsing to palatable tree species that establish within it (Figure 7.3c). Colonization by woody species is aided by (p.178)

(p.179) spreading of seeds by birds, for example by caching of acorns by Eurasian jays, Garrulus glandarius. As these trees grow, they eventually shade out this scrub to produce a woodland grove (Figure 7.3d). Even if gaps appear in these groves, regeneration of trees is prevented by grazing and browsing by large herbivores. Exceptions may occur where seedlings are sheltered from large herbivores by the branches of fallen trees, allowing regeneration to take place. Otherwise, though, the degeneration of the canopy results in an open parkland landscape with scattered individual and groups of trees interspersed with grassland (Figure 7.3e). The process is re-started when thorny scrub re-establishes in the grassland. The cultural landscape thought to most closely mimic this cyclical succession is wood-pasture (Figure 4.5 and Section 7.4.4).

**Fig. 7.3** The theory of cyclical succession of woodland, scrub, and grassland mediated through grazing (from Olff et al. 1999; Vera 2000). Tree foliage is shown in light grey and scrub foliage in dark grey. See Section 7.1.4 for details.
7.1.5 Changes in biodiversity in relation to growth stage and structure

The age and structure of stands profoundly affect their fauna. In general, the richness of the flora and fauna of woodlands and forests increases with their structural complexity—there are more niches for different species to occupy in a more structurally complex habitat. Several groups show fairly consistent patterns of change. Changes in bird assemblages have been particularly well studied.

Species richness of breeding and wintering birds usually increases with age of stand and measures of structural and vegetation diversity (e.g. Buffington et al. 1997; Donald et al. 1997, 1998; Manuwal and Huff 1997; Laiolo et al. 2004). The proportion of tropical migrants also changes with stand age, but follows different patterns in Europe and eastern North America. In Europe the proportion of tropical migrants (mainly Old World warblers Sylviidae) is highest in early successional forest and scrub, particularly in vegetation 1–4 m high, with this proportion declining during the thicket/stem-exclusion phase but then increasing again in more mature forest. In eastern North America the proportion of tropical migrants increases with vegetation height, and is greatest in vegetation taller than 10 m (Mönkkönen and Helle 1989; Donald et al. 1998). The proportion of cavity-nesting birds also tends to increase with age of stand, in response to the increase in numbers of suitable large and decaying trees. Large stands of old-growth typically support a range of species associated with ancient large trees and decaying wood that are rare in or absent from younger woodlands. Many bird species are associated with scrubby, edge habitat, while forest-interior species require large blocks of old-growth or other suitable high forest.

(p.180) 7.1.6 Quantities and types of dead wood

Dead wood is particularly valuable and supports an exceptionally diverse assemblage of invertebrates, particularly beetles and flies, as well as fungi, mosses, liverworts, and lichens. It is the process of decay that provides the conditions required by this diverse range of species.

Larger-diameter dead wood on the ground is often termed coarse woody debris (CWD). There is no strict definition of the minimum diameter of CWD, with definitions usually varying between greater than 10 cm and greater than 15 cm diameter.
Invertebrates that are dependent on dead wood during at least part of their life cycle, wood-inhabiting fungi and other species associated with this habitat, are termed saproxylic. Saproxylic invertebrates are also commonly referred to as dead-wood invertebrates.

Dead wood is important for woodpeckers and other birds that feed on invertebrates in it. Snags (standing dead trees) and other standing dead wood provide habitat for cavity-nesting birds. The cavities excavated by woodpeckers provide nest sites for other birds and small mammals. Holes in dead trees provide roost sites for bats.

There is a wide range of forms of dead wood and associated microhabitats, each supporting its own characteristic invertebrate fauna (Hilszczanski et al. 2005). These include:

- heart rot—decay that occurs primarily in the heartwood of living trees,
- dead wood on living trees,
- birds’ nest cavities,
- fungus-infected bark,
- fine dead branches and twigs,
- fallen dead wood,
- rot holes,
- bracket fungi, particularly long-lived fungal fruiting bodies,
- sap runs,
- snags,
- stumps,
- burnt wood,
- wet fallen wood,
- roots.

Invertebrate species also differ in their preference for dead wood in full sunlight, semi-shade, or complete shade (e.g. Jonsell et al. 1998; Lindhe et al. 2005).

(p.181) Trees can rot in two ways: from the outside (sapwood decay) or the inside (heart-rot decay). Heart-rot decay (rotting from the inside of the tree) is especially valuable. It supports a more specialized invertebrate fauna than sapwood and is used by woodpeckers to excavate nest holes. In general, large-diameter wood is most valuable and tends to be less common than smaller-diameter wood.
Different types of dead wood also support different fungal assemblages. Factors explaining variation in fungal diversity include the species of tree and the volume, diameter, age and stage of decomposition of the dead wood, and its degree of contact with the soil (Heilmann-Clausen and Christensen 2003; Norden et al. 2004; Heilmann-Clausen et al. 2005; Kuffer and Senn-Irlet 2005). Species composition of dead-wood-inhabiting mosses and liverworts appears to be less influenced by tree species, and more by the suitability of the surrounding microclimate. Many species of dead-wood-inhabiting mosses and lichens require relatively stable, humid conditions (Heilmann-Clausen et al. 2005).

Dead wood is of such high value for wildlife that there can be no justification for removing it from areas managed for nature conservation. All dead wood should be left to undergo its natural decay process, unless it poses unacceptable safety risks. Where it does endanger life, then the first option to consider is re-routing public access so that it avoids the dangerous tree. If this is not possible, then removal of tree limbs by competent trees surgeons will be necessary. Any tree surgery should remove the minimum quantity of wood necessary to make the tree safe, and should minimize further cutting of the removed branches. Removed timber should, wherever possible, be left where it falls. It is surprising, though, how often timber removed from nature reserves is cut into short lengths and neatly stacked. Worse still is leaving it on site so that it becomes colonized by the larvae of saproxylic invertebrates, and then removing it. If it is necessary to remove the timber, for example if it falls across a track, then placing it in dappled shade will probably provide the widest range of conditions for saproxylic invertebrates (Kirby 1992b; Lindhe et al. 2005). Always think of the best way to mimic natural processes.

In commercially managed woodlands the quantity of dead wood retained will be a compromise between the needs of timber production and conservation.

7.1.7 Presence of gaps, glades, forest edge, and associated habitats
A large proportion of the species found in large blocks of forest and woodland are associated with patches of non-forest habitat, particularly grasslands and wetlands, and the edges of
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wooded and open ground. Many insect species require a mixture of woodland and open areas.

7.1.8 Variation in soils, topography, and drainage
Variation in soils, topography and drainage will increase the variety of ground conditions within the woodland and thereby increase the range of plants and animals, especially invertebrates, within it. Small-scale variations in topography are caused by falling over of shallow-rooted trees (Figure 7.4).

7.2 Types of forest and woodland
A number of terms are used to describe forests and woodlands in terms of their age and history. Virgin or primary are used to describe forest and woodland

Fig. 7.4 Pits and mounds. Exposed root plates, such as on this fallen Norway spruce, *Picea abies*, create valuable diversity in soil conditions and topography. The root plate provides nest sites for birds and eventually breaks down to form a mound. The pit formed by pulling up of the root plate exposes the mineral soil beneath the litter, increasing the diversity of soil types and conditions for plant growth. Pits that fill with water form valuable temporary and permanent ponds.

Pits and mounds created by fallen trees are characteristic of older-growth forests. Root plates should always be left intact to
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7.2.1 Old-growth

Most old-growth is coniferous and confined to high altitudes and high latitudes. There are few remaining areas of old-growth broad-leaved forest. They are particularly valuable as reference points against which to compare the features of managed high and secondary forests. In particular, old-growth contains:

- the majority, if not all, of the forest tree and other plant species native to that given area, and in more similar proportions to those that would occur in a present-natural (Section 2.3) situation than in managed forests and woodlands;
- a greater number of large, mature, and over-mature trees compared to managed forests, and far higher abundance of standing and fallen dead wood (Figure 7.5);
- relatively complex vertical structure and variation in horizontal spatial structure due to a long history of tree falls and other canopy loss at different times in different areas of the forest, resulting in different stages of re-growth; in many cases, though, they may contain large areas of relatively uniform structured re-growth following large-scale disturbance;
- natural variation in soils, topography, and drainage; a long history of large tree falls will have helped to increase the smaller-scale variation in

provide this diversity of conditions (Yremossen, Västergötland, Sweden).
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topography through the pulling up of root plates of shallow-rooted trees.

Old-growth often supports a range of species that are rare or absent in more recently and more intensively managed forest. These include birds that require tree cavities or large-crowned trees for nesting and mature trees, snags, dead limbs, and branches for feeding (e.g. Newton 1998; Imbeau et al. 2000; Poulsen 2002). Old-growth is especially important for its fungi, lichens, mosses, liverworts, and dead-wood invertebrates. The quantity of dead wood (p.184) varies enormously between different types of old-growth, for example between 20–60 m³/ha in Scot's pine- and Norway spruce-dominated boreal forests near to the timberline in Lapland (Sippola et al. 1998) and 476–1189 m³/ha in Douglas fir–hemlock, _Pseudotsuga–Tsuga_, forest in the north-west USA (Harmon et al. 1986).

