Biodiversity, forestry and wood

An analysis of the biodiversity benefits of modern forestry and wood production

A CONFOR SPECIAL REPORT

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Promoting forestry and wood

The importance of modern forestry and wood production in sequestering carbon and tackling the climate emergency is well known. Yet the role they can play in slowing and reversing the 'nature emergency', which is becoming imperative across land uses, is less widely understood. This Confor report provides a review of evidence on this subject in three main areas:

- the habitat value of forests planted for wood production,
- the potential of bringing neglected native woodland into management through the development of small-scale wood production and local supply chains,
- the importance of a home-grown, low carbon resource in helping reduce the pressure to exploit natural and semi-natural forests globally, tackling the drivers of biodiversity decline around the world.

1

Forests planted in the UK for wood have significant biodiversity value

A substantial body of science suggests that, at present, the forests planted in the UK for wood production have significant value as a biodiversity habitat, in spite of their young age and largely non-native species. Evidence-based management measures have become standard forestry practice in enhancing these maturing habitats, such as creating structural diversity and incorporating native tree species.

2

Wood production can help improve the condition of native woodlands

UK woodlands include native forest habitats of global importance, yet the majority of these are degraded and fragmented, with priority species showing declines. This report surveys evidence to argue that wood production can make a threefold contribution to nurturing these into ecological health through:

- sensitive extraction such as thinning and coppicing,
- promoting tree growth and forest regeneration for example by preventing browsing damage,
- providing a sustainable income stream to fund active management and create value for the owner, as the basis for high quality native woodland expansion.

3

Home-grown wood is important for biodiversity far beyond the local forest

Wood production sequesters carbon, provides the raw material for green jobs and low-carbon manufacturing, and reduces the UK's reliance on imported timber which may be harvested unsustainably from natural forests. They provide natural capital benefits like reducing flooding and improving air quality. Wood-producing forest in the UK helps to tackle the fundamental causes of nature decline at a global level by reducing our demand for resources produced elsewhere.

4

We already possess the knowledge, tools and frameworks to deliver wood production and biodiversity benefit simultaneously

UK forests are already delivering biodiversity benefits, and these are increasing as forests mature and are brought into modern design and management standards. Yet multiple barriers to woodland creation and management remain, resulting in missed opportunities to develop the potential to increase production of the renewable materials our economy needs in ways that enrich nature. In the face of the climate and nature emergencies these opportunities must be seized.

5

The report also provides recommendations of areas for further research

These include new woodland creation, management advice on important UK species assemblages, restoration of woodland ecology beyond the trees, studies of forestry within the wider landscape, invertebrates, the ecology of the forest floor, and interactions between forest biodiversity and public access.

1 INTRODUCTION

Too little attention has been paid to the importance of forestry and wood production in supporting biodiversity, and its potential to play a much greater role in reversing biodiversity loss. Their importance in helping to mitigate climate change is well known, and has led UK governments to set targets for woodland creation, use of wood and woodland management. This report seeks to present a coherent analysis of the evidence on forestry and biodiversity, with a view to ensuring forestry policy delivers confidently for nature as well as for climate.

Globally, nature is declining and species are becoming extinct as a direct result of human activity. Besides the moral issue of the destruction of life, nature's decline poses a direct threat to our economies, food supply, health and quality of life. It is caused directly by human activity: a triple attack from climate change, resource extraction and pollution. According to the comprehensive Global Assessment of Biodiversity, reversing this decline will require 'a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values' (*IPBES 2019*). In other words, protecting nature must be integral to human business, not a separate activity alongside it.

Over the course of human history, unsustainable harvesting of wood for human use has exploited and destroyed rich forest habitats across the planet. Yet forestry can also be restorative: growing the forests first to provide what we need. In the historically-deforested UK, foresters in the nineteenth and twentieth centuries had to be planters and managers first and loggers second. For two hundred years, a British silviculture and forestry profession has developed to suit these unusual circumstances. Policy frameworks delivered the land-use change required and forests were created: novel habitats of Sitka spruce, Douglas fir, Norway spruce, larches, pines, true firs, Western Hemlock, Western red cedar and other species suitable for timber (*Quine 2015*). Early mistakes sometimes made in siting and design helped develop a strong governance framework, robust body of evidence and high level of professionalism to ensure that, going forward, the restorative role of forestry is more certain and delivered faster. However, fear of mistakes resulted in fundamental change to incentives for forestry and introduced such a strongly precautionary approach that the culture of planting and management developed over the past two centuries collapsed (*figure 1*), and at the start of this century, biodiversity and wood production were, outside the forestry sector, again widely perceived as in conflict.

This report argues on the basis of substantial scientific evidence that this perception is not based on reality. Unlike in countries where fully natural old-growth forest survives on a large scale, in the UK, wood production from both native and non-native trees can, and already does, enhance the biodiversity value of a woodland.

First, it shows that the wood-producing forests of the twentieth century have developed their own importance as habitat, and that as they mature and expand, managed within the UK's strong governance frameworks, this importance is increasing.

Second, it demonstrates that the decline in broadleaf woodland management is largely responsible for the decline in its value as habitat, and that bringing it back into sensitive and appropriate active management for wood production will deliver rapid and significant improvements in habitat quality.

Third, it sets UK forestry in the wider context of the climate emergency and development of a renewable, low-carbon economy, to demonstrate the crucial role of these working forest habitats in our sustainable future.

Figure 1. New planting of conifers in the UK 1971 - 2019 *(Ward 2019)*

CASE STUDY 1

Forest wildlife on the west coast of Scotland

John Little MICFor, Tilhill Area Manager, West Highland District North

In 30 years creating, managing and restocking forests I have seen many positive examples of ecology in action. Hen harriers now hunting and nesting on larger restock sites in Mid-Argyll and Mull. Sea eagles nesting and hunting in numerous forests throughout Argyll. We are monitoring golden eagles breeding success to see whether a mix of productive woodland, native woodland and open hilltops will benefit them from improved prey availability; certainly the afforestation of the 1970s and 80s does not appear to have had the negative impact on the golden eagle population as was predicted by some at the time. Forestry has increased the numbers and variety of other raptors as well, provided diverse habitat for birds like black grouse, and walking any forest fence the contrast in bird song with open hill is striking.

In my time I have seen more red squirrel more often throughout Argyll as the forests of the 1960s 70s and 80s have matured. Tilhill and forest owners on Loch Aweside are cooperating with the Port Sonachan Red Squirrel Group to encourage squirrels into the permanent native woodland areas in and around the productive conifers areas. The increase in squirrels and other prey results in increases in predators such as pine marten and wildcat. There also appears to be a healthy otter population throughout Argyll, and although it is hard to attribute this to solely to forestry it does not appear to be doing them any harm. Wood ants also seem to have a preference to build their nests of spruce needles on the boundary between productive and native woodland.

Most forestry in this area has been created on ground previously used for extensive low stock density rough hill grazing. Areas of existing native woodland have been protected and expanded in the process of creating our productive conifer woodland, and significant areas of peat bog, wetland, species-rich grassland have been retained within the overall forest designs.

My observation, as a working Forest Manager over many years, is that in terms of species diversity and biomass, forestry delivers a significant improvement for biodiversity on the previous land use.

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Sea eagles on the Isle of Mull

2 BIODIVERSITY IN FORESTS FOR WOOD PRODUCTION

With few remaining semi-natural woods or native tree species suitable for large-scale wood production, the UK relies on planted forests of primarily non-native species to supply its timber requirements.

Unfortunately, the merits of native versus exotic trees has come to dominate much of the debate about forestry and biodiversity in the UK, to a degree which would be unthinkable for other produce. Few conservationists would argue farmers should produce only UK native food such as raspberries, hazelnuts, duck and venison. Exotic staples like wheat, oats, cabbage, peas, apples, chickens, sheep and cattle have been cultivated in Britain for millennia, supplemented by recent additions like rapeseed, potatoes, tomatoes, sugar beet and maize. It is widely accepted that farmland biodiversity could be substantially improved through management: timber growing should be no different. Native oak, beech, Scots pine and birch can yield valuable wood when selectively bred and carefully managed; there is a resurgence of interest in their silviculture. Yet on their own, even assuming their intensive management and a significant reduction in resource use and waste, these species could not yield the volume and qualities of wood required to build zero-carbon homes and displace energy intensive and oil-based materials. Exotic trees like sweet chestnut and sycamore have been cultivated for centuries; more recently, spruces, firs and larches have become staple ingredients of the forestry palette, with new species being explored to diversify it further.

The forest is home to thousands of species of mammals, birds, herptiles, vascular plants, bryophytes, invertebrates, lichens and fungi. The trees themselves provide the structure to extend the habitat deep into the soil and high into the canopy, giving it a scale and variety unique in land-based ecosystems. Native woodlands have a special importance, explored below, particularly for certain groups including invertebrates. Yet the majority of forest ecology does not rely on particular species of tree (*Bellamy 2012*), and the exotic species introduced for wood production have developed rich forest assemblages of their own (*Coote 2012*).

The Pacific North West conifer Sitka spruce is the most widely-grown and valuable species for wood production, and is likely to remain so for some time even with strong interest in diversification. It is easily established, has relatively low maintenance costs, produces high yields and its timber is in high demand across many markets. Douglas fir, Corsican pine, Norway spruce and until recently larches all play important roles. New species require extensive testing and breeding to compete on quality and quantity of wood production, and the composition of a forest can only be changed at harvest. UK forests where Sitka spruce is the dominant species are sometimes said to be much lower in biodiversity than forests of other types. Given the importance of Sitka for wood production it is crucial to assess the evidence on biodiversity in Sitka specifically, and other exotic conifers, within the context of UK forest biodiversity as a whole. This assessment is possible thanks to a significant body of detailed scientific research assessing a wide range of biodiversity indicators in different types of UK forest.

