Appendix A – Woodland habitats

Perry, S., Goldberg, E., Wilkins, T., Howe, C., Cox, J., Drewitt, A.

Preamble

Wooded landscapes are a feature throughout England, from sea level to an altitude of between 600 m and 900 m (Harmer *et al.* 2010). Trees occur as isolated individuals in hedges and in farmland, in wood pastures where trees and livestock co-exist and in woodlands where the trees are so close together their canopies meet (Rackham 2006). The occurrence and species composition of the different types of woodland is strongly influenced by natural physical environmental factors such as geology, soils, hydrology and climate, but the species present in the woodlands of today's landscapes are largely the product of human activity, and may bear little or no relation to the natural vegetation.

English woodlands contain an extraordinary amount of variation, but many of the issues facing woodlands are pertinent to all the various types. Centuries of human intervention have manipulated the mix of tree and shrub species and woodland structures in order to produce goods and services including timber, cover for game species, and magnificent landscapes for grand country houses. Over history, the balance of land-use between arable, pasture and woodland has oscillated. The presence of woodland usually indicates the presence of areas where soils are less amenable to profitable agriculture (Hooke 2010). In modern landscapes, new woodland only develops where human activities allow or encourage it.

Woodland habitats can be described in many ways, and in-depth descriptions about the history, structure and management of woodlands are available from a variety of sources, including Clements (1916), Tansley (1939), Rodwell (1991), Peterken (1996), Rackham (2003), Harmer *et al*. (2010) and JNCC (2011).

This paper refers to the two broad woodland types, upland woodland and lowland woodland, as described by Peterken (1996). Wet woodlands (including floodplain woodland) are a natural constituent of the habitat mosaic in both upland and lowland woodlands. Upland woodland is here defined here as occurring above approximately 250 m in altitude.

A1. Habitat Variation

A1.1 English lowland and upland fringe

Native lowland woodlands are generally composed of shade tolerant trees (species which are capable of growing under a forest canopy) such as small-leaved lime, beech, wych elm, hornbeam, field maple, and locally large-leaved lime. Species and individual trees are in competition with one another for light and space. Ash can become abundant in light gaps. In a naturally functioning woodland before canopy gaps are created, most trees would reach 30 m with a slender form and narrow crown: the tallest would reach around 35 m; the largest diameter at breast height (1.3 m above ground) would be 230 cm; and the largest trees would be oaks. Individual trees up to 500 years could be present, but most would be no more than 200 years old.

The main tree species are not evenly distributed throughout the lowlands. Wych elm and oaks are naturally more abundant in the north and west. Beech and hornbeam occur throughout the lowlands but are more common in the south and east. Generally, limes are present throughout but more abundant in the north and west, with the exception of *Tilia platyphyllos* which is very rare outside the Midlands as a presumed native and very rare even as a planted tree in the northwest. The assemblages growing on extreme sites are quite distinctive. In a naturally functioning lowland woodland in England, willow, alder and aspen will be dominant in the wetter areas.

Oak is a light demanding, or shade intolerant, species which in a naturally functioning woodland may be replaced by the shade-tolerant species hornbeam and beech. In England, tree species such as sycamore and sweet chestnut are generally considered to be 'naturalised' rather than native. Beech is found in northern parts of England, mainly as a result of planting.

Coastal woodlands are an important part of the habitat variation exhibited by lowland wooded habitats, from the Atlantic woodlands of the west coast to small slippage sites around the soft cliffs of the south east coast.

A1.2 Broadleaved upland

The uplands of England support fewer tree species than the lowlands, due in part to the poorer soils. Beech, hornbeam, limes, maple, wild service tree and a number of shrubs are absent, whereas wych elm, ash, oaks and birch are more abundant. Bird cherry and holly are more common, but in general upland woodlands are less diverse than those in the lowlands. Ash is more common than birch, and the principal shade-tolerant species is wych elm.

Upland woodland is not subject to flooding in the same way as lowland woodlands due to the generally steeper terrain. The soils, which are thin, leached and more acid, offer less secure rootholds. The canopy is less vigorous so the understorey, generally composed of hazel, holly and rowan and occasionally dwarf shrubs, is more prominent.

A1.3 Floodplain forest

In a naturally functioning floodplain forest, larger rivers drain catchments through wide valleys. Rivers are often naturally braided from their middle reaches due to the supply of gravels from upstream. The bulk of the floodplain land is formed from well-drained, alluvial soils with a high water table. Debris dams and back-up lakes are common, most of the woody debris having originated from fallen trees undermined by migrating channels. Flooding can occur at any season, but is more frequent in winter and rarely lasts longer than a week.

Such woodland is composed of alder, black poplar, tree willows (crack willow, white willow) and lesser willows (almond willow, osier) line the main channels and develop on shoals and small islands (sites where the river has recently deposited gravel, course sand and silt). This community forms a narrow strip, partially shaded by mature oak forest behind, but expands on the inside of meanders. The composition varies according to the minute differences in elevation. Ash and alder occupy damper depressions, whilst oak is prominent on floodplain terraces and other higher ground for example on glacial features such as moraines.

Overall there is very little natural floodplain woodland left in England. Remnants are more often located in the lowlands and as a consequence floodplain woodland is more typically considered in the lowland context.

A2. Factors affecting ecological position in the landscape

Closed canopy woodland is described by Clements (1916) as being the natural climax vegetation community, the ultimate result of succession from bare ground, and this theory has been perpetuated by ecologists such as Tansley (1939) and Peterken (1993). This theory of ecological succession has more recently been challenged by Vera (2000), who describes both open wood pastures and closed canopy groves as natural woodland types. The majority of woods in England are highly modified, fragmented versions of a natural habitat, which has important implications for what is perceived as natural woodland (Peterken 2019).

The predominantly north-south alignment of the British Isles results in a strong latitudinal effect on the climate which is reflected in the distribution of certain woodland species. Field maple, hornbeam and understorey plants such as violet helleborine (*Epipactis purpurata*) show a strong southerly bias, while a suite of species with strong links to Scandinavia or north-central Europe have a more northerly distribution including bird cherry, globeflower, melancholy thistle and twin flower.

The Gulf Stream and the Atlantic Ocean also have a major effect, creating a more stable and milder climate than in other countries of comparable latitude. This oceanicity is most pronounced in the west, but even in the east species such as bluebell and ivy occur, which are uncommon on the Continent.

A pronounced west-east rainfall gradient is present, enhanced by the presence of higher ground in the west, creating a rain shadow over the east of England. As a result, much of East Anglia could be classed as semi-arid, whereas the west coast has enough rainfall to support “temperate rainforest”. In England the wettest conditions are found in the Lake District where mountains rise close to the sea. Upland woods generally have a higher humidity, high rainfall and higher moss cover than their lowland counterparts, and often support significant mollusc faunas. The most spectacular effect of our oceanic climate can be seen in the diversity of lichens, mosses, liverworts and ferns that thrive in western oakwoods. For example the hay-scented buckler fern (*Dryopteris aemula*) has much of its world distribution along the west coast of Britain. The bryophyte-rich Atlantic woodlands of the west coast, particularly those in the South West of England are important coastal woodland sites.

This large-scale climate variation across England contains micro-climate variations, some of which are created by small-scale changes in geology and soils. For example, on the thin, unstable soils of the North Downs, the woods are dominated by beech and yew with a scrubby understorey which includes box, whitebeam and privet. In East Anglia there are woods on sticky boulder clays where ash and maple thrive over dog’s mercury or bramble; deep acid sands with birch and oak over bilberry and wavy hair grass; and woods on wet peats. Within woodlands, local changes in soil alkalinity give rise to variations in woodland character (Rodwell 1991).

Lowland woodland habitats typically form mosaics with grassland, heathland and scrub communities. The co-existence in wood pastures of ancient trees and grassland or heathland is due to the presence of grazing animals (Vera 2000). Woodland rides may support rich mixtures of grassland and edge species of vascular plants, many of which have been largely eliminated from the intensively farmed land around the woods (Peterken & Francis 1999).

Wetland habitats within woodlands, such as streams, flushes and ponds are present where the woods have not been subject to intensive land management practices such as drainage, and are often notable for the species they support. They tend to have naturally impoverished higher plant communities but high diversity of mosses, liverworts and invertebrates. This said, gaps in the canopy create pools of light which higher plants assemblages exploit.