![Fig. 7.5 Old-growth. An often striking feature when entering old-growth forest is the massive quantity of standing and fallen dead wood and the huge size of the trees. This mixed, old-growth forest in Bia owie a National Park, Podlaskie, Poland, contains many enormous, relatively straight-trunked deciduous trees reaching 35–42 m in height. These are quite different in size and form to trees in...](image)
7.2.2 Recent secondary woodland and scrub

Scrub and secondary woodland establish following abandonment, or a reduction in intensity, of management of agricultural land, grassland, and dwarf-shrub habitats, or as the result of succession in wetlands. Scrub is also an important component of wetlands, grasslands, and dwarf-shrub habitats.

More recent secondary woodlands will in most cases have been subject to little if any traditional management. They will thus lack the attributes of cultural habitat, but neither have attained the valuable attributes of old-growth. As they are only recently established, many will still be in the thicket/stem-exclusion or understorey-initiation phase and hence be relatively structurally uniform and uninteresting for biodiversity. Their trees and shrubs will usually comprise mainly shade-intolerant, vigorous-growing, and widely dispersive species. The lack of structural and tree-species diversity means they usually support only an impoverished woodland flora and fauna, in many cases exacerbated by isolation from potential colonists.

7.2.3 Managed high forest

These are forests containing relatively straight, single-stemmed trees that are, or have been, managed primarily to provide straight, unblemished timber. They are usually made up of only a limited range of favoured tree species, often alien/exotic ones. Managed high forest will have little variation in vertical and horizontal structure and usually lacks a well-developed understorey and field layer. The extent of this impoverishment, though, depends on the type of forestry management (see Section 7.4.7). Managed high forest can be derived from old-growth, secondary woodland established on un-forested land, or have been specifically planted for timber production.

7.2.4 Coppice

Coppicing involves cutting broad-leaved trees close to the ground to produce harvestable re-growth of straight poles from their stumps (stools). Coppicing was formerly widespread in much of Europe, where it was undertaken in areas of long-
established woodland, in many cases representing a continuation of forest cover from original primary forest. Most areas of coppice woodland contain scattered, more mature trees, known as standards. These are allowed to grow tall and are harvested periodically for timber. As in other woodland-management systems, tree-species composition has usually been highly modified through selection for species that produce the best coppice products and timber from \( \text{(p.186)} \) standards. The structure of coppice-with-standards woodland is most similar to that of dense scrub containing scattered, taller trees. An important feature of coppice woodlands is the presence of open rides, along which timber is extracted.

Most short-rotation coppice has been developed relatively recently on former arable land in Europe and North America to provide wood for power-generation, so-called bioenergy. Short-rotation coppice also includes osier, \( \text{Salix viminalis} \), beds grown in wet areas to produce flexible willow stems for basket-making and other uses. Short-rotation coppice managed for production of bioenergy comprises single-species stands of fast-growing willow cultivars, (usually based on osier), or poplar cultivars, \( \text{Populus spp.} \). Management of short-rotation coppice for bioenergy differs from that of coppice woodland in its extremely short coppice rotation, use of fertilizer to increase coppice growth, control of so-called weeds to reduce competition with the coppice, and lack of standard trees.

7.2.5 Managed open woodland systems

There is a range of open woodland-management systems that have been used for combinations of grazing, cultivation, and harvesting of tree products such as cork, olives, fruit, timber, and wood for charcoal production.

**Wood-pasture** (also known as pasture-woodland) is open woodland used for grazing and browsing by cattle, sheep, horses, ponies and deer, pasturing of pigs in autumn to feed on acorns and beechnuts, and pollarding or shredding of trees. Pollarding involves cutting branches of broad-leaved trees to a height above that of livestock and deer, to prevent the regrowth from being browsed. The branches removed are used for timber and fuel and their leaves for forage. Pollarding has also traditionally been carried out on trees to mark boundaries and on willows in open habitats. Shredding involves cutting
the side branches of the tree to leave one main branch (the leader) to form a tall pole.

**Wood-meadow** is an ancient and now rare system in Europe. It is similar to wood-pasture in consisting of usually widely spaced, pollarded, or shredded trees. It differs in containing scattered, usually coppiced bushes and small trees, and because the grassland beneath and between the fields was cut for hay and aftermath grazed. Branchwood was also burnt and the ashes used to fertilize the grassland.

Other systems include orchards, olive groves (Figure 7.6), and the wooded dehesas (Spanish)/montados (Portuguese) of the western Mediterranean (Figure 1.3). (p.187)
Olive groves. Ancient olive, *Olea europaea*, groves and other lowintensity silvicultural systems can be of high cultural and aesthetic value as well as providing good wildlife habitat.

The olive groves of Puglia in southern Italy contain many beautiful, ancient olive trees. The periodic cultivation used to prevent establishment of woody plants maintains a rich ruderal plant fauna, here supporting numerous field marigolds,

*Fig. 7.6*
7.3 Managing scrub

Scrub can be made up of a diverse range of shrub species, particularly on base-rich soils. It is especially valuable where it:

- is open and structurally diverse;
- has plenty of edge;
- forms transitions from open habitat to scrub and through to woodland;
- is scattered within open habitats.

These types of scrub can all support high densities of breeding birds, although usually comprising mainly relatively widespread species. Mosaics of habitats provided by scattered scrub, glades, and edges provide a wide range of vegetation types and microclimates for invertebrates. Scrub can protect grassland plants from grazing, benefiting grazing-intolerant species, especially some bulky forbs, and providing areas of taller vegetation, litter, nectar, and seed sources that are scarce in more heavily grazed habitat. Scattered scrub in open habitat can provide nest sites, foraging, song, and look-out posts for birds that otherwise exploit open grassland and dwarf-shrub habitats, including perch-hunters such as shrikes Laniidae and raptors. Scattered scrub may also have a negative effect by deterring species that require extensive areas of open habitat, such as many open-ground nesting birds.

As described in Section 7.1.2, a marked change takes place in the structure, flora, and fauna of scrub following coalescence of the canopies of individual shrubs. Canopy closure reduces levels of light reaching the ground, restricting the field layer to a small number of shade-tolerant plants. It is also associated with a marked reduction in bird species richness and loss of invertebrates associated with open, sunny conditions. Few, if any, bird or invertebrate species prefer large blocks of uniformly aged, closed-canopy scrub. Closed-canopy scrub can be surprisingly stable and long-lived, especially where there is no seed source of tolerant tree species to grow up beneath it.

Where scrub occurs in association with open habitats, the primary decision will be its desired area, distribution, and age structure. This will depend on:

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**Calendula arvensis**, and star of Bethlehem, *Ornithogalum umbellatum* (Madonna Incoronata organic olive farm, Mattinata, Puglia, Italy).
• the conservation value of the scrub compared to that of the open habitats it is replacing;
• the extent to which scattered scrub enhances or decreases the value of these open habitats.

Options for management include:
• removing the scrub;
• diversifying the structure of uniform, closed-canopy scrub;
• increasing the extent of scrub.

In practice, patchy removal of scrub can be used to also diversify its structure. The other consideration when scrub is out-competing more valuable, open vegetation, is whether the management of these other vegetation types can be altered to prevent the scrub from establishing. For example, grazing pressure can be lowered to reduce the availability of germination gaps for scrub seedlings, or livestock such as primitive sheep introduced that are effective at controlling young scrub (Section 4.4.2).

Scrub and associated open habitats can also be important components of otherwise dense woodlands and forests. Scrub and open edge are often in limited supply in many types of woodland. Where scrub occurs within otherwise closed-canopy forest, the main options will be to:

• maintain it as scrub, by preventing its succession to woodland;
• allow the scrub to eventually develop into woodland through non-intervention.

( p.189) If the woodland or forest lacks scrubby and open habitats, then it may be a priority to increase the extent of scrub (Figure 7.7).

7.3.1 Scrub removal

In some cases the aim may be to remove the entire area of scrub. If it is only intended to remove a proportion of it, it is usually best to remove more recently developed scrub, since this will usually be easiest to revert back to the habitat it has encroached on. Older scrub will have accumulated a deeper litter layer, making it more difficult to revert to nutrient-poor, species-rich grassland or
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(p.190)

(dwarf-shrub heath. Older scrub is also likely to have developed on land generally more conducive to scrub establishment in the first place. Leguminous scrub fixes nitrogen, which can favour the growth of more competitive plants following its removal. If the scrub is of very low conservation value, though, and removed using large-scale machinery such as a forestry mulcher, then it may be more efficient to remove large blocks in one go. The main method for removing scrub is by cutting it close to ground level and treating the cut stumps or re-growth with herbicide. Herbicide can be poured into holes made in cut stumps or by spraying the re-growing foliage. Livestock and deer can prevent re-growth of more palatable scrub.

Removing scrub from the margins of large blocks provides opportunities to diversify its edge structure (Figure 7.8). This can be done by removing more widespread and uninteresting shrub species, while retaining those of greater intrinsic value and which provide more valuable habitat for other species, such as valuable food plants and sources of nectar.
Fig. 7.7 Soft and hard edges. Many patches of woodland, especially in lowland areas, are surrounded by often intensively managed cropland or grassland of little value to woodland-edge species. Even if the woodland is bounded by semi-natural habitat, then this boundary is often hard and abrupt, and lacks a soft, gradual transition from grassland to scrub and woodland required by many species ((a) Goor-Asbroek, Antwerpen, Flanders, Belgium).

It can be tempting to expand woodlands by planting gaps and adjacent areas with trees. In many cases, though, there will be greater conservation benefits in providing grassy areas and soft, scrubby edges to the woodland instead.