A comparison of ancient oak and ash woodland in Ireland with closed-canopy spruce, opposite ends of the forest scale in terms of age, native species and structural diversity, found that 'the species richness of non-native spruce-dominated plantations can be as high as that found in semi-natural woodlands' (*Irwin 2014*). Another large, cross-taxa study found that 'in terms of overall species-richness there was no significant difference' between Sitka spruce and native Scots pine, or between Norway spruce and native oak (*Quine 2010*). Fungi, bryophytes and ground- and canopy-dwelling spiders have all been found to be 'facilitated' in Sitka, that is, found in greater diversity and abundance, compared with Scots pine, oak and ash (*Humphrey 2000*, *Quine 2010*, *Smith 2008*, *Irwin 2014*). Conifers support important population expansion of capercaillie, crossbill, long- and short-eared owl, goshawk, nightjar, woodlark, firecrest, grasshopper warbler, redpoll, redwing, barn owl, crested tit (*Avery 1990*), woodcock (*Heward 2018*), merlin (*Little 1995*, *Parr 1994*), siskin (*Mckenzie 2007*), hen harrier (*Geary 2018*) and wood ant (*Procter 2015*). Diversity of canopy beetles was somewhat higher in Scots pine, Corsican pine and Norway spruce than in Sitka, but abundance was higher in Sitka (*Jukes 2002*). Reptiles have only been studied in another exotic conifer, Corsican pine, found to support all six species of British reptile (albeit smooth snakes show a preference for open heath if it is in good condition) (*Jofre 2016*). Siskin, coal tit and common crossbill populations expand

CASE STUDY 2

Woodlark and nightjar in Thetford

Andrew Stringer, Head of Environment and Forest Planning, Forestry England

Planted in the 1920s and 30s, Thetford forest in Norfolk and Suffolk covers 18,000 hectares and is a SSSI. The dominant species is Corsican pine, alongside Scots pine and some broadleaves including oak, beech, lime, walnut, red oak and maple. The forest has become an important habitat for scarce breeding birds, including woodlark, nightjar *(pictured)*, goshawk, willow warbler, crossbill and siskin. Stone curlew breed on the edges of the forest. Forestry England's Thetford Forest Plan was widely consulted on and ensures the succession of forest and open habitat created through timber harvesting is managed to maintain habitat quality.

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in years of good Sitka cone crops, and show a strong preference for forestry over garden bird feeders (*Mckenzie 2007*). The UK's wood-producing forests are one of a suite of novel forest habitats around the world which have developed their own significant biodiversity value (*Quine 2015*, *Sax 2004*, *Primack 2018*).

Expanding forests

There are strong reasons to expand forestry for wood production in the UK. The UK has 13% forest cover compared with a global average of around 30% and in Europe 40%. The UK imports 81% of its wood products, making it the second biggest net importer of wood in the world (*Ward 2019*). China, the only country with greater net imports, has created three times as much new forest as any other country since 1990 (*Payn 2015*). The UK has demonstrated no serious intent to tackle its timber trade deficit this century. Reliance on imported wood not only raises questions about future supply and economic disadvantage, but has serious implications for global climate change and biodiversity, discussed below (p.23).

The arguments for increasing UK forest cover are also compelling for biodiversity reasons. The State of Nature report emphasises 'the importance of maintaining, increasing and enhancing woodland for nature conservation' (*Hayhow 2019*). There is clear evidence that the biodiversity benefit of forests increases qualitatively as well as quantitively with size. Large woods of suitable structure are vital for specialists such as nuthatch, marsh tit, long-tailed tit, chaffinch, great spotted woodpecker, dormouse and yellow-necked mouse (*Bailey 2007*). Fragmented semi-natural woodlands can lose the viability of their ecosystems (*Cordingley 2015*). Specialist woodland birds require larger woods, so new woodland creation should be at least 20 hectares (approximately the minimum required for wood production), or added to existing woods (*Whytock 2017*, *Dolman 2007*). Key woodland species like vascular plants, wood ants and many deadwood species cannot cross to new locations (*Bailey 2007*, *Burton 2018*, *Honnay 2002*, Proctor 2015, *Jukes 2001*). Kielder forest provides a striking example of the importance of connection whether for native and non-native woodland creation: despite being one of the oldest and largest woodland creation schemes in the UK and home to England's most important red squirrel population (*Case study 4*), its assemblage of semi-natural woodland flora lags well behind most planted co-

CASE STUDY 3

Planting the seeds

Imam Sayyed, Production Director, Maelor Forest Nurseries

Maelor Forest Nurseries employ a network of seed collectors across the UK to source seeds of wide genetic variety and provenance for their native tree stock. Our seed orchards breed improved varieties of silver birch (*below*), sycamore, and ash (now used to identify strains resistant to *chalara*). Maelor are also developing innovative propagation techniques to multiply rare and valuable genetic material by using a technique called somatic embryogenesis (*right*). We are propagating rare native *Populus nigra* by cuttings and are supplying these to conservation projects. We also work to develop a wide range of high-yielding and resilient conifer species such as Douglas fir, Norway spruce, western red cedar, *Pinus pinaster,* Western hemlock, spruce hybrids and sequoias, to diversify future wood production. Maelor employ around 115 full-time equivalents, and collaborate with the Confor Nursery Producers Group, Conifer Breeding Co-op, Future Trees Trust and National Tree Improvement Strategy. We have ongoing research projects with Aberystwyth, Bangor, Cumbria, Ohio and Oxford universities looking at topics including tree physiology, genomics, pest resistance and tree diseases. Sitka spruce, with its reliable growth and high quality timber, remains the 'bread and butter species', providing nurseries, as for the whole sector, the economic foundation for research and experimentation to develop the diverse forests of the future.

MAELOR


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nifer forests, probably due to the lack of previous tree cover in the area (*Ferris 2000*). Supplementing and connecting UK woodlands, whether fragmented broadleaf or isolated twentieth-century conifer blocks, with new planting will not only add to but multiply the benefits of the whole, at the same time as providing the wood resources we need.

A major challenge for forest expansion is the concern regarding the impact of afforestation on the habitats being planted. This is far from a trivial issue: 'every level from global to local' is needed to reverse biodiversity decline (*IPBES 2019*). The harvesting and replanting with conifers of some ancient semi-natural woodlands in the mid twentieth century led to the foundation of the Woodland Trust for their protection (*Pryor 2002*). The afforestation of 30,000 hectares of the Flow Country in the 1980s, much of which damaged intact peatland habitat, undoubtedly contributed to huge growth in membership of the RSPB. Commentators at the time, recognising the importance of increased wood production, expected that woodland creation would move onto less sensitive sites (*Avery 1990*), but instead planting rates collapsed (*figure 1*) and confidence was lost (*Bellamy 2012*).

By the 1970s foresters were aware that relatively small adjustments could provide disproportionate benefits for biodiversity and environmental protection. This awareness resulted first in the Forest and Water Guidelines in 1988, and subsequently the UK Forestry Standard (UKFS) in 1997. All government-funded woodland creation must comply with UKFS, and existing forests are brought into compliance with UKFS as they are harvested and restocked, as a condition of government-issued felling licenses. In addition, over 80 percent of UK wood is grown in forests whose management is independently certified to Forest Stewardship Council (FSC) and/or Programme for the Endorsement of Forest Certification (PEFC) standard through the UK Woodland Assurance Standard (UKWAS). Certification is a key collaboration between foresters and conservationists, based on UKFS and annually audited at the owner's expense to ensure sustainable forest management is demonstrated.

To avoid past mistakes, UKFS takes a cautious approach to afforestation, for example excluding deep peat and designated sites. In addition, regulations require proposals of significant size or on potentially sensitive sites to undertake an Environmental Impact Assessment. The extensive Bioforest survey in Ireland, where a far wider range of sites were being planted with far more intensive ground preparation techniques than in the UK, concluded that while intact peatlands or certain scarce semi-natural grassland habitats should be avoided, grassland which had been improved or bogs 'cutover' for peat in the past would deliver greater biodiversity value through

CASE STUDY 4

Red squirrel in Kielder

Andrew Stringer, Head of Environment and Forest Planning, Forestry England

Kielder forest in Northumberland, planted in the 1920s and 30s, is England's largest planted forest, covering 65,000 hectares. Kielder is home to around 50 per cent of England's red squirrel population, and without it this species would be almost entirely absent from England. The reason for their success is that the dominant tree, Sitka spruce, is not suitable for its competitor the invasive grey squirrel.

HAZEL CLARK

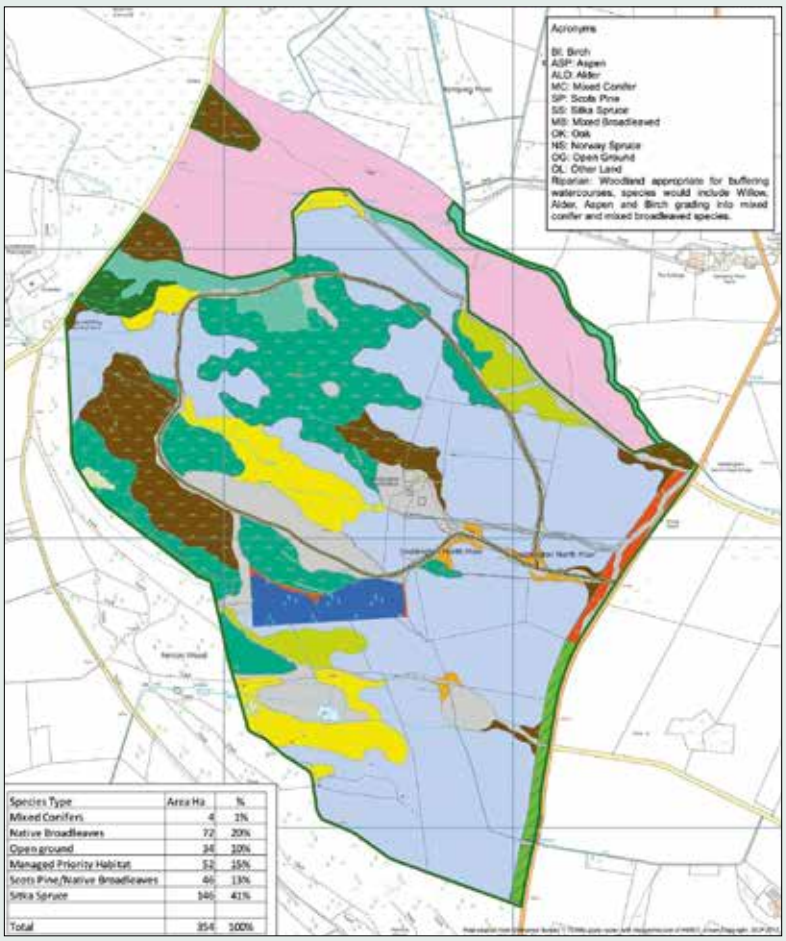
CASE STUDY 5

New productive woodland creation in Northumberland

Andy Howard, Manager, Doddington North Forest

Doddington North Moor, planted in 2017-18, is the largest new forest in England for 25 years. The site is 354 hectares, of which 75 per cent is planted with a mixture of Sitka spruce (42%), native broadleaves and Scots pine. Much of the open ground is managed priority habitat, including a rare peat mire being restored as part of the project, with drainage reduced and invading rhododendron, birch and Scots pine removed. In 2020 a bird survey was undertaken by the ecologist who surveyed the site before planting, providing empirical evidence of the changes in bird life over the first years of a new forest. In the two years since planting began there has been an increase in important species including kestrel, barn owl, hen harrier, nightjar *(nest, below right)*, wall butterfly *(below)* and petty whin have moved in or increased in abundance.

Right: Doddington planting plan



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forestry, particularly if it incorporated features standard in the UK such as native broadleaves, open ground, and retention of existing micro-habitats such as wet areas or hedges (*Smith 2006*).

