The Conservation of Lower Plants in Woodland

Joint Nature Conservation Committee

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JNCC

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Glossary

crustose: crust-like; one of the basic forms of the lichen thallus.
ectomycorrhiza: a mycorrhiza growing on the outside of the host plant root, with little or no growth within the root.
endophyte: a fungus growing entirely within the tissues of another plant.
epiphytic: growing on other plants.
foliose: leaf-like, the thalli with a distinct upper and lower surface; one of the basic forms of the lichen thallus.
fruticose: bushy, tufted or beard-like, with thalli more or less radial or flattened in cross-section; one of the basic forms of the lichen thallus.
humicolous: growing on leafy debris and humus.
hypha: a fungal filament, many of which form the fungal mycelium.
lignicolous: growing on exposed wood (not bark).
Lobarion: a community of lichens, usually epiphytic, characterised chiefly by large foliose species in the genera *Lobaria*, *Sticta*, *Peltigera* and *Nephroma*.
macrolichen: an imprecise term used to distinguish foliose or fruticose species from crustose species.
mycelium: the body of a fungus, composed of hyphae.
mycorrhiza: an association of fungal hyphae and the root system of a vascular plant.
mycotrophic: deriving nutrients from fungi.
oceanic: referring to the damp, mild, western seaboard of Britain and Europe.
pleurocarpous: (of mosses) usually straggling, branched plants with inflorescences (and therefore capsules) produced on short lateral branches, rather than terminally on the main stem.
saprophytic: deriving nutrients from dead plant material.
saproxylic: deriving nutrients from dead wood (heartwood).
saxicolous: growing on rock.
symbiont: one of two organisms in a symbiosis (e.g. a fungus in a mycorrhizal relationship with a tree).
terricolous: growing on the ground.

1. Introduction

The fact that one of the major biological attributes of British semi-natural woodlands lies in their wealth of 'lower' plants has only recently been generally realised. Woods have long been valued for their flowers and birds, and of course for the trees themselves, but the bryophytes (mosses and liverworts), lichens and fungi have been less widely appreciated. This is now certainly changing among those involved with conservation, and the general public, too, is gradually beginning to appreciate the existence and value of the lower plants. Several important Flora projects are either underway or have been completed recently (for example, *The lichen Flora of Great Britain and Ireland*, Purvis *et al.* 1992), and these are bound to engender further interest in lower plants.

With the increased interest in the lower plants of woodland has come a desire among conservationists, and many others involved in woodland management, to manage woodland positively for lower plants, or at least in a way sympathetic to them. Lower plant conservation has suffered from a lack of precise experimental research on which advice can be based. While this is still the case, there is now a substantial and growing body of observational and circumstantial data that should be made available to woodland managers who wish to take lower plants into account. This document aims to present some of this information with a view to broadening the discussion on woodland management. Some of the material may be controversial, unsupported as it is by much rigorous experimental work, and any comments on it would be very much appreciated.

Fungi (including lichens), although not now generally considered plants, are treated as 'honorary plants' for the purposes of this document. Nomenclature of taxa mentioned in this booklet follows Hill, Preston & Smith (1991, 1992, 1994) for bryophytes; Purvis, Coppins & James (1994) for lichens; Buczacki (1992) for fungi, with the exception of a few rare species; Stewart & Church (1992) for stoneworts; and Kent (1992) for vascular plants.

2. The ecological importance of lower plants in British woodlands

Woodlands support far more species of lower plant than of vascular plant, and in many ways the lower plants are more significant, particularly in the west of Britain. Most of these woodland lower plants are fungi, bryophytes or lichens. Free-living algae are not an important component except for *Trentepohlia*, which sometimes forms extensive rust-coloured colonies on tree trunks; the pollution-tolerant *Pleurococcus*; and some freshwater communities.

Woodland fungi are important decomposers and vectors for the transport of nutrients. Woodland covers about one sixth of the world's land area and has the highest biomass of all habitats. Woody material contributes 90% of this biomass, and fungi are vital in recycling this resource. With their ability to break down cellulose and lignin, fungi are a crucial driving force in the carbon cycle. It is inappropriate always to regard fungi that cause decay of the standing tree as pathogenic. On the contrary, there is often a mutually beneficial relationship at work here, decay being an essential ingredient contributing towards the longevity of individual trees. Heart-rot fungi, usually regarded as pathogenic (wrongly, since heartwood is already dead), may actually be instrumental in prolonging the lives of trees. Most ancient trees are more or less hollow, because of the action of heart-rotting fungi, but still standing and alive. A hollow tree is perhaps more likely to remain standing than a solid one, as the loss of its core greatly reduces its weight with only a slight loss of strength (Green 1993).

The significance of mycorrhizae in the ecology of woodlands has only been widely realised in the last thirty or forty years. The association of the fungal hyphae with the tree's root system may be essential for the health and optimum growth of both symbionts, and it may be particularly important for the tree at the seedling stage. Indeed, some trees (e.g. pine) are obligately mycotrophic. Fungal mycelia permeate woodland both inside and outside the vascular plants and are central to the ecology of woodlands, redistributing nutrients in often unexpected ways. For example, yellow bird's-nest *Monotropa hypopitys* is a flower which lacks chlorophyll and draws nutrition from tree roots via a shared ectomycorrhizal mycelium (Rayner 1993). Carbon may also pass from tree to tree via the same network.

Many woodland invertebrates are dependent on fungi. Wood-boring beetles tend to require wood infected by fungi as most of the insects associated with wood-decay lack the enzymes necessary for digesting uninfected wood. The combined action of insects, fungi and rain can produce water-filled rot-holes which are the breeding places of numerous rare flies and beetles. Other invertebrates feed directly on fungi: fungus gnats (Mycetophilidae), a few species of moth and some beetles are dependent on the fruiting bodies of fungi, and several woodland molluscs show a preference for feeding on fungi. The invertebrate community associated with rotting wood changes as the fungal succession proceeds, and the invertebrates are more dependent on the type of decay than on the species of tree. It is possible that fungus-eating invertebrates are an important dispersal mechanism for fungal spores, since the invertebrates will seek out the correct niches for the fungi.

It is quite common for fungi to live inside the tissue of a tree with no apparent damage to the tree (non-pathogenic endophytes). However, they may become important pathogens when adverse environmental conditions put the host tree under stress. *Daldinia concentrica* on ash and *Hypoxylon fragiforme* on beech are thought to behave in this way, colonising and living in the wood unnoticed until the tissue becomes aerated, when they switch to a more active, pathogenic phase (Boddy & Griffith 1989). It has also been suggested that non-pathogenic endophytes could be beneficial to their host tree by protecting it from active pathogens (A. Rayner pers. comm.).

Oak mildew can be a serious foliage disease, resulting in a reduction in growth and acorn production and an increased susceptibility to attack from other parasites. Bark and shoot pathogens such as cankers can invade following physical damage and diseases of the acorn and the seedling (damping-off fungi, etc.) can also be economically important. Honey fungi *Armillaria* spp. are seldom primary pathogens on oak (although pathogenicity varies considerably between the species), but instead often work as a secondary agent on already weakened trees (Murray 1974). On the other hand, honey fungus can be a very destructive force in artificial situations, such as in conifer plantations on ex-hardwood sites.

The ecological importance of bryophytes and lichens may be less obvious than that of fungi, but in western woods they greatly outweigh the herbs, in terms of biomass, and contribute to maintaining the humidity regime, often holding large amounts of water. They are vital in limiting the effects of heavy rainfall, as they are capable of intercepting and absorbing large quantities of water (Gradstein 1992), which can then be released gradually over a period of days. Without this effect, streams and rivers in areas of heavy rainfall could be subject to catastrophic surges of water, which would lead to erosion and flooding downstream. They are also important in stabilising the ground on the steep slopes and banks characteristic of many western woodlands, and providing an infrastructure for other woodland organisms to live in and with. It is possible that trees benefit from having a coating of epiphytic bryophytes and lichens. Some scale insects can penetrate through some kinds of lichen but not others, so the idea of the lichens forming a 'protective layer' has some credence. The amount of ivy present on a tree may also be influenced (not that ivy is normally a problem for trees): ivy seems unable to put down roots on/through certain types of lichen, but can do so on others (Rayner 1993). Lichens are also important in nutrient cycling and as food and shelter for invertebrates.

3. Factors affecting lower plant diversity in British woodland

The composition of any woodland lower plant community is closely tied to the prevailing conditions. These include climatic factors, location and aspect, available habitats and microhabitats, pollution levels and management history.

In practice it is often difficult to distinguish between the effects of all these on the lower plant communities because the oceanic west side of the country is, coincidentally, also the area with the least pollution and the most rugged terrain: the mountains, ravines, boulder fields, etc., contrast with the softer, more gentle - and more polluted - landscapes of the south-east. The Weald of Kent and Sussex, where there is a limited development of Atlantic lower plant communities, provides a hint that many so-called Atlantic species might be more widespread in the south-east if the topographic conditions and substrates were available. The New Forest, where there is an extraordinary survival of extensive semi-natural habitats in a lowland area, also has a unique assemblage of lower plants and gives an indication of what the lower plant flora of other; now heavily modified, parts of Britain may have looked like in the past.

a. Climate

There is a wide variation in climate over the British Isles, and this is reflected in the lower plant flora. In the central south-east, in the vicinity of Cambridgeshire, the climate is 'continental' in character: dry, with annual rainfall below 750 mm and the number of 'rain days' (days with at least 1 mm of precipitation) below 120. Here there is a wide temperature fluctuation between the hot summers (July mean of 16-17 °C) and the cold winters (January mean of 3 °C or below). This contrasts with the western side of Britain, with its strongly 'oceanic' or 'Atlantic' climate: little temperature fluctuation and a lot of rain and atmospheric humidity. In these Atlantic areas, annual precipitation may average over 1500 mm, with more than 200 rain days per year, and mean temperatures may be 14 °C or less in summer and 5-6 °C or even more in winter (data from Hill, Preston & Smith 1991). Consequently many lower plant species and communities are more or less restricted to the west and a few other limited areas where more oceanic conditions occur locally (e.g. the Weald of Kent and Sussex). Lower plant growth is also more luxuriant in these areas. Some lower plants, particularly lichens, have eastern, continental, distributions. Most of these are inconspicuous species.

