WOODLAND TRUST

Restoring plantations on ancient woodland sites

Conversion to native woodland or conservation of ancient woodland communities?

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1 The opportunity and challenge of PAWS restoration

1.1 The 'PAWS resource'

Ancient woods are sites that appear to have been wooded continuously since at least AD 1600 (Peterken, 1981). They were identified and mapped in the Ancient Woodland Inventories (Spencer & Kirby 1992; Roberts et al 1992). Approximately 44% of the ancient woodland surviving in Britain has been converted to plantation, giving around 220,000 ha of Plantations on Ancient Woodland Sites (PAWS) (Pryor & Smith, 2002). All sites recorded as PAWS showed some evidence of having been planted: aerial photography, name, historical records and old maps. Recent analysis of data from the National Inventory of Woodland and Trees (Pryor & Smith, 2002) shows that 60% of the canopy area is coniferous, and of that which is broadleaved 85-90% is native. The vast majority of PAWS were converted from semi-natural stands in the 20th century, and over half of the total area of PAWS was established between 1941 and 1970 (Spencer & Kirby, 1992; Kirby, 1988), primarily as a response to war-time timber shortages.

Ancient woods have a rich assemblage of characteristic species (Peterken & Game, 1984), are one of the richest and most diverse habitats in Britain, and are, by definition, irreplaceable. PAWS have obviously been changed a great deal, but many of the features of ancient woodland are still extant. Unlike Ancient Semi-Natural Woodland (ASNW), they have received very little special protection in forestry or nature conservation policy in the last 20 years. For example, the UK Forestry Standard (Forestry Commission & DANI, 1998) stipulates that special treatment (under 'Standard Note 5') is only applicable to PAWS 'where restoration is an objective of management'. In contrast to the substantial public funding for the creation of new native or broadleaved woodland since 1985 there have been very limited incentives to promote restoration of PAWS (Pryor, 2001).

1.2 Restoring PAWS

Restoring PAWS to native woodland cannot hope to re-create unaltered ASNW, but it is an opportunity to conserve and enhance remnants of ancient woodland communities, and to create 'restored native woodland on ancient sites' (RNWAS). The desirability of restoring PAWS to native tree species was not recognised nationally until it featured in the Habitat Action Plans for native woodland (UK Biodiversity Steering Group, 1995) and, independently, in forest certification standards (FSC, 1998; UKWAS, 1998). The substantial fall in the profitability of softwood timber production in recent years (Forest Enterprise, 2001) has reduced substantially the economic obstacles to restoration, and opened up a major new opportunity. Forest Enterprise is responsible for 40% of the total area of PAWS (Pryor & Smith, 2001), and has been carrying out a major assessment of its resource in England (e.g. Hutchby et al, 2000) and Wales with a view to developing strategies for restoration.

The process of restoration is often perceived as being simply a matter of clearfelling the existing crop and replanting native species. However, early experience suggests this is not always straightforward, and can have adverse results particularly on heavy soils (Rod Leslie, *pers. comm*.). Deciding on priorities for restoration can also be complex. In 2000 the Forestry Commission sought to address this knowledge gap by issuing for consultation draft guidance on restoring PAWS, and a final version is in preparation.

The Woodland Trust has called for greater protection for ancient woodland, and 'no further loss'; and it has also identified restoration of coniferised ancient woodland as a priority for action (Tickell & Thackrey, 2000). The Woodland Trust is also a major owner of PAWS, with over 2000 ha within its estate. It thus has an interest in both the policy and practice of restoring PAWS.

2 Aims and approach

2.1 Aims

Alongside this policy development and implementation, there is considerable uncertainty about the best methods of restoration, and some concern that in the process of restoring PAWS we may be jeopardising the inheritance of ancient woodland features and communities. This study was commissioned to examine experience of restoration by the Woodland Trust and address this lack of ecological and silvicultural information. This report is a summary of the main findings of the study and is intended to be a practical document for woodland managers and policy makers.

The aims of this study were, firstly, to explore the survival of ancient woodland communities within PAWS and, secondly, to evaluate the means by which they may be restored to native woodland. This meant focusing on the ecology of ancient woodland communities and evaluating the silvicultural techniques that have been used to convert even-aged plantation crops to semi-natural woodland. A further aim of the study was to identify key silvicultural and ecological questions relating to restoration and proposals for a series of scientific trials under which they could be investigated are made in a separate report (Curtis & Pryor, 2002). The study focuses on restoration at the stand level and does not address landscape-scale issues.

The study comprised a literature review and field assessment of Woodland Trust PAWS where restoration was underway or planned. The primary focus was conifer plantations on ancient sites, and the fieldwork did not include beech and other broadleaved plantations. Conifer crops present a defined and higher priority focus for study because they are morphologically quite distinct from the native canopy species on most sites, creating changes in stand conditions that are likely to be more divergent from semi-natural conditions than those under most broadleaf crops.

2.2 Previous studies

The earliest publications focused specifically on PAWS considered the impact of the crops on ancient woodland communities (Hill, 1979; Mitchell, 1987; Kirby, 1988). Ferris & Simmons (2000) examined the effect of different tree species and mixtures on ground flora, and also found that woodland species were not well represented in PAWS seed banks. The first appraisal of restoration was for some Argyll oakwoods (Kirby & May, 1990). More recently Radford (1998) looked at the recovery of the ground flora in four lowland woods, and Mathews (1999) surveyed stands in Salcey Forest subject to various restoration treatments.

