Evidence review: How do woodland creation approaches give rise to differences in woodland structure?

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Abstract

1. There is increasing demand to expand the extent of native woodland in the UK, to tackle both climate change and biodiversity crises. In general, there are three approaches to woodland creation – natural regeneration/colonisation, direct seeding and tree planting. However, much is uncertain about the effects of each strategy on woodland structure. This review compiles available evidence on the effects of establishment approaches on woodland structure to inform the Woodland Trust's guidance on woodland creation.

2. Natural regeneration and colonisation of woodland can be rapid but also highly variable, depending on a wide range of factors including soil quality, seed dispersal and grazing pressures. Natural regeneration can produce good seedling density and increase spatial and vertical heterogeneity when compared to planted sites. However, a key limitation is ensuring sufficient ground cover to shield out competitive vegetation, such as grasses.

3. Direct seeding allows for more control and consistency and can create a good level of seedling density. This is particularly the case if direct seeding is used in combination with cover crops or ploughing. Direct seeding can create a great variety of woodland structures but is technically challenging and may require supplemental plantings.

4. Tree planting offers the most controlled woodland creation method, with utility for specific situations where rapid results are required, specific species compositions are needed or on challenging sites. Planting easily achieves a high sapling density, but cluster planting/applied nucleation is required to achieve naturalistic canopy appearance and assist regeneration.

5. It is largely unexamined whether different woodland creation approaches deliver quality habitats. Initial establishment approaches may leave a fingerprint on new woodland, but there are other contributing factors, including management and other natural processes

which determine the trajectory of woodland development and shape its structure. For the best possible outcomes, the woodland creation approach should be considered with the type of management required to achieve stated objectives and whether this is likely to take place. The relative merits of choosing one woodland creation approach over another is likely to be a question of cultural and social expectations as much as it is about effectiveness.

1. Introduction

The motivation for this review is to inform the Woodland Trust's forthcoming guidance on best practice in woodland creation. There are many ways to create new woods, as evidenced by the diversity of projects in the UK and globally. Broadly, three approaches to new woodland creation are natural regeneration/colonisation, direct seeding, and tree planting. This review begins with the starting point that each approach can result in successful tree establishment in the right circumstances. These can be used alone or in complement, and they can be considered on a scale from more passive to active interventionism. Practices for applying these approaches do vary, but each may leave a long-term 'signature' in terms of woodland structure, species and functional composition (Freitas *et al.* 2019). This review aims to present the available evidence on how the initial tree establishment strategy can give rise to different aspects of horizontal and vertical structure in new woodland. Understanding how these differences arise, and which factors influence them, is key to good woodland design, which is appropriate for its intended use, and hence success towards the identified objectives. For the Woodland Trust, this activity prioritizes native woodland creation for the benefit of people and wildlife.

The different structural attributes of woods can serve as indicators of ecosystem function and biodiversity provision (McElhinny *et al.* 2005). Structure can be considered at different scales: at the level of a landscape, woodland site, stand or individual tree. At a stand level, structure may be horizontal or vertical. It can include - but is not limited to - measures of tree or shrub abundance and richness, stem size and spatial configuration, canopy stratification and deadwood volume. Diversity and complexity of woodland structure reflects the 'better' aspect of the four Lawton principles (Lawton *et al.* 2010), which summarise what is required for wildlife sites and wider ecological networks (where the others are 'more', bigger' and 'joined'). In woodland, improvements in habitat quality will benefit certain taxa, where increases in habitat size or connectedness will benefit others. All species have individual requirements, so McElhinny *et al.* (2005) caution that there is no index, or definitive suite of structural attributes, to capture all possible niche spaces for wildlife.