Trees in oceanic western woodland are usually quite different in appearance from their counterparts in the 'continental' east, simply because of the difference in lower plant luxuriance. In a western wood, the trunks are usually covered with epiphytes, often extending up the branches and even onto the twigs. Here, the bryophytes and lichens take full advantage of the high ambient moisture to reach their full potential. In contrast, the trees in eastern woods are not infrequently almost devoid of epiphytes, a combined effect of the climate and pollution. When epiphytes *are* present, there is a limited diversity of species, and these only occasionally ascend to high up on the trunk and onto the branches. Some parts of eastern Scotland, where atmospheric pollution has never been at a high level, do however have good epiphytic communities, though these are composed mainly of less conspicuous crustose lichens. In the east, bryophyte growth is usually extensive only on parts of the trunk corresponding to the relatively shady northern side of the tree or to a water drainage channel. In a western wood, bryophytes and lichens often grow all around the tree trunk.

Similarly, a wood in southern Britain is likely to have a different species composition to one in the north. In the south, the woodland lower plant flora may contain Mediterranean or other southern elements, whilst boreal species, perhaps more associated with Scandinavian woodland, appear in the north, and particularly in the north-east of Scotland.

b. Position and topography

The species composition of any wood depends to some extent on topographical factors, altitude and aspect. Valley woodland, being more sheltered and humid than hilltop woodland, and probably also less exposed to pollution, is likely to have a different lower plant flora. Woodland on a slope facing north-east has less exposure to direct sunlight than woodland on a south-facing slope, and so usually supports a richer bryophyte flora. However, the lichens are often richer in the more sunny woodland since, for the most part, lichens need plenty of light in order to flourish.

c. Geology and terrain

Geology is extremely important in the composition of the lower plant flora. A wood on, say, granite will have very different species to one on limestone or chalk. The harder rocks also tend to outcrop more than the soft ones, providing a greater variety of habitats for lower plants. However, where softer, more water-retentive rock is exposed it is often very valuable for lower plants, offering an ideal substrate, e.g. chalk faces, crumbling limestone, soft sandstone, etc.

Flat, dry, featureless ground is usually relatively species-poor, with only a small number of common species represented. The diversity increases with uneven or steeply sloping ground, cliffs, ravines, rock outcrops and the presence of rocks and boulders. Wet ground also tends to be more diverse than dry ground, often leading to much more luxuriant lower plant growth and sometimes more specialised communities such as *Sphagnum* carpets and bryophyte flush communities.

d. Forest structure

The structure of a particular piece of woodland depends to some extent on the factors of climate, position and substrate, discussed above. It is also largely determined by past and present management, tree species present, the humidity and shade regimes, and features such as rides, glades, paths, etc. The nature of the lower plant communities in a woodland depends in turn on these factors.

Many lower plants are restricted, because of their narrow ecological tolerance and often inefficient dispersal mechanisms, to areas of woodland, often ancient, that have not been subjected to drastic change for a long period of time. These woodlands are not exactly undisturbed, but any disturbance has been cyclical on a timescale compatible with the ecology of these species. Such species rely on the ecological continuity that the woodland has provided. Many only colonise trees of a certain age, when the bark chemistry is suitable and specialised niches such as rain-free crevices have formed. Most of the 'ancient woodland' bryophytes need a constant regime of humidity and shade, while the lichens often need more light, as found at the edge of woodland clearings and rides. Ancient woodland bryophytes and lichens are listed in *Guidelines for selection of biological SSSIs: non-vascular plants* (Hodgetts 1992). There are likely to be species of fungi which are restricted to ancient woodland, but no list of these exists at present. Orton (1985) listed some species that appear to be confined to Caledonian pine woodland.

Ancient woodland tends to contain a greater variety of structure (mainly because of the diverse age range of the trees) than recently planted woodland, leading to a greater diversity of habitats for lower plants. Lower plant habitats in woodland fall into three broad groups - epiphytic and other 'tree-based' habitats (heartwood, etc.), terrestrial or freshwater - and each of these tends to be more diverse in ancient woodland. Rides and glades can be important for lower plants too: communities normally characteristic of heathland, pasture or wetland can sometimes be found there. Many rare and scarce ephemeral bryophytes are as frequent in woodland rides as in more open habitats, because the microhabitat is just as suitable. Because of their very exacting habitat requirements, epiphytic lichens

are often remarkably concentrated, even in ancient woodlands, on sheltered but well-lit trees in or bordering glades and rides. In the valley woodlands of Exmoor, epiphytic lichens of the *Lobarion* community (explained below, page 10) are usually restricted to small pockets of ancient oak, ash and sycamore in the valley bottom. In contrast, the valley slopes are dominated by dense, neglected oak coppice which supports a less demanding epiphytic community (D. Boyce, pers. comm.).

Different tree species tend to have very different epiphytic floras, depending largely on the characteristics of the bark. For example, elder is the epiphyte tree *par exellence* for bryophytes, with base-rich, rough, spongy bark, with many crevices and ridges for plants to establish themselves on and in. Ash, willow and, although an introduction, sycamore are all good trees for epiphytes because of their base-rich bark. Elm was one of the most valuable trees before Dutch elm disease destroyed most of the mature elm population, and even exotic trees such as walnut and tulip-tree can be very rich, particularly ancient specimens in old parkland. Oak bark is intermediate in terms of pH, although it tends to become less acidic with age, but ancient oaks can be very rich in epiphytes, probably because the epiphytic flora on oaks has had a long time to develop in Britain, along with the native oak woods. Indeed, the native oaks have more species of epiphytic lichen recorded on them than any other British tree species (Rose 1974). Alder and birch, with their very acidic bark, are poor for epiphytes, as are conifers in most circumstances. Some trees vary in their diversity of epiphytes according to where they are. For example, sweet chestnut is usually very poor for epiphytes in Britain but in its native range (southern France to the Balkans) it is often the major host tree for rich *Lobarion* communities. Many species of fungus, both mycorrhizal and saproxylic, have a high degree of host specificity. The differences in leaf litter and shade produced by different trees also affect the composition of the woodland lower plant flora. For example, many woodland bryophytes and lichens cannot tolerate the deep shade and persistent leaf litter produced by beech.

4. Woodland types and communities of major importance for lower plants

British woodlands are internationally important for their lower plant flora. Ancient woodland anywhere in the country is likely to be moderately rich in all lower plant groups, within the constraints of the local climate and pollution levels and depending on recent management. Even secondary woodland overrun by sycamore and plantations of alien conifers can be of some value for fungi. A number of major areas of importance can be identified.

a. Atlantic woodland

Concentrated on the western side of Britain and Ireland, Atlantic or oceanic woodland is characterised by the cool, wet climate with few temperature extremes and the luxuriance of bryophyte and lichen growth. In the National Vegetation Classification (Rodwell 1991), the richest examples belong to NVC type W17 (*Quercus petraea-Betula pubescens-Dicranum majus* woodland), with the most bryophyte-rich sub-community being W17a, the *Isothecium myosuroides-Diplophyllum albicans* sub-community. Good Atlantic bryophyte communities, very rich in Atlantic species as defined by Ratcliffe (1968) and Averis (1991), can also be found in the *Blechnum spicant* sub-community of *Quercus petraea-Betula pubescens-Oxalis acetosella* woodland (W11b). However, Atlantic woodland exhibits a wide variety of habitats and microhabitats according to substrate, aspect, altitude, etc. (see above). Typically, rich Atlantic woodland will be on a north-east facing rocky hillside dissected by shady, humid ravines. Though often over-grazed, these woodlands have a conspicuous lower plant flora, with boulders, tree-trunks and branches thickly covered with bryophytes and lichens. Even ultimate branches are often festooned with lichens such as *Usnea* and have cushions of the moss *Ulota* growing on them. Hazel is usually a rich substrate in these conditions, and supports a great variety of crustose lichens in particular. The presence of base-rich rock exposures greatly increases the species list. These woodlands are among the richest habitats for bryophytes and lichens in Europe (Hodgetts 1993).

The most well-known epiphytic lower plant community is the *Lobarion pulmonariae*, described, along with the other lichen communities mentioned below, by James, Hawksworth & Rose (1977). The *Lobarion* is principally a tree-trunk community characterised by large foliose lichens such as *Lobaria* spp., *Sticta* spp. and *Nephroma* spp., along with conspicuous squamulose species such as *Pannaria* spp. and *Parmeliella* spp., and bryophytes such as *Frullania tamarisci* and *Isothecium myosuroides*. This community reaches its optimum development in unpolluted Atlantic woodland, particularly in more open stands where there is slightly lower precipitation and the tree bark pH is *c.* 5.0 or above (F. Rose pers. comm.) and on individual isolated trees in Atlantic areas. In natural conditions it would be the climax epiphytic community in north-western Europe, but it has unfortunately disappeared from most areas because of tree felling and pollution.

On more acidic substrates, the *Lobarion* tends to be replaced by the *Parmelion laevigatae*. This community dominates in Atlantic areas subject to the leaching effect of extremely high rainfall and in areas further east (e.g. the Cowal Peninsula, Argyll) or south (e.g. Cumbria) which receive significant impacts of 'acid rain'. It is characterised by *Parmelia* spp., *Menegazzia terebrata*, *Sphaerophorus globosus* and *Ochrolechia* spp. Bryophytes such as *Plagiochila spinulosa*, *P. punctata* and *Scapania gracilis* are also much in evidence. However, in areas more exposed to sea-spray (e.g. western Skye) the *Lobarion* tends to replace the *Parmelion laevigatae*.

The community characteristic of smooth bark and twigs is the *Graphidion scriptae*, which consists predominantly of crustose lichens, most conspicuously of the genus *Graphis*. This alliance can be very rich in crustose lichens in Atlantic areas, and is also characterised by the presence of small cushion-forming mosses of the genera *Ulota* and *Orthotrichum*, along with hepatics such as *Lejeunea ulicina*, *Frullania dilatata* and *Radula complanata*.

