

Biodiversity implications of coppice decline, transformations to high forest and coppice restoration in British woodland

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Abstract

Coppice systems are amongst the earliest forms of woodland management known and on some sites their use has been documented for centuries. Distinctive assemblages of plants and animals are associated with such systems and are highly valued in nature conservation terms. The richness of such assemblages, and conversely, the species that do not thrive under coppice, are linked to the alternation of relatively short light and dark phases and the juxtaposition of stands at different stages in the coppice cycle.

We review how and why the biodiversity of former coppice woods changes in response to abandonment and conversion to high forest. We focus on the situation in the UK, based on recent published literature searches and the authors' extensive experiences of the practical issues involved in the conservation of coppice woodland systems.

Vascular plants in the ground flora, invertebrates of open glades and scrub, and small birds of the understorey may have become more abundant in coppice than they would have been under 'natural' forest conditions. By contrast epiphytes dependent on mature trees and species of large-sized deadwood are less favoured by coppice management.

Coppice systems developed to meet the local community needs. As social and economic conditions changed, so coppicing declined and the woods were transformed into high forest through neglect or deliberate management. High forests differ from coppice stands in their spatial and temporal dynamics and consequently in their wildlife particularly with respect to their vertical structure pattern; extent of open space and young growth; spatial heterogeneity; tree and shrub composition; and browsing levels.

Three issues for the conservation of biodiversity arise from these changes:

- what priority and resources should be given to halting further decline, by maintaining coppice compared to allowing sites to develop with more ‘natural’ high forest structures and dynamics; will associated high-forest species recolonise?
- if we restore coppice systems, will the species assemblages present in the past also recover, under current and future changes in environmental conditions; i.e is the transformation reversible under current environmental conditions?
- are there other ways in which ‘coppice-associated’ species might be maintained?

We identify research gaps and proposals to address these issues.

Keywords: coppice, Britain, conservation, wildlife, restoration, high-forest

Introduction

Our ancestors would have noted, perhaps often with frustration, that cutting down a tree does not necessarily kill it: many broadleaved species send up several or more vigorous shoots from the cut stump, at least some of which may be capable of becoming big trees in their own right (Koop 1987). The evolutionary origin of this adaptation is uncertain, but it is undoubtedly a useful response to the activity of beavers in floodplain landscapes, to avalanche and landslips on steep slopes, the effects of windblow, or even, it has been suggested, to the damage that might have been caused by the lost mega-fauna that once roamed Europe (Monbiot 2013).

Nor were our ancestors slow to take advantage of the coppice habit. The small straight stems arising from a stool were easily cut, transported and worked in societies that relied primarily on human muscle power. Evidence from prehistoric settlements and trackways across Europe suggest that coppice material was commonly being used even then (Kreuz 1992; Rackham 2003; Out 2010). Classical writings refer to the practice (Grove and Rackham 2001). From the Medieval time onward there are frequent writings dealing with how coppice woods ought to be managed, as well as court records dealing with situations where such management guidance had not been observed; for example livestock being allowed into the woods and causing damage to the coppice regrowth (Rackham 1990, 2003). Many different crafts and industries built up that made use of coppice products (Edlin 1949). Scattered amongst the underwood some trees (standards) might be left to grow on to provide larger-sized timbers. People might collect litter and bracken for animal bedding, deadwood for firewood, fungi, berries and honey for food. Some controlled stock grazing and even small scale arable cultivation might take place amongst the trees and shrubs.

Across Europe relatively large areas are still recorded as coppice (Buckley and Mills 2015a), particularly in south-eastern countries; rising fuel prices have revived interest in the use of firewood in

both urban and rural areas. However, this is set against a general pattern of decline in this way of managing woodland elsewhere.

In this paper we review how and why the biodiversity of former coppice woods changes in response to abandonment and conversion to high forest. We focus on the situation in the UK, based on recent published literature searches (Buckley and Mills 2015a,b) and the authors' extensive experiences of the practical issues involved in the conservation of coppice woodland systems. We identify some key issues that need to be addressed by conservation managers and foresters if the distinctive species assemblages of coppice are to be maintained in future and identify some research gaps and proposals to address these issues.