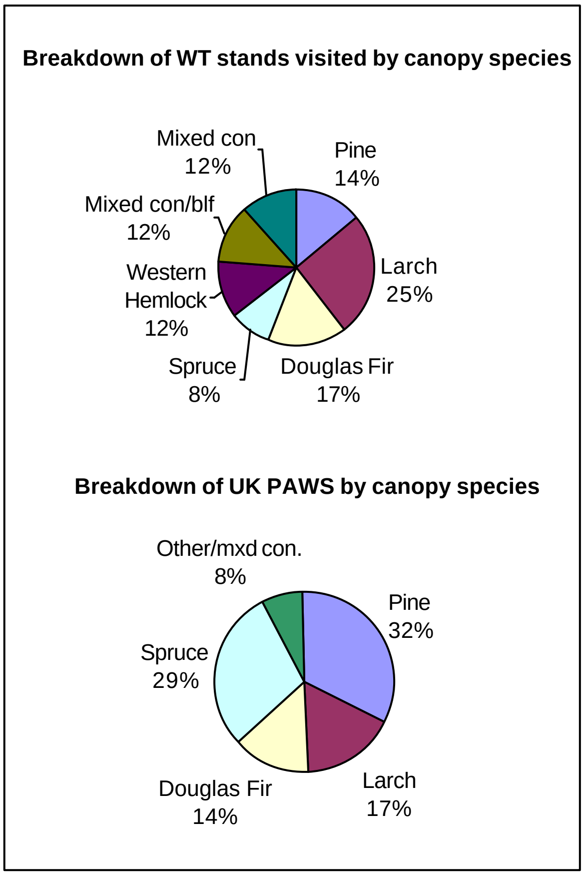
2.3 Fieldwork

The fieldwork involved visiting 40 Woodland Trust sites, and assessing over 100 PAWS stands, during the Spring and early Summer of 2001. Sites were chosen to represent a range of upland and lowland site types across Britain, and also to reflect the national frequency of different crop species (Pryor & Smith, 2002). The main criteria in stand selection was that restoration operations had been completed or were imminent at the site, but other nearby PAWS stands not yet subject to restoration and semi-natural stands were also assessed for comparative purposes. The restriction to Woodland Trust properties may suggest an atypical sample. In fact since the Trust has purchased most of the sites in the last 10– 15 years, and they were previously managed by either the Forestry Commission or the private sector, they are reasonably representative of the conifer PAWS resource, (see breakdowns in Figure 1, overleaf). They do, however, differ in having a high proportion under restoration to native broadleaves.

Field methods involved assessments of surviving ancient woodland communities, assigning scores for survival of ancient woodland flora, deadwood and veteran trees. The protocols for assigning scores are summarised in the Appendix. Other elements and features, such as rides, topography and drainage, were also recorded. Information on the standing crop was collected, including basal area, mean diameter and top height. Percentage canopy cover was estimated, and structural information such as planting pattern and under-storey density was recorded. Other management information, such as age, thinning history, and recent management operations was also recorded or inferred from evidence on site.

The data collection was systematic and consistent across sites, but essentially observational. The intention was to look for evidence of patterns and effects across a wide range of sites, which might guide restoration practice in the short-term and be investigated further thereafter. The fieldwork thus involved making simple assessments at a large number of sites rather than doing detailed surveying of a much smaller number. The work was thus essentially aimed at formulating hypotheses, and identifying suitable sites on which they could be examined and tested more rigorously.

These observations were complemented by discussions with the Woodland Trust Officers for most of the 40 sites visited, which provided details of management to date, responses and future operations planned.



- UK data is taken from figures in Pryor and Smith (2002)
- Pine, larch and Douglas fir proportions are similar
- Spruce is by comparison under-represented in the WT stands. This is likely to be attributable to undersampling in terms of area of upland / Scottish sites
- Western hemlock and mixed crops are over-represented in WT stands
- Species-impacts on woodland flora in Figure 7, (section 4.5) appear to group pine with larch and spruce with western hemlock. Grouped like this into 'species-impact categories', the charts would be even more similar.

Figure 1. Comparison of species breakdown between UK PAWS and study stands

3 Ancient woodland communities in PAWS

3.1 Characteristics of ancient woodland species

The plant and animal communities found in ancient woodland are distinctive due to their higher species diversity and the particular assemblage of species they contain. A higher proportion of the species are specifically adapted to woodland conditions (Kirby et al., 2000) and many of those present are at least partially restricted to ancient woodland. Such assemblages can be said to represent 'species quality' (Hambler and Speight, 1995; Honnay et al., 1999).

Species showing a strong or obligate association with ancient woodland have been identified as 'ancient woodland indicators' in some regions (e.g. Rose, 1999). Such indicator species, along with other species that show strong links to ancient woodland conditions, may usefully be termed 'woodland specialists'. Examples of woodland specialists are recognised in most woodland taxa. Vascular plants are especially well documented (Peterken, 1974; Peterken & Game, 1984; Rose, 1999; Kirby et al., 2000), as are lichens (Rose, 1976; Rose 1992; Hodgetts 1992), but the profile also fits some fungi (Helgasson et al.,1998; Miller and Lodge, 1994; Peterken et al., 1995; Hodgetts, 1996) and mosses and liverworts (Ratcliffe, 1968; Hodgetts, 1992). Animals include beetles (Harding & Rose, 1986; Speight, 1989); moths and flies (Marren, 2000); birds (McCollin, 1998; Smart & Andrews, 1985); land molluscs (Boycott, 1936); and mammals, principally bats (Holmes, 1996; Corbett & Harris, 1991) and dormice (Bright, 1996).

It is important to recognise that the term 'woodland specialist' includes many valuable species that can be an important part of ancient woodland systems and have an affinity for ancient woodland conditions, but are not obligate, or indicative species e.g. birds (Smart & Andrews, 1985) and bats (Holmes, 1996). The term also includes species identified in some regions as ancient woodland indicator species, and these can clearly still be 'woodland specialists' when they are outside a region where they are indicators.

3.2 Functional attributes and strategies

As a group woodland specialists have an 'ecological profile' sharing several key functional attributes (Hermy et al., 1999) and ecological characteristics. The most significant of these are as follows.