The lower plant communities of Atlantic woodland include many near-endemic species and species with widely disjunct distribution patterns. Atlantic woodland on the west coast of Scotland is the richest of its kind in Europe for bryophytes and lichens, and a small ravine woodland may contain about 200 species of each group. In the favourable climate of Atlantic woodland, lower plant communities that are typically epiphytic often spread onto boulders, especially near the coast. However, there are also distinctive saxicolous communities to be found. Possibly the most characteristic, and the most diagnostic of a 'good' site for Atlantic bryophytes, is the community of minute liverworts which forms thin wefts over shaded, damp or humid rock, often more-or-less vertical, where the more robust species have difficulty in obtaining a hold, often in the splash zone of waterfalls or at the sides of streams in ravines. Most of the characteristic species of this community are liverworts in the family Lejeuneaceae: *Lejeunea patens*, *L. lamacerina*, *Aphanolejeunea microscopica*, *Cololejeunea* spp., *Drepanolejeunea hamatifolia*, *Harpalejeunea ovata* and occasionally *Colura calyptrifolia*. These are usually mixed with slightly larger liverworts such as *Radula aquilegia*, *R. lindenbergiana*, *Frullania microphylla* and *F. fragilifolia*, and in very rich sites the rare *Acrobolbus wilsonii*, *Lejeunea mandonii* (a globally threatened species), *Radula voluta* and *R. carringtonii* may be found. Some of these species also occur as epiphytes, and it is possible that this phenomenon was more common before human modification of the structure of many woods.

Typical bryophyte communities of boulders in the woodland consist mainly of larger, tuft and hummock-forming species, including the liverworts *Bazzania trilobata*, *Lepidozia cupressina*, *Scapania gracilis*, *Plagiochila* spp. and (a good indicator of canopy continuity) *Adelanthus decipiens*, with the mosses *Hylocomium* spp., *Rhytidiadelphus* spp. and *Dicranum* spp. The abundance of large hummocks of pleurocarpous mosses in Atlantic woodland does not necessarily indicate a rich site:

these hummocks tend to be composed of a few robust grazing-resistant species. Characteristic lichens of boulders in Atlantic woodland include many *Cladonia* spp., *Peltigera* spp. and *Sphaerophorus globosus*.

The composition of terricolous communities depends upon the grazing regime and the slope. Level ground is usually bryophyte-dominated, with large hummocks of robust pleurocarps such as *Rhytidiadelphus loreus*, *Hylocomium splendens*, *H. brevirostre* and *Sphagnum* spp. Sloping ground, particularly steeply sloping rocky banks, tends to be very much richer, with an intimately mixed community of mosses and liverworts, and to a lesser extent lichens. Communities characteristic of wetter ground may occur locally, richer in *Sphagnum* spp. and with *Hookeria lucens* and *Trichocolea tomentella* sometimes present.

Streamside communities are frequently rich and varied in Atlantic woodland. There is a zonation of vegetation, with *Hyocomium armoricum* often conspicuous just above the water level, along with *Brachythecium* spp., *Racomitrium* spp. and *Thamnobryum alopecurum*; submerged, or subject to periodic submergence, are *Rhynchostegium riparioides*, *Hygrohypnum* spp. and more rarely *Rhynchostegium lusitanicum*, *Fissidens polyphyllus* and *Isothecium holtii*. Communities of crustose lichens such as *Verrucaria* spp. also grow on stream rocks, and submerged algal communities become important too, with species of *Hildenbrandia*, *Batrachospermum*, etc.

b. Caledonian pinewood

This very restricted community is more or less unique to the Scottish Highlands. Falling into NVC type W18, *Pinus sylvestris-Hylocomium splendens* woodland, it has very characteristic lichen and fungus communities, with many species confined to it. It is richest where the pine cover has an unbroken history back to the ancient natural pine forest. Pine plantations on previously unwooded ground have an impoverished lower plant flora even after several centuries of tree cover. Orton (1985) listed fungi confined to this habitat, and also provided lists of fungi that occur both in pine woodland and in conifer plantations.

Several of the most characteristic communities grow on the bare, very hard lignin of dead trees and branches, the 'bones' of pine trees so often found in ancient pinewood. Some associations of the *Calicion hyperelli* community are characteristic of this habitat in eastern and central Caledonian pinewood. It is composed of small crustose species of lichen, particularly of *Chaenotheca* and *Calicium*, which have their fruits elevated on small stalks above the thallus. Western Caledonian pinewood tends to support other characteristic species, such as *Cavernularia hultenii*, *Alectoria sarmentosa*, *Hypogymnia bitteriana*, etc. Other characteristic pinewood lichens include species of *Xylographa*, which have their fruits elongated along the grain of the wood, *Platismatia glauca* and some species of *Bryoria*. *Bryoria furcellata* is capable of colonising old fence posts, in areas of pinewood where it is well established! Few lichens are common to both Caledonian pinewood and western oak woodland but mixed stands can be rich.

There are numerous fungi whose natural home is Caledonian pinewood, but many of these can grow in coniferous plantations as well (Orton 1985). Some are, however, confined to the pinewood, including *Suillus flavidus*, *Lactarius musteus* and *Rozites caperata*. Other typical pinewood fungi include boletes such as *Boletus badius* and *B. pinicola*, and species of *Cortinarius*, *Pholiota*, *Russula* and *Tricholoma*. The habitat is particularly rich in ectomycorhizal fungi such as tooth-fungi of the genus *Hydnellum* (e.g. *Hydnellum caeruleum*, *H. peckii*, *H. ferrugineum*) and *Bankera fuligineo-alba*.

In the NVC, the *Scapania gracilis* sub-community (W18e) is an oceanic pinewood community rich in Atlantic bryophytes and lichens. The *Sphagnum capillifolium*/*S. quinquefarium* sub-community

(W18d) is also rich in bryophytes, with deep tussocks of *Sphagnum* species, particularly the two species mentioned, and often an abundance of the beautiful moss *Ptilium crista-castrensis*.

c. Pasture woodland and parkland

This type of open woodland may contain well-spaced ancient trees which are of unsurpassed value for lichens and fungi. Parklands are often also very rich in invertebrates characteristic of dead wood and ancient trees (Harding & Rose 1986; Kirby & Drake 1992). Parkland in a British sense is now almost unknown elsewhere in Europe, although it was widespread in France, Spain, Germany and other western European countries until the 19th century. Indeed, F. Rose (pers. comm.) is aware of only one old *Lobarion*-rich parkland that survives in continental western Europe (north of Pamplona in Spain). Parkland is widely distributed in Britain, and is very susceptible to damage from atmospheric pollution and agricultural spray-drift, particularly in the south and east. Much parkland is now unfortunately in a moribund condition, with the lower plant interest being confined to a few very old trees and no tree regeneration taking place.

The main value of parkland and pasture woodland lies in the presence of very old trees, which provide the continuity of substrate so important for the scarcer epiphytes. These trees are usually more-or-less isolated, and therefore receive a substantial amount of direct sunshine on the south side, which favours the growth of many lichens. In parks where the pasture has remained 'unimproved', the trees will have escaped the worst effects of fertiliser and herbicide drift. In some parts of the country this combination of factors means that parks are often the only remaining sites for many lichens. The interest of many parks has, unfortunately, been destroyed or much reduced by increasing the livestock density, application of fertilisers and herbicides, and even by ploughing up the pasture for conversion to arable.

Old, unpolluted parks, with plenty of ancient trees, are a characteristic habitat for the *Lobarion pulmonariae*, and are the last outposts of this community in some parts of Britain. (See above for a description of the main features of this community.) Some associations of the *Xanthorion parietinae* alliance are also characteristic of ancient parkland, mainly in the south of Britain, particularly in drier, more open stands which either have or have had in the past herds of domestic grazing stock (preferably cattle). Bark pH can apparently be raised to 6.5 or more by windblown dust enriched with ammonia from animal urine or faeces, and levels of nitrogen and phosphorus are also raised (F. Rose pers. comm.), leading to conditions favourable for the *Xanthorion*. Of course, too high a stocking density, or an excessive use of artificial fertilisers, can be disastrous, leading to a bloom of algae on the trees to the detriment of the lichens. Species of *Xanthoria* and *Physcia* (*sens. lat.*) are typical of this alliance, along with *Ramalina*, *Caloplaca*, *Buellia* and more rarely *Teloschistes flavicans*, *Anaptychia ciliaris*, *Parmelia acetabulum*, *P. quercina*, *P. tiliacea* and *P. laciniatula*. Species of *Parmelia* such as *P. pastillifera*, *P. quercina* and *P. borreri* are characteristic of one community found mainly on very well-illuminated upper branches in the extreme south of England. Most of the species mentioned here require well-lit mature tree trunks of the sort now almost restricted to parkland sites.

Ancient trees in parkland and pasture woodland can be of great importance for fungi. The 'over-mature' stage in the life cycle of a tree is the very point at which numerous species of fungi, particularly brackets, become important in its ecology, rotting down heartwood. Many of these species are highly host-specific, and therefore rely entirely on the presence of a particular species of tree of a suitable age. Sites such as Windsor Great Park, Berkshire, where there are numerous ancient oaks, also support an exceptional range of fungi, including rare species such as *Boletus regius* and the bracket fungi *Buglossoporus quercinus* and *Phellinus robustus*. The New Forest, Hampshire, is the only remaining locality known for the wood-rotting fungus *Hericium erinaceus*. Numerous woodland

fungi can also occur in parkland, if an appropriate management regime is practiced.

Old parkland trees can sometimes have important bryophyte communities, with *Leucodon sciuroides*, *Tortula laevigata* and *Orthotrichum* spp. often present. The beautiful moss *Leptodon smithii* can be found in this habitat in the south of England. The rare *Habrodon perpusillus* should always be looked for.