Wet woodland forms along flushes and in other areas of soil where water is naturally retained, and often occurs within and adjacent to drier woodland types in accordance with natural gradients of soil wetness. In headwater catchments, for example, the higher slopes may be dominated by beech and yew, giving way to willows and alder downslope where springs and flushes form. Alongside the fens and streams that form further downstream, alder and willow carr dominate. Wet woodlands are present in the uplands and lowlands, and in both locations may form mosaics with fens, bogs and wet grassland.

In today's landscapes, most upland woodlands occupy the slopes between the enclosed fields of the valley bottom and the extensive moors above, frequently forming a mosaic with extensive stretches of blanket bog and upland dwarf shrub heath, in the wet, cool climate, especially in the extremely oceanic climate of the western seaboard. As a consequence of land and woodland management and the impact of grazing animals, upland woods are generally small, at less than 20 ha.

Over the last 100 years, large areas of coniferous plantations have been established in the uplands, reflecting land prices. Ground preparation for such plantations generally involves major changes to natural patterns including widespread drainage and fertiliser application to ensure planting success. These plantations, dominated by conifers, have replaced some natural woodland in upland landscapes, as well as filling open high ground which would otherwise support habitats of conservation value.

The natural 'treeline', a zone of slow-growing trees of low stature punctuated by cliffs, outcrops, screes, very steep slopes, landslips and rocky streambeds, is an important ecological feature of the uplands. Commonly, upland woods now only occur on steep valley sides inaccessible to livestock. The natural tree line is the ecological limit of tree growth, between 600 m and 900 m (Harmer *et al.* 2010), and is considerably higher than the tree line generated by recent upland agricultural management.

A3. Ecological functions and relationships

A structurally diverse and mixed species woodland with a high degree of natural function will support well developed natural habitat transitions, from closed canopy stands, through open woodland with a more dense understorey, to areas with scattered scrub and open grown trees in mosaic with open areas of grassland or heathland, either in large glades or along the edges of wide rides. Such transitions maximise woodland edge features, including scrub, which are beneficial to a wide range of species.

Nutrient cycles within woodlands are driven by the actions of soil fungi, bacteria and other microbes which creates humic, woodland soils. Where the soil is able to accumulate and become deep and stable, comprised of rotting leaves and wood decay from fallen branches or whole trees, distinctive vegetation communities develop.

In naturally functioning woodland systems, dense tree canopies are broken up by disturbance events such as storms, wind and the presence of disease and pests which may be fatal (such as Dutch elm disease or *Hymenoscyphus fraxinus* (ash dieback)). When trees fall and their rootplates are lifted out of the ground, small areas are created where light and humidity levels are increased at ground level allowing the development of young-growth, to which many woodland wildlife species respond - for example breeding birds respond to treefall gaps (Fuller 2000).

Fallen trees and branches create an uneven floor at a micro-scale, and soil disturbance exposes long-buried dormant seeds that germinate and take advantage of the additional light, for example violets (*Viola spp.*), which are the foodplants for the pearl-bordered fritillary butterfly (*Boloria euphrosyne*).

Fungi are essential to a healthy woodland ecosystem, and a huge source of biodiversity in their own right. Healthy fungal communities are indicators of good air quality, natural soil nutrient levels and stable ecological conditions, fundamental to the formation and maintenance of woodland brown earths and recycling minerals and nutrients. In addition, fungi confer to plants resilience to pests and diseases and other environmental stresses. Mycorrhizal fungi create a wood-wide web of mycelia and are important for maintaining the health of tree roots (and the roots of other plant species) facilitating the exchange of water, nutrients and minerals between the tree and the soil. Fungal fruiting bodies themselves provide food, shelter and a location for the development of some insect species larvae. An ancient woodland is more likely to support a healthy soil ecosystem and a rich fungal community than a newly planted woodland. For example, the soil under woodland established on ex-arable land will have no residual woodland fungal and microbe community present.

All stages of dead wood and wood decay are essential elements of a naturally functioning woodland ecosystem. In a natural system, wood decay accumulates in over-mature and dead trees and as branches drop off. The decay process takes place over a long period of time and is facilitated by the agents of material recycling including microbes from the saproxylic complex, saprotrophic fungi, saproxylic invertebrates, and birds such as woodpeckers, all of which are critical to the natural and healthy functioning of woodland ecosystems. A great many species of fungus and insects depend on decaying wood, as well as birds such as lesser spotted woodpecker, marsh tit and willow tit and omnivorous mammals such as badgers, creating a complex food chain. Natural cavities created by decaying wood provide roost sites for bats, and nesting sites for birds such as willow tits, nuthatches and woodpeckers.

In the uplands, thin and poor soils develop on the extreme gradients where trees grow slowly, and have a poor foothold. Canopy gaps are more frequently created as wind is tunnelled along narrow valleys and the trees are more prone to falling.

Natural functioning of woodland ecosystems includes grazing animals, and their predators. Trees within grazed woodland can be of very high conservation value for species such as lichens. However, in the absence of control by natural predators, such as is the case in England, populations of large herbivores can build up, and may have a significant impact on woodland ecosystems for example by holding back natural regeneration and nibbling ground flora. Where it exists, thorny scrub offers natural protection to seedlings and saplings from grazing and browsing animals.

Pests and diseases are important components of a naturally functioning woodland system. Natural regeneration of trees and shrubs promotes genetic diversity in contrast to most planted nursery stock, and this confers ecological resilience on populations. More resistant, naturally selected strains of tree and shrub species survive pest and disease outbreaks.

Under natural conditions in English woodlands, fires are unlikely to start, and if started are unlikely to spread. Our temperate maritime climate, the shade and humidity generated by canopy cover and the dominance of broadleaved trees (as opposed to conifers), all reduce the likelihood of fires occurring naturally.

In naturally functioning woodland ecosystems, ‘keystone’ species have an important influence on community composition and dynamics and their absence has had a significant impact. For example, the extinction of the European beaver, along with land drainage, has contributed to the loss of natural wetlands from the landscape. Maintaining or restoring natural hydrological features can benefit other species, especially in the damp or wet woodlands favoured by species such as willow tit and nightingale.

For many of the smaller, less mobile species, the critical feature of woodlands is continuity of habitat in both time and space. Once a species is lost from an area, either through intensive woodland management such as regular coppicing, or complete removal of trees and/or woodland, recolonization following a return to sympathetic woodland management or woodland re-establishment is unlikely, particularly where there is a lack of populations nearby.

Ancient woodlands can protect some landscape features from intensive land management, for example streams in their natural courses and microtopographical features formed under periglacial conditions.

Peterken (2013) describes meadows and woods as part of a common mosaic sharing the important interfaces between the two types of vegetation, although in vastly different proportions; indeed he suggests that meadows may have their origins in woodlands. (Peterken 2009, Peterken and Francis 1999). Woodland rides and glades may support the only areas of herb-rich grassland in an intensively managed arable landscape. Old hedges, ancient meadows, long-established pasture and ancient woods are refuges of uncultivated ground, where the soil has a natural structure and is often much wetter and less fertile than adjacent farmland (Peterken 1996).

Individual trees in the landscape can be important in their own right, and scattered trees can provide stepping stones and sources of shelter and pollination. In wood pasture situations, where grazing animals maintain an open canopy structure (Vera 2000), the higher and more varied light levels increase lichen diversity (Sanderson and Wolseley 2001) and higher temperatures benefit some invertebrate species.

Upland woods tend to be dominated by light demanding species such as oak and birch, regenerating in open areas. The diffuse natural boundary between woodland and moorland, and their fluid location in the upland landscape, is due to fluctuations in the intensity of grazing and woodland management. Vegetation in the remaining woodlands has been severely modified by grazing.

A4. Current levels of natural function

Historically, woodlands have co-evolved with people and there is a close link between forest history, forest management and biodiversity which depends on overlapping generations of post-mature generations of trees (Alexander 1998, Vera 2000). Woodlands are complex, dynamic systems where, under natural processes, spatial and temporal continuity provide stable conditions. Ancient woodlands (land which has been wooded for several centuries) are valued because they offer relatively stable conditions for the development and persistence of humic woodland soils that support a high diversity of flora and fauna. Similarly, ancient trees, which may be hundreds of years old, are valued for the stable environmental conditions they support.

Our lowland woodlands today bear little resemblance to their appearance prior to the advent of modern man, both in extent and character. Human choices and economics have created a limited diversity of natural tree species in today's landscape. For example, oak was favoured above other tree species in medieval wood pasture management (Hooke 2010). The simplification of species composition, age structure and genetic diversity has greatly reduced opportunities for biodiversity.