(b) shows a former hop, *Humulus lupulus*, field, which has been left to revert naturally for about 10 years. The mixture of flowery grassland, low brambles, *Rubus* spp., and silver birch scrub that has developed provides superb woodland-edge habitat. These open areas also provide summer nectar sources for insects, which are in short supply in the surrounding, dense woodland (Tudeley Woods, Kent, England).
7.3.2 Diversifying the structure of closed-canopy scrub and preventing scrub from succeeding to woodland

The structure of closed-canopy scrub can be diversified by cutting small patches to ground level to produce areas of younger regrowth. Cut scrub may need to be fenced to prevent browsing by livestock and deer.

Periodically cutting and removing scrub prevents it from succeeding to woodland. Alternatively, relatively stable scrub can be created within woodland by cutting down young trees and treating their stumps with herbicide, to allow shrubs and creepers to remain dominant. This technique has been used to prevent trees from touching power-lines running through forests and has benefited a number of scrub bird species (Askins 1994). In the USA birds nesting in these corridors of scrub through woodland have been found to suffer lower rates of brown-headed cowbird brood parasitism and nest predation than those breeding in scrub close to open habitats (Yahner 1995).

7.3.3 Increasing the extent of scrub

Trees and shrubs establish best when there has been a period of heavy grazing or other disturbance that has created suitable germination gaps for seedlings to establish in, followed by relaxation of grazing of cessation of other disturbance that then allows these seedlings to grow. Alternatively, scrub can be planted and protected from grazing by wild grazing animals and livestock using tree tubes.

7.4 Managing woodlands and forests for conservation
The range of options available for managing woodlands and forests for conservation depends on the type of woodland or forest, its history, and current state.

Old-growth does not usually require management to maintain its conservation value. The only exceptions may be removal of alien/exotic plants and the re-introduction and management of previously exterminated large herbivores and their predators to facilitate more natural forest dynamics. Because of the rarity and immensely high conservation value of old-growth, any further intervention will be damaging.

The various forms of managed high forest can be regarded as impoverished forms of old-growth. Stands of trees in managed high forest usually lack the following valuable attributes found in old-growth:

- a diversity of tree species;
- structural diversity;
- a well-developed field layer;
- large, mature trees with thick stems and branches;
- standing and fallen dead wood;
- pits and mounds on the forest floor caused by windblown trees;
- variation in hydrology;
- surrounding open habitats of high conservation value.

Quantities of dead wood in high forest managed by clear-felling or types of selective felling are typically between only 3 and 30% of those in comparable unmanaged old-growth (Kirby et al. 1991; Christensen et al. 2005; Gibb et al. 2005; Marage and Lemperiere 2005).

The overall structure of managed high forest can be more diverse, because individual stands are cut for timber at different times, creating a range of different age classes and structures within the forest as a whole.

The main priorities when managing forests impoverished by past management for timber production will be to increase their structural diversity, the quality of their edge habitat and increase quantities of dead wood. Lack of management is an
issue in the eastern USA, where there is a lack of early successional, scrubby habitat in many woodlands.

Recent secondary woodland also lacks structural variation, gaps, old trees, and dead wood, in this case because these features have not yet had time to develop. The main management priority in these recent secondary woodlands will be to enhance these features where possible.

Woodlands managed as coppice, wood-pasture, and open woodlands, such as wooded dehesas/montados, orchards, and olive groves, lack most of the features of old-growth, but instead comprise distinctive and highly valued cultural habitats that support characteristic assemblages of species, many of high conservation value. The main conservation objective for these cultural habitats will be to maintain their existing interest through continuation or re-instatement of their former management. The exception to this involves the management of abandoned coppice woodlands that have lost their assemblage of open coppice species. Here, an option will be to allow the former coppice to develop into high forest. Most short-rotation coppice is relatively recent and the main conservation aim is usually to maximize its potential for breeding birds.

**Grazing and browsing** by domestic and wild herbivores has important effects on tree and shrub regeneration, the field layer and structure of the understorey in a range of types of forest and woodlands. Fire-prone types of woodland maintained can be managed by controlled burning to maintain their characteristic species-composition and structure, and to decrease fuel loads to reduce the risk of larger, more catastrophic wildfires. In all types of forest and woodland there will be a presumption to remove alien/exotic plant species.

*(p.193)* Removal of the litter, humic and grassy layers in woodlands, usually referred to as sod cutting/litter stripping has been used on a small scale to improve conditions for germination and growth of seedlings, reduce nutrient levels, raise soil pH, and increase species richness of ectomycorrhizal fungi (Devries *et al.* 1995; Baar and Kuyper 1998; Dzwonko and Gawroński 2002). This management mimics the effects of litter removal that formerly took place as part of traditional woodland management in some parts of Europe. It is thought
to counteract the effects of nutrient enrichment and increased litter production caused by inputs of anthropogenic atmospheric nitrogen deposition. However, this technique has not been applied widely in the conservation management of woodlands and forests and is not discussed further.

Regeneration of trees is necessary for woodlands and forests to persist, and the extent of regeneration will be a consideration in all types of woodland management. However, because of the long lifespan of most tree species, significant regeneration usually only needs to take place at very infrequent intervals to replace trees lost. Patchy regeneration will maximize the variation in growth stage and structure.

7.4.1 Enhancing formerly managed high forest and recent secondary woodland

The main techniques for enhancing these types of forest and woodland for wildlife are by:

- thinning to increase structural diversity and creating and maintaining gaps, glades and rides;
- providing dead wood;
- restoring natural variation in hydrology by blocking any artificial drainage.

Grazing and browsing by large wild and domesticated herbivores can also affect the structure and composition of the understorey and, by affecting tree regeneration, also influence long-term tree-species composition and structure. The effects of grazing and browsing are discussed in Section 7.4.5. Improving the value of dull forests and woodland and wildlife may also involve felling of undesirable alien/exotic trees and shrubs. In some types of woodland and forest burning can be used in combination with these techniques to provide the desired structure and tree species-composition (Section 7.4.6).

**Thinning and creating gaps, glades, and rides**

Structural complexity within a structurally uniform woodland will increase without intervention as trees out-compete one another (self-thinning), and (p.194) individual and groups of trees fall over and create gaps in the canopy. However, these natural processes can take a long time. The rate of increase in structural diversity can be accelerated by felling individual, or groups of, trees or by pulling trees over using a winch. Thinning can be carried out selectively to modify tree-species composition.
Pulling trees over using a winch not only creates gaps but also provides additional benefits by exposing the root plate (Figure 7.4). Felling or winching single or small groups of trees is only safe to carry out in relatively open woodlands, or along existing edges, where the felled or winched trees will fall to the ground, rather than lean un-fallen against other trees. Felled areas can either be left to regenerate into scrub or woodland, or if larger, maintained as more open habitat by subsequent grazing or cutting. Care is needed to avoid prejudicing the long-term future of the woodland for short-term gain. Medium-aged trees are potential ancient/veteran trees of the future.

The ideal when creating gaps in forest for regeneration of trees and shrubs is to leave the fallen trees in situ, thus providing a source of dead wood and cover for small birds and mammals, and more closely mimicking the process of natural windthrow. Gaps produced by felling groups of trees will provide suitable conditions for a range of clearing specialists, particularly insects that feed on flowers, the foliage of young saplings, fallen tree crowns, and the regenerating understorey. Retaining the dead wood will provide suitable conditions for a different range of dead-wood invertebrates to those in more closed canopy forest, including warmth-loving species and those whose adults visit flowers, such as many longhorn Cerambycidae and jewel beetles Buprestidae (Bouget and Duelli 2004; Bouget 2005). Tangles of branches from fallen trees can protect establishing seedlings and saplings from grazing animals. Dead trunks and branches can themselves provide important micro-habitats on which tree seedlings can then establish.

In practice, the cost of creating gaps in the canopy is usually met by the sale of the timber removed. A compromise is to cover the costs of the management by sale of a proportion of the timber, but to leave the remainder where it falls.

Most creation and enhancement of open areas within woodlands takes place along existing rides, where it is logistically easier to undertake. Much of this work has been focused on widening existing rides and creating new rides and open glades to provide open, sunny conditions, primarily to benefit woodland-edge butterflies and other woodland-edge invertebrates (Warren 1985; Greatorex-Davies et al. 1992;
Figure 7.9). This enhancement may also involve creating soft edges around the margins of existing woodland or forest (Section 7.3).

**Figure 7.9** Ride-widening and box junctions. Usually the most efficient way to increase woodland-edge habitat is to widen existing narrow rides and create glades.
interior, but whose adults require nectar sources which can otherwise be rare in many areas of high forest and secondary woodland.

Rides need continual management to prevent them from becoming colonized by scrub or woodland, in the absence of high densities of deer or other herbivores. Grazing by domestic livestock is usually impractical, so open conditions are normally maintained by periodic cutting. Cutting regimes should aim to provide a variety of types and structures of grassland, dwarf-shrub vegetation, and scrub along rides to maximize the variety of food plants, nectar sources, variation in sward structure, and shelter for invertebrates. As with all such management, managing short stretches on rotation is best to help maintain a continuity of suitable conditions in close proximity to one another.

At their junctions, so-called box-junctions. The connectivity of rides also facilitates dispersal of woodland-edge species. The photograph shows a sunny ride that has been widened to benefit butterflies and other insects. It contains a range of types and structures of herbaceous vegetation across and along it, containing a variety of food plants and nectar sources, together with scattered scrub. The edges have been scalloped to further increase the length of edge and to provide sunny bays sheltered from the wind (Oakens Wood, Surrey, England).
Providing dead wood

All dead wood should be maintained through non-intervention in woodlands and forests managed for conservation, unless it poses unacceptable safety risks. It is also possible to increase the quantity of dead wood, although this is rarely done in practice.