The most remarkable area of pasture woodland in Britain is the New Forest, the largest area of this type of woodland in north-western Europe, the largest area of lowland semi-natural vegetation in Britain and one of Britain's richest sites for epiphytic lichens. However, several other smaller, but very rich, areas of pasture woodland remain in Cornwall, Devon, Dorset and Sussex; all are former or extant deer parks of mediæval origin. The importance of pasture woodland for lichens (amongst other things) was highlighted by Kirby *et al.* (1995).

Stone walls are a subsidiary interest of parkland, particularly in some areas of lowland England, often supporting a rich assemblage of saxicolous lichens in areas where natural rock exposures are rare. These should be maintained on a long cycle to preserve the lower plant interest.

d. Scrub

While not matching the three categories above in importance, scrub of many different kinds, from elder thickets in inner city wasteland to oceanic hazel scrub, is often very rich in epiphytic bryophytes and lichens. Elder, sometimes poorly rated by conservationists, is particularly suitable for epiphytes as it has a spongy, base-rich bark of high natural pH (6.0 or above) that appears to be efficient at buffering pollution effects. When growing in a dense thicket, where pollution is to some extent filtered out and humidity is locally high, its epiphytic flora can be exceptional. Coastal willow scrub is also often a rich habitat.

The value of scrub for lower plants lies mainly in the epiphytic bryophyte flora and sometimes in the lichen flora. Even in eastern areas, elder thickets and the various kinds of willow scrub may support pollution-sensitive bryophytes such as *Lejeunea ulicina*, *Ulota crispa*, *U. phyllantha*, *Orthotrichum* spp., *Metzgeria* spp., *Cryphaea heteromalla*, *Frullania dilatata* and *Radula complanata*, as well as the more usual pollution-tolerant bryophytes such as *Aulacomnium androgynum*, *Hypnum cupressiforme*, *Lophocolea heterophylla*, *Bryum flaccidum*, *B. capillare*, *Rhynchostegium confertum* and *Amblystegium serpens*. Rich *Xanthorion*-type lichen communities can often develop on elder, particularly near the coast, and carr is also often rich in lichens. The lichen *Teloschistes chrysophthalmus*, not seen in Britain since 1966, was an epiphyte of scrub (particularly Rosaceae) in southern England.

Occasionally, rarer species such as the liverwort *Cololejeunea minutissima* may be found in sheltered humid scrub. Swampy riverside scrub may also support scarce or uncommon species, including the mosses *Amblystegium varium* and *Myrinia pulvinata*. Box scrub in the Chilterns has recently been found to support the liverwort *Metzgeria fruticulosa* growing on leaves, the first time this phenomenon has been observed in southern Britain.

Scrub in western areas is usually even richer, with species of *Ulota* common, along with Lejeuneaceae, Frullaniaceae, and even semi-pendent colonies of *Plagiochila* and other leafy liverworts. *Ulota calvescens* is particularly characteristic of hazel scrub in Atlantic areas. Strangely, species of *Orthotrichum* seem to become more scarce in oceanic areas where *Ulota* spp. tend to take their place. Crustose lichens are also very common, principally members of the *Graphidion* communities described above, and often also larger, foliose and fruticose species.

e. 'Dwarf' woodlands

Some specialised 'dwarf' communities of woody species exist in upland areas, such as Wistman's Wood on Dartmoor and *Salix* stands in the Scottish mountains. The former is rich in bryophytes, although there is evidence of a catastrophic decline in the pollution-sensitive moss *Antitrichia curtipendula* in recent years (Proctor, Spooner & Spooner 1980). Montane *Salix* stands can support rare mycorrhizal fungi such as *Amanita nivalis*.

f. Other woodlands

Many woodlands not included in the above categories can also include a wide range of habitats available for colonisation by lower plants. Some of the more obvious ones are discussed here, but there is a myriad of other microhabitats that there is not space to include. As a general rule, the more diverse the habitats within a woodland, the more diverse the lower plant flora.

i. Bryophytes and lichens

Outside Atlantic areas, the presence of Atlantic elements and a diversity of epiphytes can be indicative of a woodland rich in bryophytes and lichens generally. Ash is often the best woodland tree for epiphytes, and frequently supports colonies of mosses such as *Ulota* and *Orthotrichum* spp. It is the usual host for the scarce (but possibly increasing) moss *Platygyrium repens*. Many lichens also favour ash bark as a substrate, as it seems to resist the pH-lowering effect of acid rain to some extent. Sycamore can also be a valuable tree for lichens, for the same reason.

Features such as springs, streams, rivers and waterfalls support characteristic aquatic bryophytes, lichens and algae, and the neighbouring rocks, banks and trees may be havens for humidity-demanding species that are rare in south-eastern or midland areas.

Swampy areas may be rich in terricolous bryophytes, with *Hookeria lucens* and *Trichocolea tomentella* occasional in flushes. Tufa formation with extensive swards of *Cratoneuron commutatum* can sometimes occur in calcareous springs in woodland. The higher ambient humidity and sheltered nature of swampy woodland often means that the epiphytes are locally much richer than elsewhere in the area. Wet birchwood can support *Sphagnum* communities, and the blurred margins between heathy woodland and scrubby heathland can also be valuable for bryophytes and lichens.

Other terrestrial features in a wood that tend to increase species diversity include ditches, woodbanks and old pits. Rock features nearly always increase the lower plant diversity, particularly in sheltered and unpolluted situations. Sheltered cliffs or crevices among boulders often provide havens for species normally found in more oceanic areas. These species are often difficult for the untrained eye to detect, but are of great importance when assessing the bryophyte flora of a wood (see above for more detailed descriptions of oceanic communities). The wooded sand-rock sites of the Weald are a prime example of this, supporting internationally important bryophyte communities on the damp sandstone rock exposures.

Trees with sloping trunks are often more valuable for epiphytes than very straight trees, particularly in the south and east. This may be because moisture is held more readily on a sloping trunk. Trees at the woodland edge or around forest glades or rides are often particularly rich in lichens, because of the extra light they receive. As mentioned above, rides and glades are in themselves often important for species normally associated with non-woodland habitats.

Epiphytic communities of lichens and bryophytes can sometimes be found on individual isolated trees, particularly those with base-rich bark such as ash, elm and sycamore, or in small wooded patches. The communities are similar to those described for parklands, but are often restricted to the base of the trees in polluted areas.

ii. Fungi

Woodland fungal communities are more difficult to define than bryophyte and lichen communities because the species are not as constantly visible as the bryophytes and lichens, except when they are in fruit. Watling (1974) gives five categories of macrofungi in oak woodland, and these are broadly applicable in other woodlands too (Watling 1984, 1992):

1. Parasites
2. Suspected mycorrhizals
3. Lignicolous saprophytes i.e. on woody debris
4. Humicolous saprophytes i.e. on leafy debris and humus
5. Associated elements.

The parasites, or pathogens, attack living trees and include numerous species of great ecological and economic importance (see above). Each species of tree has its own suite of pathogens, and different fungal pathogens may attack different parts of the tree at various times of the year. The fungal pathogens of oak were described by Murray (1974).

Mycorrhizal species tend to be among the most visible fungi in woodland, often producing conspicuous fruiting bodies. Members of the Russulaceae and Boletaceae, in particular the genera *Russula* and *Lactarius*, are among the most prominent fungi that are mycorrhizal with British woodland trees. Some species of these two genera seem to have a close correlation with ancient woodland (F. Rose pers. comm.). Many species of *Cortinarius* and *Leccinum* are particularly associated with birch woodland, and *Boletus* with oak woodland. The chanterelle *Cantharellus cibarius* is a mycorrhizal species. Generally speaking, a diversity of tree species of different ages and long ecological continuity lead to a diversity of mycorrhizal fungi in woodland. A stand of Sitka spruce in an area of otherwise broadleaved woodland can increase the species list for a site considerably, as numerous mycorrhizal species may be associated with this tree. However, these are not specific to Sitka spruce, but opportunists that derive mainly from native birch and pine woodlands (Alexander & Watling 1987). Indeed, Sitka spruce tends to support fewer mycorrhizal fungi than either Norway spruce or European larch, and is much less rich than native pinewood, so in relative terms it is still a poor tree for fungi. In Britain, the relative richness of Norway spruce and larch may be, in part, because they have been in the country longer and therefore tend to have older stands (V. Fleming pers. comm.).

Wood, both standing and fallen, is of great importance for fungi that are lignicolous saprophytes, as has already been mentioned. Most of these fungi are not specific to particular kinds of wood, but there are about 20 species which seem to be specialists of oak stumps, trunks and branches, including the well-known beefsteak fungus *Fistulina hepatica* and dryad's saddle *Polyporus squamosus*. Many species colonise the heartwood of living trees. A section through a tree will often reveal intricate patterns of competition between different species of fungus, and also competition between different colonies of the same species (defined by black 'zone lines'). The results of this kind of territorial behaviour have been likened to a battlefield by Rayner (1993). Some fungi even specialise in inhabiting the zone between competing colonies (Rayner 1976).

Saprophytic fungi of leafy debris and humus are a varied group, but species of *Mycena* and *Marasmius* are often prominent, along with other small species of primary decomposer.

The final category of fungus descibed by Watling (1974) is a mixed bag of epiphytes, dung fungi, fungi of bonfire sites, etc. Epiphytic fungi are most abundant in Atlantic woodland, where the trees have extensive bryophyte cover and the moist climate favours many species of fungus.

It is often possible to use the fungal flora of a wood to interpret its history. Fungi characteristic of certain types of woodland often persist long after the woodland itself has changed or even disappeared. For example, fungi typical of pinewoods may persist in highland birchwoods (Watling 1984) long after the pine itself has disappeared. The extent to which the fungal composition of a site depends upon species of tree or upon other factors, such as soil pH, is not clear, but it is likely that all the various factors interact in a complex way.

The fungus flora of ancient woodland in the south-east and midlands of Britain can be very rich. A greater diversity of trees usually leads to a greater diversity of mycorrhizal species, and the presence of plenty of standing and fallen dead wood is usually indicative of a rich fungus flora. 'Over-managed' woods, where the dead wood is removed and stacked or burned, tend to have an impoverished fungus flora. It is possible that a greater diversity of types of dead wood and leaf litter in a woodland inhibit the spread of pathogens, such as certain forms of honey fungus, through increased competition from other fungi. This competition may be much reduced or absent in an even-aged stand of a single tree species.