In reviewing the available evidence on biodiversity effects of woodland expansion in the UK, Burton *et al.* (2018) found that structural diversity positively benefits certain indicator species groups such as birds and carabid beetles. They conclude that 'diversity in new woodland species mix, structure, and stand age over time is expected to be beneficial to a range of taxa'. Studies of UK woodland creation sites, e.g. WrEN (Woodland Creation and Ecological Networks) project sites, indicate that they can be beneficial for biodiversity, with some woodland species able to colonise within a few years (Fuller *et al.* 2014). However, when evaluating habitat quality of these new woods (up to 160 years), improvements in structure, such as increased variation in tree stem diameter, increased understorey cover and maintenance of open space, were among the suggestions made (Fuller *et al.* 2018). No single structural attribute seems most important to rare species. For the 256 Biodiversity Action Plan (BAP) species (now 'Priority Species') associated with woodland in England, the known niche requirements most reported were veteran trees, glades and rides, and closed-canopy woodland. Thus, these species of conservation concern each require different structural attributes via processes operating in the short term (years) and long term (tens of decades) (Webb *et al.* 2010).

2. Methods

The review question was explored by drawing on evidence relating to structural attributes arising through woodland creation. Briefly, the question was first broken into components- in a PICO format, noting inclusion and inclusion criteria, following guidance and standards for evidence synthesis (CCE, 2018). This constrained evidence to examples of newly established trees and woodlands, and so studies of structure and biodiversity in established woodlands were not included. Further details, including database search terms, are included in Appendix 1. Evidence was located by searching of scientific and other online databases, yielding both peer-reviewed and grey literature. Additionally, for unpublished evidence, a call for submissions was made within the Woodland Trust, and to experts in forestry and woodland conservation. Some of their learnings from unpublished trials are reflected here.

The evidence gathered is divided into sections: natural regeneration and colonisation, direct seeding, tree planting. Studies were included if they were conducted in the UK or include UK native species. Other reviews or experiments from other ecosystems are included where they feature relevant principles or exemplary study designs. These can be learned from, whilst acknowledging that the ecosystem ecology can be very different.

3. Results

3.1. Natural regeneration and colonisation

Here, natural regeneration is used to refer to the establishment of new wooded habitats by natural seeding or vegetative regeneration and includes the term 'natural colonisation'. It is increasingly highlighted for its numerous benefits and as a tool for socio-environmental transition, enabling more wooded landscapes to sustain people and nature (Chazdon *et al.*

2020). Alternatively, natural regeneration can be viewed unfavourably, as an unreliable means to establishing forestry crops, undesirable land abandonment, or as unwelcome encroachment into other semi-natural habitats (Spencer 2020). For natural woodland regeneration, there must be both a nearby seed source and suitable conditions for seed germination or emergence and for sapling growth. Results can range from very high tree density to total failure, as determined by a range of influencing factors. These include soil quality, seed limitation and dispersal, microsite availability, predation and grazing pressures. These seemingly complex requirements may have discouraged more routine use of natural regeneration, but despite this it is used in practice, particularly as a central part of continuous cover forestry (Evans, 1988; Kerr 2008).

3.1.1. Density

The density or frequency of tree establishment is well-documented in ‘old field’ and land abandonment studies in many countries across Europe and North America. In the UK, succession to woodland in various circumstances is well-documented, ranging from the description of Adamson (1932) to Farjon & Hill (2019). The example of the Knepp Estate as a flagship of the rewilding movement has contributed to the increased appetite for use of natural regeneration to establish trees. The Sussex farm, divided into three blocks, has progressively ceased conventional agriculture and has documented the return of wildlife since. Twenty years on, a plot survey of the fields in each block indicates variability in the amount of tree cover (Kirby, 2020). Each block differed in starting conditions and animal grazing pressure. The northern and middle block have taken longest to establish tree cover, starting from grassy pasture. The southern block has shown the greatest increase in tree cover, mostly comprising goat willow. This block developed from arable fields and was initially left un-grazed. Based on the plots sampled, if the current oak saplings continue to grow, they would establish at a density of 15-61 oak trees per hectare.