Coppice in the UK

In the UK coppice management started to go into decline in the late 19th, early 20th centuries (Buckley and Mills 2015a) with many areas not cut since the second world war. It hardly features in recent forest inventories (Figure 1), although there are reasons to believe that it has been under-recorded (D. Bartlett personal communication). (Areas of mature coppice may not be distinguishable from abandoned stands in aerial photographic surveys; coppice working may fall outside the usual requirements for felling licences if the stems cut are of small diameter; it may not qualify for any restocking grants, so is not picked up in the general forestry regulations systems.) Abandonment of coppice systems may leave the woods open to damage through unrestricted grazing or clearance; or the woods may continue to exist, but be transformed through neglect into high forests. High forests frequently have a different tree and shrub composition to the coppices they replace and certainly a different structure and dynamic pattern.

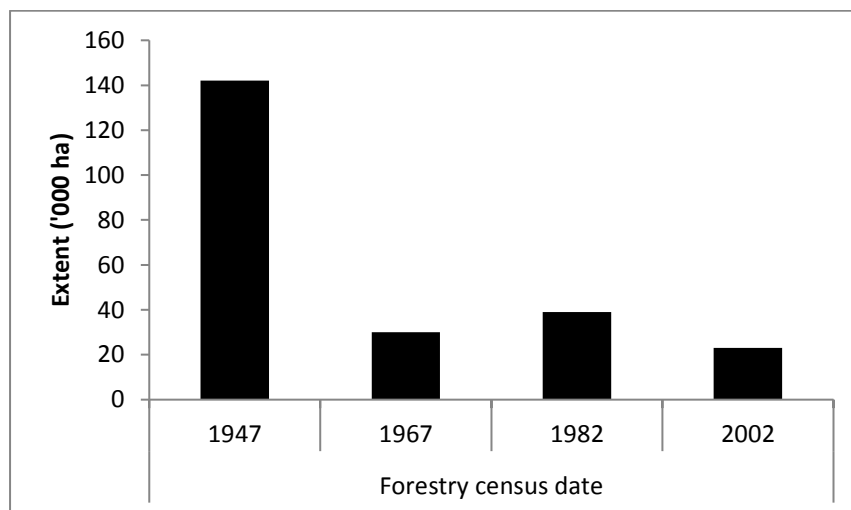


Figure 1. Extent of coppice ('000 ha) in Great Britain (from Hopkins and Kirby 2007, based on Forestry Commission census reports).

The decline of coppice management in Britain has been proposed as contributing to declines in particular groups of species during the twentieth century (Hopkins and Kirby 2007; Buckley and Mills 2015b); examples in Table 1. We therefore explore what are the features of the coppice system that allowed a distinctive suite of species to thrive; how these assemblages change in the transformation to a high forest structure; and the feasibility of maintaining ‘coppice’ species either through restoration of coppice management, or other means.

Table 1. Studies suggesting a link between species-declines and loss of open woodland and young growth, such as is created by coppicing

- Of six butterfly species associated with clearings in woodlands, three have shown marked national declines: a 77% decline since 1970–82 in the case of the High Brown Fritillary *Argynnis adippe* (Asher et al. 2001).
- Kirby et al. (2005) found a reduction in ground flora species richness in woods surveyed in 1971 and 2001 associated with increasing basal area of trees and shrubs (basal area often being closely associated with canopy cover).
- The decline of coppice woodland management is probably a significant factor in the present scarcity of dormice, *Muscardinus avellanarius* (Bright and Morris 1990)
- Changes in woodland structure were thought to be the most likely driver for many of the bird declines observed in a resurvey in 2003/4 of woods first visited in the 1980s or earlier. These structural changes may have been driven by changes in woodland age, reduction in management and deer browsing (Amar et al. 2006). Fuller (1992) reported on the high densities of migrant song-birds that could be sustained in worked coppice.

Note that throughout this paper reference to coppice systems includes simple coppice and coppice-with-standards plus variations on these, unless specified otherwise. Pollarding and wood-pastures are however not considered (Hartel et al. 2015; Plieninger et al. 2015).