To summarise, many species of fungus rely on trees as a substrate and as a host, and often also as a source of nutrients, from microscopic 'mirror fungi' growing on the living leaves, endophytic fungi growing inside the tissue of the leaves and woody parts of the tree without causing any obvious symptoms, to heart-rot fungi and other potentially pathogenic or saproxylic fungi which usually make their presence known by producing fruiting bodies. Very old trees are particularly valuable for fungi, as well as for a huge range of insects. Indeed, the fact that they have reached an advanced age at all is probably due in no small part to their relationship with fungi (see above).

5. Management

Woodland management for lower plants is far from being a simple affair, and may sometimes conflict with the management of woodland for other groups. The main difficulty with recommending management prescriptions for lower plants, as with their conservation in general, is that little formal research has been done on the subject. Most of what follows is based on anecdotal information and more or less casual observation. However, enough is now known for the following advice to be given with confidence. Inevitably, substantial areas of uncertainty still remain, and where possible it would be valuable to put some of the recommended management prescriptions to the test. Therefore forest managers are invited to comment on the chapter, act on it, and report on the results. Unless otherwise indicated, the management recommendations below all refer to ancient semi-natural woodland or secondary woodland of long standing.

a. General points

To recommend that a piece of ancient semi-natural woodland rich in lower plants should not be felled may seem almost too obvious a piece of advice to be worth writing down. In general, however, the conditions that are needed to maintain a good woodland lower plant flora are those of medium shade and reasonably constant, high humidity. Well-lit but sheltered glades have almost certainly always been a feature of more natural woodlands because (at least in part) of the uneven grazing of large herbivores and the effects of fungal pathogens. The New Forest ancient woodlands may be our closest surviving examples of what the 'wildwood' looked like. However, grazing levels in the New Forest are currently considerably higher than in other near-natural forests in the temperate zone (K. Kirby pers. comm.). Clear-felling removes shade, reduces humidity drastically and destroys epiphyte substrate. It also takes away dead wood and, if the stumps die, it removes the hosts of ectomycorrhizal fungi, as some of these may rely on a continuity of *living* tree roots on a site (V. Fleming pers. comm.). Replanting clear-felled ground with introduced conifers is as damaging to most lower plants as it is to other wildlife. Although conifer plantations can be rich in fungi, this does not necessarily make them a conservation priority, since conifer plantations are not an indigenous vegetation type. Replanting with trees native to the region is better, but is no substitute for retaining ancient semi-natural woodland with a varied structure and diversity of tree species.

Rock outcrops and boulders frequently provide refugia for shade-loving species eliminated from elsewhere in the wood by previous large-scale felling. A canopy should be retained in these areas to encourage the spread of these species back into the woodland proper. Ancient trees, as noted above, can be particularly important. Any felling proposals should seek to ensure that the maximum age range of trees is preserved.

In managing a piece of woodland for lower plants, there are several basic things to consider.

- What geographical region is the woodland in?
- What is the lower plant interest?
- What other wildlife interest is there in the woodland?
- What other factors have to be taken into account (e.g. farming, amenity)?
- What (therefore) are the management objectives and prescriptions, and who is going to implement them?

In an ideal world every wood would be managed according to detailed management guidelines laid down *specifically* for that wood, taking into account the conservation of all the biological interest of the wood. In practice, this is not usually possible (at least not in detail, for every biological group), but broad management strategies can be identified and are set out below. These are therefore compromises between blanket statements and having a different management prescription for every site.

b. Coppicing v. high forest

The long-standing debate on the relative merits of managing woodland for conservation by coppicing or by maintaining high forest is something of a red herring, as the management of any particular piece of woodland should depend entirely on what the major biological significance of that piece of woodland is. Different taxonomic and ecological groups require different forms of management. Only occasionally will the same piece of woodland be of equal interest for two or more groups with different management needs, and even then compromise is usually possible. A useful table, showing woodland types and their relative suitability for coppice restoration from a nature conservation viewpoint, was provided by Kirby (1993).

In recent history, coppicing has been practiced more in some parts of Britain than in others. It was common in woodlands in lowland Britain until very recently (about 40 years ago), and in upland areas until about 80 years ago, but was then largely abandoned, with the exception of sweet chestnut woods in south-eastern England. Chestnut coppice is still actively managed in parts of south-eastern England, although suffering some decline, and it can be important for mosses and hydnaceous species of fungus, particularly where the stools are old and large. Coppicing is now returning on a limited scale, particularly in some woods managed for nature conservation. In Scotland the practice has been less widely used in recent centuries, but in earlier times may have been more widespread than is generally supposed. Coppicing in Ireland declined very early (most Irish woodland having been lost) and has indeed all but died out (Rackham 1990).

Responding to different management regimes, variations in climate, geology and biogeographical differences in British woodlands, different woodland floras have evolved in different parts of the country. In the south-east and midlands, where coppicing of ancient woodland is (or was) the normal practice, there is often a rich herb layer, with orchids, *Primula* species (most notably *P. elatior* in the boulder clay woodlands in the 'continental' area of south Cambridgeshire and Bedfordshire), and a wealth of other 'ancient woodland' herbs. The paucity of bryophytes and lichens in these woods is often equally striking. For example, Bradfield Woods, Suffolk, has only 15 epiphytic lichens in 1 km^2, in contrast with the ancient pasture woodland of Horner Combe, Somerset, where there are at least 176 in 1 km^2 (Rose 1992).

The abundance of spring flowers that typically occurs for a few years after coppicing is a response by the ground flora to the extra light that coppicing admits. In a more natural woodland, these plants would be less abundant and less vigorous, being prominent only in naturally-formed glades and along woodland margins, and occasionally thriving when the canopy is destroyed by gales. Coppicing causes a cycle in which the temporary opening up of the canopy, with a consequent admission of direct sunlight and reduction of the ambient humidity, alternates with very dense shading of the stems. Few epiphytic lichens seem able to withstand this drastic regular environmental fluctuation, and so coppicing can be highly detrimental to the lichen flora. This may be of less concern in the east and midlands, as the lichen flora is likely to be poor anyway, owing to airborne pollution. In the west, however, coppicing can be damaging. In the hazel woodland on Eigg, Gilbert (1984) found that the areas richest in epiphytes were those least disturbed by coppicing. Most hazel coppice in western Scotland is poor in epiphytes. The flora is richer on hazel that has 'coppiced itself' naturally (i.e. regrown branches after the eventual collapse of old limbs), as in the woods near Lochinver, in Sutherland (F. Rose pers. comm.). On the other hand, some stands of short rotation ash and willow coppice in the Netherlands have been found to support excellent epiphytic bryophyte communities. This is because, by and large, bryophytes are more opportunistic than lichens and can colonise more quickly. Also, the dense shade cast by some stages of coppice is probably less damaging to bryophytes than to lichens. It thus appears that air pollution is the main factor restricting the growth of bryophytes in active coppice in eastern England.

Flowering plants are often relatively poorly represented compared to lower plants in western oakwoods. Adopting a 'high forest' style of management, with no clear-felling, is therefore more appropriate because it avoids the disruption of the moisture and light regimes associated with coppice that severely limit the growth and diversity of epiphytes.

If coppicing is to take place at all in a wood rich in lower plants, the lower plant flora should be surveyed thoroughly beforehand. It is crucial to know what the main features of interest are, and whether the species and communities are mainly lovers of humidity and shade (as are many bryophytes) or of light and warmth (as are many lichens). However, because of the often 'mutually exclusive' distributions of important bryophyte and lichen communities, it is often possible to target active management such as coppicing and thinning on the floodplain and sunnier slopes, while retaining a more *laissez faire* high forest regime on the north-facing slopes (D. Boyce, pers. comm.). Frequently, rich woodland bryophyte floras and rich woodland lichen floras do *not* coincide.

In areas where coppicing is practiced, it is advisable to retain some parts of the woodland in 'high forest' management, with minimal intervention ('non-intervention' is not an option in most modern woodlands). This is necessary because even in areas where bryophytes and lichens are not abundant, the fungi require the range of habitats provided in high forest to reach their maximum diversity.

c. Grazing

The question of grazing - whether one should and, if so, how much and with what - is a perennial headache for those who manage habitats for nature conservation. It is rather difficult to make firm rules on grazing in woodlands important for their lower plants because of the lack of formal research. However, it is well worth remembering that our rich woodland lower plant flora developed over millennia when large herbivores were probably plentiful, so one would expect that stock grazing at moderate levels would help these communities. Furthermore, there is now enough circumstantial evidence available to allow some recommendations. Direct grazing of lower plants by stock is seldom a problem, as they are often unpalatable because of thick cell wall material or the presence of unpleasant chemicals, and they offer little nutritional return for large animals. Lichens are sometimes grazed, but bryophyte gametophytes very rarely are. Smaller animals, most notably molluscs, frequently graze fungi, lichens and bryophyte capsules, but not usually to the extent that it is a conservation problem. Indeed, slug grazing may actually be an important vector for the dispersal of propagules. Fungi are, of course, eaten by many animals but these are simply fulfilling part of their ecological rôle, and grazing of fungal fruiting bodies cannot be considered a conservation problem. Indeed, the dispersal of truffles *relies* on foraging by mammals.

Broadly speaking, the management of grazing in a wood rich in lower plants is a matter of balancing the benefits of a low level of grazing against the drawbacks of too high a level. A low level of grazing controls the growth of rank vascular plants, allowing the bryophyte layer to flourish by removing competition, and preventing heavy shading of tree boles by dense masses of sapling trees and shrubs (particularly holly, in some areas). F. Rose (pers. comm.) has observed dramatic declines in epiphytes when former pasture woodland has had stock (or deer) totally excluded, and the same decline may well occur in other types of woodland if grazing ceases completely. However, a certain amount of vascular plant growth is beneficial in many circumstances, where the additional shade and protection offered to a rock exposure by, say, a patch of brambles, may be important for some species. Grazing must not, of course, be so high that tree regeneration is prevented, but regeneration need only occur in episodes that may be decades apart in order to sustain a woodland. Mitchell & Kirby (1990) came to the conclusion that a low level of grazing by large herbivores in woodland provides a greater diversity of vegetation structure and species composition than either overgrazing or a complete absence of grazing.