The often-repeated cliché 'the right tree in the right place', with its implication that there is one 'correct' tree for each location, has often resulted in planting no trees at all due to a failure to understand the benefit of trees on a given site (*Howard 2018*). Doddington forest in Northumberland, the largest area of new planting in England in a generation, was only delivered following years of uncertainty and a national campaign (*Case study 5*).

While tree planting is rigidly regulated, other habitat changes caused by human management face no such restriction. There is evidence that declines in livestock numbers are changing grassland composition and creating an 'extinction

debt', that is, likelihood of future loss of flowers and plants, in these habitats (*Mitchell 2016*). Diversifying farms with forestry and concentrating managed grazing on grassland habitats with greatest importance could help to reverse this trend. The UK's 1.4 million hectares of upland acid grassland expanded by almost 100,000 hectares in Scotland and Wales between 1997 and 2008 (*Bullock 2011*). Bracken covers another million hectares and is expanding at 10,000-30,000 hectares per year (*RSPB 2011*). Forestry, which largely shares the same landscape, increased at an average of only 3,000 hectares per year in the first two decades of this century, barely enough to replace the timber production capacity lost to habitat restoration, windfarms and restructuring of older planted forest, and a fraction of the 30,000 hectares recommended by the UK Committee on Climate Change to meet zero-carbon targets (*Davies 2020*).

Managing conifers

There are a range of practices designed to enhance forest biodiversity, in many cases while also increasing wood production and lowering risks, which thanks to UKFS and UKWAS have become standard in management of conifer-dominated forest. This section surveys some of the extensive research done to assess whether their implementation over the past 20 years, as forests have been harvested and replanted, has delivered these benefits.

Species mixtures

No more than 75 percent of a forest area may be planted with a single species. Species mixtures provide a more continuous supply of seed for birds (*Broome 2016*) and enhance invertebrate diversity (*Oxbrough 2016*). They diversify light levels in the forest, with species like pine facilitat-

CASE STUDY 6

Researching stand structure and biodiversity at Stourhead

Nick Hoare, Stourhead (Western) Estate and Patrick Cook, Butterfly Conservation

The Stourhead estates, on the border between Wiltshire and Somerset, cover 1,000 hectares. Trees were first planted two hundred years ago, and today almost 50 per cent is forestry including Douglas fir, spruce, larch, western red cedar, western hemlock, oak, ash, beech, sweet chestnut, sycamore and alder, producing 3000m^3 timber per year in a developing continuous cover system. The estate is working with Butterfly Conservation to investigate the effect of different management regimes on moths. In 2019, 216 species of moth were recorded, with abundance slightly higher in the irregular stands compared to the even-aged stands, with no difference in species richness. Further data collection is required in 2020 before conclusions can be drawn from the data. In 2020, the project will expand to include surveys for vegetation, spiders, birds and bats.

Below: Moths at Stourhead (l-r): Buff tip, Rosy footman and Canary-shouldered thorn

PATRICK COOK

ing a herb layer of more light-demanding graminoids (grasses) and ericoids (like heather), in contrast to the bryophytes (mosses and liverworts), ferns, and forbs (like wood sorrel) characteristic of spruce (*Hill 1979*, *Ferris 2000*). Diversifying forests is also an important consideration for wood production, to mitigate risks from pests, extreme weather and market fluctuations (*Freer-Smith 2019*).

Open areas

At least ten percent of a forest area must be left unplanted, and in practice this is often greater as open areas must include, where present, deep peat, priority habitat, heritage features, and buffer zones around water courses and water bodies. Permanent open space within forests have long been known to be valuable for ground flora (*Hill 1979*) and have been demonstrated to increase the diversity of ground beetles (*Jukes 2001*), facilitate colonisation by wood ants which expand along woodland edges (*Proctor 2015*), provide nest sites for Hen harrier (*Geary 2018*) diversify epiphytic lichens and bryophytes through the creation of edge habitats (*Coote 2008*), and enhance overall biodiversity benefits (*Quine 2010*). The requirement to create buffer zones around water courses when new forests are planted or existing ones harvested, is important for a wide range of freshwater invertebrates (*Weatherley 1993*). Open areas may also be important silviculturally to create a wind-firm boundary between felling compartments. Farmers are taking opportunities to use these spaces to integrate forestry with farming to improve grazing management, offering an additional synergy with low-input food production (*Harris 2017*, *SF 2019*).

Diverse and dynamic habitat

First-generation even-aged forests must be restructured at harvest into a mosaic of diverse ages. Adjacent compartments are only felled when the restocked forest reaches two metres in height, although there is a case for varying this rule on some occasions, as there is also evidence that 'contagion' between adjacent restock and

CASE STUDY 7

Landscape-scale restoration of forest and peat bog

John Gallacher, Forest Ecologist, Tilhill

Between the 1960s and 1980s grants were available to farmers to drain their marginal hill land. While this yielded little benefit in terms of agricultural improvement, it badly damaged the hydrology, carbon storage and ecology of large areas of upland peat. A 1,400 hectare estate on the west coast of Scotland was an opportunity for restoration on a landscape scale. 400 hectares of productive conifer on the lower ground provides the income stream and secures management oversight of the site. Integrated with 140 hectares of amenity woodland and improved access it will create a significant new forested area for people and wildlife. On the higher ground, the forestry company accessed blended finance to restore 350 hectares of drained peatland, creating

JOHN GALLACHER

2,234 dams to slow the flow of water (*above*). As well as the extensive habitat creation, the restoration of forest and wetland will reduce the risk of flash flooding in the local community, improve water quality, store carbon and provide recreational opportunities.

pre-thicket coupes may facilitate vascular plants (*Eycott 2006*) and ground beetle dispersal (*Jukes 2001*). Management of a forest for diverse stand stages delivers a range of biodiversity benefits (*Quine 2010*). It increases diversity of beetles (*Jukes 2001*, *Mullen 2008*, *Burton 2018*) and birds (*Calladine 2016*) and improves habitats for reptiles (*Reading 2018*). A study of planted conifers in the Belgian Ardennes, similar to those typical of the UK, found a greater number of bird species associated with internal edges within the forest than where the forest adjoined other land uses (*Dolman 2007*). The successional habitat created by pre-thicket planted forest under ten years old creates pseudo-scrub recognised internationally as an important habitat (*Calladine 2018*) in which vascular plants (*Ferris 2000*, *Eycott 2006*) shrubland birds (*Calladine 2016*), voles and predators such as Hen harrier flourish (*Geary 2018*, *Petty 1994*). Black grouse which colonised newly-planted forests were negatively impacted by their canopy closure and lack of new planting, but restructuring of forests offers opportunities for habitat enhancement (*Geary 2013*). Age diversification is only now beginning to be visible as late twentieth century UK forests are restructured, particularly as, in addition to the inevitable even age of any young forest, the drop in planting after 1988 created an unbalanced age profile across the forest portfolio.

Deadwood and old growth

UKWAS requires forest managers to 'take action to accumulate large dimension standing and fallen deadwood and deadwood in living trees in those areas', and create natural reserves and long-term retention areas where they will deliver greatest conservation benefit (*UKWAS 2017*). Non-native wood-producing forests in the UK are richer in deadwood than native woodlands thanks to their active management, particularly when stumps left from thinning and harvesting are included (*Ditchburn 2020*, *Woodman 2013*). Deadwood and older-growth forest facilitates bryophytes (*Ferris 2000*, *Smith 2008*), fungi (*Humphrey 2000*), hoverflies (*Smith 2008*), slow-growing lichens (*Quine 2010*) and provide niches of ecological continuity for species such as forest specialist ground beetles (*Jukes 2001*) as well as vital roost sites for bats (*Carr 2019*). Located next to semi-natural woodland they can enable wood-producing forests to buffer and en-

CASE STUDY 8

SCOTTISH WOODLANDS

Evaluating the potential for ancient woodland restoration within a commercial woodland

Kate Tuer MICFor, Senior Forest Manager, Fort William Office, Scottish Woodlands Ltd.

Fassfern Forest near Fort William is a large-scale commercial forest with clear objectives of maintaining a sustainable timber production yield and maximising the potential for future commercial conifer area. The estate has its own woodfuel drying plant which utilises the small roundwood while sawlog material is sold to the local BSW K2 Sawmill at Corpach. However, the 4,000 hectare forest also presents significant opportunities to restore Ancient Semi-Natural Woodland (ASNW), some of which is classed as Plantation on Ancient Woodland (PAWS).

Far from this becoming the conflict of objectives it might at first appear, Scottish Woodlands have joined forces with The Woodland Trust to map and assess the ASNW and PAWS, and to integrate ancient woodland restoration projects into the Forest Plan. Working together site surveyors from both teams have stratified the large area of ASNW/PAWS, evaluated its potential for recovery or restoration, and prepared outline management objectives for each strata. This information then supports the forest manager in selecting the 'best' sites to restore via the forest plan, while also identifying those areas of PAWS with a lower biodiversity significance or without the potential to recover.

The collaboration so far has led to the consolidation of restoration projects in specific areas of the forest: those which have the highest current, and potential future, biodiversity criteria including riparian zone connectivity, rare butterfly (Chequered skipper), red squirrel and otter habitats, and fish and freshwater pearl mussel spawning sites. This approach also allows the commercial conifers to be consolidated in the most suitable areas elsewhere in the forest.

CASE STUDY 9

Turtle dove success story on the Eltisley Estate

Cheryl Lundberg MICFor, Senior Forestry Consultant, Lockhart Garratt

The Eltisley Estate is one of the few places left in Cambridgeshire to host the turtle dove, the UK's only migratory dove species, which is threatened by the loss of suitable nesting and feeding habitat in the UK. The woodlands at Eltisley have developed a range of stand types and a varied structure through an annual programme of management for wood production.

When preparing a Woodland Management Plan in 2013, we invited RSPB to advise on management for turtle dove, known from a previous bird survey. The upshot was scrub management on a bold scale with the aim of developing a patchwork including bramble, low and young scrub, mature 'rangy' hedges and retention of older scrub areas. We used a large-scale mulcher to push through patches of older scrub and bramble to create a good starting point. Management over time will develop the range and structure of suitable nesting habitat. The estate team have ensured adjacent ponds provide suitable drinking places with perches, and have developed feeding areas, approximately 60 % open ground with seed-bearing plants such as fumitory and black medick, plus some supplementary feeding.

Last year, we invited Dr Vince Lea, head of wildlife monitoring at the Countryside Restoration Trust, to undertake a bird survey linked to Red List Revivial project and provide further advice on management. It was fantastic to learn that Vince recorded turtle dove in this location last year.

The management work was not onerous or expensive. Small tweaks to management, based on the knowledge and advice of local experts, can perpetuate and often improve or create new habitats for wildlife.