Distinctive features of coppice from a biodiversity perspective

Views differ on whether the natural landscape of Europe was predominantly closed forest or more like wood-pasture (Peterken, 1996; Vera 2000; Kirby and Watkins, 2015b). Both might contain natural analogues of coppice structures, with presumably at least, some of the species seen in coppice today. However the assemblages that we now associate with coppice woods, and value from a conservation perspective, are the product of many centuries, possibly millennia of management. Coppices are as much a form of cultural landscape as hay meadows or heathland.

The distinctive biodiversity of coppice woods (Buckley 1992; Buckley and Mills 2015b), compared to high forest stands can be linked to a number of features summarised below: the short cutting cycles, the high degree of spatial heterogeneity, high woody species diversity, freezing of genetic composition, lowered risk of wind-throw, high export of nutrients, limited amounts of fallen deadwood, limited/controlled grazing pressure.

Coppices are typically cut on cycles of 5-30yrs. The open stands after cutting have much higher richness and cover of vascular plants, e.g. Ash and Barkham (1976), Ford and Newbould (1977). Clear-fells in high forest can show a similar level of plant richness, but at any one time a smaller proportion of the wood will be in the open stage because stands are cut-over only every 80-120 years (Kirby 2009, 2015). Plants that rely on seed banks to survive the dark phase of forests have a higher chance of being able to last from one open phase to the next in a coppice than in high forest (Van Calster et al. 2008); there are more frequent opportunities for the flowering of species that survive the dark phase in vegetative form (Barkham 1992). However species that survive better under partial shade and high humidity, such as some bryophytes, are likely to be disadvantaged by these regular periods of opening up of the canopy with higher light and temperature conditions (Edwards 1986).

Cutting of coupes tends to be on a relatively small scale with all ages of coppice being maintained close together: this produces a high degree of spatial heterogeneity. Invertebrates of temporary gaps are thus more likely to be able to spread from one gap to the next, but equally there can be good spatial continuity for species such as the hazel dormouse *Muscardinus avellenarius* that are predominantly arboreal (Fuller and Warren 1993; Bright et al. 2006). Localised heterogeneity of woodland structure allows opportunities for a variety of different songbirds to co-exist (Fuller and Henderson 1992).

High woody species diversity often occurs in coppice crops because there are regular opportunities for light-demanding species to regenerate; in high forest systems shrubs and short-lived trees tend to decline as the tree canopy matures and becomes denser. This provides more opportunities for serial feeders such as hazel dormice that rely on a sequence of flowers, fruits and seeds over the season (Bright et al. 2006). However, at various times and places this diversity of woody species has been reduced by deliberate selection for particular trees or shrubs to ‘improve’ the coppice, favouring hazel *Corylus avellana* in southern England, sweet chestnut *Castanea sativa* in Kent, or oak *Quercus* spp, in western Britain (Peterken 2015).

Some freezing’ of the genetic composition of stands may have occurred because of the predominance of regrowth from the stools, which can be hundreds of years old. However the degree to which this has happened in practice, and its significance, is uncertain (Buckley and Mills 2015a). Stool regeneration may have preserved genetic diversity that existed prior to strong selection for straight timber trees, or reduced it because there have been reduced opportunities in the last few centuries for new combinations of genes to emerge that are selected for current, rather than distant-past conditions.

There can be a lower risk of windthrow because the stems are shorter compared to high forest systems, which also means reduced soil disturbance from pit and mound formation: in South-east

England the 1987 Great Storm re-introduced English ecologists to this phenomenon in neglected coppices (Kirby and Buckley 1994). Lack of such natural soil perturbation may be countered by high anthropogenic disturbance through the creation of sawpits, charcoal hearths, woodland banks and ditches, and any past arable cultivation (Rackham 2003).

Greater export of nutrients may occur from coppice woods because the poles are harvested young when there is a greater proportion of bark to wood than with the felling of high forest stands (assuming that the branchwood is left on site). This may not lead to nutrient deficiencies if the rates of nutrient release in the soil from weathering of the underlying parent material are sufficient to compensate for such losses over the growth cycle. On acid, nutrient-poor substrates, there may however be the potential for some nutrients to become limiting, particularly if the losses are exacerbated by other practices such as litter collection. Reduction in nutrient availability has been suggested as a possible reason for the trend to lengthening cutting cycles seen at some sites over time (Rackham 2003).