- They are **sedentary**, and will only colonise or recolonise extremely slowly. Woodland specialist plants often rely largely on vegetative spread, and rates of spread under present climatic conditions often appear to be only a few metres per century (e.g. Brunet & von Oheimb, 1998; Davie & Ackroyd, 1988; Honnay et al, 1999).
- If not slow colonisers themselves they may be dependent on other species or features that are slow to develop and characteristic of long established or **'late-stage woodland'**. Such features can include mature trees and dead wood, undisturbed soil conditions, and the presence of other woodland specialists. For example, some fungi are specifically associated with 'late stage' forest conditions (Frankland, 1998), many epiphytes require 'veteran' trees, and saproxylic invertebrates need large dimension deadwood (Read, 2000).
- They are generally adapted to shaded, moist and relatively **undisturbed environments** (Kirby et al., 2001). Adaptation to stresses such as shade by vascular plants are associated with other characteristics in a general 'stress tolerator' strategy, as distinct from 'ruderal' or 'competitor' strategies (Grime et al., 1988). (This is similar to the terms 'k-selected', used to describe organisms adapted to stable conditions, and 'r-selected', referring to organisms which are able to respond rapidly to changing conditions.) The corollary of this however is that they are at a competitive disadvantage when conditions change. Similar strategies have been observed in fungi (Pugh, 1980), and epiphytes, which will generally be sensitive to the desiccation and loss of habitat associated with disturbance (Hodgetts, 1996).
- Woodland specialist plants generally **do not have long-lived seed** (Bierzychudek, 1981). As a result they will be absent or a minor part of seed banks, especially if the plant is not present in its vegetative form (Ferris and Simmons, 2000).
- They have complex interactions with an **ecological system**, which has taken several millennia to develop. For instance saproxylic species of invertebrates will often require a combination of dead wood from veteran trees and pollen from other sources such as *Crataegus* and *Umbellifer* species (Key, 1996). As well as supporting integrated communities of ancient woodland species, the complexity also provides a rich habitat for other less specialist woodland species, such as birds (Smart & Andrews, 1985).

3.3 Implications for PAWS restoration

These functional attributes mean that woodland specialists are well adapted to stable and continuous woodland conditions. They also have important implications for their potential survival and recovery in PAWS:

Re-colonisation from adjoining or nearby ASNW will be very slow (Davie & Ackroyd, 1998; Honnay et al, 1999), so at a site level, species are 'extinction-prone' (Terborough, 1974)

Sudden changes in microclimate are likely to put them at a competitive disadvantage in relation to ruderal and 'r-selected' species (Battles et al., 2001)

Woodland specialist plants will not appear 'phoenix-like' from long-dormant seed banks (although there are exceptions, such as Luzula sylvatica). With ancient woodland plant communities 'what you see is what you get'

- Simply replanting native canopy species cannot hope to re-establish a complex and mature ancient woodland system.

3.4 The components of ancient woodland surviving in PAWS

Based on the assessments of PAWS, the ancient woodland features and communities that were found to have survived were grouped into the following categories:

Ground vegetation and shrub layer

Semi-natural trees and underwood

Veteran trees (usefully defined as trees that were clearly post-mature at time of conversion to plantation), dead wood and associated communities

Soil profiles

Small-scale topographical features

The characteristics, distribution and value of these surviving components are summarised in Table 1 (overleaf). It was clear from the sites visited that survival of at least some key components of the ancient woodland community was the norm. Only 16% of the 98 stands analysed had no surviving veteran trees or significant woodland ground flora surviving in them; see Figure 2, below:

Figure 2 Chart showing infrequency of sites with no ancient woodland component survival

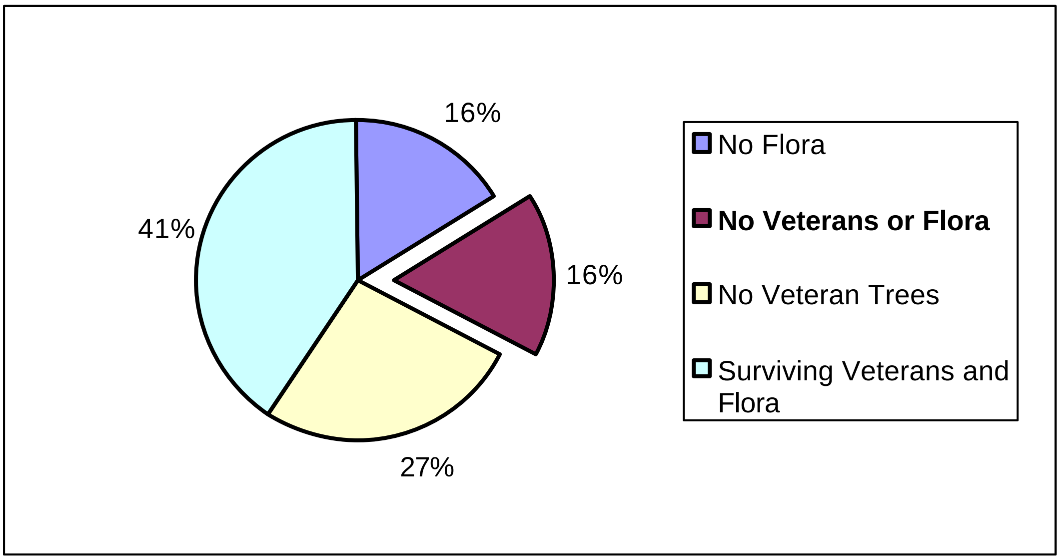


Table 1. Ancient woodland components surviving in PAWS, their ecological characteristics, distribution and value

Surviving ancient woodland component	Characteristics	Distribution	Value
Ground vegetation and shrub layer	Includes 'indicator' species usually associated with AW, plus other woodland specialists and sometimes non-woodland species	Often concentrated into 'hotspots' where plantation conditions and operations were less intense	Provide food source e.g. fruit and nectar (Marren, 1990) and micro-habitat; may have popular appeal (e.g. bluebells)
Semi-natural trees and underwood	Overstorey trees (including stored coppice) retained from previous stand; underwood and naturally regenerated trees that have re-grown with the planted crop or from retained overstorey trees	Their distribution patterns may be natural or reflect past management, but have usually been altered by the conversion process and subsequent plantation treatment	They provide genetic continuity with previous semi-natural stand; semi-mature trees also will provide the next cohort of mature and eventually senescent woody habitat (Read, 2000)
Veteran trees, dead wood and associated communities	Large, old trees (often standards) surviving from previous stand; stumps and root systems of standards, stubs and stools; plus coarse woody debris (stems and limbs) left from original felling up to 50 years earlier	Their location is often historically meaningful (e.g. boundary trees) (Rackham, 1976)	They provide direct genetic continuity with previous stands, and may be particularly rich in associated communities, particularly fungi, epiphytes, invertebrates, birds and bats
Soil profiles	Never having been cultivated, ancient woodland soils have been described as 'archive soils' (Ball, 1981), often retaining undisturbed profiles (Peterken, 1993) along with low and spatially variable nutrient levels	Profiles and nutrient levels are spatially variable (Wilson et al 1997), reflecting both management history and subtle edaphic variation	This variation and diversity forms part of the site's 'habitat quality' (Honnay and Hermy, 1999) and many woodland specialists are adapted to specific soil conditions
Small-scale topographical features	Drainage ditches; gullies, ravines, wet patches, streamsides; rock outcrops; buildings; boundary banks, walls, hedges; ride edges and wood margins; rides and glades	They are often associated with, or cause, gaps and 'anomalies' in the plantation crop which in turn leads to pockets of surviving communities and 'hotspots' of biological diversity	These provide a diversity of habitat niches, and can also be of cultural or geomorphological interest