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hance fragmented native woodland effectively (*Humphrey 2000*). While forest management aims to avoid windthrow, where this has occurred it creates valuable habitats associated with much older forests (*Ferris 2000*). While any newly created forest will necessarily take decades to develop, the fast growth and harvesting of conifers means mature ecological characteristics such as deadwood, large canopy area and diverse structure develop more quickly. The National Forest Inventory Woodland Ecological Condition data demonstrates the huge potential to manage the UK's largely young forests more actively for deadwood and 'future veterans', given the great importance of these for biodiversity and the small cost to wood production (*Ditchburn 2020*).

Managing light and shade

Perhaps the most frequent ecological criticism of forestry is the effect of thicket stage shade, after the canopy has closed (*Bunce 2014*). The rapid expansion of UK forestry followed by a long cessation of planting has exaggerated the impact of thicket stage in the short term. Shading is a function of stand stage rather than species (*Burton 2018*), although certain species such as western hemlock and beech cast particularly heavy shade. This period of shade lasts longer under slow-growing broadleaves than conifers (*Harris 1997*). The most obvious impact is the suppression of the herb layer – vascular plants on the forest floor (*Hill 1979*, *Eycott 2006*, *Ferris 2000*, *Irwin 2014*) – which in turn suppresses species supported by these, including ground beetles (*Jukes 2001*), smooth snakes (*Reading 2010*) and possibly also spiders (*Irwin 2014*). However, the shade facilitates other forest specialists which are usually outcompeted, in particular ferns and bryophytes which flourish except under the deepest shade (*Eycott 2006*, *Ferris 2000*) and rare orchids, although these are seen more often in beech than conifer as the latter are rarely sited on suitably lime-rich soils (*Harris 1997*).

More frequent thinning, increasing light in the forest, speeds up growth of the remaining trees making it a profitable economic activity and increasing carbon benefit, so long as there is a market for the thinned wood, valuable for products such as fencing, pallets, panelboard, paperboard and biomass fuel. Thinning has considerable potential to accelerate the habitat value of

CASE STUDY 10

Restoring ancient woodland within a productive forest

Tom Black MICFor, Forestry Manager, Savills

Sitting on the upland fringe, Craigadam is a productive forestry block that forms part of a larger Dumfries & Galloway holding. Although generally well-designed, a gully area of ancient semi-natural woodland had exotic conifers introduced in past decades. Changes to forest structure can be slow to effect, due to rotation lengths, but guided by the UKFS the opportunity has been taken to restructure this secluded gully with habitat restoration as the main objective. The areas of Douglas fir, Sitka spruce and hybrid larch are now being removed and the existing broadleaves will be expanded with mixed native species that are ecologically suited to the site referencing the former ancient woodland type. Timber removal required sensitive management to avoid diffuse pollution, a challenge which the restructuring will remove from future operations. Income from harvesting will aid in funding this work, and the connected areas of open ground and other permanent habitat within the productive block will provide the ecological network of a larger forest.

young forests (*Fuller 2018*), and indeed has been demonstrated to be so effective in increasing the biodiversity of Sitka that it can be considered as a surrogate indicator of biodiversity (*Smith 2008*). It can increase seed production, supporting birds (*Broome 2016*), facilitates the herb layer (*Ferris 2000*) and is good for bats (*Carr 2019*) and ground beetles (*Jukes 2001*), while reducing vulnerability of the forest to damage by bark beetles (*Freer-Smith 2019*).

Light and shade in a forest changes in four dimensions: not merely across the forest floor, but through the vertical canopy and over time. Shade at ground level means a large area of forest canopy above, which itself creates a forest habitat rich in birds (*Calladine 2016*), invertebrates (*Irwin 2014*, *Harris 1997*, *Quine 2010*) and faster-growing lichens (*Coote 2008*). A harvesting regime of restocking, thinning and coupe-harvesting creates a dynamic distribution of light in a matrix landscape. The particular importance of young restocked forest, creating scrub habitat which is otherwise rare in the UK, means that forests harvested on shorter rotations for commercial reasons provide fortuitous biodiversity benefits (*Saraev 2019*). Continuous cover forestry (CCF) using shade-tolerant species as an understorey has been shown to increase total bird diversity in a single stand ('alpha' diversity) (*Ennos 2019*, *Calladine 2016*), but perpetuates the disadvantages of heavy shade at ground level (*Quine 2010*) and lacks the diverse matrix of habitats across the forest ('beta' diversity) associated with rotational forestry. CCF can improve forests' resilience to windthrow and fire; but thinning and harvesting fast-growing trees on short rotations is also an effective way to minimise this risk (*Freer-Smith 2019*). Since in places where CCF and rotational forestry are both practiced on a large scale, CCF shows significantly lower tree

growth, any biodiversity benefits come at a cost of carbon capture and wood production (*Bianchi 2020*). In many upland forests thinning and CCF is impossible due to windthrow risk, although it is easy to find the fallen stands of optimistic foresters who tested its limits. The choice is not binary: the forester can deploy a variety of intermediate systems with smaller coupes eventually merging into group selection CCF, and longer or shorter rotations. As the UK's forests and supply chains mature, the management options open to foresters are expanding and we are likely to see growing diversity in management delivering a wider range of forest habitats at 'alpha' and 'beta' scales.

Forestry and biodiversity: the opportunity

In a small, crowded country like the UK, writes David Attenborough, 'the whole countryside should be available for wildlife. The suburban garden, roadside verges – all must be used' (*Vidal 2014*). Forests grown for wood production are created by human agency not natural processes, but so are many wildlife habitats: bird tables, green roofs, former quarries repurposed as nature reserves (*Avery 1990*). The value for biodiversity of sustainably-managed planted forests is internationally recognised (*Lindenmayer 2006*). These forests are not only the production centres of the renewable low-carbon economy, they are simultaneously an important driver of ecological restoration, whose value will increase as forests mature and expand.

CASE STUDY 11

Bringing ancient oakwood into management through timber production

Graeme McVittie FICFor, Senior Conservation Officer, Exmoor National Park

Burridge Wood is a twenty hectare SSSI ancient woodland within the extensive Exmoor & Quantocks Oakwoods Special Area of Conservation. Once an estate's native oak coppice, it was planted with European oak of high timber quality in the late nineteenth century. Following a period of neglect after the second world war, it was gifted to benefit the people of Dulverton, and since the 1980s has been managed for conservation and public access.

Oak timber has long been a 'by-product' of woodland management at Burridge, with around 20m^3 a year from thinning, coppicing and felling used for signage, waymarking and gates (*below right*). This saves money, reduces our 'timber footprint', creates beautiful infrastructure with a story, and contributes to forest ecology as over time they host lichens and other deadwood species. Burridge Wood supplied the timber for the new Woodside Bridge in 2020, built from large sections of oak (p.28).

Around eight years ago members approved proposals for a more strategic use of the whole 600 hectare woodland estate to develop an income stream, integrating timber production with conservation management. Since then we have built knowledge of local markets and users including firewood markets, timber frame construction and furniture making. Identifying specialist applications around the UK such as boat building and historic reconstruction repays in high sale prices. Local foresters have been generous in providing expertise to identify which trees should be felled to combine the greatest conservation benefit with the highest timber value (*below: manually splitting oak in Burridge wood*).

The increase in habitat quality through the harvesting of timber from Burridge Wood has been clear. Following the removal of rhododendron, shade-tolerant holly was threatening to dominate. Thinning to increase

EXMOOR NATIONAL PARK

EXMOOR NATIONAL PARK

light beneath the canopy has helped bluebells and other ground flora to expand, as well as the epiphytic lichens for which the oak woods are particularly important. Some timber has been made into nest boxes for pied flycatchers, thanks to a collaboration with BTO. This has resulted in a dramatic rise in successfully fledged chicks, with ringed offspring returning from migration to colonise new woods the following year. This demonstrates the importance of active management in providing nest boxes in woods with few veteran trees, alongside the nurturing of 'future veterans'.

EXMOOR NATIONAL PARK

Our hard work to communicate to National Park members, the parish council and the public repays when felling operations are taking place in highly visible areas. We rarely receive complaints and our contractors are often thanked for the work they are doing to manage the wood. Local school children help to install and monitor nest boxes (*above*). They also adopt clearings where canopy opening results in oak regeneration: they measure the new growth and thin it out, and learn about woodland management.

Timber income has become essential to conservation work. When the Park faced cuts to public funding due to austerity, the income from timber enabled us to save a crucial staff member by demonstrating that over half their salary was paid for by timber, and thanks to their work carbon was being locked up, habitat improved, a local resource supplied, and a great story told to members.

We import timber from places all over the world which don't have the UK's very well regulated forestry sector. We know this is fuelling all kinds of environmental catastrophes. So if we can harvest timber on our own doorstep, why don't we use it?

Why are UK native woodlands important?

In the Tertiary period, between the dinosaurs and the ice ages, Britain's climate was warmer and covered in rich forest including sequoias, liquidambar, laurels, magnolias and palms alongside more familiar species. As the climate cooled and dried, species were lost and east-west barriers (Sahara, Mediterranean, Alps and Channel) prevented trees returning when the climate became more favourable. For this reason, the native tree flora of Europe, at 265 species, is significantly lower than at similar latitudes in the USA (1,455) or China (4,678). In the UK it is only 85, 41 of which are whitebeams, rowans and service trees which readily hybridize into new species; while 10 are species of willow, sallow and osier (*Spencer 2018, BGCI 2019*). Humans have shaped present UK woodland ecology for much of its 12,000-year existence since the end of the last ice age. By the time Britain became an island, around 6,000 years ago, the Neolithic Revolution was transforming forest to farmland. Long before auroch, lynx, bears, wolves and beaver became extinct, humans had outcompeted other megafauna as the driver of landscape change: clearing lime forests from prime arable land, removing other species from what became oak woodlands, introducing sycamore, sweet chestnut, apple, plum and walnut (*Harris 1997*). Over the past 200 years woodland area has expanded substantially from 4 percent, but industrial-scale coppicing and grazing, introduced trees, and invasive species such as rhododendron, grey squirrel and Spanish bluebell, have changed and in many cases damaged the remnant ecology. With so few species of trees, so little forest left, and none of it 'intact', is there a UK woodland biodiversity worth preserving?