In western oakwoods, it is sometimes perceived that lower plants benefit from heavy grazing, because woods subjected to it often have sparse herb and shrub layers and large cushions of moss. However, these cushions are nearly always composed of a few common robust species which happen to be unpalatable to sheep. In fact, a high stocking density can be as damaging to lower plants as to vascular plants, resulting in eating, trampling, rubbing, nutrient enrichment and poaching. On the other hand, many western oakwoods form an important winter refuge for deer and sheep, and in many cases their presence seems to be beneficial to the epiphytes, as they control development of scrub. There is also evidence (Orton 1985) that the production of fungal fruiting bodies is suppressed by the growth of rank grasses, but most abundant in deer- or sheep-grazed swards. Anecdotal evidence suggests that cattle are damaging in this respect. According to Orton (1985) the introduction of cattle into highland woods can be disastrous for the agaric flora, because of the large quantites of dung they produce and, because they are heavy animals, the physical damage to the fungal mycelia. Orton goes on to suggest that "not more than twelve or fifteen cattle roaming over a large area might do little harm, for they will obviously cause less damage than a large herd restricted to a small area. Even in a large area a large herd can cause considerable damage to the agaric flora".

Clearly, then, grazing of some sort is beneficial, but the level and type is critical. Even in the New Forest, grazing levels have locally tended to become too low (F. Rose, pers. comm.), resulting in 'explosions' of holly, and shading out of lower plants, both epiphytic and terrestrial. Too little grazing is a problem in many pasture woodlands. Coppicing and pollarding of the holly soon leads to a dramatic improvement in the epiphytic lichen flora (Sanderson 1991).

Preliminary results from studies in Naddle Wood, Cumbria, (Averis 1992) appear to show that the optimum grazing level for bryophytes there is controlled, light grazing in the winter months. At higher levels, several prominent hummock-forming mosses seem to be favoured, but there may be a detrimental effect on other species, largely because of poaching, nutrient enrichment and physical damage resulting from grazing and rubbing. It has even been postulated that the ideal level of grazing in western oakwoods is that which results from the odd stray sheep or deer breaking through a completely fenced wood.

In wet woodland, the presence of cattle can be very damaging to fragile flushes and streamsides, and they should be excluded wherever possible.

Excessive levels of grazing in parkland can lead to physical damage to epiphytic lichen and bryophyte communities. Sheep and cattle tend to congregate underneath the large isolated trees for shelter, and epiphytes are rubbed off. They can also suffer in this situation from enrichment from stock urine and dust.

The other major problem caused by grazing is the the inhibition of regeneration caused by the destruction of tree seedlings. This is particularly marked in western oakwoods, where the combination of deer and sheep often make it quite difficult to find an oak seedling, and woodlands are becoming senescent (although the age of individual trees is usually not great). Fencing small exclosures within woodland may be done to enable tree regeneration to take place but adequate light *must* be provided. This may mean felling a small group or enlarging an existing gap by felling, say, one or two trees, but this may, in turn, lead to a denser growth of scrub which would have to be thinned. Larger areas can be fenced to exclude grazing animals, but this is expensive and may result in too much shade (see above). Another possibility is to use individual tree tubes to protect seedlings from grazing. Management suggestions for a heavily grazed, bryophyte-rich, neglected oak coppice in the Lake District (Kirby, Mitchell & Hester 1994) included fencing areas under gaps in the canopy and protection of individual trees in glades.

Regeneration is also usually prevented in parkland unless individual tree seedlings are adequately protected against the depredations of roving stock.

The effects of overgrazing can be quite dramatic in the Scottish highlands where the deer population has increased in recent years to unprecedented levels. Consequently there is very little natural regeneration in some Scottish woodlands, and this is particularly unfortunate in the internationally important Atlantic oakwoods and Caledonian pinewoods. These are gradually becoming more and more senescent, even moribund in some cases, rather like some English parklands. Better management of deer (and sheep) populations in the uplands is seen as a matter requiring urgent action

(Scottish Natural Heritage 1994). Short term remedies include fencing large areas of woodland, which is expensive; fencing smaller exclosures; and planting individually protected trees. Birch and probably rowan will rapidly colonise deer exclosures if there is a nearby source of seed. Oak will also probably appear of its own accord eventually, though it might be desirable occasionally to plant it (see below).

d. Replanting

In most woodlands replanting of trees should not be necessary in order to maintain the wood's lower plant interest. Natural regeneration should suffice if the level of grazing is not too intense. Often, replanting in native woodland is a waste of time, and it can damage the wood if the choice of species is inappropriate or the pattern and scale of planting is too unnatural.

However, in a minority of cases replanting is advisable, for example in moribund parkland. Where there are ancient trees supporting interesting lower plants but there has been no tree regeneration to ensure a supply of future host trees, replanting is a means of providing the next generation of trees in the shortest possible time. However, the newly planted trees are unlikely to provide suitable habitat for at least a couple of centuries and it is most important that the ancient trees are conserved in the meantime. Considering the long time scale involved and the 'shock' that transplanting causes to any tree, it may be better to regenerate parkland by promoting germination of tree seed *in situ* rather than try to gain a few years by planting saplings. Ideally, regeneration should use the existing ancient trees as a seed source, thereby ensuring the genetic stock of the new generation is as close as possible to the existing trees. It is also important that all the tree species which are native to the site are included in the regeneration programme. Occasionally the lower plant interest is found on exotic tree species, including sycamore, Norway maple, walnut and tulip tree, and in these cases it is advisable for these exotic species to be included to some extent within the regeneration programme in order to give the best chance of providing the correct habitat for the lower plant community in the future. Mature sycamores in parks can provide excellent epiphyte habitat, supporting lichen communities naturally found on elm, oak and ash.

Planting can also be used where quick results are required when, for example, an area rich in Atlantic bryophytes has become, or is becoming, too open, and delay (while awaiting natural regeneration) might result in communities disappearing. As indicated above, replanting of certain species can be a partial remedy for overgrazing by deer, and may be necessary in Caledonian pinewood (pine) or Atlantic woodland (oak) that has become moribund through overgrazing.

In other situations, planting may be used sparingly as a tool, but it should be remembered that woodland processes are very slow by human standards, and it may be better just to 'let nature take its course' under the correct grazing regime, even though this is a slow alternative.

Urban situations with interesting lower plants may be special cases where more extensive planting is justified. For example, natural regeneration of exotic species often takes place, in the absence of any grazing pressure, leading to new, 'artificial' communities. It may be best simply to accept these for what they are, along with any concomitant lower plant interest, rather than try to replace them with 'natural' communities. It is not unlikely that any planting of, say, oak in an urban situation, where the soil may be thin and superimposed on rubble, will eventually fail anyway.

e. Pollarding

This ancient method of tree management had largely fallen into disuse, but there has been a recent resurgence of interest in it as a management tool for retaining ancient trees (Read 1991). Pollarding may be particularly valuable as a means of prolonging the life of ancient lichen-rich trees in parkland. Re-pollarding old pollards and the formation of new pollards from younger maiden trees in some circumstances are also beneficial to many epiphytes, as they may prolong the life of important old pollards and let in more light to the trunk. Techniques vary from tree to tree, but there seems to be general agreement that at least one limb should be left on a neglected pollard after re-pollarding, or there is a risk of killing the tree. This is especially the case with beech. There may be interesting lichens growing on the upper part of the tree that would be removed by pollarding (though this is not usually a problem), and this should be ascertained before any work commences. Epiphytes further down the tree may also be affected by pollarding, and trees should be comprehensively examined by specialists before pollarding starts so that damage to important epiphyte colonies can be avoided.

f. Dead Wood

The importance of dead wood in the woodland environment has already been stressed, particularly as a habitat for saprophytic fungi, which are central to the ecology of most broad-leaved woodlands (Alexander & Green 1993). Wherever possible, standing dead wood should be left standing, and fallen dead wood should be left where it has fallen, where it can interact with the forest-floor fungi. Also, at least some 'lop and top' from felling and thinning should be left on the ground as a substrate for fungi. Dead wood arranged in stacks is considerably less valuable as a substrate because the upper layers of the stack tend to desiccate. The worst of all possible dead wood management is to burn it. This in effect shortens the woodland nutrient cycle and leads to a depletion of material available for recycling by decomposition, thereby diminishing the fungal diversity of the woodland.

g. Introduced conifers

As has already been said, introduced conifers are generally of low value for lower plants. However, they occasionally support a limited epiphytic flora in the west of Britain, and stands of them should not be disregarded, as many fungi are characteristically mycorrhizal associates of conifers. Mature specimen trees in well-lit situations can support notable lichen species. The habitat of the very rare moss *Buxbaumia viridis*, listed on Schedule 8 of the Wildlife & Countryside Act 1981, is rotting conifer stumps and logs (including Norway spruce).

Mature coniferous forest can be a rich habitat for lower plants, as is demonstrated by spruce forest in Scandinavia and silver fir forest in the central European mountains, where these trees are native and often form stands of ancient forest. However, conifer plantations in Britain are managed on a short rotation (usually about 55 years), so they rarely reach the mature stage in which they could support a rich lower plant flora. It would be interesting to let some areas of spruce plantation grow on indefinitely, to see if anything approaching the Scandinavian old-growth forest develops. Indeed, establishing areas of old-growth conifer plantation as long-rotation stands for the benefit of the fauna and flora has been suggested recently by several authors (Peterken 1993; Peterken *et al.* 1992; Ratcliffe & Petty 1986).