The ground flora has received the greatest attention in previous studies of PAWS, and in managers' assessments of stands. However, the communities associated with veteran trees and deadwood are very rich, and include saprotrophic fungi (Ing, 1996), bryophytes and lichens (Rose, 1974; Marren, 1990), saproxylic invertebrates (Speight, 1986; Harding & Rose, 1986; Kirby & Drake, 1993; Key, 1996), birds (Smart & Andrews, 1985) and bats (Holmes, 1996). In terms of survival of ancient woodland species a scattering of veteran trees and ancient coppice stools may be as valuable as the ground flora. While veteran trees are present in a high proportion of sites, their prominence is very variable; a small number of stands, 7%, had distinctly valuable and frequent veterans.

The presence and value of deadwood surviving from the previous ASNW has not been previously noted in PAWS and yet this was frequent surprisingly, with coarse woody debris in almost 40% of stands. Occasionally whole felled trees remained from the precursor ASNW (e.g. Common Wood, see Figure 3).

Figure 3 Whole felled tree remaining from precursor stand under Norway spruce at Common Wood, Gower

3.5 Distributions of surviving ancient woodland components

Ancient woodland components were usually found to be distributed unevenly through the PAWS stand. This followed a dichotomous pattern, with 'hotspots' of relative abundance and diversity, in amongst the general stand 'matrix'. Surviving ancient woodland components were either absent from the matrix, or showed lower abundance and species diversity than in the hotspots.

It was noted that hotspots tended to be associated with features or 'anomalies' within the plantation stand. Typical features were either linear such as along watercourses or ride edges, or patches such as damp spots, small areas of failed plantation or surviving semi-natural trees.

It is important to note that rather than just containing the 'edge' or 'wetland' species normally characteristic of these features, the hotspots are usually refuges for a variety of ancient woodland specialists, albeit in sub-optimal conditions.

4 Factors affecting survival of ancient woodland components

The fieldwork confirmed that survival of ancient woodland components is variable and site-dependent, but also indicated various factors that influence the extent and condition of survival. These include the nature of the stand that existed before conversion to plantation, the operations carried out during conversion, and the subsequent management of the plantation. Such factors, especially past management, often present little evidence and, at best, can only be inferred, but the evidence of other factors is more clearly visible and definitive.

In this section the main stages in the life of a PAWS, and the conditions and impacts associated with them, are summarised first. The likely impacts of the individual factors are then reviewed, backed up by observations from the fieldwork, and finally the implications are considered.

4.1 The process and impact of conversion to plantations.

To understand what has survived in PAWS we need to be aware of the stages in the establishment and subsequent development of a plantation on an ancient woodland site. Apart from the direct absence of semi-natural stands and associated habitats, the planting and development of a coniferous crop will have adverse impacts on the woodland ecosystem. Figure 4 summarises the stages in PAWS development and the following associated impacts:

- **Direct damage:** Removal or destruction of ancient woodland components occurring mechanically or chemically through herbicide use during clearance, planting and weeding and subsequent thinning operations (Mitchell, 1987).

Shade: Conifer plantations are generally evergreen and densely stocked, casting heavy and continuous shade. The light levels are lowest during the thicket and pole-stage (stage 4) and a 20 year period of intense shade may be long enough for most woodland specialists to die out, and will also exceed the life expectancy of their seed (Mitchell, 1987; Kirby 1988; Hill & Jones, 1978; Pigott, 1990; Ferris & Simmons 2000).

Canopy competition: Lateral competition and over-topping of semi-natural trees and under-storey regrowth will make them unstable and can eventually shade them out altogether.

Moisture regime: Canopy interception and transpiration of water as well as the installation of drainage systems will have dried out soils, damaging or destroying habitats for many woodland species (Ovington, 1955; Kirby, 1988).

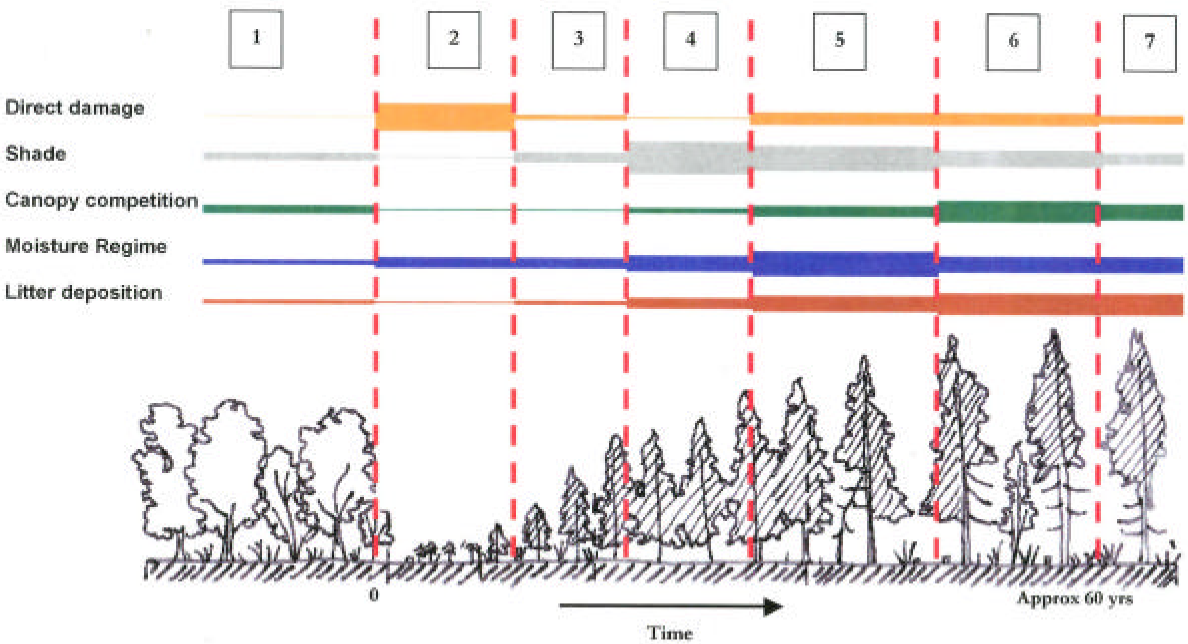
Litter deposition: Conifer litter is high in tannins and phenols. It accumulates on the forest floor, smothering plants, and in time may acidify soils (Sydes & Grime, 1981; Nys, 1981; Pigott, 1990; Amezaga & Onainda, 1997).