The answer is undoubtedly yes. UK woodlands have two features making them globally unique. The first is the moist oceanic climate, creating rare temperate rainforest rich in epiphytes. The second is the limited palette of tree species itself. These have high genetic diversity, have demonstrated high resilience to a wide range of climate changes, and are pioneers, largely lacking the shady understory characteristic of continental

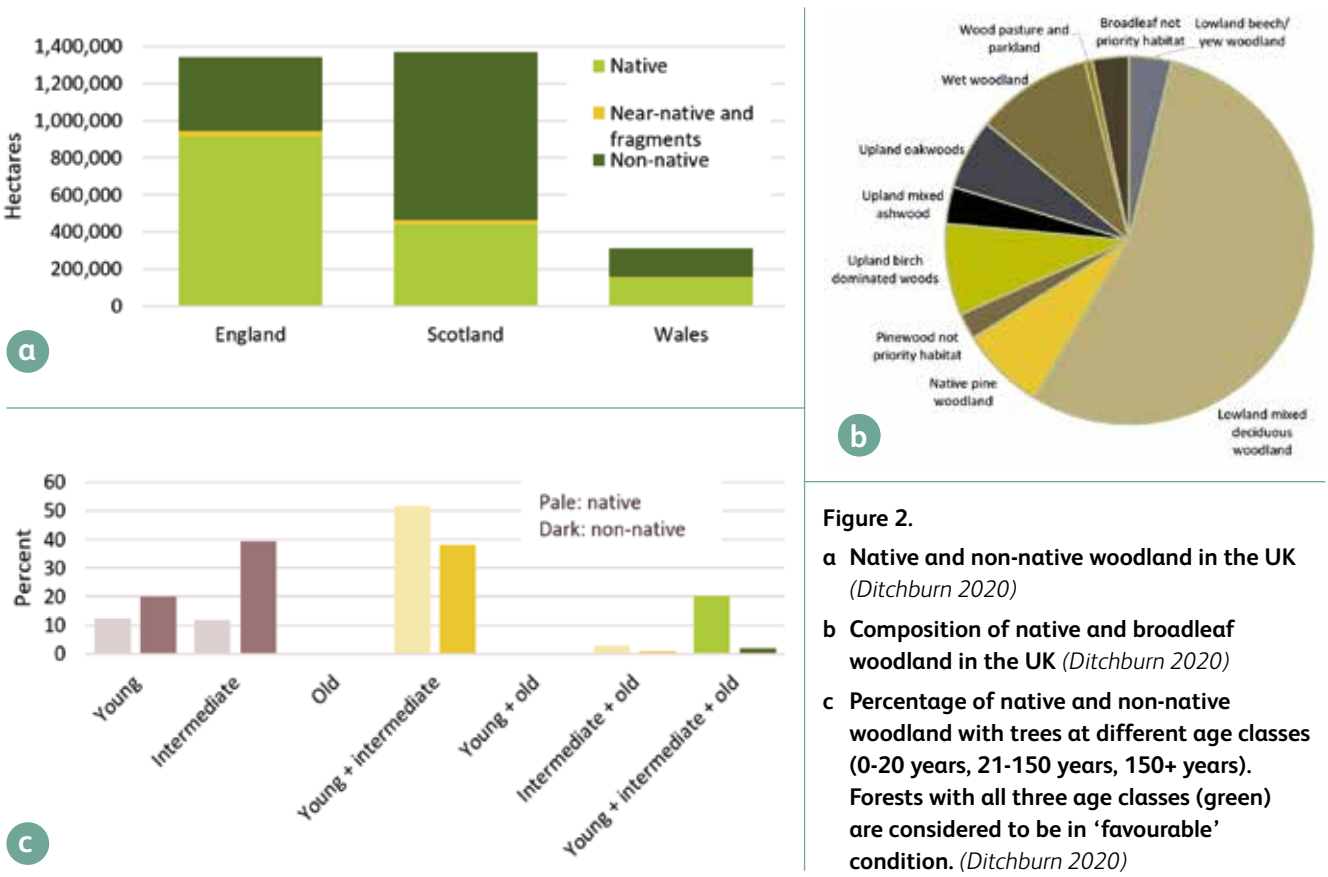

Figure 2.

a Native and non-native woodland in the UK *(Ditchburn 2020)*

b Composition of native and broadleaf woodland in the UK *(Ditchburn 2020)*

c Percentage of native and non-native woodland with trees at different age classes (0-20 years, 21-150 years, 150+ years). Forests with all three age classes (green) are considered to be in 'favourable' condition. *(Ditchburn 2020)*

forests. This combination of oceanic climate, open structure and high genetic diversity within species have led to the development of assemblages of ferns, mosses, liverworts, lichen and vernal vascular plants unique to Britain, and of global conservation importance (*Ennos 2019*, *Spencer 2018*, *Davies 2014*, *Coote 2012*).

Some forest species are 'obligate', that is, they will only associate with certain native trees. Of over a thousand species found in ash woodlands, 45 species of fungi, lichens and invertebrates are solely associated with ash, while a further 56, plus 53 vascular plants and bryophytes, have high association (*Broome 2017*). UK oak woods are even richer, hosting at least 2300 species of which 555 fungi, invertebrates and lichens are obligate or high association (*Mitchell 2019*). White-letter hairstreak butterflies will only feed on elm, Dark bordered beauty moths are largely associated with aspen (*Case study 15*), and for these and many other specialists the loss of these trees has resulted in substantial declines (*Clarke 2011*). Common crossbill thrives in spruce, but the endemic Scottish crossbill is adapted only to eat pine seeds (*Summers 2012*) – although the former prefers Sitka spruce and the latter Lodgepole pine to their native Norway and Scots forage (*Calladine 2018*). Aspen supports a high diversity of epiphytic mosses and lichens, facilitated by the genetic diversity within aspen itself (*Davies 2014*). These special associations are why it is vital that native woodlands are conserved, managed, protected from pests and diseases, researched, and expanded. Since 1985 all new forestry has been obliged to include at least 5 percent native broadleaves, and this has also been a condition of felling licenses where older forests are harvested and restocked. Restructuring the UK's 1.6 million hectares of conifer will have required planting a minimum of 80,000 hectares of new native woodland, and in practice due to site considerations substantially more.

Bringing native woodland into management

Native woodlands make up almost exactly half of forest cover across the UK although this is not evenly distributed: two thirds in England and one third in Scotland are native (*Ditchburn 2020*, *Figure 2*). Around a third are ancient woodlands, in existence long enough to develop rich forest eco-

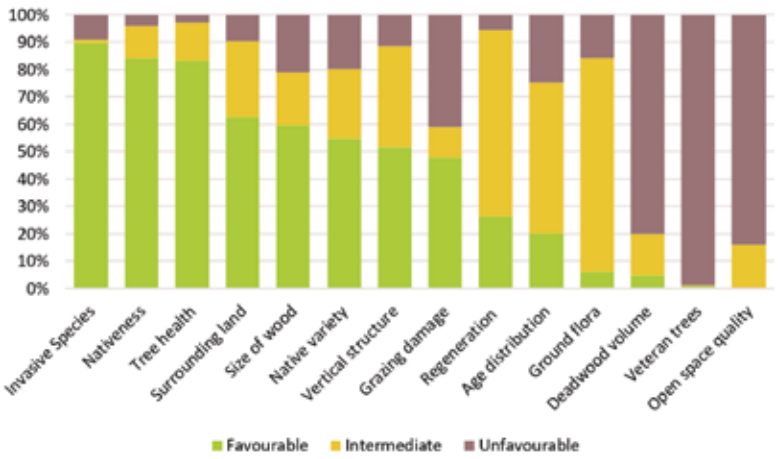

Figure 3. Condition of UK native woodland *(Ditchburn 2020)*

CASE STUDY 12

Dormice in Douglas Fir

David Edwards FICFor, Regional Manager for Wales & Marches, Tilhill Forestry

A forest manager is occasionally lucky enough to glimpse the wildlife you are helping to conserve. The photograph shows a dormouse I spotted enjoying the managed habitat of a planted forest in Herefordshire, mostly spruce but with a significant Douglas fir and larch component, and broadleaves including mature beech.

DAVID EDWARDS

systems although these may have subsequently been degraded, while around 15 per cent have been created since 1990 (*Patterson 2014*, *NRW 2020*, *NE 2020*, *Ward 2019*). Over three quarters of native woodlands lack trees of over 150 years old (*Ditchburn 2020*). The majority of the native woodland resource is neglected both on the ground and in the literature, and is under-delivering for biodiversity, carbon and wood production.

For biodiversity, lack of woodland management is a key driver of decline of nature (*Hayhow 2019*, *Fuller 2005*, *Hewson 2009*). Over half of native woodlands suffer from grazing damage, three quarters do not have healthy regeneration, and only a tiny proportion have ground flora or open space in favourable condition or a healthy proportion of deadwood or veteran trees. With the exception of regeneration and veterans, non-native forests show better ecological condition on all these indicators, but improving them in native woodlands is vital as some forest species associate with deadwood or veterans of a particular tree species (*Ditchburn 2020*).

The UK's 1.5 million hectares of broadleaf could theoretically provide a sustainable yield of six million m3 of wood, increasing the UK's wood production by two thirds (*Brewer 2014*). While it would not be commercially practical nor ecologically desirable to harvest at this level, it does suggest considerable potential to generate income streams for conservation management, while reducing the UK's reliance on imported timber without the need for land use change or a long wait for trees to grow.

Across Europe, species richness is only higher in unmanaged than managed forests when they are large and ecologically intact (*Paillet 2009*). Following millennia of human interference, the UK has no fully natural woodlands, and what remains requires active management to reverse the trend in decline in their condition: fencing and controlling herbivores, removing invasive species, managed disturbance such as thinning, and growing woodland remnants (*Fuller 2005*). Studies of fragmented woodland found that woodland characteristics such as stand structure were of overriding importance for biodiversity, more than size or isolation, suggesting that improving management should be as high or higher priority for native woodland biodiversity than new planting (*Humphrey 2015*). There is growing interest in silviculture focused on restoring

CASE STUDY 13

Red squirrels and broadleaf timber production in Cumbria

Ian Jack, Trustee of Penrith and District Red Squirrel Group and former head forester, Lowther Estate

Lowther has grown high-quality sycamore, oak, and ash timber for generations but latterly this has only remained possible thanks to the regional programme of red squirrel conservation. Penrith and District Red Squirrel Group maintain six full time paid rangers over a 650 square mile area, and every year we cull around 3,500 greys. Our rangers are focused and dedicated boots on the ground, tackling greys efficiently and monitoring populations in a scientific manner over many years. We know that when greys invade an area, reds will be lost, but as soon as we tackle the greys the reds bounce back. We have also found that voluntary culling by estates does not deliver sufficiently focused control: what is needed is collaboration by estates and a professional ranger service. We require a minimum of £150,000 a year to maintain control of the greys, but funding is always fragile. A budget of £1m would enable us to make the whole of Cumbria a red squirrel zone.

Grey squirrel control is driven by conservation; but without it, we would be unable to grow hardwood timber. We know that whenever greys have been allowed to gain a foothold, tree damage follows. Re-establishing hardwood timber growing in the UK will not be possible without a major programme of grey squirrel control.

Growing hardwood timber will also require a major revival in skills. I was taught by the previous generation of foresters and have had the opportunity to use what I learned at Lowther, but many younger foresters have not been as fortunate. Unless grey squirrel can be controlled to the point where these skills are useful, enabling them to be passed on and put to use, we are at risk of losing the skills of growing broadleaf timber altogether.