Reduction in soil fertility through these processes could also contribute to the richness of the ground flora by reducing the potential for competitive species to dominate (Dzwonko and Gawroński 2002) on reasonably fertile sites. On less fertile sites plant richness might decline, but the effect would be less obvious because acidic, low nutrient, woodland communities tend to be poorer in vascular plant than rich ones to start with (Rodwell 1991).

Fallen dead wood is usually very limited in worked coppice, particularly in the larger size classes, because most stems are harvested while still small. Any material lying on the ground was likely to have been removed for firewood, even down to small twigs for kindling. Kirby et al. (1998) reported less than 20m³/ha of fallen deadwood in worked coppices, but up to 60m³/ha in those that had been abandoned.

Recently, more attention has been paid to dead wood and its attendant species within living trees (Siitonen and Ranius 2015): this habitat may be provided to a small degree in large old coppice stools and in pollards created on boundaries of coupes or the wood itself. In the past the standard trees in coppices would generally have been harvested while still comparatively young and sound. However, as a result of abandonment many former standard trees are now important for their internal deadwood resource because they have reached the age (c.150 years) where hollowing of the main trunk is likely to start (Ranius et al. 2009).

Coppice regrowth is potentially vulnerable to grazing and levels of grazing were therefore limited and controlled. When the woods were still actively worked in the 19th century, deer numbers in the UK were low and there would have been many more people working in the woods on a daily basis to keep wild animals away from the regrowth. Livestock grazing was often permitted within

woods but generally not for the first few years after cutting. Internal boundaries such as banks were used to keep animals temporarily out of areas (Rackham 2003) and stock might be herded to the same effect. Control of grazing levels to protect regrowth would also inadvertently improve conditions for grazing-sensitive species. Many ‘woodland’ plants now show reduced flowering or growth under heavily grazed conditions: Cooke and Farrell (2001) for example illustrate various impacts of deer grazing on bramble growth (*Rubus fruticosus*), bluebell (*Hyacinthoides non-scripta*) growth and flowering. Sensitive plants may become limited to situations such as rock ledges inaccessible to the animals (Kirby 2001).

All the above factors could and did vary in different ways across sites, landscapes, regions and over time, creating highly heterogeneous conditions and a rich variety of wildlife.

The consequences of the transformation from coppice to high forest for biodiversity

Transforming coppices to high forests changes their composition, structure and dynamics: these will also be affected by whether the transformation is by neglect or active management. Commonly there are changes in the vertical structure of the woodland, reduced scope for open stage species, reduced landscape-scale heterogeneity, changes in the tree and shrub layer composition and in browsing/grazing levels.

Usually the biggest change is in the vertical structure of the woodland, with some loss of density in the understorey, the development of a taller canopy layer and a deeper overall foliage profile. Individual trees may grow to larger sizes, with greater potential for cavity development and formation of internal dead wood (Ranius et al. 2009). Larger trunks and branches mean more potential for increased fallen dead wood where the transformation is through natural processes (Kirby et al. 1998). Active management may involve additional clearance of the understorey and felling large trees before they start to hollow out.

There will be reduced scope for species of open space. A lower proportion of the woods are in the open stage at any one time and there are longer periods between light phases occurring at any one point. However under a managed transformation thinning, selective felling, and ride maintenance, may ensure some continuity of this habitat element (Warren and Fuller 1993).

Landscape-scale heterogeneity is likely to be reduced because a large part of the mid-rotation of a high forest cycle is relatively uniform in terms of the plants and animals it supports. The most distinctive periods in conservation terms are the early post-felling phase and the old growth stage (which is usually not reached in managed high forest because it is beyond the felling age) (Warren and Key 1991). Landscape-level uniformity in woodland structure may be exacerbated where large areas of forest undergo a shift in structure at the same time. In Britain many former coppiced

broadleaved woods were cut over in the Second World War (HMSO, 1952; Foot 2010), but then largely left unmanaged in silvicultural terms. A large proportion of the broadleaved resource is therefore in the middle of the high forest rotation phase, of limited value to coppice specialists, but also generally not old enough to have developed old growth features. This seems likely to have contributed to declines in open stage plant and bird species richness at a national level (Hopkins and Kirby 2007). There are likely to have been biodiversity gains in terms of closed canopy species (Hamblen and Speight 1995), but mainly of species that were common anyway.