Trees in a naturally functioning woodland are more likely to have an age-class distribution where all life stages are represented from young trees and saplings right through to ancient hollowing trees. Ancient hollowing trees, the result of hundreds of years of stability, contain wood decay (red rot and white rot) and wood mould because of an unbroken succession throughout the historical period. Today, the trees and the valuable dead wood they contain are regarded as unproductive or unsafe and are often removed. Inappropriate woodland management compounds this issue through 'tidy minded' woodland managers removing dead wood and dead trees.

Historians generally agree that much of the English 'wildwood' had been removed by the late Bronze Age, and the amount of woodland then present was little greater than found today. Deliberate management of woodlands at that time seldom led to any long-term deterioration of the woodland (Rackham 2003); later expansion of agriculture is the most likely explanation for any loss of woodland. In later Anglo-Saxon times, woodlands became an increasingly valued habitat for hunting, which appears to coincide with a period of regeneration.

In England, even the Royal Forests were thoroughly exploited by the Medieval times. Royalty and the nobility were able to control the landscape in order to maximise their hunting opportunities. Forest Law protected woodland from agricultural development over many centuries. Woodland that originally owed its preservation to hunting laws frequently remains intact today, such as the New Forest wood pasture system.

Wood pastures, especially on common land, were a significant feature of the landscape in many parts of England well into the post-Medieval period, and their almost complete disappearance since then has ensured that we now think of ‘semi-natural woodland’ largely in terms of ungrazed coppices (Barnes & Williamson 2015). In many cases it was Parliamentary Enclosure and disafforestation in the 19th century that saw the final demise of the wood pasture land management system.

Coppice with standards has become the predominant nature conservation woodland management approach in modern times. Over the last two centuries, grazed woodland (pasture woodland) has effectively disappeared (Williamson *et al*. 2017), alongside a steady expansion of plantation forestry, a gradual abandonment of coppice management and decline in the numbers of farmland trees.

The land management practice of forestry (as opposed to the legal Forest system of controlling land use) became increasingly influential after John Evelyn wrote his seminal work ‘Sylva’ in 1664 (Evelyn 1664). Management systems were developed to provide sustainable yields of wood and timber from the mid-17th century to the end of the 18th century especially on the European continent and particularly in Germany. The establishment of the Forestry Commission in Britain in 1919 resulted in a massive increase in the area of wooded land, species mixes and woodland management in Britain (Kirby and Watkins 2015).

Over history, the balance between arable, pasture and woodland has oscillated. The presence of woodland usually indicates the presence of areas of more intractable soils (Hooke 2010). In modern landscapes woodland only develops where human activities allow or encourage it. Surviving woodland has become increasingly fragmented in an intensively managed landscape. Woodland blocks are small and dispersed, dissected by infrastructure (roads and railways) which may or may not be linked by other woody landscape features such as shaws (created by the first ‘farmers’ by leaving strips of woodland as they created small fields) or hedgerows with or without hedgerow trees. In recent times, links between habitats, niches and wood decay biomass is decreasing as individual trees in the wider landscape are neglected and rarely replaced.

Today the Forestry Commission’s National Forest Inventory (NFI) reports average woodland cover across the UK to be 13%, and 10% in England (FC NFI 2017) and tree cover outside of woodlands to be 3.2% for GB and 4.3% for England, with 14.6% of the land area of England covered with tree canopy (Forestry Commission 2017). Compared with Europe as a whole (30% cover) and other European countries (eg France 29%), England has low woodland cover (Forest Europe 2015).

Summaries of current levels of natural function in lowland and upland woods are provided in Tables A1 and A2 respectively. Further explanation in relation to each key component of natural function is given in the text below.

Table A1. Indicative levels of natural function in lowland woodlands.

State of naturalness	Prevalence of state within the habitat resource				
	Hydrology	Nutrients	Soil/ sediment	Vegetation control	Species compositio n
Good	Low	Low	Low	Low	Low
Intermediate	Low	Moderate	Moderate	Moderate	Moderate
Poor	High	Moderate	Moderate	High	High
Confidence	*Moderate*	*High*	*Moderate*	*High*	*Low*
Comments	*Often affected by artificial drainage systems, damaging wet components of the woodland habitat mosaic*	*Atmospheric deposition of nitrogen has a significant impact. Lichen and fungal assemblages are vulnerable.*	*Soil processes are affected by loss of organic carbon from timber removal, as well as drainage and nutrient enrichment, all of which impoverishes soil biota. Effects are compounded by compaction.*	*Over grazing by large herds of deer affects species composition and woodland structure*	*Often manipulated to favour commercially viable species*

Table A2. Indicative levels of natural function in upland woodlands.

State of naturalness	Prevalence of state within the habitat resource				
	Hydrology	Nutrients	Soil/ sediment	Vegetation control	Species composition
Good	Low	Low	Moderate	Low	Low
Intermediate	Low	Moderate	Moderate	Low	Moderate
Poor	High	Moderate	Moderate	High	Moderate
Confidence	*Moderate*	*Low*	*Low*	*High*	*Low*
Comments	*Drainage impacts constrain the development of wet woodland in the uplands*	*Atmospheric deposition of nitrogen has a significant impact. Lichen and fungal assemblages are vulnerable.*	*Drainage, compaction by heavy sheep grazing, and additional loss of soil stability due to progressive loss of trees, have all led to loss of natural soil function in the uplands.*	*High historical and contemporary sheep grazing levels are suppressing woodland and scrub development in the uplands*	*A range of diseases are affecting native tree species that naturally occur in the uplands.*

- **Hydrology**

Many watercourses and other aspects of the hydrological system in our woodlands have been significantly modified, either by the creation of drains and ditches, and occasionally by groundwater abstraction.

Landscape scale drainage schemes, along with the loss of beavers, has resulted in the loss of wet woodland habitat, while smaller drainage systems have caused the loss of some wetland aspects of woodland mosaics such as ponds, flushes, mire patches and streams, changing the natural presence of small scale habitat mosaics within the broad habitat. The overall impact is a simplification of woodland habitat mosaics in a range of landscapes. Drainage has also disrupted natural soil processes by affecting the levels of organic matter, soil carbon and soil micro-flora and –fauna. The lack of keystone species such as beaver has undoubtedly had an impact on the type and quality of woodland in our landscapes and the reintroduction of this species could help to restore elements of lost natural ecosystem function.

Land drainage and associated agricultural improvement has caused the loss of the vast majority of floodplain woodlands from the English landscape. Even where they survive the underlying natural processes have been lost, species composition is compromised and management has created an unnatural age structure. In its natural state such woodland has a generally high water table and is regularly inundated with water, minerals and nutrients from upstream. These processes are now prevented by flood defences and land drainage. Where natural soil wetness still exists, land parcels are commonly planted up with poplar cultivar plantations rather than retaining their characteristic native woodland assemblage.

Within woods, streams may have escaped channelisation whereas streams in farmland have been altered to ditches or constrained in simple channels. Remaining natural headwater streams are now largely confined to more naturally functioning woodlands, having largely been removed from the rest of the landscape. Flood attenuation opportunities within woodland exist, for example blocking woodland drainage ditches with woody dams

The vascular plant community of upland woods is generally poor but can be diverse where base-rich flushes and wet areas occur. Those upland woods growing on limestone are noted for their richness and occurrence of rare water-loving species, particularly bryophytes and ferns, but enhanced drainage eliminates the wet areas these species need. The loss of trees at higher altitudes in ghylls has exacerbated the impact of drainage activity by causing stream channel incision, lowering the stream bed and enhancing the dewatering and associated erosion of land above.

Woodland and trees can help alleviate downstream flooding because tree root systems can penetrate deep into the soil, increasing water infiltration and reducing surface water flow. The loss of trees from upland landscapes has had effects on flood generation and downstream flood risk.

- **Nutrient status**

Across Europe as a whole, widely distributed pollutants are changing forest soils, ground vegetation and tree growth, limiting the chances of re-establishing natural processes. High levels of nitrogen deposition across Europe have affected fungal populations. Eutrophication of woodlands takes many forms, from diffuse aerial deposition of nitrogen to localised nutrient increases through fertiliser drift, slurry spreading and intensive animal husbandry such as the rearing of large numbers of game birds including pheasants.

The *Lobarion* lichen community is considered a climax species assemblage on the bark of trees, and its loss from European forests is partly attributable to acidifying pollution. Nitrogen deposition has also had an impact on the condition of woodlands and their soils and dependent fungi, in particular causing a reduction in the species of lichen and fungi intolerant of higher levels of pollutants in the air and in the soil.