There is no simple answer to how much dead wood to create. In old-growth not subject to recent catastrophic disturbance by wind or crown-fire, approximately 10% of all standing trunks are dead. This figure is remarkably consistent across a range of forest types in Europe and North America. The percentage of dead trunks in old-growth tends to be highest among the largest size classes (greater than 50 cm diameter at breast height; Nilsson et al. 2003), because these trees remain standing for longer. However, it is important to recognize that the quantities of dead wood present at any one time are the product of ongoing processes. Large quantities of dead wood can be due to a small number of large, dead trees that have stood for many years. Targets for creating dead wood should be more modest and the long-term impacts on stand dynamics should be considered. It is also unclear whether artificially created dead wood functions as well as natural dead wood. Some of the key fungi involved in decay need to establish in the dying tree.

(p.197) There are two approaches to creating dead wood. The first is to inflict damage on parts of trees to initiate the decay process and thus provide a continuity of dead wood in a variety of stages of decay. This method is primarily aimed at benefiting dead wood invertebrates. Fungal infection and decay can be induced by drilling holes in parts of trees to allow water to enter, particularly in axils between large branches. In practice, this method can be logistically difficult and dangerous and is rarely undertaken. Damage inflicted on trees during thinning and gap, glade, and ride creation can also provide a route of entry for fungi. Any damage created during such management should be left, rather than cleaned up to prevent fungal attack.

The second approach is to kill whole trees to produce snags, or to kill large branches. Snag creation has generally been used to provide habitat for cavity-nesting birds. The following methods can be used:
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- killing parts of or whole trees by girdling (making a continuous cut around the trunk);
- injecting with herbicide;
- blowing off the crown of conifers using dynamite.

These methods can also be accompanied by inoculation of fungi to speed up decay. These techniques should only be used on younger trees, preferably healthy ones, and not on older or partly dead trees that are already of high value. It is preferable to damage only part of the tree, since whole dead trees fall over more quickly and thereby lose their value to cavity-nesting birds. However, narrow-diameter snags will be unsuitable for species that require larger cavities. Summers (2004) suggests that snags created from Scots pine trees in Scotland should ideally be at least 40 cm diameter at breast height to provide suitable cavity nest sites for birds and habitat for other wildlife. Brandeis et al. (2002) found no difference in decay characteristics and woodpecker activity in Douglas firs, *Pseudotsuga menziesii*, killed by girdling, herbicide injection, and cutting off of the base of the live crown with or without inoculation of fungi.

7.4.2 Managing coppice woodland

Coppice woodlands are important cultural habitats in Europe and, where subject to a long history of coppice management, usually support a characteristic flora and fauna whose persistence is largely dependent on continuation of this form of management. In particular, coppice woodlands can be important for their:

- spring-flowering, woodland forbs;
- invertebrates associated with the early stages of coppice re-growth and rides;
- songbirds found in the earlier stages of coppice re-growth.

*(p.198)* In general, managed coppice contains little dead wood, and is therefore unlikely to support specialized saproxyllic species. For example, Kirby (1992a) found quantities of dead wood in 0–30-year-old mixed coppice of between 1 and 7 m³/ha. The repeated cutting damage to old coppice stools can, though, sometimes create a reasonable quantity of dead wood in old stools, especially if the stumps have been cut relatively high.

The main considerations when managing coppice woodland are the:
Forests, woodlands, and scrub

- length of the coppice rotation;
- size of individual areas cut, known as ‘coupes’;
- spatial arrangement of coppice coupes and their linkage together by rides;
- level of grazing and browsing by deer.

Soil type will influence the woodland flora and its response to coppicing.

**Length of the coppice rotation**

Conditions for wildlife change rapidly during the coppice cycle (Figure 7.10). Harvesting of coppice re-growth suddenly enables light to reach the ground. The coppice stools re-grow quickly, in a similar way to establishing, or re-establishing, scrub during the stand-initiation or regeneration phase of woodlands (Section 7.1.3). This is usually referred to as the establishment phase. The re-growth from adjacent stools then coalesces to form a closed-canopy, this period being known as canopy closure. The time until canopy-closure depends on the rate of coppice re-growth and density of stools, but is typically 4–10 years. The prevention of light reaching the ground marks a significant change in conditions for most groups. This process is akin to the thicket or stem-exclusion phase of establishing woodlands. The canopy then remains closed, this period being known as the maturation phase, and is then re-harvested.

The field layer of coppice consists of two main groups of plants:

- shade-tolerant, woodland forbs;
- shade-avoiding annuals, biennials, and short-lived perennials with a long-lived seedbank.

The flora of coppice is usually distinct from that of even sensitively managed, selection, or group-selection high-forest (Section 7.4.7), in supporting a greater proportion of spring-flowering, shade-tolerant, perennial forbs, especially species that propagate from bulbs, tubers, and corms (e.g. Decocq et al. 2004). The persistence of the characteristic coppice field layer is dependent on alternate periods of open conditions following harvesting of coppice poles, and shady conditions following canopy closure. The shady conditions are necessary (p.199)
(p.200) to prevent the flora becoming dominated by more competitive light-demanding species, typically grasses, similar to the flora found along continually open, sunlit rides. The light conditions following harvesting of the coppice are important in allowing woodland plants to flower in profusion and in providing suitable conditions for any characteristic open-ground coppice invertebrate fauna. Flowering of the field layer typically peaks in the second spring following harvesting. The main conservation interest of coppice woodland for
invertebrates is that of the small, but distinctive, range of species associated with the open conditions during the short period between harvesting and canopy closure, especially several species of fritillary butterfly. The larvae of these fritillaries feed on the prolific growth of woodland flowers. Both adults and larvae require the warm, light conditions provided by these open conditions. Numbers of butterflies can rapidly increase in numbers following coppicing, mirroring the growth of their food plants. However, these fritillary butterflies are rapidly lost as the canopy closes, typically after 3–4 years following cutting.

There is little information on the value of the coppice for invertebrates following canopy closure. It is assumed that there is only limited invertebrate interest associated with post-canopy-closure stages, which are too shaded to open-ground species, but which also lack the valuable features of older-growth forest for invertebrates.

The birdlife of coppice woodland is dominated by songbirds typical of scrub, and changes rapidly in relation to the height of re-growth. Total densities of songbirds tend to increase up to about the time of canopy closure and decline thereafter. However, there are differences in changes in density in relation to age of re-growth between species, and in particular between densities of migrant and resident birds. The proportion of migrants is highest in younger re-growth (e.g.

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**Fig. 7.10** Flowers in coppice woodland flowers. Conditions for flowers in coppice woodlands changes dramatically during the coppice cycle.

The increase in light following coppicing (b) causes prolific growth and flowering of vernal plants, such as this oxlip, *Primula elatior* (a). As the coppice regrows the canopy closes, allowing only more shade-tolerant plants such as ramsoms, *Allium ursinum*, to persist (c).

A long period of canopy closure eventually limits growth and flowering of most of the field layer altogether (d). At this stage the coppice is usually re-cut, thus re-starting the cycle. This woodland has been under continuous coppice management since 1252 (Bradfield Woods, Suffolk, England).
Fuller and Moreton 1987; Fuller and Henderson 1992). Birds associated with later stages of forest growth are invariably scarce or absent.

Small mammals also show a succession in relation to the stage of coppice re-growth. For example, in Italy white-toothed shrews, *Crocidura* spp., and wood mice, *Apodemus sylvaticus*, are associated with young coppice re-growth, and yellow-necked mice, *A. flavicollis*, bank voles, *Clethrionomys glareolus*, and black rats with older coppice re-growth (Capizzi and Luiselli 1996).

The length of the coppice rotation in areas managed for conservation will depend on the desired proportions of different stages of coppice re-growth. Depending on the individual woodland, the length of the rotation is usually chosen to maintain a high proportion of:

- establishment-phase re-growth to increase the flowering of aesthetically pleasing woodland flowers and suitable conditions for any characteristic (p.201) open-ground invertebrate fauna, while also maintaining a suitable period of maturation phase to provide the shady conditions necessary to maintain this characteristic coppice field layer;
- establishment to canopy-closure phases to maintain high densities of songbirds, particularly of migrant species.

The length of the rotation required to maintain a given proportion of these different growth phases depends on the rate of coppice re-growth and density of coppice stools. A shorter rotation will be needed if coppice re-growth is rapid and the stools closely spaced. Rotations are usually between 10 and 25 years.

**Deer grazing and browsing**

A common issue in coppice management is heavy grazing and browsing by deer. This can:

- prevent re-growth from coppice stools;
- kill regenerating coppice stools;
- reduce the abundance of desired species of woodland flowers;
- remove the dense understorey required by some birds;
Browsing of recently cut stools coppice stools can be reduced to some extent by fencing coupes (Cooke and Lakhani 1996) and protecting individual stools by covering them with brash, similar to the protection afforded to saplings growing among fallen branches. However, these techniques are labour-intensive, whereas fencing is only successful if constructed to a high standard and checked regularly for damage. The only long-term solution at most sites is to reduce deer numbers.