The woody species composition usually changes, for example the promotion of oak through increasing the number of standard trees; the deliberate favouring of one of the coppice species; or the clearance and replanting of the coppice layer. From the 1930s until the 1980s many ancient formerly coppiced woods were replanted with conifers (Spencer and Kirby 1992). However, even where the transformation is by neglect, there is often a reduction in the shrub layer and of the shorter-lived, less shade-tolerant trees: for example the birch generation (*Betula* spp.) that invaded many woods subsequent to the Second World War, at their last major coppicing, is now dying out (Kirby et al. 2014). The shifts in the composition of the woody layers are likely to alter the vascular plants and bryophytes on the woodland floor, for example through changes in light and warmth levels at ground level, litter type and abundance; the nature of lichen assemblages because of different tree bark characteristics; the resources available as flower, fruit and seed for food for bird, mammals, invertebrates (Mitchell et al. 2014).

Livestock grazing in coppice and managed high forest has largely died out in much of Britain although it is not actually illegal as it is in parts of central Europe. In neglected former coppices in the uplands the effects of often uncontrolled grazing can have both positive as well as negative effects in biodiversity terms (Mitchell and Kirby 1990; Kirby et al. 1994). At the same time deer populations have increased with widespread effects across a range of species groups (see papers in Fuller and Gill 2001).

Does transformation matter from a nature conservation perspective?

Globally there is a focus in forest conservation on ‘natural forests’, with the general presumption to remove or reduce human impact (except for specific purposes such as controlling invasive species) and let the forests develop under their own dynamic. A series of indicators of potential naturalness has been developed for European forests (Bastrop-Birk 2014).

There certainly is a place for strict minimum intervention reserves in Britain, particularly in stands which have always been treated as high forest in a relatively low intensity way (Parviainen et al. 2000). The best documented of such reserves in Britain is, in fact, a former coppice-wood (Peterken and Mountford 2005). However among the species of greatest conservation concern are

those that are unlikely to thrive under high forest conditions and hence the emphasis in conservation guidance on trying to maintain some more open woodland, for example as coppice. The same concern can be seen elsewhere in Europe e.g Miklin and Cizek (2014).

The extent that we emphasise coppice as the desirable management system in any particular case depends on the relative value placed on ‘winners’ versus ‘losers’ in that coppice-high forest system (Buckley and Mills 2015b), but also on the extent of the overall shift from coppice to high forest in the landscape as a whole. Areas with a high number of ‘red-listed’ species dependent on coppice or other forms of open woodland should be a priority; similarly if the general trend in the landscape is towards high forest, coppicing should be promoted simply to maintain a diversity of ecosystem types.

Biodiversity of restored/maintained coppice under changing environments

An implicit assumption in the conservation community in Britain is that if coppice management is maintained, the associated plants and animals will also continue to thrive. However that assumption can be challenged.

- Many of the activities associated with coppice in the past such as litter collecting are no longer carried out; twigs and small branches are less often collected for firewood. Leaving branches and twigs scattered over the whole stand may make it more difficult for people to walk through the stand, particularly if it gets overgrown by brambles. On some sites it gets collected into piles and left, or, less so now than in the past, burnt. Such branch piles take a long-time to break down and change the soil conditions underneath them, as do bonfires where they are still used.
- Climate change and pollution mean that the environment in which coppicing takes place is not the same as in the past.
- The herbivore pressure from deer has increased.
- Tree diseases are spreading. For example, how will our ash coppices and their associated wildlife fare under the spread of ash dieback caused by *Hymenoscyphus fraxineus* (Mitchell et al 2014)?
- The landscape around coppice woods is now generally more ‘hostile’ to the spread of species between sites because of agricultural intensification. Many scattered trees, hedges and streams that provided an element of connectivity through farmland for woodland species have been cleared, increasing the effective fragmentation of the landscape (Peterken and Allison 1989).