In a UK study of 46 unmanaged urban and ex-industrial sites, abandoned for between 10 and 42 years, natural regeneration appeared relatively quick. Sites were dominated by ash, birch, goat willow and hawthorn, with 25 woody species recorded in total. The extent of colonisation was very variable and yet achieved an average density of 1500 stems ha^{-1}. This variability of the regeneration was such that 19% of the land was deemed not colonised to an ‘acceptable woodland standard’, defined as a 4x4 m quadrat containing at least four trees of any size (2500 stems ha^{-1}) or two trees >1 m height (Hodge & Harmer 1996). Site factors are important to consider; in upland settings, a Forestry Commission note outlines seed source and ground suitability as key considerations for natural regeneration by birch and Scot’s pine (Thompson 2004). The density that regeneration could achieve among soil and vegetation types varies, with certain grass cover and dense bracken indicating the worst prospects. The ‘good’, ‘moderate’, ‘poor’ criteria were based on potential densities that regeneration could achieve. For example, ‘poor’ prospects for density was indicated as 500 stems per hectare, but it is not indicated over which timeframe this is expected. As woodland establishment is a process, not an event, a low initial density of pioneer trees will produce more seeding individuals within a few years.

The effect of soils has been explored experimentally. By following plant colonisation and establishment on various plots, Rebele (2013) demonstrated that succession towards woodland can be rapid. Trees were shown to colonise continuously, first by *Acer* species and Scot's Pine, though at different rates on different substrates. On soils of low to moderate fertility (ruderal subsoil or sand), 50% cover was achieved in 13 years, and density was reported as 10 stems per m^2 on ruderal subsoil after 18 years. In nutrient-rich topsoil, density was reported as 3 stems per m^2 after 18 years. Here, both plant density and growth were inhibited, possibly owing to both increased competition from herbaceous vegetation and a lack of adaptation of the colonisers to high soil fertility. By contrast, previous studies such as that of Prach & Pysek (1994, 2001) found the impact of soils less clear. On a range of bare ground sites with different soil conditions, revegetation on mesic sites was said to be 'relied upon', but woody cover seemed most related to the dispersal strategy of colonisers. That is, wind dispersed trees such as birch, could create most cover through natural regeneration.

3.1.2. Spatial configuration

There are several studies documenting how grazing animals can drive dynamism and structure in wooded habitats (Vera, 2000). One way is through the process of associational resistance; the protection of palatable young trees by thorny species (Kuiters & Slim 2003)**.** In a study of four European sites, Bakker *et al.* (2004) show that *Quercus robur* can successfully establish in patches of *Prunus spinosa*, although the level of protection might not be afforded against all herbivores, such as rabbits. Natural regeneration of trees can thus occur on sites where herbivore pressure is not chronic and where unpalatable or spiny plants are already present or allowed to initially develop. In six agricultural grasslands with low-intensity grazing, tree establishment patterns were related to the type of cover, and to ground disturbance. Palatable saplings (>40 cm) established in tall herb and scrub patches and showed less evidence of browsing damage compared with those in grassland (Van Uytvanck *et al.* 2008). Further, Van Uytvanck *et al.* (2010) demonstrate an increase in both horizontal and vertical spatial heterogeneity when developing woodland on former arable land is grazed from the outset.

Seed rain can both limit natural regeneration and provide horizontal structure. Although some seed can travel long distances, the majority of seeds travel a short distance from their parent source (Cameron 1996). As such, more and denser tree establishment occurs closest to hedgerows or woodland edges (Laborde & Thompson 2013). Indeed, in visits to 32 commons in the south of England, (Farjon & Hill 2019) document commons which were 'virtually treeless' in maps c. 1843-'93 but are now wooded sites of diverse age and spatial structure, all thought to be self-seeded from nearby vegetation. At Knepp, greater frequency and diversity of trees and shrubs was also observed nearest to seed sources, in edge plots rather than in-field (Kirby 2020).

Indices describing stand diversity have been compared for planted vs naturally regenerated woods on coal spoil sites in the Czech Republic. 45 years after mining, Vacek *et al.* (2018) evaluated differences in structure with either biodiversity and production objectives in mind. They found that both species composition and structure varied between approaches. Planted areas mostly comprised oak, alder and birch, whereas the regenerated stands comprised aspen, willow and birch. Although planted areas showed higher mean volumes through larger stem diameters and a regular distribution of stems, regenerated areas showed varied stem-diameters and significantly aggregated stem distribution.