Persistent removal of wood and timber from woodlands reduces the quantity of available decaying wood and disrupts the natural carbon cycle. This, along with persistent collection of fungal fruiting bodies through foraging, is thought to have created a depauperate fungal community in England (Lynne Boddy pers. comm.).

Small woods in the arable lowlands are particularly affected by increasing nutrient status, for example by fertiliser drift, resulting in the loss of typical ground flora and bryophyte communities as the woodland ground flora becomes dominated by species such as nettles.

Nutrient levels in the uplands are naturally lower than the richer landscapes of the lowlands. The natural scarcity of nutrients makes upland ecosystems particularly sensitive to artificial enrichment. Atmospheric nitrogen deposition is a particular concern for upland woodlands, particularly in terms of the effects on lichen communities that are highly sensitive. Areas of the uplands have the highest levels of atmospheric nitrogen deposition in England.

- **Soil/sediment processes**

Soil health is significantly impacted in today's landscapes as a result of increased recreation pressure in woodlands, and a change in the way woods are managed. Increased compaction of woodland soils reduces soil health, in particular destroying microbial communities which in turn affects the overall health of the trees.

Fungi are an essential element of the natural functioning of woodland processes. The *in situ* retention of large woody debris is fundamental to the succession of saprotrophic fungal species and invertebrate assemblages. Habitat continuity in the form of both standing and fallen deadwood is important as each supports different biotas.

A lack of diversity of dead wood in terms of size, type and quality, remains an issue in today's woodlands. The importance of deadwood has been emphasised (Forestry Commission 2002), but Health and Safety policy and practice has been responsible for the removal of old, senescent or diseased trees and the consequent loss of deadwood and its dependent wildlife. An ongoing decline in large veteran trees across Europe is the cause of almost 18% of European saproxylic beetles (assessed at March 2018) being at risk of extinction (IUCN 2018).

In natural systems, windthrow disturbs soils and creates small dips and mounds resulting in small scale variations in soil condition, and the naturally created depressions hold water at least seasonally. Commercial management of forests requires the felling of trees before maturity, creating less diverse soils. Within natural woodlands, extreme gradients in soil wetness can exist within very small distances, and these are eliminated by drainage systems aimed at improving commercial productivity.

A healthy soil ecosystem is maintained within a woodland by avoiding compaction with heavy machinery and high numbers of livestock. It is essential to avoid chemical treatments to avoid damaging soil microbiology. Some high dependency relationships between species are the result of millennia of co-evolution. For example, some fungi are dispersed via specialised relationships with invertebrates and if conditions become unsuitable for one of these mutually dependent species, the relationship breaks down and it becomes increasingly challenging for the other species to survive.

In the uplands, woodlands may be found on steep slopes with little soil, where soil retention is only maintained by a good cover of vegetation. Where trees are lost, the thin, fragile soils become less stable and are susceptible to the impact of wind and water. Allowing woodlands and trees to be re-established can stabilise soils and help them recover. However, re-establishment of trees in such conditions is a slow process, particularly where seed sources have been depleted (see below).

- **Vegetation controls**

Changes in land use and management in the last 200 years, such as the Parliamentary Enclosures Act and land drainage has affected the lowlands more than the uplands. However, intensive management for sheep and grouse has had major impacts in the uplands, along with intensive industrial land use. Many old trees have been removed, and the semi-natural tree and shrub communities lost, breaking any links with the original natural forests. Associated species lost from the upland landscape as a result of this break in continuity include for example epiphytic lichens and oceanic bryophytes.

The wildlife associated with ancient woodland has been altered by centuries of vegetation management, such as coppicing during the Middle Ages. The remaining populations are relicts, surviving only where large trees and dead wood have been present throughout the centuries, without a break. Many species associated with large trees and dead wood are now restricted to woods where suitable habitats have been continuously present for centuries (Peterken 1996). The saproxylic species are those most likely to have been lost long ago, and today some ancient woodlands lack epiphytic lichen species due to both a break in continuity of tree bark of the appropriate age and condition, as well as air pollution. These losses are compounded by isolation from other woods.

A woodland operating under near-natural function would contain a dynamic tree population where all tree ages are represented, from seedlings and saplings in canopy gaps right up to over mature and ancient trees. Today, most woods are too small to allow the maintenance of all age classes, so coppicing is often used in conservation management to ensure the younger age classes are represented, which can lead to under-representation of mature and over-mature conditions.

Large herbivores, along with top predators, are a feature of naturally functioning woodlands. It is widely accepted that deer are now more abundant and widespread than at any time in the past 1000 years. Species of deer in England include the native red and roe deer, alongside fallow deer which were introduced in the 11th Century. More recently Introduced species include sika, Reeve’s muntjac and Chinese water deer. The increase in numbers is attributable to a combination of milder winters and the planting of winter crops, as well as a lack of natural predation (in the past the size and behaviour of deer populations would be influenced by the presence of natural predators such as lynx, bears and wolves as well as humans).

Deer can play a significant role in woodland ecosystem function by selectively browsing on the understorey and ground flora and by stripping bark off older trees, creating variation in tree age structure and levels of canopy cover. At unnaturally high population levels this activity is detrimental to woodland habitat and its vertebrate and invertebrate woodland fauna, creating an impoverished woodland understorey and reducing levels of natural tree regeneration, with consequent negative economic impacts. Control of deer populations is necessary to limit their impact, and the historical loss of natural predators has meant the role of humans has become more important. Reversing the damage to woodland biodiversity requires appropriate culls across large contiguous areas, supported by knowledge of deer numbers and fertility.

The presence of introduced species such as grey squirrel (*Sciurus carolinensis*) and Reeve's muntjac deer (*Muntiacus reevesi*) both have an ability to influence vegetation within woodlands, muntjac by eating the shoots from shrubs as well as herbs and Brambles, and grey squirrel which strip the bark from native trees as well as eating woodland plants.

The general lack of trees and the low species diversity in the uplands is not a natural situation, but the result of long term human intervention. For example, upland woodlands are frequently used to shelter livestock, particularly sheep. Where livestock densities are high, natural regeneration is absent and has been so over recent centuries. Seed sources are very low or absent and natural regeneration is often poor even when grazing pressure is relieved. The result is that woodland has been reduced to scattered trees with little or no understorey, and where the ground vegetation survives it has merged with that of the moorland communities.

- **Species composition**

Man has selectively removed or favoured various tree species and introduced non-native animal species. This, along with intensive forestry management, has reduced the diversity of tree species and associated dependent wildlife.

As well as reducing the diversity of native species, planting of non-native species has had a significant impact on woodland structure. For example, rhododendron and snowberry are both shrubs planted to provide cover for game but which are invasive and can have a negative impact on woodland flora and fauna.

Pests and diseases occur naturally, but climate change and international trade have caused an increase in their number and variety in England's trees and woods. Horticultural activities involve widespread, international movement of infected plants and plant material which may harbour pest species. The susceptibility of native trees and shrubs has been greatly increased by large scale woodland planting programmes using nursery stock which have a limited genetic diversity.

The commercial harvesting of fungal fruit bodies has had a significant impact on the status of fungal assemblages, particularly in areas such as the New Forest which are popular with fungal foragers. Although the long-term impacts of harvesting are unclear, fungal fruit bodies are essential for spore dispersal and sexual reproduction, also providing food and shelter for forest wildlife.

Intensive forestry management activities, such as the removal of deadwood, have greatly reduced the diversity of fungi.

The presence of high numbers of grazing animals in the uplands has resulted in woodland stands lacking younger age-classes, which are now largely restricted to areas that are more difficult for livestock to reach such as streamsides and rock outcrops. Disturbance by stock creates bare patches and regeneration niches for tree seedlings, but their persistent grazing keeps natural regeneration in check, and leads to the development of low diversity grassy vegetation and loss of grazing intolerant species.

A5. Scope for restoration of natural function

Restoring elements of natural function to some degree within the woodland habitat resource is highly beneficial if approached and planned appropriately. Some means of introducing natural processes carry low risk to woodland interest such as restoring genetic diversity through natural regeneration; retaining dead and standing wood; whilst others such as restoring natural hydrological processes, need to be implemented with greater caution because of the risks to remaining biodiversity. A summary of restoration potential in both lowland and upland environments is provided in Table A3, whilst further explanation in given in the text below.