Figure 4. Time line diagram depicting probable impacts and stages in PAWS development

- Impact categories correspond with descriptions in section 4.1
- Likely relative magnitude of impact depicted by line weight

Stages

1. Pre conversion
2. Clearance and Planting
3. Thicket
4. Pole
5. Middle rotation
6. Mature
7. Over-mature



4.2 Previous stand

The ancient woodland components found in a PAWS depend on the type of semi-natural woodland previously found on the site and on its history of traditional management. Together these will have resulted in the pre-conversion 'baseline community'.

Woodland type

The nature of the previous semi-natural woodland type of a PAWS, for example, NVC community (Whitbread & Kirby 1992) or Stand Type (Peterken 1981), is obviously crucial in determining the range of species originally present. There is almost always sufficient surviving shrub and ground flora for it to be determined, or reference may need to be made to adjoining stands. Failing these courses of action, 'putative woodland type' can be predicted from the site's key edaphic variables, climatic zone and whether it is upland or lowland (i.e. use of *'Ecological Site Classification'*, Pyatt, 1995; Ray et al., 1996).

Historic management regime

The management regime applied to the previous stand will have modified the 'original natural' community. For example, coppice with standards will typically have provided more diversity and abundance of vernal woodland herbs. In contrast, wood pasture is more likely to have veteran tree and dead wood habitat, but low abundance of ancient woodland specialist ground flora. On some sites historical records are available but where trees and under-storey survive, the structure of the previous stand, and hence the management regime, can be inferred. This does, however, only indicate the most recent regime, and earlier regimes may have been very different; for example, much high forest will have had an earlier history of coppice with standards (Peterken, 1993).

4.3 Felling and clearance

We seldom know how the stand was harvested, or of the early establishment regime , and although some operations leave evidence (e.g. surviving stumps) others do not (e.g. cleanings). Unknown details of the treatment at this stage may often account for apparently anomalous variations in survival. Publications contemporary at the time (e.g. Forestry Commission, 1964; Wood et al., 1967) describe the typical operations, but also reveal the wide range of approaches used to 'rehabilitate derelict woodland'. Impacts will therefore have varied widely from site to site. Some of the operations likely to have had a major impact are described below.

Extent of clearance

Guidance contemporary at the time (Forestry Commission, 1964) discusses the value of retaining some canopy in order to restrict weed growth, give frost protection and provide a sheltered 'woodland' environment. Strip and group clearance was also tried, simply to reduce high costs. Good quality poles and sometimes stored coppice stems were also retained as semi-mature trees. Where these were given no further plantation treatment they are effectively small pockets of ancient semi-natural woodland within the plantation matrix and are thus very valuable.

Veterans and deadwood

Where large veterans were retained it is not clear whether this was due to their low value, practical constraints on removing them or simply aesthetic reasons. Retained large veterans are particularly valuable not only for their own sake but also for providing gaps in the canopy, which allows ground flora to survive. The simple fact of whether the branch-wood from felled standards was removed as fuelwood, or burnt on site, rather than being left lying as deadwood on site, may radically alter the survival rate of deadwood communities. Even where branch-wood and trees do not survive the stumps often do, and not only indicate past structure but are likely to be an important below-ground resource for saprophytic fungi and soil invertebrates.

Extraction methods

Techniques referred to in contemporary literature, suggest that on most sites wheeled tractors and tracked machines would have been used, often for the first time in a site's history. Wartime fellings may have been done with some urgency, and hence with little regard to weather and season, leading to serious soil disturbance, compaction and damage to ground flora. The term 'devastated' woodlands may not have just referred to the loss of the prime timber resource. On the other hand, the limited ground capability of some machines meant that complex winch and 'high-lead' extraction systems were also used which may have resulted in almost minimal traffic across the site.

Subsequent clearance of regrowth

These impacts were often exacerbated by revisiting the site with 'heavy machines' in the 1950's and 1960's to clear the coppice regrowth. Wood et al. (1967) describes the range of blades, chains and cutters used, often with the intention of uprooting the coppice stools.

4.4 Establishment operations

Herbicides

Blanket applications of broad-spectrum herbicides were becoming common in the 1960's, and included paraquat for the ground vegetation and 2,4,5-T for the woody regrowth (Wood et al., 1967). Although these would have been devastating they are an example of an event done in just one day and leaving no record but the absence of a major part of the ancient woodland communities.

Weeding intensity

Even where herbicides were not used, the intensity of weeding operations may have had a significant impact on the survival of the coppice understorey. The timing and frequency of later cleanings would also have been crucial. Basal bark applications of herbicides were again used on occasions. It was striking how variable the survival of coppice was and it appears that past establishment regimes may have been far more important than subsequent canopy densities.

4.5 Plantation composition

The nature of the establishment regime can sometimes be obtained from site records, such as those held for Martinshaw (Leics). More often there are few or no records, but the results of the establishment regime are manifested in the composition of the plantation, which can still be observed. Furthermore, some details of its condition during its development can often be inferred from the present stand, particularly where it is under about 30 years old.

Stocking density

Planting spacing can usually be inferred from stumps and stems. Close planting was common with spacing usually under 1.8 x 1.8m and down to 1.5m x 1.5m (over 4000 stems per hectare). Higher ground flora survival was observed where stands were stocked only partially due to unsuccessful establishment.