**Size of coppice coupe**

Individual coupes need to be large enough to support viable populations of the key species associated with them. For breeding birds individual coupes, or areas of adjacent, similar-aged coppice, need to be large enough to support at least one territory of the given species to maximize their benefits. Territories of most breeding songbirds in coppice woodland are larger than 0.5 ha (Fuller 1992). For less mobile open-ground invertebrates, the coupes need to be large enough to support a viable population in a given year, and to ensure that enough individuals disperse successfully to new areas before the existing coupes becomes too shady for them. However, because the flora can often vary greatly between individual coupes, there is also an argument for cutting a larger number of different small areas of coppice, to maximize the likelihood of there being a continuity of that at least some suitable habitat present. Plots cut to maintain woodland butterfly populations are usually 0.5–2.0 ha.

**Spatial arrangement and linkage of coupes**

As with all rotational vegetation management, species will be more likely to re-colonize suitable areas of re-growth if they are closer to existing sources of colonists.

Management can be arranged to minimize the distance between early stages of re-growth. In coppice woodlands, there is the potential to link areas of early re-growth by sunlit rides. The adults of at least some species of fritillary butterflies use rides to disperse between newly cut coppice blocks. Suitably managed rides also provide habitat for other woodland-edge species. However, for the reasons mentioned earlier, these permanently open rides tend to become dominated by more competitive, light-demanding competitive grasses and forbs, and so not contain the high densities of
woodland food plants and in some cases open ground required by the larvae of fritillary butterflies (Greatorex-Davies et al. 1992).

A specific type of linkage of coupes is suggested for hazel dormice, Muscardinus avellanarius. These prefer the middle stages of coppice re-growth and are reluctant to cross wide areas of open ground. Corridors of medium-aged re-growth can be left to facilitate movement of dormice between suitable stands, and particularly over wide, open rides.

**Density of standards**

The main value of standard trees is in providing nest sites for cavity-nesting birds and high song posts, which are otherwise absent from coppice re-growth, and additional foraging habitat including dead wood. The main factors influencing the suitability of standard trees for birds are likely to be their density, age (and in particular state of decay), and to some extent type, although there is little qualitative information on the importance of these factors.

The shade cast by a high density of standard trees suppresses coppice re-growth and prevents the development of open conditions during the first few years following coppicing. Again, most of the quantified information on management is from studies of woodland fritillary butterflies. For these, a cover of standard trees of less than 25% is considered best, with characteristic coppice species generally absent from areas with a cover of exceeding 60% (Warren et al. 1984; Warren and Thomas 1992). As standard trees mature they increase their canopy cover, and so thinning might be needed to maintain suitably open conditions.

**(p.203) Tree-species composition**

Some stands of coppice are dominated by a tree species of particularly low value for wildlife. A notable example of this is sweet-chestnut coppice, which usually has a poorly developed field layer, although it can be valuable for fungi.

Any attempts to change the composition of the coppice stools will obviously be a long-term process, and unlikely to be a high priority unless the existing coppice tree species are of exceptionally poor value for wildlife. Tree-species composition of coppice can be altered by killing existing stumps by spraying the first year's re-growth following coppicing with a
herbicide and planting replacement trees. The benefits of this, though, have to be evaluated against the destruction of old coppice stools, which may support interesting fungal assemblages and a continual, albeit usually limited, resource of dead wood.

**Managing abandoned coppice**

Coppice management has ceased in many areas, because it is no longer profitable. When faced with abandoned coppice, a decision needs to be made whether to re-instate coppice management.

Coppicing can be re-instated to trees that have not been cut for at least 50 years or more, with little difference in structure of the restored coppice compared to that of continuously managed coppice. The small differences that do exist can be related to differences in canopy cover; restored coppice having a slightly higher canopy cover that result in slightly delayed coppice re-growth (Joys et al. 2004). When re-instating coppice management, it is worth considering establishing appropriate standard trees if none are present. The field layer of coppice abandoned has been found to vary little, if at all, during the period up to about 35 years beyond a normal coppicing cycle of 15 years, at least in situations where there is little potential competition from more shade-tolerant woodland forbs (Petersen 2002). However, the characteristic open-ground coppice invertebrate fauna is unlikely to survive within abandoned coppice. Furthermore, many of these species have limited powers of dispersal and, unless the abandoned coppice is connected to continually managed coppice, many of these species are unlikely to re-colonize naturally.

An alternative is to allow this abandoned coppice to develop into high forest. A common strategy is to continue coppicing a core area of the wood that has had a continuity of coppice management, while leaving areas of older coppice to revert to high forest. This will maximize variation in the age and structure of stands within the woodland as a whole.

**(p.204)** Abandoned coppice will, like other structurally uniform woodland and forest, increase in structural complexity over time through non-intervention, as it passes through the thicket/stem-exclusion, understorey (re)-initiation, and canopy break-up phases described in Section 7.1.3 (Figure 7.11).
These increases in structural and plant species composition following the thicket/stem-exclusion phase will increase the abundance, species richness, and diversity of woodland birds (e.g. Laiolo et al. 2004). The time taken to reach the more structurally diverse canopy-break-up phase will vary between different types of woodland and the degree of natural disturbance events, particularly windfall. Changes in structure are fastest on steeper slopes, where gap creation through tree-fall is more frequent, due to the thinner soils and asymmetrical growth of trees.

A method to increase the value of abandoned coppice for birds is to thin dense, multi-stemmed, abandoned coppice to produce single-stemmed trees (singling). This probably increases shrub cover and overall densities of birds, particularly Old World warblers, and probably also densities of hole-nesting species as singled trees mature (Fuller and Green 1998).

7.4.3 Managing short-rotation coppice

Fig. 7.11 Abandoned coppice. This area of former coppice has not been managed since 1944. It is developing into high forest as its trees grow large, and is developing a more patchy structure and accumulating dead wood as trees and branches fall.

The wood's transition to high forest, though, is being affected by heavy deer grazing, which is currently converting it towards wood-pasture (Lady Park Wood, on the English/Welsh border in Monmouthshire, Gloucestershire, and Herefordshire).
very rapidly and is usually harvested after just 3–5 years. Management during establishment of the coppice usually involves control of ruderal plants using broad-spectrum herbicides and application of fertilizer to increase coppice growth. Rides to allow access by machinery will probably become a common feature of large-scale, short-rotation coppice plantations.

The field layer of short-rotation coppice is initially dominated by ruderal plants, which are then out-competed by widespread perennial grasses and forbs. Short-rotation willow is planted in wetter conditions than other types of coppice, and this is reflected in the composition of the field layer. Hence short-rotation coppice does not support the specialized flora and invertebrate fauna found in many areas of long-established coppice woodland. The grassy nature of the field layer in short-rotation coppice supports a small-mammal fauna more typical of agricultural land than of woodland (Christian et al. 1997). Any open areas and rides within the coppice are usually dominated by taller and more vigorous plant species and so have a flora and invertebrate fauna more similar to that of rank grassland. Short-rotation willow coppice can, however, provide a useful early-season nectar source for bees (Reddersen 2001).

The birdlife of short-rotation coppice differs from that of traditional coppice woodland in a number of ways, probably in part due to the intrinsic qualities of the coppice, but also undoubtedly due largely to its location within agricultural land rather than existing woodland. As well as supporting typical scrub birds, short-rotation coppice can also support the following groups of species (from Christian et al. 1997; Berg 2002a; Anderson et al. 2004; Sage et al. 2006):

- breeding wetland songbirds, particularly in willow coppice, such as sedge warblers, *Acrocephalus schoenobaenus*, marsh warblers, *Acrocephalus palustris*, and reed buntings, *Emberiza schoeniclus*, in north-west Europe;
- breeding and wintering open-country birds present during the establishment of new areas of coppice, including breeding Eurasian sky larks, *Alauda arvensis*, and northern lapwings in north-west Europe;
• breeding birds typical of grassy and other open habitats that use trees on the edges of plantation as song posts and open areas of failed tree growth within the coppice blocks, such as eastern kingbirds, *Tyrannus tyrannus*, clay-colored sparrows, *Spizella pallida*, field (p.206) sparrows, *Spizella pusilla* and savannah sparrows, in North America.

As in coppice woodlands, total densities of songbird species tends to increase with the age and height of the coppice, up to the time of canopy closure and harvest. Willow short-rotation coppice tends to hold a higher proportion of summer migrants, higher overall densities of birds, and higher bird species-richness than poplar short-rotation coppice (Sage and Robertson 1996). Short-rotation coppice does not generally support types of farmland birds considered of high conservation value in Europe, or grassland species or neotropical migrants considered of high conservation value in North America. However, it does contain a higher density of birds and a more diverse avifauna compared to its main alternative land uses: agriculturally improved grassland or intensively managed arable land (Christian *et al*. 1997; Anderson *et al*.* 2004; Sage *et al*. 2006). Short-rotation coppice could increase habitat diversity within polarized arable and grassland systems and benefit some farmland bird species, such as sparrows and finches, by increasing their range of foraging habitats.

So far, most of the research on the value of short-rotation coppice for wildlife has been on relatively small, trial so-called pre-commercial stands. Future, fully commercial short-rotation coppice will probably comprise much larger, monospecific stands and be managed more intensively. Both are likely to affect their value for wildlife. Because of this, there is little information on the options for managing commercial short-rotation coppice to maximize its benefit for wildlife. In terms of birds, the group that has been best studied and for which short-rotation coppice has probably the greatest potential to benefit, the key factors affecting its value for wildlife are likely to be the:

• tree-species composition, with willows supporting a richer avifauna than poplars;
• extent of weed control during the establishment phase;
• variation in age classes of different stands; because the avifauna varies with age of re-growth, areas containing smaller blocks of a wider range of age classes should support a wider range of bird species than large, even-aged stands;
• size of area of short-rotation coppice and particularly the extent of edge habitat; this will affect the suitability of the coppice for species utilizing its margins in adjacent grassy, herbaceous, and arable habitat; the margins of short-rotation coppice plots tend to support higher densities of breeding birds than their interiors (Sage et al. 2006), and therefore creating smaller (p.207) stands of short-rotation coppice and interspersing the interior of large blocks of coppice with open rides is likely to be beneficial;
• timing of harvesting; most harvesting is likely to take place in winter, when woody material is driest and the leaves have fallen. However, in some cases the risk of damage to waterlogged soils in winter, or a need for a more continuous supply of material, might result in harvesting in summer. This would have negative effects on any birds nesting in the coppice.