Structural diversity can also be assessed using lidar. In Denmark, Thers *et al.* (2019) compared young (21 to 78-year-old) woods which had naturally regenerated from abandoned agricultural land with similarly aged, planted woodland in the same region. In measures of vegetation height, canopy cover and amount of bare ground, naturally regenerated stands had higher structural heterogeneity. However, it was noted that the pace of regeneration was slow, with shrub-dominated low vegetation and open areas persisting. In this study, the pace of development was explained by natural disturbances, such as flooding, and seed limitation at the sites.

One argument against relying on natural regeneration is for the need to achieve rapid and extensive canopy cover to shade out competitive vegetation and develop a closed canopy woodland microclimate (Kirby pers. comm. 2020). The initial ground vegetation and its likely influence on succession is a key consideration of the need to achieve rapid canopy closure. However, the goals for entire site cover by trees must be balanced against a need for more complex structure, including open space and the ecotones (transitional areas) between. On arable land abandoned in the late 1800s, a long term floristic study revealed a transition from a flora of shade-tolerant species within 20-40 years, but highest flora richness before canopy closure (Harmer *et al.* 2001). Such protracted or sparse forest establishment may advance many elements of structural complexity (Donato *et al.* 2012). In developing along an open-canopy pathway, woodlands can more quickly develop structures and old growth characteristics typically associated only with late successional wooded ecosystems. These include clumped and widely-spaced trees, vertically heterogeneous crowns and canopies, co-existence of under-, mid-, and overstories; and facilitation of shade-tolerant species.

3.2. Direct seeding

Direct seeding involves the burial or sowing of seed to establish trees, distributing seed either with precision or randomly across ground. It is consistently acknowledged as having several potential advantages over tree planting, resulting in naturalistic, denser, and more rapidly growing trees (Willoughby *et al.* 2007). The practice of direct seeding has been evaluated in several Forestry Commission studies, with success criteria usually being percentage tree cover and evenness of establishment across a site. As with natural regeneration approaches, direct seeding requires suitable microsites and conditions for the establishment of trees. Indeed, the failure of a site to naturally regenerate does not necessarily mean direct seeding is an option because many of the barriers to tree establishment may persist and site preparation, fencing or other interventions may still be necessary. Willoughby *et al.* (2007) note that in the presence of an adequate seed source, a lack of regeneration is unlikely to be improved by seeding if microsite limitation still occurs. Seed survival, seedling emergence, and early seedling survival are particularly vulnerable stages in the life of a tree. Some studies report loss of seeds to rodents, though Parratt & Jinks (2013) demonstrate that strong differences in predator preference might permit direct seeding of certain species, particularly those with smaller seeds (hawthorn and wild cherry) and chemical defence (ash). Seeds may also fail to germinate (Jinks *et al.* 2006) or die through frost, waterlogging and drought in the first few years. Direct seeding remains technically challenging, but a greater understanding of factors affecting its success will enable more informed use in the future.

3.2.1. Density

Most of the available data about early woodland structure is regarding tree density – seedlings per hectare. Few studies directly compare seeding with planting at the same site, but a US study comparing seeding and planting of *Quercus* and *Populus* species found, after four growing seasons, that stocking from direct seeding was not significantly less than from planting (Stanturf *et al.* 2009). The existing evidence describes results as very variable. Direct seeding can achieve an initially low density of seedlings, and subsequent mortality of these initial seedlings would then result in tree density far lower than would be recommended for conifer or broadleaved forestry. Thus, it is recommended to aim for the establishment of 10,000 trees per hectare (Willoughby *et al.* 2019).