Semi-natural broadleaves

Unplanted pockets of ASNW were mentioned above, but even where the whole site was planted, coppice regrowth and/or invasive broadleaves such as birch often survived, or even dominated the planted conifers. Areas where this had occurred were found to almost always be accompanied by higher levels of surviving ground flora. These formed 'hotspots' of biodiversity in often otherwise barren plantations. Stands visited

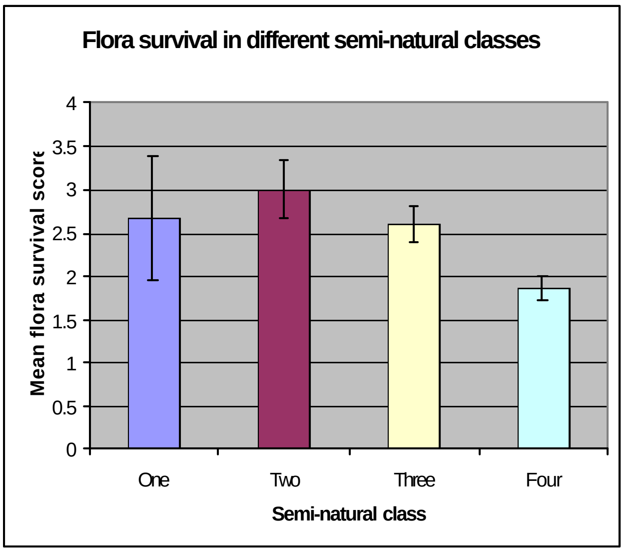


Figure 5. Average ancient woodland flora survival scores grouped by semi-natural class

- Semi-natural classes (after Hutchby et al 2001) are defined below.
- Error bars represent 95% confidence interval
- Data for Class One is unreliable due to the very small number of sites

Semi-natural class		
One	>80% s-natural	SNW
Two	50-80% s-natural	
Three	20-50% s-natural	
Four	<20% s-natural	Plantation

were allocated to the four different species composition categories used in the recent survey of Forest Enterprise PAWS (Hutchby et al., 2001), and Figure 5 shows the ground flora survival for each category. The broad pattern is not surprising, but the distinctions are perhaps not as great as one might have expected.

The pattern appeared to be true whether they were coppice or seeded stems, although the surviving coppice stools often had surviving pockets of deadwood to add to their value. Groups of semi-natural trees appear to be associated with a greater degree of survival than single trees scattered through the canopy. Where over-storey trees are retained with their crowns above a relatively complete conifer under-planting, they did not appear to benefit the ground flora, but such trees will have other components associated with them.

Figure 6. Elm and Norway spruce bands with corresponding bands of ground flora, mainly *Mercuralis perennis.*

Planted broadleaves

The inclusion of planted broadleaves was almost always found to improve survival of ground flora, whether these were group, line or band mixtures, confirming reports in the literature (Ferris & Simmons, 1999; Kirby, 1988). Bands were found to give the most successful survival, for instance at Northfield in Suffolk where there is a striking delineation in ground flora under three-row bands of Norway spruce and elm (see Figure 6).

Species

Literature from previous studies has shown that different species of conifer have different impacts on ground flora survival (Hill, 1979; Mitchell, 1987; Kirby, 1988). Observations from the field visits showed a hierarchy of mean flora survival scores against plantation species closely reflecting patterns of flora survival reported in this existing literature (see Figure 7, below). This confirmed

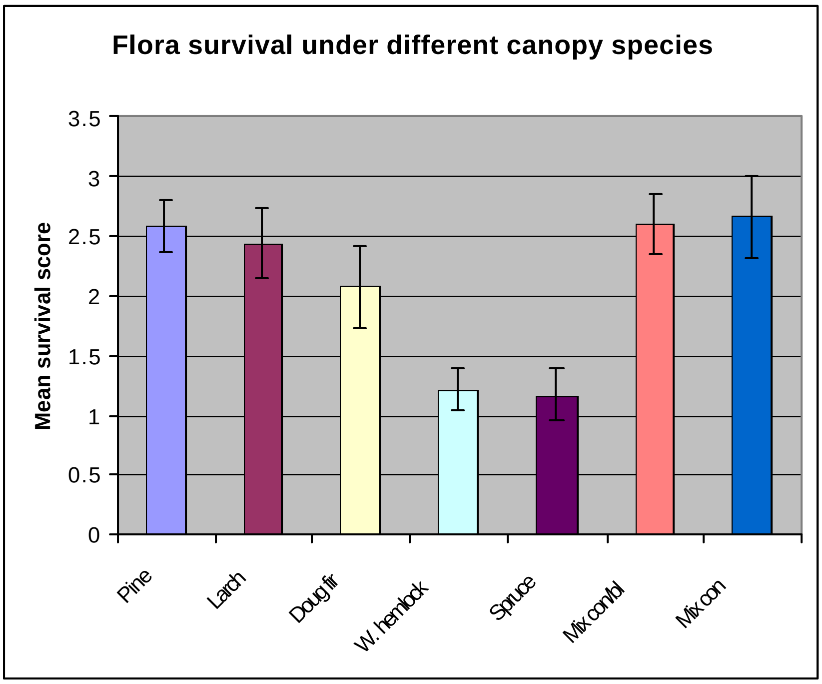


Figure 7. Mean flora survival scores under different canopy species.

- Error bars represent 95% confidence interval
- Data is from 80 stands; clearfells were excluded
- Species-flora data was checked for potentially confounding linkage with other stand factors, and these could be eliminated.

that pine and larch are most likely to retain the highest levels of survival, followed by Douglas fir. The species casting the most dense shade, Norway spruce, sitka spruce and western hemlock, all showed consistently low survival levels for ground flora. However, there was still a wide range in survival between sites, showing that species is by no means the sole or dominant factor.

4.6 Subsequent management of the plantation

Past thinning regime

Canopy density is crucial to survival of understorey and ground flora, particularly under densely shading species. Species associated with deadwood and veteran trees are also likely to be influenced by canopy density and shading, though often differently since many are not photosynthetic and temperature and moisture regime may be as important (Kirby et al., 1995).