The potential for restoring natural function of woodland habitats is limited by the small and fragmented nature of woodland blocks in today's landscape. Ideally woodland restoration would be achieved by restoring natural processes on a landscape scale, restoring natural ecological functioning by increasing the size of the woodland blocks and encouraging good quality mosaics of habitats to include open habitats, scrub and woody habitats in a suitable landscape context, alongside appropriately managed hedgerows. Woodland fragmentation can be reduced through targeted restoration of degraded woodland and the establishment of new woodland, trees and scrub preferably by natural regeneration. Remaining scattered trees may be the remnants of wood pasture systems - the restoration of wood pasture habitat is one way of replacing trees in otherwise open landscapes.

Table A3. Desirability and scope for restoring more natural function in lowland and upland woodlands.

	Hydrology	Nutrients	Soil/sediment	Vegetation control	Species composition
Desirability (Y/N/sometimes)	Y	Y	Y	Sometimes	Y
Comments	Natural hydrology should be restored where possible to restore wet woodland habitats and small-scale wetland features	Reduce or eliminate atmospheric nutrients above critical load in both upland and lowland areas. Permits restoration of	Critical for restoring fungal assemblages, soil biota generally, and tree health. Restoration largely relates to reducing inappropriate	Targeted action to restore more natural grazing levels in uplands and lowlands, for both new and existing woodland where improved natural woodland functioning is a priority. Largely relates to controlling sheep grazing in	Natural regeneration of native species where possible, allowing woodland species to establish in situations most conducive to their survival and with

	in the woodland habitat mosaic.	fungal, bryophyte, lichen and higher plant assemblages	woodland management and allowing natural processes to do the work.	the uplands and deer browsing in the lowlands.	restored genetic resilience.
Biodiversity synergies/conflicts	Supports restoration of wetland and freshwater habitats. Care needed in ancient woodlands to avoid unintended impacts on remaining biodiversity	Natural nutrient levels are generally a shared conservation goal across all habitats and species	Natural soil function is critical for woodland biodiversity so no conflicts.	Precise grazing regime required depends on precise woodland objectives – more open woodland requires higher grazing levels, but livestock type is critically important to achieve the right outcome. Restoration of natural transitions between open and wooded areas is critical to biodiversity synergies.	May result in shifts in the current distribution of species dependent on planted tree species.

Restoration of some natural processes in woodland systems takes many decades, in some cases centuries. The Carrifran Wildwood project acknowledges (Ashmole 2009) that the creation of 'wildwood' from scratch would take a century or more and the control of browsing animals is essential in order to establish native woodland. Where natural processes can be restored and there has been long-term continuity of woodland cover, some lost species may return naturally as the woodland structure and composition changes over the decades. Where continuity in time and space has been interrupted, it may be necessary to transplant those species dependent on long-term stability, particularly those saproxylic species which have relatively low colonisation ability. All this emphasises the critical importance of remaining remnants of ancient woodland, even degraded areas, as the basis for recovering lost woodland biodiversity.

The diversity of composition and structure of tree and shrub communities has been changed over time, with some species favoured and others removed. The genetic diversity of some tree species is now somewhat limited, and consequently their vulnerability to disease has increased. Allowing natural regeneration of trees ensures that the woodland character is appropriate to the location, and that species establish in situations that are most conducive to their long-term survival. It also allows natural selection to take place which will increase resilience and could ensure recovery of tree populations from disease outbreaks such as ash dieback.

A healthy soil ecosystem can be maintained by avoiding those activities which may have a negative impact on soil qualities. For example sensitive machinery should be used when carrying out management activities, and large herbivore populations should be reduced. It may be possible to create zones within the woodland according to the sensitivity of the soils, in particular avoiding naturally wet soils. Avoiding chemical treatments to prevent damage to soil microbiology is essential.

Management of woodlands is one way to simulate some of the natural processes described, for example selective felling, creating and managing coppice coupes, felling individual and groups of trees, and Continuous Cover Forestry (CCF) creates canopy gaps which in a natural system would be created by falling branches or trees. In carrying out such forestry operations the use of heavy machinery should be avoided in order to prevent compaction damage to tree roots and woodlands soils. Similar damage can also be caused by recreation pressure, which may need to be managed and maintained at low levels to allow restoration of higher levels of natural function.

Conservation efforts need to focus on long term strategies to protect old trees to ensure the vital ecosystem services provided by saproxylic beetles continue (IUCN 2018). Retaining standing and fallen dead wood *in situ* is a critical and easily adopted measure, and ensures the provision of habitat niches for fungal and invertebrate species, as well as re-establishing natural nutrient cycles on which many other species depend. There is increasing awareness of the biodiversity importance of leaving dead wood *in situ*. The diversity of deadwood in terms of the range of tree species from which it originates, and its physical size, are also important determinants of fungal diversity.

Restoration of natural tree and shrub vegetation could be achieved in both the uplands and the lowlands by targeting a reduction in grazing pressure (such as controlling deer populations) and changing the type of livestock from largely sheep to largely cattle. The grazing behaviour of cattle (pulling at vegetation rather than nibbling) allows natural establishment and growth of trees and shrubs. Overgrazing by sheep in the uplands has resulted in a very depleted tree and shrub resource, and an exhausted seed bank. It may be necessary to plant trees and shrubs to compensate for the lack of natural regeneration, focussing effort around locations such as ghylls which will benefit the riparian habitat as well as improve water quality and flood management.

Reductions in grazing pressure may not be effective in restoring open canopy woodland where a long lapse in grazing has led to the regeneration of woody material. In such cases, it may be necessary to intervene to restore open light conditions by selectively thinning dense tree growth, and cutting vegetation away to give space to older trees (also known as haloing). The effects of sudden changes to woodland conditions, including tree removal (whether by natural causes or otherwise), on habitat suitability for vulnerable species such as bryophytes need to be considered.

Restoring natural river and stream function can support the restoration of complex habitat mosaics including woodland, as well as benefitting water quality and downstream flood risk. Natural flood management measures, where flood flows are slowed by various means (e.g. blocking of ditches, restoration of stream habitat and the planting of trees in flood plains) can support restoration of natural river function if undertaken in a sympathetic way.

The restoration of hydrological function is required in order to recreate wet woodland. This can only be carried out on a site by site basis and by taking the impact on adjacent land use into account. Particular consideration needs to be given to drainage around the moorland fringe, to natural springs and flushes that have been drained, and to floodplains that have been agriculturally improved.

Woodland seepages are largely overlooked, generally having a poor higher plant community, but good diversity of mosses and invertebrates.

The scope for restoration of floodplain woodland is limited by the intensive use of many floodplains. It may be possible on a limited basis and should be pursued where there is opportunity to do so. It is most likely to be possible in smaller lowland floodplains which have escaped development, and in upland floodplains where land use is generally more amenable. Floodplain woodland restoration is most likely to be feasible as part of wider landscape restoration projects where a range of habitats (including other floodplain habitats such as open fen, raised bog and wet grasslands) and their characteristic species is being considered.

Coastal woodlands tend to require less management, and can demonstrate responses to natural function and change. For example Beast Cliff, Yorkshire is an area of woodland apparently undisturbed by man, the woodland in the Axmouth-Lyme Regis Undercliffs, Devon which has developed as a result of coastal slippage and Woody Bay, Devon where the cliff slopes steeply and drops precipitously to the sea (NCR 1977).Even where it is possible to restore natural processes, climate change may limit successful restoration of some parts of the characteristic woodland species assemblage. Lichen ranges across Europe (Van Herk *et al*. 2002; Aptroot and Van Herk 2007) are being driven by both climate change and declining air quality – whilst addressing air pollution can improve the situation, shifts in climate space cannot be readily addressed by local management regimes.

A6. Provision of habitat for priority species

Some of the most important species groups related to woodland natural processes are described below, but this list is not comprehensive. Groups such as vascular plants, Coleoptera, Diptera, moths, woodland butterflies (such as Purple Emperor) and non-lichenised fungi are not covered. In general, creating warm and well-lit conditions will benefit the majority of species – this can be achieved through restoring natural processes of glade formation where possible, or mimicking of such processes where it is not (e.g. through ride creation and management). Britain is considered to have international importance for a number of habitat-based fungal assemblages, either because their habitats are internationally restricted (such as ancient/veteran trees) or because there is evidence that British sites have some of the highest fungal species diversity recorded across Europe (namely fungi of Atlantic hazel, fungi of Atlantic oak woodland and lignicolous saprotrophic fungi on beech and oak). This is described in detail by JNCC (Bosenquet et al 2018).

A6.1 Mammals

Woodlands are of fundamental importance to many of our mammal species as they offer foraging opportunities, places for rest and hibernation and shelter from predators and weather. The quality and connectivity of woodland to other habitats is of key importance to mammals and declines in woodland extent and quality are responsible for changes in ecology and behaviour of mammals alongside reductions seen in many mammal populations.