Evaluating the success of stocking density achieved by direct seeding will depend on management objectives. For example, seeding of birch on a felled Sitka site resulted in 880 seedlings per hectare after 1.5 years. However, lots of open areas persisted, with 12% of the plots containing no birch at all (Willoughby *et al.* 2007). Such variability might not be acceptable as restocking for production but could positively contribute towards conservation objectives. The Temperate Taungya method is described as a working with nature method of creating woodland for timber production objectives (Watson, 1994). The method recognises that high predation of seeds and seedlings and competition from grasses limits tree establishment. It advocates initial ploughing of land, followed by a large amount of seed sown under a nurse crop such as barley or wheat. Influenced by this method, the Woodland Trust at Comfort's Wood seeded around 1 ha of former arable land with a mixture of species in 1991. 10 years later, an evaluation remarked success in producing the desired effect – 'dense woodland dominated by oak with a good shrub understorey and a random, natural appearance' (Tucker, unpublished). The success of the direct seeding in achieving high density is obvious (Fig. 1), and it is remarked that it was more successful at establishing cover than the adjacent planting.

Figure 1. Example of direct seeding area (left) and a planted area (right) at Comfort's wood in 2003. From *Tucker (unpublished)*.

3.2.2. Spatial configuration

Woodland established through direct seeding generally results in a great variety of tree configuration and random open spaces (Willoughby *et al.* 2004). In a seeding compared with planting comparison from the US, Twedt & Wilson (2002) recommend acorn sowing over planting when wildlife habitat is the management objective, due to the less-uniform stem distribution. Another comparative study from Brazil directly contrasted direct seeding with tree planting and with natural regeneration over 10 years of restoration, measuring multiple attributes of structure (Freitas *et al.* 2019). They concluded that, although results were variable, sites restored through direct seeding formed a stratified forest with a closed canopy that was starting to be colonized by non-planted species. Further, they argue that direct seeding projects are quickly evaluated, so the need for supplemental planting can be identified soon after.

3.3. Tree Planting

Tree planting offers the most controlled approach to establishing new woodland, as planting can be designed to help deliver against objectives more quickly and effectively. There is often a clear rationale for planting activity (Goldberg 2020), including to increase the speed and effectiveness of tree establishment, and to achieve certain species composition. It may be necessary to introduce or bolster species which have been lost or are at risk, such as for montane scrub (Mardon, 2003). Planting may sometimes be a more reliable means to establish woodlands on challenging or degraded sites and may be preferred where new woodland in the right location is urgently needed, such as for flood alleviation.

3.3.1. Density

The initial establishment density of planted woods can clearly be decided at the earliest stages of new woodland design. In general, to receive funding support in the UK, the minimum density of planting is at 3 m spacing (1,100 stems per hectare), but this can increase to 2.5 to 2m spacing (2,500 stems per hectare) depending on objectives. Many woodland creation schemes specify high initial planting density, and this is desirable for timber production; this close spacing of trees tends to result in straighter stems with minimum branching. These designs are effectively aiming to establish many trees, of which some can be thinned-out years later.

To assess the habitat resources within new woods, particularly with regard to planting density, Vesk *et al*. (2008) measured structural attributes of 5 to 130-year-old new woods. Though the initial establishment densities were not reported, they found that high-densities of trees and shrubs can limit the development of structural diversity by reducing tree girth growth rates and delaying the occurrence of large limbs, tree hollows and fallen timber. Provision of tree hollows may be delayed by decades to a century with high stem densities, whilst large, spreading limbs can be entirely limited. For woodlands created for wildlife benefit, it might be worthwhile considering the development of such features at the initial design.

Where lack of future management is a risk, Crook (1995) suggests that initial planting designs must cope with such lapses, via matrix planting techniques. This might involve single species block planting, thoughtful arrangement of pioneer vs climax species, and large open spaces which will remain open for long periods. Nielsen & Jensen (2007) appear to concur on this point in a review of urban woodlands, stating that motivation for thinning is sometimes lacking in comparison to commercial forestry and arguing for the robustness of designs concerning visual, as well as ecological aspects.

For amenity woodlands, the planting style generally termed the ‘ecological approach’ has been a popular style of woodland creation. This generally involves a high-density planting of trees and shrubs to stimulate different successional stages. By establishing pioneer trees species with more climax species at the same stage, the intention is to promote a structurally diverse woodland more quickly. Some studies have evaluated woodlands created in this way. In a study of ten young urban woodlands, Richnau *et al.* (2012) found that all had developed a stratified canopy structure to some extent, but recommended several thinnings in the first twenty years of development to promote multi-layer canopies.