Provision of conservation headlands adjacent to short-rotation coppice is also likely to increase the densities and range of bird species using them, just as it benefits farmland birds using adjacent hedgerows (Section 10.2). The location of short-rotation coppice will also affect its value for wildlife relative to that of alternative land uses. Positioning short-rotation coppice in otherwise open landscapes should maximize its value for species that use the edges of scrub and woodland and scattered trees, but reduce the value of surrounding habitat for species that prefer very open habitats. There is a strong likelihood that short-rotation coppice will preferentially be placed on land of marginal agricultural value first; that is, the same land that currently has the greatest biodiversity value on farmland, and that would otherwise be most likely to be entered into agri-environment schemes. Loss of set-aside to short-rotation coppice is a major concern for
farmland birds, as agri-environment schemes have yet to provide the same nesting and food resources to those found on set-aside.

Short-rotation coppice appears of limited value for most other groups. As in other wooded habitats, the presence of wide rides will benefit open-ground butterflies and other invertebrates (Section 7.4.1).

7.4.4 Managing open woodland systems

Many grazed, or in some cases also periodically cultivated, open woodland-management systems comprise important cultural habitats, as well as being of value for wildlife. These open woodlands are thought by some to be the closest modern analogues to what they consider to be open, original natural woodland maintained by the grazing of wild, large herbivores. Two types of open woodland system are of exceptional value for wildlife: ancient wood-pasture (Figure 7.12) and wooded dehesas/montados.

The feature of wood-pasture of greatest value for wildlife is its veteran/ancient broad-leaved trees and their associated fauna and flora. There are no strict definitions of ancient or veteran trees. They are simply trees that are very old for their particular species and which contain characteristics of old-growth, particularly (p.208)

Fig. 7.12 Wood-pasture and veteran/ancient trees. Many areas of woodpasture are notable for their ancient (veteran) trees, such as this pedunculate oak, *Quercus robur*. The continuity of dead wood provided by large groups of ancient
Forests, woodlands, and scrub

Valuable dead wood features. Areas supporting large numbers of ancient trees and a long-term continuity of dead wood can support important assemblages of saproxylic invertebrates and probably also be important for fungi. Ancient trees can also support characteristic and valuable assemblages of lichens (Kirby et al. 1995). Cavities in ancient trees can be important roost sites for bats. Extensive, wooded dehesas/montados are especially important for their birdlife. The grasslands in wooded dehesas/montados can be very botanically species-rich. Wooded dehesas/montados usually support more diverse assemblages of songbirds and butterflies than neighbouring more densely wooded habitats or grasslands (see review by Diáz et al. 1997). Olive groves support high densities of wintering songbirds.

Overall, the main conservation priority in these open woodland systems will be to maintain their characteristic species assemblages by continuing existing management. This will involve continuing low-input grazing, without over-grazing or agricultural improvement, and continuing low-input periodic cultivation where this disturbance helps maintain high plant species-richness. It may also be a priority to minimize or avoid treating livestock with anti-parasitic drugs, especially in areas important for bats (Section 4.4.3).

The most important features of these grazed systems are the trees. The priority should be to maintain ancient trees through pollarding, where this is integral to the maintenance of the cultural habitat such as in wooded dehesas and montados, and to ensure that replacement trees are planted and protected from grazing. It will be difficult to predict which species of trees will be best suited to future climatic conditions.

Veteran/ancient trees in wood-pasture have often been managed by pollarding. This is thought in some cases to increase their life of a tree by preventing them from becoming top-heavy and falling over. Pollarding also helps create dead
wood, by the cutting of branches leaving openings for the
entry of fungi into the heartwood. Re-pollarding trees that
have not been pollarded for a long period (lapsed pollards) can
kill the tree (Green 1996). It is probably usually better to leave
lapsed pollards alone, the only requirement for management
being if limbs or trees become so unstable that they present a
health and safety risk. If so, the options outlined in Section
7.1.6 should be followed including, of course, leaving any cut
or fallen wood in situ.

Many dead-wood invertebrates feed on nectar during their
adult stage, so in ancient wood-pasture it is important to
retain or provide additional, suitable nectar sources. In
Western Europe a large number of dead-wood invertebrates
emerge as adults in early summer, when hawthorn, *Crataegus
monogyna*, can be a particularly important nectaring shrub in
wood-pasture. Various umbellifers also provide valuable nectar
sources later in the summer. Stocking levels should be low
enough to allow development of these areas of scrub and to
allow flowering of suitable nectar-providing plants within the
sward.

7.4.5 Grazing and browsing

Grazing and browsing by domestic livestock and wild deer
influence the:

- structure and species composition of the field
  layer and understorey and consequently their
  suitability for other species;
- long-term tree-species composition by affecting
  regeneration.

The effects depend partly on the type of herbivore, but particularly
on grazing pressure. Grazing and browsing characteristics of
different types of livestock are described in Section 5.4.1. Pigs and
wild boar create soil disturbance.

(p.210)
Grazing reduces the density of vegetation in the field layer and encourages low-growing grasses and bryophytes at the expense of taller grasses and forbs (e.g. Cooke and Farrell 2001; Figure 7.13). This reduces the suitability of the field layer for some small mammals.

Grazing helps maintain open conditions beneficial for warmth-loving, woodland-edge invertebrates, but also removes the food plants of some species.

Grazing helps maintain open conditions along rides and in glades.

Fig. 7.13 Grazing, browsing, and open understoreys. Grazing and browsing by domestic livestock and deer can greatly modify the structure and species composition of the field layer and understorey. Moderate to high levels of grazing and browsing remove the understorey, prevent regeneration of trees and shrubs, and encourage grazing-tolerant grasses and bryophytes at the expense of more palatable forbs. In the top photograph heavy sheep grazing of oak woodland is having a beneficial effect in maintaining the open conditions required by the wood's rich bryophyte flora (Borrowdale Woods, Cumbria, England).

Grazing and browsing of the understorey, in the bottom photograph by white-tailed deer, *Odocoileus virginianus*, can, though, also reduce foraging and nesting habitat...

Herbivores encourage tree regeneration by providing gaps in which tree seeds can germinate, but inhibit growth of seedlings by browsing. Seedlings can be released by reducing or excluding grazing, but this usually creates a dense, even-aged understorey. Regeneration of tree seedlings is often poor once grazing levels have been reduced, because of the lack of gaps for germination and competition with seedlings from tall grasses and forbs. Medium levels of grazing and variations in grazing levels are most likely to produce patchy and periodic tree regeneration.

Numbers of deer can be reduced by culling, followed by erection of deer fences to prevent re-colonization. Deer fences can, though, kill woodland grouse that fly into them. Collisions can be reduced by marking fences, although they may still result in unacceptable high levels of mortality to small and vulnerable populations of woodland grouse (Baines and Andrew 2003; Figure 7.14).

7.4.6 Burning
Burning profoundly influences tree-species composition and structure by killing fire-intolerant tree species, thereby allowing fire-tolerant tree species to attain dominance (Figure 7.15), especially species of fire-tolerant pines, oaks, *Quercus* spp., and *Eucalyptus*.

Fires in forests and woodlands can be divided into:
Forests, woodlands, and scrub

- surface fires which remove the litter, field layer, shrubs, saplings, and fallen dead wood but do not reach the forest canopy;
- crown fires that burn the canopy and kill large trees, causing a change in dominant tree-species composition.

Crown fires usually develop where high fuel loads result in a more intense fire that ladders up the lower branches of trees to reach the canopy. Prescribed surface fires can be used to:

- maintain the characteristic species composition and structure of fire-prone forests and woodlands and their associated species;
- prevent accumulation of large fuel loads (dead wood and other combustible material on or close to the ground) to reduce the likelihood of larger-scale, catastrophic crown fires (e.g. see Fernandes and Botelho 2003).

(p.212)

Using frequent surface fires to reduce fuel loads is known as ‘hazard-reduction burning’. Fuel loads can also be reduced by thinning. Suitable precautions should obviously be taken when burning, similar to those described in Section 5.6.
Prescribed surface fires are also used to encourage flush of regrowth of herbaceous plants to improve grazing. Burning of open habitats can be used to provide suitable conditions for germination and growth of seedlings of tree species, such as Scots pine (Hille and den Ouden 2004; Hancock et al. 2005), to aid forest regeneration. The key considerations when using prescribed surface fires are the:

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

\[ \text{Fig. 7.14 Deer fencing and woodland grouse. High, wire deer fencing in woodlands can substantially increase mortality of woodland grouse. The fencing is difficult to see and the grouse fly into it at high speed.} \]

Collision rates of grouse can be reduced by marking fences to increase their visibility. One of the most practical, cost-effective, and durable forms of marking involves attaching vertical lengths of wood, known as droppers, to the wire, as shown on the left. Few other bird species are thought to collide with deer fences in significant numbers (Abernethy, Highland, Scotland).
In practice, prescribed burning is restricted to times of year when it is easiest to control the burn, usually the cool conditions of late winter and spring. This will be at a different time of year to the majority of wildfires, which take place during the hottest and driest periods of the year. Therefore, as in other habitats, prescribed (p.214) fires burn less intensely than the natural wildfires that the vegetation has previously been subject to, and thereby probably have different effects. Burning should obviously not be carried out during the bird-nesting season. Burning in late winter and spring will probably interfere more with amphibian breeding activity than

*Fig. 7.15* Fire. This was formerly considered damaging to wildlife and natural fires were suppressed. Since then, research has shown that fire is an important, natural process that removes fire-intolerant plants and maintains characteristic fire-prone forest types. In the top photograph prescribed fire has been used to facilitate reproduction by giant sequoias, *Sequoiadendron giganteum*.