Thinning history was seldom known, so observations could not be related to current survival, but it seems likely that an early start to thinning would have helped survival. If subsequent thinning was frequent, heavy and tended to be 'crown' rather than 'low' in type then the canopy is likely to have been more open. Past stand density may be indicated by the stand mean diameter relative to appropriate yield table standards. Low diameters relative to stand age will indicate high stand density during the plantation's life, irrespective of current density. In order to test for a statistical correlation with flora survival it would be necessary to obtain an index that combines diameter with age and yield class variables. This proved unreliable, but certainly many 'under-thinned' stands, with small diameters for age, appeared to have low levels of survival.

Current canopy cover

Current canopy cover was assessed at all sites visited; placing them into 4 categories based on a visual estimate of percentage canopy cover. The mean ground flora survival for each category is shown in Figure 8 (below). Current density may be very different from past density, and so cannot give a clear picture of the impact of this factor. This may at least partly account for the lack of any difference between gappy and closed canopy. Also, while it may appear from the low survival in 'open' sites that clearfelling is damaging, the score is actually largely determined by pre-felling stand conditions. The data does however reliably show that dense canopies do adversely affect survival of ground flora, across a wide range of species and sites.

Selective thinnings and cleanings

Cleanings and removal of planted broadleaves in selective thinnings may have had positive and negative impacts on the survival of ancient woodland components. They will have temporarily opened the canopy but will also have removed semi-natural and broadleaved trees leading to loss of light in the medium term.

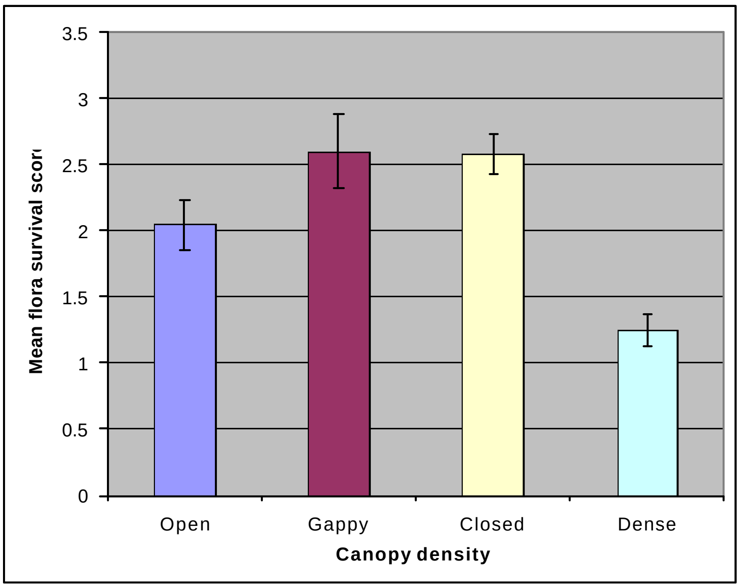


Figure 8. Mean flora survival scores under different canopy densities

- Error bars denote 95% confidence intervals
- Canopy cover classes are defined below

Canopy cover	
Dense	>90%
Closed	60-90%
Gappy	30-60%
Open	<30%

4.7 Implications of the factors affecting survival

Knowledge of the factors affecting survival could be of potential use to woodland managers in three main ways:

An understanding of the adverse impacts of past management facilitates the remedying and reversing of such impacts through the restoration process (e.g. appropriate canopy densities and thinning intensities)

It allows the most, and least, damaging practices to be identified, and if a stand is not being restored immediately to native species then at least more benign regimes can be adopted (e.g. conversion from spruce to pine or larch)

It might assist in predicting the stands most likely to have high and low levels of survival.

However, this review suggests that this final 'predictive' application is not reliable. There are many factors to consider and many unknowns, so predicting from just a few parameters is precarious and could lead to major errors. For example, assuming high survival under larch or pine stands may often be right for ground flora, but will not take into account survival of deadwood and associated communities. It may also be completely wrong in some cases, for example due to grazing in the previous woodland, or past applications of herbicide. Deer browsing may also severely alter survival of both woody and herbaceous vegetation; Muntjac damage to flora was prominent at a number of sites, for instance on the flowers of *Primula elatior* at Northfield (Suffolk).

Devising a strategy for restoration must therefore be based on a field assessment of the actual features surviving in the stand and not simply done on the basis of species, age or thinning history. Reference to the components in Table 1 (section 3.4) shows that only readily identifiable features need to be assessed, and detailed species surveys are not necessarily needed in order to gain an overall assessment of the survival of ancient woodland communities.

5 Restoration in practice

The process of restoring PAWS to native woodland essentially comprises three distinct operations ("the three R's"):

Removal of the plantation crop

Restocking or re-establishment of a canopy of native species

Retention and management of semi-natural components of the existing stands.

These operations are often planned and implemented as a sequence of separate stages, but in fact they are closely inter-related. This section reports on restoration operations observed during the fieldwork; the implications for planning of restoration are discussed in the next section.

Approaches to plantation removal and restocking varied widely, largely according to site and stand characteristics. There were several good examples of gradual crop removal, using continuous cover systems, and the use of natural regeneration to supplement restocking was frequent. However, conventional clearfelling and replanting has clearly been used in the past. It is now only being used in a minority of sites, and future plans are much more orientated towards continuous cover systems, but there was still a widespread emphasis on relatively rapid restoration , both in crop removal and restocking. This reflects the typical interpretation of restoration in the wider forestry profession (Forestry Commission, 2000). The impacts of standard approaches to restoration silviculture, and possible means of ameliorating these impacts, are covered in Table 3 (section 6, page 21). Alternatives to rapid, clearfell-based approaches to restoration are discussed in section 6, 'Planning PAWS Restoration'.

5.1 Removal of the planted crop

Removal of the conifer crop is seen as a priority in order to stop its detrimental effects and make way for a successor stand of semi-natural species. The way in which the crop is removed may however be critical to the continued survival of populations of woodland species. Approaches to crop removal observed on the Woodland Trust estate are outlined below, with proportions of sites managed under the different approaches summarised in Figure 9 below.