IAN JACK

Sycamore timber growing at Lowther

ecological processes, such as reintroducing pine marten to control grey squirrel or facilitating natural regeneration. However, all of these activities involve work and therefore cost. While more sophisticated techniques may deliver a more richly functioning ecosystem in the long run, they incur additional cost particularly when they are new and require testing and training. To deliver ecosystem restoration on a large scale therefore requires a secure income, and the most secure income for forests is the sale of its products. Three areas of synergy between forestry and conservation could be key to achieving native woodland restoration, potentially delivering biodiversity gains faster and more richly than through new native woodland creation:

Wood extraction to enhance forest structure

A study of the effect of the October 1987 storm on undermanaged broadleaf woodlands found that the disruption it caused resulted in a significant increase in biodiversity, suggesting how activities like thinning and stand diversification can replicate natural events in a controlled manner and on a small scale appropriate for fragmented UK woodlands (*Smart 2015*, *Case study 11*). A study of bats in native broadleaf woodland found that thinned woodland supported a significantly higher richness of bats in numbers and species diversity, while retention of standing deadwood and veteran trees was essential to provide roosting opportunities (*Carr 2019*). In Plantations on Ancient Woodland Sites, or continuous cover management of the conifers may provide the best strategy for preserving the valuable ground flora, which depends on light levels rather than tree species, while maintaining an income stream for ongoing conservation (*Brown 2014*).

In many woodlands, coppicing is a particularly important technique (*Bellamy 2012*, *Fuller 2013*). Management for diverse stand ages in coppice has been found to be beneficial for moth, plant and bird diversity (*Broome 2011*, *Fuller 2005*). A recent study of dormice in hazel found a 72 percent decline between 1993 and 2014, caused by a decline in coppicing, exacerbated by conservation concerns about disturbing individual dormice (*Goodwin 2018*, *Case study 12*).

CASE STUDY 14

Mixing species at Crofthead

Andrew MacQueen, Forest Manager, Tilhill

Crofthead is a new woodland creation project near Moffat, surrounded by mature plantations, native riparian woodland and neglected farm woodland. In its 54 hectares, it aims to link these habitats together in a diverse planting scheme including oak, hornbeam and cherry for quality hardwood timber, and improved birch, Sitka spruce, Douglas fir and diverse conifer growing fast-growing fibre. The forest aims to work with the ecology of the ground, expanding existing native woodland, mixing alder and Sitka to mimic the natural synergies of Pacific north-west forests (*Deal 2013*). It also supports red squirrel conservation, while accelerating carbon capture and timber production across the whole site through careful silviculture.

ELEANOR HARRIS

Encouragement of wood growth

Getting trees growing is fundamental to both wood production and conservation. Some native woods may require as much investment in regeneration as a newly planted woodland before any sustainable harvest can be considered. In many native woodlands regeneration is suppressed by browsing animals. At the beginning of this century, ancient Caledonian pine forest in Strathspey and Glen Affric had fewer forest specialist ground and canopy beetles than commercial forestry because the trees had become so widely spaced; it would be interesting to revisit sites like these following recent conservation and regeneration efforts (*Jukes 2001*, *Jukes 2002*, *Case study 15*). Deer browsing impacts plants and birds in broadleaf woodlands: for example, an experiment in coppice demonstrated that increased deer browsing since the 1980s has been

a cause of nightingale decline in the same period (*Holt 2010*). Grey squirrel is one of the biggest barriers to growing hardwood timber due to the damage it causes to trees (*Fuller 2015*, *Broughton 2019*). Active forest management is also important in selecting species and genetic diversity of new growth to deliver greatest biodiversity benefit as well as promoting timber quality (*Broome 2017*, *Davies 2014*). Since so much UK broadleaf woodland is less than a century old, active management to deliver larger trees more quickly is important to accelerate its habitat value (*Whytock 2017*). Oak, the UK's ecologically richest tree, faces a range of threats within the context of deterioration in the health of 600 oak species globally (*Mitchell 2019*). The valuable timber oak produces enables land managers to protect it from pests, nurture it to maturity, and expand the area of oak woodland (*case studies 11, 13 and 14*).

Creation of an income stream

At present native woodland management largely relies on philanthropic or public funding. Producing wood could both secure its future management – 'the wood that pays is the wood that stays' – and make native woodland a valuable contributor to the renewable low-carbon economy. It is more difficult for native woodlands to turn a profit through wood alone: their growth rate is slower, and without decades of investment their wood is less valuable. Selective thinning or coppicing is more costly than more intensive management. In commercial woodlands with ancient woodland fragments, wood from the commercial areas can fund non-extractive management of the ancient area (*case studies 8 and 10*), but some native woods will have large areas requiring management with little or no extraction. Training foresters, farmers and contractors in the skills required to bring these woods into management for both conservation and hardwood production will also be a substantial investment.

CASE STUDY 15

ELEANOR HARRIS

Productive forestry and conservation in Cairngorms National Park

Piers Voysey MICFor, Rothiemurchus Estate

The forestry estates within the Cairngorms National Park and Speyside use the UKWAS certification process to ensure that nature conservation and timber harvesting go hand in hand. Ancient pinewood is being extended through productive forestry, with a transition of habitats from old-growth, non-intervention areas with difficult access, to commercially-managed stands where disturbance stimulates new growth. There are many UK and local Biodiversity Action Plan priority species associated with native pine, birch, oak, riparian and montane woodland types. Capercaillie are perhaps the most significant, but also pine hoverfly, Kentish glory moth (birch), dark-bordered beauty moth (aspen), Scottish crossbill, shining guest ant, twinflower, green shield moss and goshawk. Attention is also being given to managing riparian woods to ensure they are fit for the arrival of beavers.

WILL ANDERSON

Protecting global biodiversity

Recognition is growing of the vital role of planted forests in protecting natural ones by reducing pressure to harvest them. In 2009, wood supply from planted forests globally reduced harvesting from natural forests by 26% (*Buonogiorno 2014*). Growing sufficient wood on already-degraded land ensures irreplaceable intact natural forest habitats can remain unexploited and have room to expand (*Agrawala 2018*, *Freer-Smith 2019*, *Silva 2018*, *Buongiorno 2014*, *Attenborough 2019*). Planted forests comprise around 7% of global forest cover but contribute 46% of the wood we use thanks to centuries of development in silviculture and genetics (*Payn 2015*).

The impact on global forests of the UK's low forest cover and offshoring of its timber demand is a matter of serious responsibility. The UK has far lower levels of biodiversity intactness – the proportion of natural biodiversity remaining in local ecosystems – than many of the countries from which it imports wood (*Newbold 2016*, *Ward 2019*). Whether timber extraction is degrading the intactness of these countries to the level of the UK, or whether the existence of a flourishing forestry industry is helping to protect the forests in these countries and keep them at a higher level than the UK, the implication is the same: biodiversity would benefit from growing more at home. Globally, the area of planted forest increased rapidly from 1990 to 2005, but the rate of expansion then slowed substantially, although global demand for timber is predicted to treble by 2060 (*Payn 2015*, *Agrawala 2018*). The UK, with large areas of potential forest land, has the opportunity to take a lead in reversing this trend, ensuring pressure does not grow to plunder the world's natural forests (*Bastin 2019*).

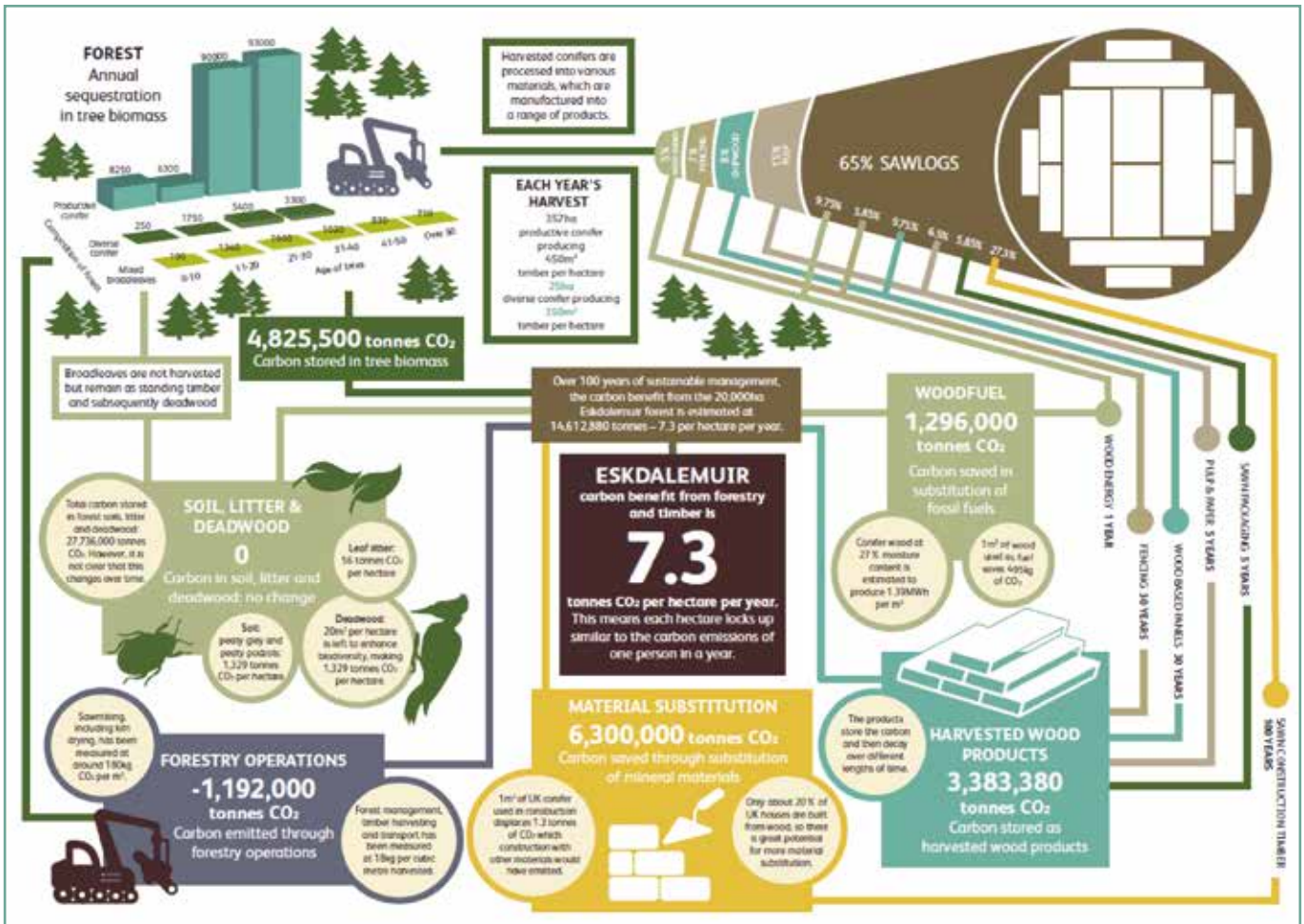

Figure 4. Full lifecycle carbon sequestration from a UKFS managed forest for wood production: carbon stored in the forest, carbon stored in harvested timber, carbon emitted through forest operations, and carbon emissions avoided through the use of wood products. (*Greig 2015*)

Tackling climate change

A forest planted in the UK today sequesters carbon dioxide from the atmosphere and turns it into usable timber. This carbon is stored in the standing trees and continues to be stored in long-lived wood products, such as timber and board used in construction, while restocked trees sequester more carbon on-site. Even if carbon is ultimately released back into the atmosphere, as long as the pool of houses and other products made from the forest increases, the carbon store is growing. More importantly, this timber is used for products where, without it, materials with a high carbon footprint (and high biodiversity impacts) would have been used instead, such as concrete, steel, plastic, coal and oil. The combined benefits of sequestration, storage and substitution are calculated in an existing UKFS managed forest to deliver 7.3tCO_2 benefit per hectare per year indefinitely (*figure 4*, *Greig 2015*). The cost-effectiveness of wood from planted forests has been calculated to have resulted in wood use increasing globally, suggesting it is already displacing these materials (*Buongiorno 2015*).