Prescribed burning and cutting and removal of vegetation are also used to reduce fuel loads to decrease the risk, or spread, of larger-scale, catastrophic fires. In the bottom photograph, cutting and burning have been used to remove the understorey in strips either side of a road to create a firebreak/fuel break. The road also provides access for fire-fighting
burning during hot, summer weather when many species shelter below ground. Wetter areas tend to remain un-burnt, providing refuges for species, and result in greater medium-scale variation in vegetation composition (e.g. Lilja et al. 2005).

The most common approach to determining the frequency of prescribed burning is to mimic the frequency of natural fires, reconstructed from fire scars on trees. Using fire scars to estimate fire intervals can, though, significantly underestimate the length of the fire rotation (e.g. Baker 2006b).

Frequent surface fires and thinning maintains a more open shrub layer and, by preventing shading, benefits herbaceous plants that require more open conditions and which are tolerant of, or regenerate well following, fire. The short-term reduction in litter, shrubs, and saplings caused by burning usually results in short-term increases in numbers of ground and aerial-foraging birds, but decreases in numbers of ground-nesting birds (e.g. Wilson et al. 1995; Artman et al. 2001). The open conditions also benefit some small mammals and invertebrates (e.g. Moretti and Barbalat 2004; Converse et al. 2006), and provide burnt dead wood for saproxylic invertebrates, which can otherwise be rare in areas that have been subject to fire suppression (Hyvärinen et al. 2006). The effects on fire on amphibians are less well understood. The open conditions created by burning and thinning will benefit some species, while others will be disadvantaged by the reduction in fallen dead wood and litter, and possibly by reduction in CWD in streams used for breeding (e.g. Schurbon and Fauth 2003; Bury 2004). The open conditions created by surface fires should also benefit many reptiles (Bury 2004). High frequencies of surface fires in ponderosa pine, Pinus ponderosa, forest in the western USA can result in invasion of unwanted, alien/exotic annual, grasses, similar to in dwarf-shrub vegetation in this region (Griffis et al. 2001; Dodson and Fiedler 2006; Keeley and McGinnis 2007).

The effects of burning on bird species-composition have been particularly well studied in forests managed to benefit red-cockaded woodpeckers in the south-eastern USA (Figure 1.1). Here, burning on a less than 5-year rotation, often
accompanying by thinning, has been used to remove broad-
leave trees and restore and maintain open pine-dominated
forests. This increases the densities of birds typical of open
pine-grassland habitats, such as red-cockaded woodpecker,
northern bobwhite, *Colinus virginianus*, and blue grosbeak,
*Passerina caerulea*, but decreases the densities of birds
associated with broad-leaved trees, such as tufted titmouse,
2002). Bachman's sparrows, *Aimophila aestivalis*, benefit
from short fire intervals (<3 years; Tucker *et al.* 2004).
Prescribed burning is also be used to kill stands of trees in
order to encourage desired stages of re-growth, and to
stimulate regeneration. In Michigan, USA, burning is used to
kill stands of old jack pine, *Pinus banksiana*, to provide young
(7–21-year-old) stands suitable for Kirtland's warblers,
*Dendroica kirtlandii* (Byelich *et al.* 1985).

Burning can also be combined with other forestry techniques.
In managed Norway spruce forests a combination of partial
harvesting, creation of dead wood, and burning has been used
to restore more natural post-burn characteristics (Lilja *et al.*
2005). In this example the production of large quantities of
fallen wood through partial cutting was important in
determining the intensity of the fire. It was only where high
quantities (60 m³/ha) of fallen wood were created that there
was a large enough fuel load to create a crown fire to kill
significant proportions of retained trees, and thereby create
valuable large-diameter burnt and dead wood.

**7.4.7 Integrating conservation management with commercial
forestry**

Forests managed for timber production usually contain only a
limited variety of tree species, lack structural diversity, and
the trees are harvested before they attain the important
features characteristic of older growth. The first consideration
when creating and managing commercial forestry for wildlife,
though, is avoiding planting trees on valuable open habitat.

High-forest management systems differ in their planting,
thinning, and harvesting regimes, resulting in differences in
their vertical and horizontal structure, age composition of
stands, and tree-species composition. There management
systems can be modified to benefit wildlife. Hence, a major
way of improving the value of forestry plantation for wildlife is
by modifying harvesting, thinning, and planting regimes. The other two main methods of creating these valuable features within commercial forestry are:

- creating and maintaining open rides and their junctions (Section 7.4.1) and planting favoured tree and shrub species along the edges of these rides;
- providing dead wood.

**Avoiding planting trees on valuable open habitat**

Commercially managed plantations are unlikely to ever be of equal or greater value for wildlife than existing semi-natural habitat, so they should obviously not be planted on areas of these. As when creating other areas of habitat, the effects (**p. 216**) on surrounding habitats should also be considered. For example, plantations may harbour widespread predatory species, such as crows and red foxes, which might detrimentally affect wildlife in surrounding areas. Planting of trees can also disrupt existing drainage systems. Studies suggest that avoiding forestry operation within 10 m of watercourses will be sufficient to protect the watercourse's physical and chemical properties, but that buffer strips of greater than 30 m are probably necessary to maintain suitable habitat conditions within the watercourse and its margins for wildlife (Broadmeadow and Nisbet 2004).

**Modifying planting, harvesting, and thinning regimes**

Systems of high forest management are described below. The most important ways in which these systems differ in the value for wildlife are in:

- their vertical and horizontal structure: variation in horizontal structure is greatest where only individual or small groups of trees are felled at any one time (selection and group-selection systems) and least where very large areas of trees are felled together (clear-cutting);
- the presence of more mature trees: these are only retained in variable retention harvesting.

Other factors that can be modified to benefit wildlife are the:

- densities of trees, which are influenced by planting densities and thinning regimes;
• type and mix of trees, particularly whether broad-leaved or coniferous;
• length of the harvesting rotation, since this will influence the age structure.

Systems in which felling and regeneration take place continually and irregularly throughout the forest are termed continuous-cover forestry (CCF), because they retain a continuous cover of trees over a given area. The main CCF techniques are shelterwood, selection, and group-selection systems. The alternative is clear-felling and strip and wedge felling, in which large blocks of trees are felled and re-planted at the same time. Clear-felling is particularly favoured on windy sites, where the numerous small gaps created by CCF techniques result in greater windthrow. CCF techniques are more suitable for so-called windfirm sites; that is, those not prone to windthrow.

**Clear-felling** and **strip and wedge felling** involve periodically harvesting all the trees from either a large (typically more than 0.25 ha) area (clear-felling) or in narrow strips (strip and wedge felling). The next cohort of trees can be planted or the area left to regenerate naturally (Figure 7.16a). Trees are periodically thinned to provide timber and space for retained trees to expand into (p.217)
comprising two age-classes of trees. Both age classes are felled at the same time.

(p.218)

(p.219) In the shelterwood system the next crop of trees is established beneath the shelter of an existing, open canopy. The existing canopy is thinned in stages (Figures 7.17a and 7.17b) to provide sufficient light for the establishment and growth of the next crop of trees beneath it (Figure 7.17c). This thinning can be carried out uniformly throughout the stand (uniform system) or in groups around existing patches of saplings (group system). This next crop is usually established through natural regeneration, but sometimes by planting. It is thinned as it grows up and the canopy of retained trees felled. During the establishment of

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**Fig. 7.16** Changes in stand structure during the clear-felling rotation. Xs indicate trees about to be felled. See text for details.

**Fig. 7.17** Changes in stand structure during the shelterwood rotation. Xs indicate trees about to be felled. See text for details.
this next crop, the woodland contains both a canopy and a developing understorey. Burning can also be used in combination with the shelterwood management to remove unwanted fire-intolerant tree species, for example to reduce competition with regenerating oaks by tulip poplars, *Liriodendron tulipifera*, and other undesired hardwoods in broad-leaved forests in the south-eastern USA (Lanham *et al.* 2002).

**Selection and group-selection systems** involve periodically harvesting individual trees (selection) or small groups of trees (group-selection). This creates gaps to allow existing trees with good timber potential to expand in size and natural regeneration of trees to take place (Figure 7.18). Group-selection forest consists of very small patches of even-aged trees. Selection systems create an even more intimate mix of different-aged trees. The difference between group-selection systems and clear-felling is really a matter of scale. Harvesting a very large group of trees, more than about 0.25 ha, would be considered clear-felling.

**Variable-retention forestry/green-tree retention** (GTR) involves retaining a proportion of live trees and snags during harvesting, as well as creating additional high-cut stumps (Figures 7.19a and 7.20a). The next crop is established among these retained trees (Figure 7.19b). The aim of this system is to provide a proportion of more mature trees among the subsequent crop, and increase the quantity of standing and fallen dead wood, both specifically for conservation (Figure 7.19c). Variable-retention forestry usually involves retaining blocks or dispersed trees within relatively large, clear-felled areas.