All of England's bat species are dependent to some extent on woodland habitat whether to forage, roost, breed or hibernate. Some are woodland specialists, including Barbastelle (*Barbastellus barbastellus*) and Bechstein's bats (*Myotis bechsteinii*) which are amongst the rarest bat species in England. These species in particular rely on mixed-species, structurally diverse woodlands, although their use of woodland differs significantly. Bechstein's bats utilise woodlands for roosting and for foraging (Greenaway and Hill 2004), whereas Barbastelle bats only rely on woodlands for roosting and will forage some miles distant in open habitats. Structural diversity is important for both species because it offers a range of different roosting opportunities, variation in temperature and humidity throughout the woodland through a well-developed understorey and running water in some instances. For Bechstein's, structural diversity also provides abundant insect prey.

The common dormouse (*Muscardinus avellanarius*) is an arboreal species, naturally associated with mature broadleaved and mixed woodland and scrub but also exploiting hedgerows and even conifer plantations. They thrive in well-connected semi-natural ancient woodlands with a high plant diversity and dense understory. However, population densities tend to be highest in coppiced woodland and thicket stage mixed plantations, since they provide large amounts of the successional stage of woody vegetation preferred by dormice. Historically, coppice woodland management was frequently used across the UK and woodlands typically consisted of different aged blocks of coppiced underwood with standards which were separated by grassy rides (White and Hurt undated). However, coppice management has declined in British woodlands and this alongside other changes in woodland management techniques and loss of semi natural ancient woodland has had negative consequences for dormice abundance, resulting in a reduction of around half of their geographical range of Britain during the past century. The dormouse is a species that can benefit from specific woodland management and the revival of long rotational coppicing in some areas alongside reintroduction programmes has improved distribution. Further work is however needed to improve connectivity between woodland patches and ensure habitat contains a high diversity of interconnecting trees, hedgerows and shrubs to ensure continuity of food throughout the seasons.

The pine marten (*Martes martes*) is one of our rarest mammals in England due to habitat loss and persecution. They are a woodland specialist, spending most of their time in deciduous and coniferous woodland. They can be seen as an indicator of a healthy woodland ecosystem as they favour diverse woodland habitat with a well-developed ground and shrub layer and 'old growth' woodland features such as cavities for den sites. As a native predator, the pine marten plays an important role in regulating potential pest species. In Ireland dramatic declines of grey squirrels have been observed alongside an increase in pine marten range and numbers, which may have positive benefits in terms of restoration of red squirrel abundance and distribution (Sheehy and Lawton 2014). Whilst the pine marten population in Scotland is recovering and expanding, populations in England have shown limited signs of recovery and the species remains at low densities with a very restricted distribution. For this reason there are a number of feasibility studies underway looking at the potential of a formal reintroduction of this species into England. The species has been successfully reintroduced in Wales as part of a series of population re-enforcement exercises undertaken by the Vincent Wildlife Trust associated with the pine marten Recovery Project, which began in 2015.

It is widely accepted that deer are now more abundant and widespread now than at any time in the past 1000 years (Yalden 1999). Species of deer in England include the native red (*Cervus elaphus*) and roe (*Capreolus capreolus*) alongside fallow (*Dama dama*) which were introduced in the 11th Century and are now naturalised and introduced sika (*Cervus nippon*), Reeve's muntjac (*Muntiacus reevesi*) and Chinese water deer (*Hydropotes inermis*). The increase in numbers is attributable to a lack of natural predation, which in the past would have been generated by lynx, bears and wolves as well as humans, milder winters and changes in farming systems such as the planting of winter crops. Deer can play a significant role in woodland ecosystem function by selectively browsing on the understorey and stripping bark off older trees, creating variation in tree age structure and levels of canopy cover. Control of deer populations is necessary to limit their impact, particularly in ancient semi natural woodlands. At unnaturally high population levels this activity is detrimental to woodland habitat and its vertebrate and invertebrate woodland fauna and can also have negative economic impacts (Harmer *et al*. 2010). With the historical loss of natural predators in England the role of human control becomes more important, requiring appropriate culls across large contiguous areas, supported by knowledge of deer numbers and fertility (Wäber *et al*. 2013, Quine *et al*. 2004).

Wild boar (*Sus scrofa*) were once an integral feature of British woodlands. The date of their extinction from Britain is unclear though they are thought to have disappeared from England sometime around the late 13th, early 14th century. Wild boar are considered to be ecosystem engineers due to the disturbance caused to vegetation by their rooting behaviour, which can both increase and decrease plant cover and species richness (Gill and Waeber 2016). One example is the impact of wild boar on the bluebell (*Hyacinthoides non-scripta*), a species valued for its floral displays in British woodlands. Rooting by wild boar has been found to reduce bluebell percentage cover and density by up to 95% in extreme cases, but rapid recovery is seen after cessation of rooting (Sims *et al*. 2014). Re-establishment of native boar in England may therefore see bluebells return to a more natural presence in the woodland understorey, opening up opportunities for other native plant species and a more diverse woodland flora. The genetic provenance of animals is an issue, particularly since feral populations of wild boar currently in the UK are likely to include a genetic contribution from farm stock and this may affect their ecological behaviour. With no natural predators to control populations, re-introduced populations would require careful monitoring and subsequent action in order to prevent disturbance from reaching damaging levels.

A6.2 Birds

Woodland bird assemblages vary depending on wide range of factors including altitude, type and age of the woodland and the structure of the vegetation. A summary of habitat requirements of priority bird species is given in Table A4.

Woodlands with a sparse shrub layer and good ground cover, often in the uplands, are necessary for breeding wood warbler, tree pipit and other declining species such as pied flycatcher and redstart. Species requiring a more well developed shrub layer for nesting, include dunnock, song thrush, bullfinch and other, non-Section 41 species which are rapidly declining, such as willow warbler and nightingale.

Another group of species requires natural transitions from woodland to more open areas including glades and wide rides or scrubby areas with scattered trees. In the uplands, although scarce, such areas are favoured by foraging black grouse, which is particularly dependent on young birch in the winter and early spring. In lowland areas woodland edge and scrubby mosaics with scattered trees, particularly on heathland or grass-heaths, are important for breeding nightjar and woodlark. Open scrub mosaics in grasslands and heathlands are also important for grasshopper warbler, yellowhammer and linnets. Lesser redpolls and willow warblers both favour young, regenerating woodland, particularly birch, and this habitat is also exploited by nightjars and woodlarks. Other species are more often associated with mature trees in open woodland, wood pasture or parkland, including spotted flycatcher and hawfinch.

Standing or fallen dead wood is an important habitat component for many woodland birds. . Standing dead wood provides natural cavities for nesting and, particularly in the case of the willow tit, rotten wood suitable for nest excavation. Both standing and fallen wood provides important foraging opportunities for species which feed on invertebrates in the rotting timber, including lesser spotted woodpecker, marsh tit and willow tit. The latter is also particularly associated with wet woodlands.

Table A4. Section 41 bird species strongly associated with woodland habitats. (B = breeding, NB = non-breeding)

Species	Season	Habitat requirements
Black grouse	B & NB	Upland birch scrub
Turtle dove	B	Scrub and hedgerows, woodland edge
Cuckoo	B	Open woodland, dense scrub
Nightjar	B	Scrub mosaics, woodland edge, clear-fell
Lesser spotted woodpecker	B & NB	Mature trees with rotting wood, tree holes
Woodlark	B	Scrub mosaics, woodland edge, clear-fell
Tree pipit	B	Open woodland, woodland edge
Dunnock	B & NB	Woodland, dense scrub, hedgerows
Song thrush	B & NB	Woodland, scrub, hedgerows
Grasshopper warbler	B	Scrub mosaics with grass, heath
Wood warbler	B	Mature Woodland, open understorey
Spotted flycatcher	B	Open woodland, hedgerows, parkland
Marsh tit	B & NB	Open woodland, parkland, tree holes
Willow tit	B & NB	Wet woodland, tree holes
Starling	B & NB	Woodland, tree holes
Tree sparrow	B & NB	Hedgerows, parkland
Lesser redpoll	B & NB	Woodland, scrub
Bullfinch	B & NB	Woodland, scrub, hedgerows
Hawfinch	B & NB	High forest, parkland
Yellowhammer	B & NB	Hedgerows, scrub

B = Breeding; NB = Non-breeding

A sustainable approach to woodland management for birds would allow the development of natural transitions from closed canopy stands of mature trees to open woodland with a denser understorey and eventually to areas with scattered scrub in a mosaic with open areas of grassland or heathland, either in large glades or along the edges of wide rides. Such a transition would maximise woodland edges features which are beneficial to a wide range of birds.