England and Wales have unusually high rates of masonry construction, accounting for 77 per cent of new houses in England in 2018; in contrast, 83 per cent of Scottish housing starts are timber frame (*STA 2018*). Increasing the number of timber frame homes in the UK each year from 60,000 to 270,000 could reduce embodied emissions in the residential construction sector by 0.5-1MtCO_2e per year, a substantial addition to UK greenhouse gas emissions reductions which to date have averaged around 12 MtCO_2e per year across all sectors (*Holmes 2019*, *Stark 2019*). The UK will need to increase its wood consumption substantially to achieve an upgraded housing stock which is zero-carbon in embodied materials as well as lifetime emissions. Forestry and wood provide the opportunity for synergy rather than conflict between resource provision and decarbonisation by transforming the human environment – the city – from carbon source to carbon sink.

Developing the renewable low-carbon economy

Forestry and timber already adds £2bn to the UK economy, with the potential for significant real growth if government planting targets are met. In more afforested countries, trees are already providing the feedstock for the development of low-carbon manufacturing, such as offsite timber housing, cross-laminated timber for large construction projects, and biorefining which has the potential to produce everything from pharmaceuticals to clothing to jet fuel: everything we make from a barrel of oil can be made from a tree (*Freer-Smith 2019*). The UK already only grows 19 per cent of the wood it needs. Without planting the future raw material now, it risks being left behind by 2050 as technology moves away from mineral materials.

Forestry and timber support over 80,000 green jobs, largely in rural areas. All creation of new productive forest or neglected woodland brought into management creates opportunities in 'outdoor STEM' and low-carbon industry. Nursery producers, planting and harvesting contractors, forest managers, sawmill operators, haulage contractors, timber buyers, marketing and investment managers, researchers, administrators and many more: all derive their living from the ability of a tree to convert atmospheric carbon dioxide into a versatile, renewable material which we rely on for basic commodities every day of our lives.

Forests deliver a wide range of natural capital benefits besides wood and carbon capture, including reduction in air pollution and opportunities for recreation which benefit physical and mental health. Every £1 private profit generated through the management of forests for timber delivers £18 public benefit (*Trenbirth 2020*). Catchment management for flood prevention is an important consideration in forest design. Opportunities to visit forests, whether mountain-biking, 'forest bathing', forest schools or nature prescriptions, are increasingly important given our society's disconnection with the natural world.

Forests expanded and managed for sustainable resource supply, wildlife and carbon is not merely a strategy to avert climate and biodiversity disasters. It is a vision of a future society which is more healthy, more connected with nature, and more truly prosperous.

5 CONCLUSION

The UK's forests range from young forests planted for wood production, to ancient semi-natural woodlands, with a wide spectrum of forest types and management objectives in between. At present much woodland is managed with a strong priority for either wood production or biodiversity, with a substantial amount not managed at all. Too many analyses of UK woodlands have presented ecology and profitability as competing alternatives, forgetting that wood production is the product of ecological processes, and good ecological condition depends on income to fund management.

This report has presented evidence to show that we know a great deal more about the biodiversity value of UK wood producing forests than is generally appreciated, and about how wood production can be an important component of conservation management in a wide range of woodland types.

It has been suggested elsewhere that European tree species are more acceptable than other exotics because it is only due to the accident of the English Channel that they are not native (*Harris 1997*). This report's analysis of the evidence points towards the managed expansion of both resilient UK native tree species and exotic species from across the world (*Ennos 2019*).

Around the world scientists, policymakers, forest managers and investors are increasingly interested in the idea that production and nature conservation must be treated as two sides of the same question (*Toomey 2016*, *Freer-Smith 2019*, *Fuller 2018*, *Biodiversity and Industry 2010*, *Dandy 2019*, *Mather 2006*, *Defra 2020*). The integration of forestry and biodiversity presented in this report aims to contribute to this wider current of thinking.

Growing timber can benefit, and is already benefiting, biodiversity, and the practices delivered through UKFS and UKWAS are based on strong science. Bringing woodlands into management for wood production can enhance forest structure and provide income and incentive for the landowner to enhance and expand the woodland. Producing more wood in the UK delivers a low-carbon, renewable resource and relieves pressure overseas to over-harvest natural forests or create unsustainable plantations to supply wood. This evidence forms a challenge to the view that wood production and biodiversity are alternatives, and a strong foundation to develop management for both.

The evidence-base of this report focuses on the British Isles, except where international research is demonstrably applicable. While this might appear (literally) insular, the approach of strong integration between wood production and conservation may not be applicable in many countries which have significant areas of old-growth forest. However, it is hoped that this analysis will shed light on the factors which give UK forests their global value and the specific challenges they face, while having wider applicability to countries such as Ireland, New Zealand and Iceland which also combine unique and historically-degraded native forests with new, mainly exotic planted forests.

Looking forward, there is potential for more woodland to be managed overall, with a more diverse range of management objectives. When combined with the process of bringing twentieth-century planted forests into conformity with modern management standards, this report shows that the result should be more diverse forests, more renewable resource for low-carbon manufacturing, more income to support management for biodiversity and other benefits, and more biodiversity across forest types.

It is imperative that we act with all urgency to tackle the climate emergency and biodiversity decline. Through modern forestry for wood production and bringing more woodland into sustainable management we can both help tackle these huge challenges and develop a sustainable, low-carbon economy. Yet this is not simply a strategy to avoid catastrophe, but a vision for a better future. Our forests can be managed to deliver both restoration of nature and renewable supplies of wood to help decarbonise the economy, create green jobs thanks to the income they yield, and integrate better into other land uses. This is the 'fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values' we require (*IPBES 2019*). There is no time to wait: it is time for trees.

We know a great deal about UK woodland ecology and about the opportunities for synergy between wood production and biodiversity. Some of the key studies are summarised on p.29. However, this study has also identified some key areas where further research would be valuable.

Much work has been done to develop robust survey methods and metrics to measure forest biodiversity. Counting woodland specialists is important as well as total species (*Bailey 2007*). Several studies note the need to measure a forests in three dimensions, which is what gives high forests such ecological richness (*Ferris 2000*, *Coote 2008*, *Calladine 2016*, *Quine 2010*). Appreciating the habitat above our heads requires surveying hard-to-measure taxa, as groups like birds and vascular plants are not reliable surrogates (*Irwin 2019*, *Smith 2008*). Various robust structural surrogate measures for biodiversity have, however, been developed, such as thinning (*Smith 2008*), deadwood (*Quine 2010*), or mapping National Vegetation Classification and microhabitat types, which can predict likely presence of protected species and measure ecological value of planted forests (*Broome 2018*, *Ferris 2000*). Structural surrogates, which future research can further refine, provide the basis for UKFS and UKWAS, and management of smaller woodlands through tools like MyForest (*Sylva 2019*).

New woodland creation and landscape ecology

Since 1997, UK woodland has expanded through a substantial amount of new native planting, a smaller amount of conifer, and some natural regeneration projects. There have been few studies of the biodiversity of these new woodlands. *Savory 2016* and *Douglas 2020* provide studies of birds in new native woodland similar to that done by *Moss 1979* on conifers, and suggesting broadly similar results. *Smith 2006* surveyed the impact of conifer afforestation in the first five years. *Fuentez-Montemayor 2018* found similarly abundant moth assemblages in ancient and secondary woodlands, but the secondary woodlands were mature, up to 150 years old. A fuller analysis of the biodiversity of new woodland: native and exotic, planted and naturally-regenerated, 0-20 years old, and with diverse management objectives, would be valuable in informing woodland creation policy. The Woodland Ecological Condition and National Biodiversity Network datasets provide a rich starting point (*Ditchburn 2020*, *Hayhow 2019*).

Only a few studies compare open land and forest for certain groups, including birds, reptiles and beetles (*Savory 2016*, *Mullen 2008*, *Reading 2018*). This could be done more extensively through the Countryside Survey, through collaboration with foresters to develop a more sophisticated understanding of forest management (harvesting should not be recorded as 'restoration to open habitat') (*Countryside Survey 2007*). A valuable comparison would be between the Environmental Impact Assessments done before large woodland creation projects, and a field survey of the forest now on the sites. This might include assessing whether a degrading ecosystem is replaced with an improving one, fragmented woodland re-connected, generalist species are replaced with specialists – or if the reverse has been the case. This can feed into studies weighing up ecosystem services from different land uses over landscapes (*Jiang 2013*).

Impact of UKFS and UKWAS on existing forests

The long timescales of forestry mean that the introduction of a framework for sustainable forest management in 1997 has taken time to have an effect on existing forests. Now that most have now been through a cycle of harvesting, it would be valuable to study its impact. Provisions such as age and species diversification, deadwood, different thinning regimes, old-growth areas and water management can be tested for their benefits, and surrogate indicators of biodiversity verified and refined. There is an opportunity to return to previous study sites (such as *Ferris 2000*, *Irwin 2014*, *Quine 2010*) to review the effect of time and management changes. Biodiversity should also be studied as part of new forest management regimes for climate change resilience, for example new species mixtures.