The complex vertical and horizontal structure produced by the selection and group-selection systems will tend to support a more diverse fauna and flora, especially of birds, than the even-aged, single-storied stands created by large-scale clear-cutting. Selection and group-selection systems more closely mimic the effect of small-scale, patchy tree-falls. Shelterwoods, by maintaining a more continuous canopy cover, will be better at preserving species requiring shady and moist conditions compared to clear-felling (Hannerz and Hanell 1997). *(p.220)*
Fig. 7.18  Changes in stand structure during the selection system rotation. Tree species intolerant of shade are shown in light grey and tolerant species in dark grey. Xs indicate trees about to be felled. See text for details.
Clear-felling creates large, even-aged, single storied stands, and more closely mimics the earlier stages of re-growth following large-scale disturbance, such as extensive windthrow or large-scale insect herbivory. Clear-felling usually provides less dead wood than other high-forest management systems (Sippola (p. 222))

Fig. 7.19 Changes in stand structure during the variable-retention forestry rotation. See text for details.
(p.223) *et al.* 1998). The effects of the other high-forest management systems are intermediate in terms of their effects on structural complexity.

**Fig. 7.20** Wildlife-sensitive commercial forestry. A number of methods can be used to maximize the value of commercially run forestry operations.  
(a) Creation and retention of standing dead trees (snags), and a proportion of unharvested commercially profitable trees, provide habitat for dead-wood invertebrates, feeding areas for woodpeckers, and nest sites for
Forests, woodlands, and scrub

| Retention of a proportion of trees during harvesting is now common practice in many areas, but its long-term effects are yet to be fully evaluated. In the first few years of re-growth, areas of forest where patches of trees have been retained support higher densities of breeding birds typical of more mature forest, particularly ground and tree-nesting and forest canopy-gap species, than in forest managed by clear-felling (Annand and Thompson 1997; Merrill et al. 1998). A high proportion of retained trees often fall over in the first few years following felling operations, 40% by the end of the second season following felling in a study of Norway spruce forest (Hautala et al. 2004).

The diversity of tree species and age composition can also be increased within individual stands, and by planting small stands of different trees species (Figure 7.20b). Tree-species composition can obviously be diversified by planting mixtures of tree species, and by retaining naturally regenerated native trees within planted blocks. There is evidence that species richness of birds on conifer plantations is greater if, for a fixed area of broad-leaved trees, these are dispersed throughout the

### Notes:

- **(b)** Increasing tree-species diversity by planting different tree species in small blocks and allowing commercially valuable tree species to regenerate naturally within them. This can increase bird-species diversity, but is unlikely to benefit habitat specialists of high conservation value (Omberg, Västergötland, Sweden).

- **(c)** Sensitive thinning can be used to create an open understorey, thus benefiting the field layer and associated species. Western capercaillie, *Tetrao urogallus*, feed on bilberry, *Vaccinium myrtillus*, in the open understorey of this 50-year-old managed stand of Scots pine (Yremossen, Västergötland, Sweden).
conifers, rather than concentrated in a few large blocks (Bibby et al. 1989).

In parts of Western Europe the main bird conservation interest of areas of coniferous plantations on sandy soils is in the bird assemblage associated with felled areas and the very early stages of tree growth (Figure 7.21).

Management to maximize timber production involves minimizing gaps in the canopy to maximize the light intercepted by the trees and converted to timber. This is achieved by planting trees at high density, and then thinning them to allow retained trees to expand into the gaps created. Maximizing canopy cover, though, inhibits development of an understorey, thus reducing the value of the forest for the numerous species dependent on it. The understorey can be encouraged by bringing forward thinning operations to create and maintain a more open canopy, although this will have commercial costs (Figure 7.20c).

**Providing dead wood**

Large-diameter dead wood can be increased in plantations by:

- creating high-cut stumps;
- retaining naturally dying trees;
- lengthening the rotation period to increase the quantity of dead wood produced by aging trees;
- retaining living trees at harvest, which will eventually provide dead wood as the trees age;

(p.224)
minimizing the quantity of fallen dead wood destroyed during preparation for the next crop.

Volumes of smaller diameter dead wood can be increased by retaining a proportion of harvesting residue. Retaining naturally dying trees and fallen dead wood and creating high-cut stumps provides significant quantities of CWD for a period following harvesting. Retaining naturally dying trees and creating cut stumps are especially cost-effective methods of providing dead wood. Lengthening the felling rotation increases the quantity of CWD towards the later stages of the rotation as trees age, but is a relatively expensive option (Ranius et al. 2005). A continuity of CWD throughout the felling rotation can, though, only be provided by also retaining suitable numbers of live, mature trees following harvesting (see variable-retention forestry) to provide a continuity of newly created dead wood (Ranius et al. 2003).

High stumps are created by cutting live trees with a harvester, typically to a height of about 4 m. The beetle fauna of high-cut stumps varies in relation to tree species and presence or absence of key decay fungi. Studies have also found total species richness of dead-wood beetles and that of red-listed species to increase with stump diameter and the degree of sun exposure (Lindhe and Lindelow 2004; Jonsell et al. 2005).

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Fig. 7.21 Heathland birds in forestry plantations. The conditions following planting of conifers on sandy soils provide suitable conditions for a range of birds typical of Atlantic heathlands. These species require bare, sandy soil (especially wood larks), short, open areas and scattered trees (tree pipits) and woodland edge, rides, scattered trees, and relatively young re-growth (Eurasian nightjars).

Suitable breeding sites for some early successional species, such as wood larks, can only be created by clear-felling moderate-sized blocks of trees (Bowden 1990; Thetford Forest, Norfolk, England).
High-cut, sun-exposed stumps tend to support a more limited range of species than natural stumps. This is probably because their uniform method of creation provides a more homogenous dead-wood resource compared to natural stump formation (Jonsell et al. 2004). High-cut stumps are also unlikely to support the full range of species associated with other types of dead wood, particularly dead wood in shade and that created by unmanaged, self-thinning deciduous trees and in old-growth (Jonsell 1998; Lindhe et al. 2005). The suitability of plantations for rare dead-wood beetles can be increased by leaving a higher proportion of standing live trees following harvesting and, in fire-prone boreal forests at least, by burning retained trees (Hyvärinen et al. 2006).

Logs retained during harvesting can support more diverse fungal communities than high-cut stumps, with larger-diameter logs supporting more species-rich assemblages (Lindhe et al. 2004) and being more valuable for dead-wood invertebrates (Nitterus et al. 2004). A large quantity of the volume of fallen CWD is, though, destroyed during scarification to prepare conditions for the next crop, for example 68% of it in one study (Hautula et al. 2004). The quantity of CWD retained through the felling cycle can be increased by:

• employing the least-destructive harvesting methods;
• reducing the use of scarification during preparation for the next crop;
• not removing trees from areas that already contain abundant dead wood.

Whereas all dead wood should be retained in woodlands and forests managed for nature conservation, a more pragmatic approach is necessary at sites where timber production is also an objective. Table 7.1 suggests some benchmarks to landowners on the quantities of dead wood to be retained in semi-natural broad-leaved woodland.

**Table 7.1 How much dead wood to retain?**

The following tables give suggested management to provide suitable quantities of dead wood to be retained for conservation in semi-natural broad-leaved woodland managed for timber production (from Butler et al. 2002). Methods for
calculating whether moderate, high, or very high levels of dead wood should be retained are given by Butler et al. (2002). These are based on the existing and potential value of woods for their dead-wood fauna and flora and the priority the landowner affords conservation. Butler et al.’s very high category (not shown) involves retaining all dead wood (as should be the case in all woodlands managed for nature conservation) and thinning 50-120-year-old stands to encourage the development of more than 20 veteran trees per hectare.

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<th>Management</th>
<th>Quantity of dead wood</th>
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<td>Minimum</td>
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<td>Minimum of an average of three</td>
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<td>standing and three fallen stems per</td>
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<td>(b) Stands of 50-120 years old</td>
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<td>Vary thinning intensity to improve crop</td>
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<td>to be retained for perpetuity and canopies</td>
</tr>
<tr>
<td></td>
<td>freed to allow full crown development</td>
</tr>
<tr>
<td></td>
<td>Twenty per cent of native stems per ha</td>
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<tr>
<td></td>
<td>to be retained for perpetuity and canopies</td>
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<td></td>
<td>Twenty per cent of native stems per ha</td>
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<tr>
<td></td>
<td>to be retained for perpetuity and canopies</td>
</tr>
<tr>
<td>Management</td>
<td>Quantity of dead wood</td>
</tr>
<tr>
<td>------------</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Percentage of cut wood retained on site</td>
<td>5</td>
</tr>
<tr>
<td>(c) Stands of greater than 120 years old</td>
<td></td>
</tr>
<tr>
<td>Percentage of fallen wood retained</td>
<td>100</td>
</tr>
<tr>
<td>Retention of standing dead wood</td>
<td>Five per cent of standing stems to be dead or contain significant dead-wood features</td>
</tr>
<tr>
<td>Thinning regime</td>
<td>Five per cent of native stems per hectare to be retained for perpetuity</td>
</tr>
<tr>
<td>Percentage of cut wood retained on site</td>
<td>5</td>
</tr>
</tbody>
</table>

(p.227)  (p.228)