Other habitats within conifer plantations can of course be important for lower plants, e.g. rides, streams, ditches, rocks, flushes, small areas of broadleaved woodland, and these should be considered in the management of any plantation.

h. Invasive species and the effects of herbicides and fertilisers

One of the main management problems in many woods on acid substrates, particularly in the west, is the spread of *Rhododendron ponticum*, which takes over large areas of woodland at the expense of native vegetation. Woods rich in lichens and bryophytes tend to be particularly suitable for the growth of rhododendron, and while many species can withstand a degree of shading, the rhododendron can eventually become so dense that even these plants are shaded out. Once rhododendron has been removed from a wood, the lower plant flora is usually capable of recovery. This has happened at Dinnet Oakwood in Grampian, where rhododendron eradication has been followed by an increase in lichen colonisation, both on the ground and on tree trunks (O'Dare & Coppins 1995).

Rhododendron is notoriously difficult to control, the most effective methods being labour-intensive and expensive, and often the only option is to limit its spread rather than eliminate it completely. The best way of dealing with it seems to be cutting it off at the base and treating the stump with a herbicide such as glyphosate, followed by several years of pulling up seedlings as they appear. Direct spraying of mature rhododendron plants should be avoided, as this is potentially damaging to the lower plants and ineffective as a means of rhododendron control. If resources are limited, it may be advisable to limit activity to the removal of seedlings in newly-colonised and outlying areas, rather than tackling the 'core area' of mature rhododendron immediately. The effects of herbicides on lower plants have not been thoroughly investigated. Casual observations suggest that many bryophytes may be killed or damaged by herbicides but preliminary studies by Perkins & Marrs (1993) have shown that at least some species of lichen are only damaged at very high concentrations.

The spread of beech may also be a threat in some areas where it is not native, such as in the Exmoor valley woodlands, where it seems to be associated with a very poor epiphytic lichen flora (D. Boyce, pers. comm.). The shade-tolerant seedlings of this tree are much less palatable to sheep and deer than those of oak and ash, and beech is therefore capable of being very invasive. Although little is known of its effects on lower plants, it is likely that the deep shade cast by its foliage and its deep leaf litter accumulations are detrimental.

Other invasive exotic woody species that may be damaging to the lower plant flora include sycamore, cherry laurel and holm oak. In the same way, even native species such as holly are capable of being a threat in some areas. Clearly, different species are threats in different parts of the country and in different habitats: whereas sycamore may be a valuable substrate tree for lichens in parkland and secondary woodland, it may be an invasive nuisance in ancient woodland.

Bracken usually has little direct effect on woodland lower plant communities, as it tends to cover large areas of relatively uninteresting ground, from a lower plant viewpoint. However, the shade it casts on tree bases may be detrimental to lichen communities. Where it is a problem, the usual way of dealing with bracken is to spray it with a herbicide such as asulam. This seems to have a minimal effect on lichens, except at very high concentrations (Payne & O'Dare 1990). It should only be used with water as the dispersant; wetting agents should be tested carefully before use as some are toxic to lichens (R. Woods pers. comm.). Herbicides have a more severe effect on delicate leafy liverworts and on some of the rarer ferns. Payne & O'Dare (1990) found that the herbicide Roundup had the least effect on lichens of the herbicides tested. Any area being considered for treatment with an anti-bracken herbicide should be surveyed for lower plants in as much detail as practicable beforehand. It is possible to give physical protection to important lower plant communities during spraying using polythene sheeting. In areas with a concentration of lower plant interest, which are likely to be limited in extent, physical control of bracken should be considered: repeated cutting of young growth will usually be effective in three to four years.

In general, spraying of any sort should be kept to a minimum, or preferably not used at all, in a woodland with a rich lower plant flora, although the sort of direct spraying used in 'spot weeding' usually has little effect on woodland lower (or higher) plants as a whole. Spraying should always be done on a still day. It is preferable to use chemicals in pellet form when applying fertiliser to grassland in parkland, rather than as sprays or dust. Spray drift from surrounding land may also affect lower plants (Perkins & Marrs 1993), particularly in relatively open situations such as parkland.

Enrichment of substrates by fertiliser drift is probably more of a threat than outright damage to the plants from pesticides and herbicides. Brown (1992) cites several studies showing that addition of nitrates and phosphates often favours the growth of vascular plants at the expense of lower plants. The effects of fertiliser drift can be seen in many parks in the midlands, where the lower parts of trees are often covered with a layer of algal growth, with few or no lichens present. Spray drift can be minimised by planting thick hedges or shelter belts on boundaries likely to be affected. Perhaps adjoining landowners could be persuaded to reduce the use of pesticides and fertilisers in a zone abutting the wood, and only to spray on still days.

i. Pollution

Pollution is perhaps the most insidious and least controllable threat to lower plants. It is well-documented that lower plants are, in general, more sensitive than vascular plants to atmospheric pollution (Barkman 1968; LeBlanc 1968) and that high levels of pollutants in the atmosphere have a detrimental effect on many lichens and some bryophytes. Furthermore, short episodes of high levels of atmospheric pollution may be at least as detrimental as prolonged exposures at lower levels (Wolseley & James 1991). In woodlands the effects of atmospheric pollution are often most noticeable at the relatively exposed boundaries, so the degree to which this boundary effect can penetrate into the wood can be controlled to some extent by maintaining boundary thickets. The exposed tops of hills and edges of ravines are also susceptible to air pollution, and lower plant interest is often confined to the deepest, most sheltered ravines in polluted areas such as the midlands. Of course it is often difficult to distinguish the effects of pollution from those of other exposure-related factors such as wind, relatively low humidity and high light intensity.

Historically, the most important atmospheric pollutant limiting lower plant growth and distribution has been sulphur dioxide, SO_2. However, SO_2-sensitive species have tended to increase in many urban areas in recent years, with the enforcement of the Clean Air Act, the general reduction of SO_2 levels in power station emissions, and the wider dispersion of SO_2 because of the introduction of taller chimneys. SO_2 oxidises to H_2SO_4, leading to acid deposition. This is less directly toxic to lichens than atmospheric SO_2 but it acidifies the bark of trees and rock surfaces, so changing the composition of lower plant communities.

At present some of the most important atmospheric pollutants are those emitted principally from vehicle exhausts, such as hydrocarbons and nitrogen oxides, both of which are precursors of 'ozone smog', and atmospheric nitrates. In excess, these are all detrimental to lower plant health. Nitrification is particularly damaging. Most lower plants thrive in environments with a low nitrate input, and are quickly out-competed by coarse and weedy vascular plants, or sometimes nitrate-demanding species of algae, when nitrate levels are excessive.

Woodland managers should keep a watching brief on any possible new industrial developments in their area which could affect the lower plants. This is particularly important in the west. For example, if a coal-fired power station were to be built on the west coast of Scotland, the consequences for the internationally important lower plant communities in the area could be disastrous. The predominant epiphytic lichen community in south-west Argyll, within reach of the industrial centres of Glasgow

and Belfast, is already the acidophilic *Parmelion laevigatae* (see above), while further north in the west of Scotland the more pollution-sensitive *Lobarion pulmonariae* community is more widespread.

Capsule production in at least some bryophytes is thought to be affected by atmospheric pollution. Several species (e.g. *Homalothecium sericeum*, *Rhytidiadelphus triquetrus*) apparently produce capsules readily in areas where the air is relatively clean, but only rarely or not at all in polluted areas. The fruiting of many lichens, notably *Lobaria* species, is also thought to be adversely affected by pollution.

There is evidence that mycorrhizal fungi are sensitive to pollution such as 'acid rain', and that some observed declines in tree health may be directly attributable to the effects of acid rain on the mycorrhizal fungi (Schmitt 1990). Pollution may also act directly on trees, stressing them to such an extent that they become vulnerable to attack by pathogenic organisms. Nitrogen deposition may also have an impact on the production of fungal fruiting bodies.

Water pollution may be a threat to lower plant diversity in some woodland streams and ponds. It is known that some riverine lower plants (such as the Schedule 8 lichen *Collema dichotomum*) are sensitive to water pollution. Eutrophication of water bodies and water courses can lead to an expansion of nutrient-demanding algae at the expense of other lower plants.

Climate change, partly or wholly caused by pollution, may also result in changes to our woodland lower plant flora.

j. Rearing game birds

Many woods, particularly small farm woods, are used for rearing pheasants and sometimes other game birds. This can mean large, artificially open, fenced-off areas where most of the ground is covered by straw and where there is a damaging amount of nitrification and general disturbance. Operations like this should be discouraged in woodland rich in lower plants, or at least limited in extent, so that the most valuable areas are not affected. It is often possible to accommodate both open, dry, pheasant-rearing areas and closed-canopy, damp areas rich in lower plants within a single wood.

k. Collecting

There are two kinds of collecting that can affect lower plant communities: indiscriminate and discriminate. The first kind occurs when, for example, large amounts of woodland moss are raked up for horticultural use in hanging baskets, etc. This kind of activity affects mainly common species but can disrupt whole moss communities, and may sometimes unwittingly destroy rarities. Whether or not it is a problem depends on where it is happening. It is potentially highly damaging in bryophyte-rich ancient semi-natural woodland, but not in conifer plantations. Activities of this sort should therefore be directed towards woods of low importance for nature conservation, such as recent plantations. It is possible for landowners to prosecute unauthorised moss-collectors under the Wildlife and Countryside Act 1981 or the Theft Act 1968.

The other kind of collecting (discriminate) includes collecting by botanists for scientific and allegedly scientific purposes and collecting fungi for food. This is a potential threat to rare species, and the locations of these species are sometimes (though not often) kept secret in order to protect them. Collection of small samples may often be necessary for the identification of certain species. In this case, *bona fide* scientific collecting should not be discouraged, and collection even of species specifically protected by the Wildlife and Countryside Act 1981 is possible under licence from the appropriate statutory conservation agency. If collections are to be made from a site where it is known that there is the possibility of collecting a protected species 'by accident', a permit can be obtained beforehand.