UK forest assemblages and habitat complementarity

While recommendations for priority species management are well-developed and integrated into productive forest management, there is a need for more accessible information for foresters on the most important forest assemblages in the British Isles, with management recommendations for developing these. This follows the conclusions of *Bailey 2007*: 'restoring functional woodland community should become the goal rather than biodiversity gain. For this to be achieved we need to draw on community ecology, to define the features required in woodland restoration and develop benchmarks with which we can measure success'. This should include better awareness of 'ghost forests', where forest ecology survives on sites such as under a bracken canopy or on individual veteran trees. It should also include better understanding of how newly-created forest habitats (both non-native and native) can complement existing habitat, including providing greater climate change resilience.

Active management for functional woodland ecology 'beyond trees' is

important for all kinds of woodland. Planting vernal flowers such as daffodil is common in native woodlands, but these are too often non-native and sometimes invasive. Biological pest control and nursery stock inoculated with mychorrizal fungi are regulated practices within commercial forestry. Species including capercaillie, pine marten, beaver and twinflower have been the subject of reintroductions, and there is huge potential to build on these conservation and silvicultural practices to accelerate the restoration of functioning forest ecosystems in the UK. Provision of nest boxes for barn owls in forests too young to have veteran trees, can be transformative for this threatened species, and provide welcome control of voles for the forester (*Petty 1994*). The regulated introduction of other keystone elements of forest ecology such as deadwood from ancient woodland, native vascular plants, or wood ants is a management technique worthy of more research.

Invertebrates

Globally, tree canopies are crucial habitats for invertebrates and believed to hold the key to their immense species richness (*Jukes 2002*). Invertebrates are also one of the most threatened groups: abundance of insects in the UK may have fallen by over 50 percent since 1970 (*Goulson 2019*). Reversing this decline is urgent: invertebrates play a vital role in recycling waste, pollinating plants, and providing food for birds and animals. The ecological and economic impact of invertebrate loss would be devastating. Conifers support diverse and abundant populations of ground and canopy beetles equal or only slightly lower than semi-natural woodland; but beetles comprise only seven percent of canopy invertebrates (*Quine 2010*, *Jukes 2001*, *Jukes 2002*, *Irwin 2014*, *Oxbrough 2016*). Spiders and rove beetles have been found to be as diverse in Norway spruce as in ash (*Oxbrough 2016*). Spruce and pine forests host functional predator-prey invertebrate communities (*Jukes 2002*) and are good habitat for wood ants (*Procter 2015*). There is a lack of research on molluscs in UK forests; Canadian research suggests these show a significant preference for broadleaves (*Abele 2014*).

Understanding the role of invertebrates in forests is not merely important for ecology; it is vital for timber production. Ecological imbalance in populations can be disastrous, as the catastrophic damage to timber crops in central Europe by spruce bark beetle demonstrates (*Lopatka 2019*). It is virtually impossible to breed trees resistant to invertebrate attack, when insects can breed so much faster and adapt to any defence (*Freer-Smith 2019*). Biological control is already effectively used in UK forestry to control the invasive beetle Dendroctonus micans through deployment of its host-specific predator Rhizophagus grandis to each outbreak (*Fielding 2012*). Developing more sophisticated forest management practices to encourage predators could benefit both wood production and biodiversity, for example exploring assisted migration of slow-dispersing wood ants (*Proctor 2015, Case study 1*), or providing the complex habitat requirements for hoverflies (*Smith 2006*). There is evidence that high numbers of birds can enhance tree growth by keeping insect pests suppressed (*Fuller 2018*, *Berecki 2014*).

The forest floor

Our understanding of the biodiversity of the UK forest floor is patchy and intriguing. Enriched soils prevented woodland plants recolonising former agricultural land (*Bailey 2007*). Deep litter is negatively related to species richness and diversity, and bracken domination generates large amounts of litter (*Ferris 2000*). Two lowland Scots pine forests, Thetford (sand on chalk with low rainfall) and the New Forest (brown earth, gravel, high organic content and much wetter), hosted very different communities of carabid beetle (*Jukes 2001*). Conifers are rich habitats for fungi (*Humphrey 2000*). Forest nurseries supply trees inoculated with mychorrizal fungi to promote tree growth, or even truffles to harvest. Collating, developing and applying this piecemeal research could have a range of benefits for wood production, biodiversity and carbon management.

Deciduousness

Most surveys take place in summer; but the biggest difference between conifer and broadleaf woodlands is in winter. There have been few studies of the effect of deciduousness and evergreenness for flora, fauna or people: an evergreen forest may be more hospitable for winter shelter, food and recreation; while deciduous trees provide more varied light levels and seasonal interest. A better understanding of this topic would help to inform mixed woodland design, including informing the importance of non-native broadleaves (such as sycamore, beech and sweet chestnut) for wood production.

People and forest biodiversity

In the crowded UK, forests are also required to be good places for people. Time spent in forests and in wood buildings is good for mental health, reducing stress, improving concentration, and lowering heart rates (*Wood for Good 2019*). Biodiversity, whether the sound of birdsong; ferns, flowers and fungi on the forest floor; the glimpse of a red squirrel or a dragonfly-haunted pond in a sunlit glade, the scent of moss and sap, are integral to the 'forest bathing' experience. Thinning, that magic ingredient for biodiversity and wood production, also enables a forest to be walked through. Old-growth areas develop aesthetic and spiritual values, which mean

retention areas can double up a forest's benefits, while keeping the public away from dangerous forestry operations (*Humphrey 2005*).

Yet biodiversity and amenity benefits are not always aligned (*Burton 2018*, *Valdes 2019*, *Harrison 2014*, *Schröter 2014*), and nor is wood production and amenity. Before sustainability guidance, harvested sites would have been cleared neatly, the brash often burnt, and ground prepared for the new crop. One of the most frequent complaints about modern forestry practice is the unsightliness and inaccessibility of restock sites: while transformative for biodiversity, the brash mats, standing deadwood and disrupted landscape are shocking and even offensive to many observers, especially if they had previously been able to walk in a thinned forest. Visitors with dogs, cars, mountain bikes, picnics and litter are rarely beneficial to forest wildlife. The fashion for foraging is stripping forests of their fungi (*Carrington 2014*), and like dog-walking, foraging is becoming commercialised. Between controversy around forest operations, damage to ecosystems, and safety, there are numerous complexities around public access to forests for both forest and biodiversity, and the UK has a lower cultural awareness of forests for recreation than elsewhere in Europe (*Nijnik 2016*). The liability of landowners for the safety of visitors has resulted in a tendency to fell diseased, dying or dead trees which have high ecological value (*Fuller 2005*). The link in the minds of people visiting a forest with the wood products they use is not clear. Acknowledging these challenges and targeting research and policy to resolve them will be essential to delivering true multi-benefit forestry.

Woodside Bridge, built from oak from conservation management of Burridge Wood. Exmoor National Park, 2020. *See Case study 11.*

EVIDENCE BASE AND BIBILIOGRAPHY

This table provides a summary of the methodology of some of the key studies used in this report, demonstrating the significant work which has been undertaken to understand biodiversity in wood-producing forests in the UK and Ireland. The full bibliography follows.

Study	Nature of study	Location	Species surveyed
Calladine 2016	2x bird counts at 335 points in 4 structural types of upland Sitka (CCF/CFR)	Scotland	Songbirds
Carr 2019	2x bat and insect counts in 54 paired plots (managed/ undermanaged broadleaf woodlands)	Southern Britain	Bats and insects
Coote 2008	Sampling at 4 heights on 24 paired internal/ external trees in 12 Sitka plots	Republic of Ireland	Bryophytes and lichens
Eycott 2006	4 sample points in 326 stands (6 age classes of Scots and Corsican pine)	Thetford, Norfolk	Vascular plants
Ferris 2000	Vegetation cover index (% cover at 4 heights), stand growth, deadwood and soil samples at multiple points in 48 plots (uplands, foothills, lowlands, Sitka & Norway spruce, Scots & Corsican pine, 4 age classes)	Scotland & England	Plants
Geary 2018	Surveyed nest sites 2005-2014	Mull, Argyll	Hen harrier
Goodwin 2018	300 sites surveyed by volunteers for 5+ years between 1993 and 2014	Southern Britain	Dormouse
Heward 2018	800+ national grid squares surveyed by volunteers in 2003 and 2013	Britain & Ireland	Woodcock
Humphrey 2000	48 plots in 12 sites (upland, foothill, Sitka, oak, plantation/ native Scots pine) in 4 age classes	Scotland & N'land	Fungi
Irwin 2014	Several points in 40 forests (10 2nd rotation closed-canopy Sitka, 10 closed-canopy Norway, 10 semi-natural oak, 10 semi-natural ash)	Ireland	Plants, spiders, beetles, birds
Jofre 2016	Arrays of artificial reptile refuges in 20 Corsican pine stands in 4 age classes, compared with a similar sample in neighbouring open heath	Wareham, Dorset	Reptiles
Jukes 2001	44 plots in 12 sites (uplands, foothills, lowlands, Sitka/ Norway spruce, Scots/ Corsican pine) in 4 age classes	Scotland & England	Carabid beetles
Jukes 2002	44 plots in 12 sites (uplands, foothills, lowlands, Sitka/ Norway spruce, Scots/ Corsican pine) in 4 age classes	Scotland & England	Canopy coleoptera
Mckenzie 2007	Capture and survey of birds visiting feeders over 10 years 1995-2004	Loch Lomond	Coal tit, Siskin
Mullen 2008	Several plots at 41 sites (Sitka/ Norway spruce in 4 age classes) and 10 adjacent grassland sites	South of Ireland	Carabid beetles
Oxbrough 2016	45 plots in 15 stands (5 each of Norway spruce, ash, intimately mixed)	Ireland	Ground arthropods
Procter 2015	Compared mapped ant populations 1955 with 2013, mapping 5506 nests	North York Moors	Wood ant
Quine 2010	53 plots (synthesis of several of the above studies)	Scotland & England	Invertebrates, fungi, lichen, plants, songbirds
Reading 2018	Arrays of artificial reptile refuges in 31 sites (20 within conifer plantations at a range of age classes, 11 on nearby heathland)	Wareham, Dorset	Smooth snakes
Smith 2006	48 paired sites (24x 5-year old conifer plantation, 8x improved grassland, wet grassland, peatland)	Ireland	Hoverflies, spiders, birds
Smith 2008	44 first-rotation plantations (12 ash, 20 Sitka, 12 non-intimate mix) in 5 age classes	Ireland	Plants, spiders, hoverflies

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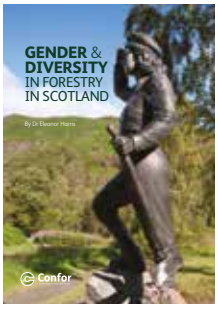

Gender & Diversity in Forestry in Scotland

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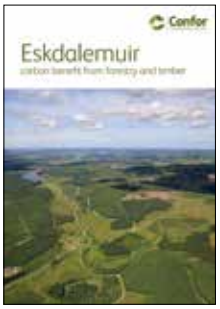

Eskdalemuir: Carbon benefit from forestry & timber