In the uplands, where the species of greatest conservation concern such as black grouse generally require more open woodlands with a sparse understorey, moderate to low grazing levels and perhaps some selective felling of trees, to create open canopy woodlands, would be beneficial. Ideally adequate grazing would be achieved by deer but in reality will need to be supplemented with livestock.

Another aspect of more sustainable woodland management would be to leave both standing and dead wood *in situ*, as far as possible, to encourage an abundance of invertebrates for foraging birds and to provide natural tree cavities for nests. It might be necessary to provide nest boxes while the woodland matures sufficiently to provide natural nesting holes, and some species can respond well to such management, e.g. willow tit, redstart, tree sparrow and spotted and pied flycatchers. Other factors include maintaining or restoring natural hydrological features, especially in the damp or wet woodlands favoured by willow tit and nightingale in particular.

Jays are important in woodland ecology as they are one of the main vectors for the movement of acorns.

A6.3 Lichens

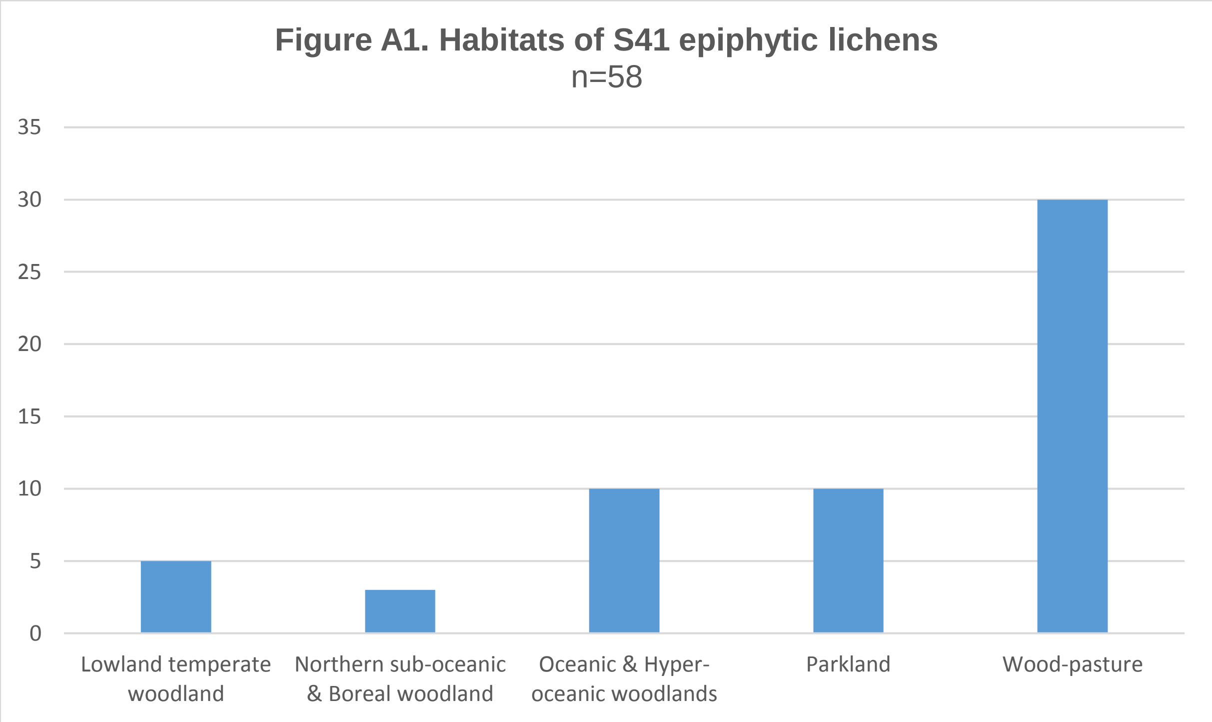
Lichen distribution in Britain is strongly governed by our oceanic climate, showing a marked east to west variation in contrast to vascular plants. Atlantic woodland (temperate rainforest) occurs under the wettest climates and is exceptionally rich in lichens (and bryophytes). In England these conditions are most strongly developed in the Lake District where mountains rise close to the sea (Sanderson 2012), as well as the coastal woodlands of the South West of England (Plantlife 2019).

Woodland lichen occurrence largely varies according to: oceanicity, temperature and altitude at a regional scale; woodland structure, composition, geology, aspect and topography at a site scale; and at a tree or stand level: tree species, age, architecture, bark characteristics and microclimate. Lichens function on different scales to vascular plants and bryophytes, both spatially and temporally (Sanderson 2012). They tend to have higher niche specificity, with low occupation rates across wide areas of seemingly suitable habitat (a prevalent feature of priority species). To achieve ‘natural levels’ of lichen diversity in woodlands would require large wooded areas over timescales of centuries to allow for old-growth stand succession across sites (Ellis & Coppins 2007).

Wood-pasture or woodland that is grazed) can be of very high conservation value for lichens in England, encompassing a wide range of woodland types that support a great many different lichen assemblages and a large number of Threatened and International Responsibility taxa (Sanderson & Wolseley 2001; Woods & Coppins 2012). Of these, Atlantic broad-leaved woodland is of greatest importance, supporting species and populations of international significance (Coppins & Coppins 2005).

Grazing animals create an open habitat structure, resulting in higher and more varied light levels – a key determinant of lichen diversity (Sanderson & Wolseley 2001). Shelter is also important but woodlands that have been excluded from grazing and other forms of management become darker, with a denser understorey and more abundant climbing plants that shade potential lichen habitat. The outcome is a much lower lichen diversity, with interest tending to be confined to the woodland edges. Restoration through grazing reinstatement is not necessarily effective: lapses in grazing over several years can lead to woody regeneration beyond the control of herbivores. In such cases, interventions such as tree thinning and haloing (removing secondary growth which may be completing with veteran trees) may be necessary.

Across taxonomic groups, lichens dominate the list of priority species that inhabit wood-pasture and parkland, representing over 50% of those listed (Webb *et al.* 2010). There are 95 lichens and two lichenicolous fungi on the Section 41 list, plus one 'Extinction Risk' taxon (98 species in total). Of these about 60% are tree-dwelling. Figure A1 below gives a breakdown by habitat.



The reasons these taxa are Section 41-listed varies but the main threats are considered to be:

1) air pollution – sulphur dioxide and acid rain (largely impacting in the past) and ammonia deposition (continuing to the present day);
2) Dutch Elm Disease which nearly extinguished a whole species assemblage;
3) loss of veteran/ancient trees (individuals) and gaps in tree population age structure (woodland) disrupting habitat continuity;
4) changes in woodland management, including neglect, a decline in traditional management practices and lack of deadwood (fallen & standing);
5) native and non-native invasive shrubs/climbers reducing understorey light levels – e.g. *Rhododendron ponticum*.

Lichen assemblages are strongly influenced by bark characteristics and thus the species of tree. The most important substrate trees for priority lichens are oak (both species), ash and beech but a number of other broadleaf trees and shrubs are known to support colonies, including neophytes such as sycamore, Norway maple and horse-chestnut. Generally trees become markedly richer in lichens after about 200 years (e.g. Fritz et al. 2008); most niche specialists do not establish until that time or much later. Veteran features can be significant, for example 'wound track' lichens are a specialist assemblage confined to sap runs. Similarly standing deadwood is important for an assemblage of 'pinhead' and lignum lichens. Lichens can also occur on rocks and the ground in woodland. Rock outcrops, boulders, scree, earth banks and open heathy glades are all woodland microhabitats that can support significant assemblages, adding to the lichen diversity of a site (Coppins & Coppins 2002).

Climate change is altering the ranges of lichens across Europe (Van Herk et al. 2002; Aptroot & Van Herk 2007). It is likely these shifts are not only climatically driven but the result of changing air quality. Woodland lichens are perhaps more buffered to climate change than in some other habitats but variations to rainfall patterns, temperature, and insolation are likely to directly impact, affecting species' distributions and abundance. Furthermore there may be significant indirect impacts, with an extended growing season, early canopy closure (Berry *et al.* 2005) and climbing plants such as ivy stimulated by rising CO2 levels (Zotz *et al.* 2006) woodland is likely to become darker, leading to declines in lichens. More storms, droughts and floods are expected to increase frequency of wind-throw and canopy damage, placing substrate trees at risk. Importantly some of these new pressures may be mitigated through programmes of adaptive management and monitoring.