Further natural regeneration can be encouraged by the planting of relatively few trees or by the provision of artificial perches. This technique is called facilitation, or nucleation, planting, which can kick-start woodland development by enhancing seed dispersal and seedling recruitment through strategic tree establishment (Fig. 2: Corbin & Holl 2012; Holl *et al.* 2020).

3.3.2. Spatial configuration

Given the increasing demand for large-scale restoration of wooded landscapes, tree planting schemes need thoughtful design and it is recommended that 'repetitive formula-driven patterns' are avoided for both naturalistic appearance and the development of structural diversity (Rodwell & Patterson, 1995). Further, planting patterns can be specified which vary the composition, size, location and spacing of cluster planting, as well as the size and location of wider open space. Cluster planting also promotes natural regeneration between clusters or groups, resulting in the admixture of naturally regenerated, early and mid-successional tree species (Saha *et al.* 2017). For fleshy-fruited trees and shrubs, the spatial pattern of seed rain depends on initial perching structures or occurrence of pioneer trees (Kollmann 1995). Evidence of nucleation effects of existing trees has been shown to persist for decades following tree regeneration around them (Holmes 2020).

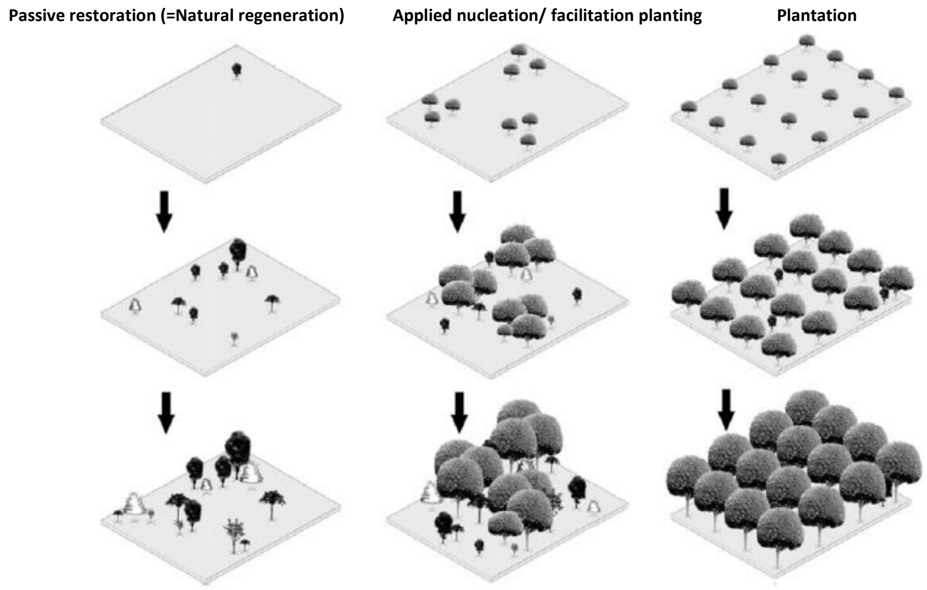

Figure 2. Time sequence of three common strategies to restore forest cover: passive restoration, applied nucleation, and plantation. As each design ages (from top to bottom), tree cover expands via tree growth and colonization. Passive restoration produces a diverse forest community, although with the least forest cover of the three scenarios. By contrast, applied nucleation results in greater forest cover compared to passive restoration, and lower cover but a more diverse community compared to the plantation. For the sake of simplicity, only one tree type is planted in the applied nucleation and all the other species colonize naturally. In reality, nuclei and plantations could vary in species composition and the number of trees planted (from Corbin & Holl, 2012).

4. Conclusions

All kinds of woodland provide a range of habitats for species, but it is generally presented that diverse woodlands with maximal structural variation provide a greater range of niches than do even-age, even-density or single-species stands. The evidence presented here shows that, for new woodland establishment, aspects of horizontal structure are most reported often as seedlings or average stems per hectare. These aspects were measured as indicators of success of the establishment method, rather than as indicators of biodiversity provision.