If there has been a break in the practice of coppicing then additional factors may limit its restoration and the recovery of its associated wildlife.

- Some of the woody species may have been lost.
- Some stools may have died, or fail to resprout when cut, resulting in large gaps in the canopy after cutting.
- The buried seed bank is likely to be depleted.

Alternatives approaches?

If restoring coppice is not practical, or may not generate the expected biodiversity gains, should we accept that some species will simply become less abundant (or less obvious) in the landscape, particularly if there are gains in other species? It is already the case that large areas of the country have completely lost some of the butterflies formerly associated with coppice clearings. We might have to consciously re-set the base-line for what we expect woodland conservation to deliver, perhaps valuing woods more for their autumnal displays of fungi associated with a build-up of deadwood, for example, rather than for an abundance of spring flowers.

An alternative is to explore how high forest systems that provide the type of wood-products that society now demands can be modified to allow greater opportunities for coppice-associated species. Managers have for example attempted to build elements of the ‘coppice environment’ into high forest systems through, for example, small-scale cutting alongside rides and tracks (Warren and Fuller 1993; Buckley et al. 1997). This has been successful in the short term on many sites, although over time the spread of coarse grasses may make these areas less suitable for maintaining the key butterfly populations (Pollard et al. 1998).

More work is also needed on whether shelterwood, group selection systems and other forms of continuous cover forestry that involve smaller-scale, but frequent interventions, are more favourable to coppice species than clear-fells. On the one hand the time between each phase of gap creation and local disturbance at a point is reduced and may become comparable to that of a coppice cycle. On the other hand the small scale of gap creation and disturbance may mean that they are quickly filled by expansion of competitive species such as bramble that are already established under the canopy.

Consideration of the condition of the landscape around coppice woods will become more important as climate change means that maintaining species at a particular site indefinitely becomes ever more uncertain. Loss of hedges, scattered trees, wooded streamsides, etc, has left woodland patches functionally isolated and fragmented, even where their area and distribution has not changed. While it seems logical to assume this will have contributed to long-term species losses direct evidence that this is the case, or that rebuilding linkages will benefit species, is scarce (Bailey 2007) although see Quine and Watts (2009), Brouwers and Newton (2010). Similarly it is hoped that some of the species formerly associated with coppices might flourish in more irregular large-scale mosaics of

grassland, scrub and woodland that might develop under large-scale rewilding projects with free-ranging large herbivores (Vera 2000). There are indications that this might be the case from projects such as that at the Knepp Estate in Sussex (<http://www.knepp.co.uk/>): nightingale *Luscinia megarhynchos* populations on the estate have increased since it was transferred from conventional farming to a more extensive rewilding-type management.

Conclusions

Coppice woods have been part of the British and wider European landscape for much of the Holocene. They have developed distinctive plant and animal assemblages that are worthy of conservation, alongside those of high forest, because they contribute to the overall diversity of ecosystems.

These assemblages change under the transformation to high forest and gap-phase species are particularly at risk of being lost or reduced substantially in abundance. Given that the general social and economic trends currently favour high forest systems, conservation efforts need to target those that may be lost and hence promote coppice and other traditional management practices such as wood-pasture. On the whole the promotion of such systems is not limited so much by lack of research, or understanding of the species needs, as by lack of markets for the products from low-intensity management systems such as coppice.

Even if promotion of coppice systems is successful in the short term in maintaining past coppice assemblages, we should expect increasing changes as the environmental context changes. National and local monitoring schemes must continue to be able to pick up changes in coppice species at stand, wood and landscape scales.

For the longer term we should explore how ‘coppice species’ can be maintained across landscapes, in non-coppice situations that fit with modern socio-economic patterns. This will require further research on which species can be maintained in open spaces within high forest systems, but also on where-else they can occur in the landscape, e.g. perhaps along scrubby motorway verges. We also need more research on how to develop landscapes that will allow coppice species to migrate through the countryside as climate change or tree diseases make some sites permanently unsuitable for them.

The alternative is to decide which species we are prepared to lose.

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