Today the degradation of lichen habitats in quality and extent is such that many priority species need targeted interventions to begin recovery before their populations can become resilient enough to survive in contemporary landscapes. A combination of woodland fragmentation, reproductive/dispersal limitations and low population turnover of some 'old-growth forest' lichens – e.g. Tree lungwort (*Lobaria pulmonaria*) – suggests that declines will continue (despite favourable site conditions) due to an extinction debt (Öckinger & Nilsson 2010). The effect is exacerbated by a reliance on asexual reproduction, resulting in clonal populations with a lower genetic diversity and reduced adaptive potential to environmental change. For similar reasons, such species show a 'recovery lag' – i.e. a delay or inability to regain their former range following threat abatement. The slowest lichens to re-establish are species of the Ancient Dry Bark community (*Lecanactidetum premneae*) (Coppins *et al*. 2001).

The implications for lichens of restoring elements of woodland natural function will depend on the type, level, and speed of changes envisaged. Many lichens are highly sensitive to small scale changes in their environments and this is especially the case for priority species, almost all of which are niche specialists. Moreover, beyond the site level, lichens are heavily influenced by climate and air quality, both of which are modified by humans. Priority species have a strong affinity with grazed old-growth woodland, a habitat which can be created but takes about 200 years to develop for most British woodland types (Sanderson 2012).

In conclusion, there are three attributes key to resorting woodland natural function for priority lichens: woodland age (old-growth characteristics; structural complexity), woodland extent (large areas with minimal fragmentation) and woodland grazing (large herbivores creating an open structure). Regrettably, the past attrition of priority lichens is such that even if this paragon were available today, some species may be unable to benefit due to an extinction debt. In these cases a bespoke recovery programme may be the only hope.

A6.4 Bryophytes

Woodland is a particularly important habitat for bryophytes, with characteristic species varying between woodland types. In lowland calcareous woodland, where trees such as ash, field maple and hazel are frequent, characteristic woodland floor bryophytes include the robust pleurocarps *Eurhynchium striatum* and *Thamnobryum alopecurum*, with *Plagiomnium undulatum* and *Fissidens taxifolius*. Tree bases support frequent *Mnium hornum* and *Isothecium alopecuroides*, whilst on the trunks and branches *Hypnum cupressiforme, H. andoi* and species of *Ulota, Orthotricum* and *Zygodon* are characteristic.

In lowland acidic woodlands, where oak and birch are frequent, the bryophyte flora of the woodland floor is less rich than in calcareous woods, with common calcifuge species predominating such as *Dicranum scoparium, D. majus, Hylocomium splendens* and *Dicranella heteromalla*. *Leucobryum glaucum* can form dense cushions that ocasionally become detached and roll around as living moss balls. Characteristic species on the trees in these woods include *Isothecium myosuroides, Dicranoweisia cirrata* and the liverwort *Lophocolea heterophylla*. The Section 41 moss *Zygodon forsteri* is confined to rain tracks and knotholes on exposed roots of ancient beech trees on acidic soils. In upland acidic woods the large bryophytes *Dicranum majus* and *Rhytidiadelphus loreus* occur at increased frequency.

Atlantic woods that occur in western oceanic areas are particularly rich in bryophytes, and are sometimes referred to as ‘temperate rainforests’ (Porley and Hodgetts, 2005). Many of the best such woods occur in Scotland and Wales, but fine examples also occur in England, such as within the Borrowdale Woodlands Complex SAC in Cumbria, where a recent survey in one area recorded 25 oceanic or sub-oceanic bryophytes, five of which were Nationally Scarce species (McLay, 2017).

Wet woodlands support a well-developed bryophyte flora, with characteristic species including *Rhizomnium punctatum, Calliergonella cuspidata* and various species of *Sphagnum*. Where calcareous springs emerge in woodlands, very distinctive tufa formations can develop with abundant growth of *Palustriella commutata* and other moss and liverwort species of base-rich flowing water. These are in turn very important for invertebrates including rare crane flies and Diptera. Epiphytic bryophytes such as *Ulota* and *Orthotrichum* species may also be frequent on the trunks and branches of willows and sallows.

The restoration of natural processes in woodlands may be beneficial for some bryophytes. However special care needs to be taken in this habitat. The creation of carefully-selected non-intervention areas within woodlands may be important for maintaining the bryophyte diversity in some woods. Short cycles of intense shade followed by high exposure to sunlight, such as may be caused by catastrophic events, creates conditions unsuitable for many bryophytes. Woodland with a continuity of cover and a more or less stable microclimate often has a rich bryophyte flora. Nine Section 41 bryophytes occur most frequently in woodland habitats, namely the liverworts *Dumortiera hirsuta* and *Jungermannia leiantha*, and the mosses *Anomodon longifolius, Atrichum angustatum, Habrodon* *perpusillus, Homomallium incurvatum, Orthodontium gracile, Rhytidiadelphus subpinnatus* and *Zygodon forsteri*.

In the case of such rare species, care will need to be taken within individual sites to ensure that large-scale changes do not have a negative effect on species that may be restricted to very small areas of habitat. An extreme example of this is the Section 41 moss *Habrodon perpusillus*, which in Dorset is known only to occur on the trunk of a single ash tree. Clearly any large-scale change, such as that caused by management works in the area, would need to ensure that the rare moss was not damaged or destroyed. However, it may not be possible to prevent the loss of such trees in the presence of tree diseases, such as ash dieback.

A7. Key messages

- Naturally functioning woodlands are complex, dynamic and unpredictable systems. Impacts on the natural functioning of woodlands are many and varied, including climate change, pollution, hydrological modification and non-native diseases. All have consequences which need to be proactively addressed.

- Woodland habitats have a long history of human intervention, and the timescale over which woods and trees function is much greater than human timescales. This needs careful attention when planning measures to restore elements of natural function.

- Woodland habitats exist in an intensively managed landscape, where the habitat has been fragmented into small blocks. Woodlands are often refugia for grassland species which are present in glades and rides within woods. Connecting habitats are not well managed, and are often poor in quality and quantity. Extensions and buffer zones would benefit existing woods, and links between existing woods should be restored, for example by developing semi-natural riparian corridors along small streams and small rivers where trees are critical to the natural small-scale mosaic of habitats.

- Particular attention needs to be paid to rebalancing the tree species mix. Natural regeneration of tree and shrub species is important for genetic resilience, and also to ensure trees and shrubs are positioned in the landscape according to their optimal environmental conditions, allowing natural habitat mosaics and transitions to develop.

- The natural variation in woodland habitats provides diversity for species to exploit. For example, variation in the degree of canopy openness and understorey density can satisfy the needs of both bryophytes and light-demanding species such as lichens.

- Fungi play a vital functional role in woodland ecosystems. Future management should focus on maintaining and developing natural conditions and processes to ensure fungal health.

- Old growth forests with wood decay and their associated fungal communities, are the ultimate expression of naturally functioning woodland systems. Ancient woodlands should be the priority for conservation management because the restoration of degraded ancient woodland is likely to be more beneficial than woodland creation on land with no such ecological history. Old-growth is particularly rare and vulnerable - assuring continuity of habitats and historic associations should be a focus for the future.

- Wood pastures represent an important aspect of natural woodlands which have become largely absent from modern landscapes, but their open nature mimics natural open woodland. The restoration and recreation of pasture woodland and parklands is important for providing wooded habitats in both the uplands and the lowlands.

- Restoration of a more natural tree cover in the uplands is essential to encourage the development of resilient upland ecosystems where natural processes can operate at a landscape-scale. Natural tree cover in the uplands will include a mixture of open canopy and pasture woodland, particularly around the natural ecological limits of upland tree growth, as well as more dense woodland.

- The loss of keystone species such as beaver, and the removal of large predators, has altered the balance of species with major consequences for the structure and function of woodlands. Restoration of natural function should include low intensity disturbance activities by large herbivores such as cattle, ponies, deer and by species we are reintroducing to the landscape such as beaver and wild boar.

- In the absence of large carnivores, it is necessary to control populations of wild deer to allow naturally functioning woodland systems to be re-established. As lost native species such as beaver and wild boar return to the English landscape, similar measures may become necessary to control their numbers to near-natural levels.

- Opportunities to restore naturally functioning floodplain wetlands should be taken where this is practicable and relevant, focusing on floodplains with less development and where floodplain woodlands can be restored as part of wider naturally functioning habitat mosaics.

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