The evidence available suggests that both natural regeneration and direct seeding may produce very high or low density of tree establishment. For natural regeneration, a sometimes-prolonged time to achieve target densities might be more to less acceptable depending on management objectives. An unpredictable spatial configuration and species composition will also vary in acceptability depending on the intended use of new woodland, for instance where there are prolonged scrub phases, short-statured species or non-timber trees. Direct seeding offers more determination of species composition, but tree planting activity offers the most control over many aspects of new woodland development.
Many available studies are limited to descriptions of how seedling density or canopy stratification is achieved by just one woodland creation approach. There are very few direct comparisons of tree planting or direct seeding vs natural regeneration against defined conservation objectives, though examples most relevant to the UK include Thers *et al*. (2019) and Vacek *et al.* (2018).

The range of influencing conditions highlights the need for paired evaluations of active restoration and natural regeneration at the same site (Reid *et al.* 2018). However, indirect evidence suggests that a variety or combination of woodland approaches, used thoughtfully, could deliver structural complexity in woodlands for ecological benefit. Other aspects of woodland structure generated during new woodland development, such as deadwood, crown architecture or stem-diameter distribution are missing from the evidence base. Some of these aspects are likely recorded in condition assessments of new woodlands and could thus be synthesised to better inform practice.

It is acknowledged that species responses to conservation activities, including woodland creation, can take some time to indicate conservation success (Watts *et al.* 2020). Such ecological time lags can make it difficult to know whether activities are effective. Some specialist birds, for example, might not be expected to colonize or increase in abundance for some time because aspects of habitat quality like increased structural diversity or formation of old growth features are considered later milestones of woodland development. Early succession is an often-overlooked aspect of woodland development; it has been suggested that initial observed differences arising through woodland creation approaches might attenuate relatively quickly. Despite the structural attributes of large diameter trees being longer-term concerns, such as spreading crown form and deadwood development, they do need early consideration. Vesk *et al.* (2008), Donato *et al.* (2012) and Thers *et al.* (2019) suggest that eventual old-growth structural heterogeneity is partially determined in the early successional stages.

For new woodland, provision of quality habitat should be a measure of success. However, it is largely unexamined whether different approaches to create them do deliver quality habitats. Indeed, Newton *et al.* (2001) note that there is a general expectation that woodlands left to develop 'naturally' will deliver restoration goals. This expectation is challenged; historical changes at the landscape or regional scale may constrain the natural development of species or community structures. Initial establishment approaches may leave a fingerprint on new woodland, but there are other contributing factors, including management and other natural processes which determine considerable part of the trajectory woodland development and shape its structure. For the best possible outcomes, the woodland creation approach should be considered with the type of management required to achieve stated objectives and whether this is likely to take place. The relative merits of choosing one woodland creation approach over another is in part a question of cultural and social expectations, as much as it is about effectiveness (Townsend, pers. Comm. 2020).

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Conflict of interest statement

The author declares no conflict of interest

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Appendix 1

	Question components	Inclusion/ exclusion criteria
Population	New woodland and tree establishment	Establishment of trees whether through direct action or passively. This might occur from grassland, moorland or other open habitats, and clear-felled woodland
Intervention	Tree planting, natural regeneration, direct seeding	Excluding under planting, seeding and regeneration in any kind of existing woodland
Comparators	Comparisons of any outcomes between interventions, or no comparator	Descriptions of any intervention. Comparisons between interventions but Not before/ after a single intervention, i.e. a contrast of structure of grassland and newly-established woodland
Outcomes	Attributes of horizontal and vertical structure in wooded habitat. Woodland-level outcomes might include: Openness, understory or shrub layer, ground flora, density, stem diameter distribution, tree spacing and configuration, dead wood Tree-level outcomes might include: Crown volume or architecture	

Searches were conducted on Mendeley web, Google Scholar, and the Web of Science interface. Searches used a search string with the intervention, such as “direct seeding” or other variations, such as “direct sowing”. Strings were made more specific by adding locations – “UK”, native trees – “*Quercus robur*”, or components of woodland structure – “density”. More general searches for woodland or forest creation or restoration were also made.