Fungal communities *may* be damaged in the long term by excessive collecting, although a low level of collecting is unlikely to be harmful. If the same site is visited over and over again, trampling and destruction of phanaerogamic vegetation may become serious, damaging the fungi. The reduction in spore-producing ability following collection may well be detrimental to many species, particularly the rarities. It is really a question of scale. While small-scale collection of fungi for scientific, educational or gastronomic purposes should not usually be regarded as a threat (indeed, should be encouraged), large-scale commercial operations of the sort seen recently in the New Forest and parts of Scotland are potentially damaging. Damage is likely to occur through impact on the habitat rather than by any direct effect of picking the fruiting bodies.

Any collecting of species listed on Schedule 8 of the Wildlife and Countryside Act 1981 (Appendix 1) without a permit can be penalised by prosecution under this Act. Collecting of other plants should only be done with the landowner's permission.

l. Other human activities

There are other miscellaneous activities that take place in our woodlands which may threaten lower plant populations. British woodlands are regarded as a recreational resource as well as a nature conservation resource, and excessive walking, climbing and scrambling can all damage sensitive areas. Walkers should therefore be encouraged to keep to paths, and scrambling, particularly by large organised parties (such as those operating from outward bound centres), should be discouraged on steep, rocky slopes rich in bryophytes and lichens. Climbing should be discouraged on cliffs with good lower plant floras.

Other activities such as cross-country cycling, motorbike scrambling and orienteering should all be well-controlled and restricted. Paint-ball war games, very popular in some parts of the country, are capable of taking over large areas of woodland and inflicting considerable damage upon it. English Nature, along with the European Paintball Sports Federation, have produced useful guidelines on this subject in a leaflet (English Nature 1994).

m. Site protection

Many of our finest lower plant sites have some measure of protection through nature reserve or SSSI designation, and it is mainly these sites which will be managed specifically for their lower plant interest. More Atlantic woodland sites may need to be protected to ensure adequate representation, and other important woodland sites either remain unprotected, or have protection but are managed with little regard for the lower plants. Many geological SSSIs are of great importance for lower plants. These sites should not, therefore, be de-notified without first checking the lower plant interest which may provide grounds for re-notification as biological SSSIs.

Even theoretically well-protected sites often find themselves under threat from a variety of ill-conceived schemes, from hydro-electric projects and reservoirs to urban and industrial encroachment. Woodland managers need to look out for these threats, and, if possible, have the arguments to counter them.

Some important lower plant sites that include habitats identified in the EC Habitats and Species Directive (e.g. old oak woods with holly and hard fern) will be designated Special Areas of Conservation (SACs). These will first be notified as SSSIs if they do not already have that status.

This is important for lower plant conservation, as it is an acknowledgement of the richness of the British lower plant flora, compared to that of many other parts of Europe.

n. Species protection

Sixty-one of the most rare and threatened lower plants in Britain have now been added to Schedule 8 (the list of protected plants) of the Wildlife and Countryside Act 1981 (see Appendix 1). Further threatened lower plants that occur in British woodlands have been or will be listed in Red Data Books for Britain and Ireland.

Four British lower plants appear on Annex II of the EC Habitats and Species Directive and on Appendix I of the Bern Convention, but only one of these can be considered a woodland plant. This is the moss *Buxbaumia viridis*, recorded very rarely in the central highlands of Scotland, usually on well-rotted conifer stumps.

o. Relationships with other groups

As mentioned above, woodland management for lower plants will occasionally come into conflict with the management needs of other groups of organisms. These difficulties can usually be overcome by good communication between specialists and woodland managers. *Habitat management for invertebrates* (Kirby 1992) is a particularly valuable text to consult.

6. New woodland

There is a great enthusiasm in some quarters for planting new woodland. This enthusiasm can often be somewhat mis-directed. New woods are no substitute for old and ancient woods, and the lower plant flora of newly-planted woodland will initially be composed of a residue of whatever was there before the trees were planted.

If possible, new woodland should be allowed to develop naturally, without planting trees. This gives the substrate time to mature, and woodland lower plants will slowly colonise the wood as time goes on. If planting is carried out, a diverse native flora can be encouraged by ensuring that the trees are native species, preferably of local provenance, and that the planning, planting and management of the wood are all done in the light of local knowledge and with sensitivity for the local flora and landscape. A new woodland is more likely to be colonised by the lower plants which are typical of ancient woodland if it is sited close to an ancient woodland. It is not possible to say how large a gap is bridgeable and it is usually assumed that the narrower the gap, the more chance there will be of species spreading from the ancient wood to the new one. However, woodland edges are a valuable habitat for both plants and animals, especially when they receive direct sunlight. Therefore, new woodland should not be planted so close to existing woodland that it will cast shade over the wood edge. A broad ride, preferably curved so as to reduce wind, should be left between the old and new woods, with occasional short narrow lengths which will provide continuous shady corridors between the two sites. Even then, many lower plants characteristic of ancient woodland may not colonise the new woodland for several centuries, if at all.

New woodland should be designed to contain a diversity of habitats, whether or not conservation is the main objective. An even-aged, close-planted 'sward' of trees is of little value. Therefore, a staggered programme of planting should be adopted (if planting is used at all), with features such as ponds, glades, rides and uneven margins programmed in from the start.

The intended site of a new wood should be thoroughly surveyed before woodland creation begins. It is a disservice to conservation if new woodland destroys good existing habitat, such as a long-standing piece of wet heathland.

Subsequent management of new woodland should take account of the recommendations given in previous chapters.

7. Conclusions

There are only five main conclusions, which are summarised here.

a. British woodlands are very important nationally and internationally for lower plants.

b. This importance should be acknowledged and followed by selection of areas for protection and management.

c. There is a need to enthuse people with the beauty and value of the lower plants in our woodlands.

d. In general, the conditions needed to maintain a good woodland lower plant flora are medium shade and reasonably constant, high humidity.

e. New woodland is no substitute for ancient semi-natural woodland.

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Appendix. Lower plants on Schedule 8 of the Wildlife and Countryside Act 1981

Mosses

Acaulon triquetrum	triangular pygmy-moss
Barbula cordata	cordate beard-moss
Barbula glauca	glaucous beard-moss
Bartramia stricta	rigid apple-moss
Bryum mamillatum	dune thread-moss
Bryum schleicheri	Schleicher's thread-moss
*Buxbaumia viridis**	green shield-moss
Cryphaea lamyana	multi-fruited river-moss
Cyclodictyon laetevirens	bright green cave-moss
Ditrichum cornubicum	Cornish path-moss
*Drepanocladus vernicosus**	slender green feather-moss
Grimmia unicolor	blunt-leaved grimmia
Hypnum vaucheri	Vaucher's feather-moss
Micromitrium tenerum	millimetre moss
Mielichhoferia mielichhoferi	alpine copper-moss
Orthotrichum obtusifolium	blunt-leaved bristle-moss
Plagiothecium piliferum	hair silk-moss
Rhynchostegium rotundifolium	round-leaved feather-moss
Saelania glaucescens	blue dew-moss
Scorpidium turgescens	large yellow feather-moss
Sphagnum balticum	Baltic bog-moss
Thamnobryum angustifolium	Derbyshire feather-moss
Zygodon forsteri	knothole moss
Zygodon gracilis	Nowell's limestone moss

Liverworts

Adelanthus lindenbergianus	Lindenberg's leafy liverwort
Geocalyx graveolens	turpswort
Gymnomitrion apiculatum	pointed frostwort
Jamesoniella undulifolia	marsh earwort
Leiocolea rutheana	Norfolk flapwort
*Marsupella profunda**	western rustwort
*Petalophyllum ralfsii**	petalwort
Riccia bifurca	Lizard crystalwort
Southbya nigrella	blackwort

Lichens

Bryoria furcellata	forked hair-lichen
Buellia asterella	starry breck-lichen
Caloplaca luteoalba	orange-fruited elm-lichen
Caloplaca nivalis	snow caloplaca
Catapyrenium psoromoides	tree catapyrenium
Catillaria laureri	Laurer's catillaria
Cladonia stricta	upright mountain cladonia
Collema dichotomum	river jelly lichen
Gyalecta ulmi	elm gyalecta
Heterodermia leucomelos	ciliate strap-lichen
Heterodermia propagulifera	coralloid rosette-lichen
Lecanactis hemisphaerica	churchyard lecanactis
Lecanora achariana	tarn lecanora
Lecidea inops	copper lecidea
Nephroma arcticum	arctic kidney-lichen
Pannaria ignobilis	Caledonian pannaria
Parmelia minarum	New Forest parmelia
Parmentaria chilensis	oil-stain parmentaria
Peltigera lepidophora	ear-lobed dog-lichen
Pertusaria bryontha	alpine moss pertusaria
Physcia tribacioides	southern grey physcia
Pseudocyphellaria lacerata	ragged pseudocyphellaria
Psora rubiformis	rusty alpine psora
Solenopsora liparina	serpentine solenopsora
Squamarina lentigera	scaly breck-lichen
Teloschistes flavicans	golden hair-lichen

Stoneworts

Chara canescens	bearded stonewort
Lamprothamnium papulosum	foxtail stonewort

*Species requiring special protection under the Bern Convention (Appendix I) and the EC Habitats and Species Directive (Annex IIb). In addition, the EC Directive requires any commercial exploitation of *Sphagnum* species, *Cladonia* subgenus *Cladina* species and *Leucobryum glaucum* to be subject to management (Annex Vb).

The Joint Nature Conservation Committee is a forum through which the three country nature conservation agencies, the Countryside Council for Wales, English Nature and Scottish Natural Heritage, deliver their special statutory responsibilities for Great Britain as a whole and internationally. These special responsibilities, known as the special functions, contribute to sustaining and enriching biological diversity, enhancing geological features and sustaining natural systems. The special functions are:

- to devise and maintain common standards and protocols for nature conservation;
- to promote, through common standards, the free interchange of data between the country agencies and with external partners;
- to advise on nature conservation issues affecting Great Britain as a whole;
- to pursue wider international goals for nature conservation (encouraging sustainable development, biological diversity and earth science conservation), including the provision of relevant advice to the Government;
- to commission new research and collate existing knowledge in support of these activities, and to disseminate the results.

JOINT NATURE CONSERVATION COMMITTEE

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