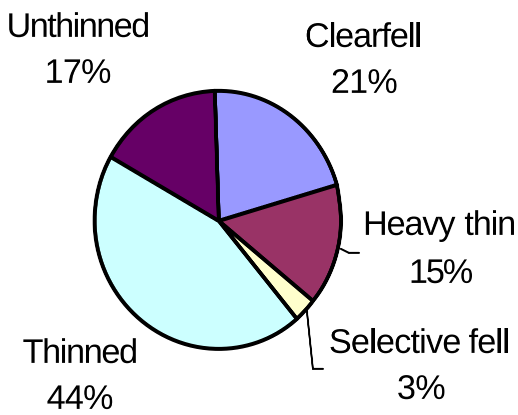


Figure 9. Management stage / regime for sites visited

Clearfelling

A fair proportion of sites had either already been clearfelled (one fifth of sites visited) or were scheduled in their management plans for clearfell, or an effective equivalent. Group (under half a hectare) or small coupe fellings (under two hectares) were common, but one has to bear in mind that from the perspective of the ancient woodland communities, and particularly pockets of surviving ground flora, these may not be very different from larger scale clearfell. There will still be a sudden loss of structure, and an abrupt change in micro-climate. It is only around the margins of groups that transitional, semi-shaded conditions will be created. It will take longer for a group system to progress through a woodland, but if ancient woodland components are lost in each group felling, the cumulative loss will be the same as clearfelling.
The main impacts of clearfelling are summarised in Table 2 (page 17).

Figure 10 Defining Clearfell

For small pockets of surviving ancient woodland flora even small scale felling coupes can create clearfell conditions, and the site impacts can be concentrated into a smaller area and intensified.

Selective felling and heavy thinning

Heavy thinning and selective felling often had provision or scope for the development of an advance successor stand. This was observed at many stands and will clearly often achieve some form of continuous canopy cover. Such stands can be considered under three categories:

Sites with a high proportion of semi-natural stems, which can be thinned to a complete canopy with very little need for new regeneration. For example Duncliffe (Dorset), Martinshaw (Leics) and Cwm George (S. Wales)

Sites managed under a shelterwood or group selection system, whereby semi-natural regrowth will be encouraged whilst selectively felling the conifer canopy. For example Hurst Wood (Kent) and Pontburn (co. Durham)

Sites with novel silvicultural prescriptions. These included ring barking of conifers in a conifer-broadleaf mix (Swineshead and Spanoak Woods, Beds) and 'halo thinning' around mature broadleaves at Hisley (Devon), Kingsettle (Dorset) and Lineover (Glos).

Thinning

This was the largest site management category, and covers a range of different scenarios. On some sites low thinning was exacerbating uniform size distributions and following a course that was leading inexorably towards clearfell. This was most prominent in pure conifer stands. Equally however, in many thinnings measures were being taken to favour semi-natural elements within the stand, for instance:

- Thinning preferentially around groups of semi-mature broadleaf regeneration
- Thinning more heavily around the edge of stands, where semi-natural elements are often concentrated (e.g. Joydens, Dartford)
- Simply favouring semi-natural trees during thinnings.

A gradual 'phasing out' of conifers in favour of broadleaves may be achieved on such sites. However, avoiding an ultimate clearfell and replant will depend on active steps being taken to favour broadleaves in the canopy and establish advance successor stands.

No thinning and unthinned

These stands may be the result of neglect under a previous ownership, difficulties in gaining access for harvesting operations, or may be unthinned because of a risk of windthrow.

5.2 Restocking with native species

Virtually all of the active restocking was being achieved through planting with native species, albeit supplemented by natural regeneration and coppice regrowth. In order to achieve stocking targets for grant aid, sites are usually planted at 1100 stems per hectare even if natural regeneration is anticipated. Restocking was usually fairly 'uniform', relying on natural characteristics developing with time rather than attempting to mimic semi-natural woodland composition and distribution through planting patterns, as per 'new native woodland ' prescriptions (Rodwell & Patterson, 1994).

Spot herbicide treatment is the most effective and cost-effective means of controlling weeds, and it was thus not surprising that this was a standard method of weed control. However, the impact on ground flora abundance was clear, particularly where spots were quite large and planting was closer. However, it was not possible to assess actual impact on diversity, nor to compare impacts with hand weeding. It is possible that herbicides could have a beneficial effect as they help control coarse vegetation.

At some sites where plantings are a number of years old, they have been greatly augmented by natural regeneration and regrowth of coppice. Examples of abundant regeneration include Moss and Height Spring (Cumbria), Coed Hafod Y Llyn (N. Wales) and Duncliffe (Dorset). Often regeneration is not of a 'desired' species mix, usually too much birch or willow, and is being removed in cleanings. At other sites natural regeneration may be hindered by a lack of seed source or by deer browsing of seedlings and stump sprouts. Some woodland officers sought advance regeneration prior to conifer removal, however no successful operational examples of this were seen.

5.3 Retention of existing semi-natural canopy components

Trees that were retained or had grown up during the process of conversion to plantations are normally retained when this process is being reversed during restoration. A number of different scenarios were observed in this regard:

- Old standards and stems stored from former coppice stools were retained after clearfelling, but these often suffered die-back of both the lower crown and root system. They were also often unstable and liable to blow, as seen at Coed Felinrhyd (Gwynedd) and Park Wood (Powys)
- Slender, young trees with narrow crowns were also often retained during felling. These have grown up with the plantation crop and are vulnerable to wind damage when it is removed. Among many examples are Pressmennan (Dunbar), Low Wood (Cumbria) and Joydens (Dartford). An alternative treatment is to fell them with the plantation and allow them to grow up from the stump. However, if this is done without adequate deer control it was clear that these components will be put under further threat
- Where retained trees were either grouped or at a sufficient density within the stand, complete conifer removal had often been achieved with little detrimental effect. Examples are at Coed Hafod Y Llyn (North Wales), Duncliffe (Dorset) and Martinshaw (Leics)
- On some sites, notably Hisley (Devon), Kingsettle (Dorset) and Lineover (Glos) conifer removal is being phased over time, which maintains a degree of shelter and shade around the semi-natural trees.

5.4 Analysis of current approaches to restoration

Restoration of PAWS is a new objective in forestry, and restoration silviculture is at a developmental stage. This study suggests that the emphasis on restoration to date has been tipped in favour of achieving rapid canopy replacement, rather than more gradual change. Findings from this study suggest that there is a case for shifting this emphasis (see section 6, below). The following reasons for the current approaches to restoration have been identified:

- Culture, expertise and machinery of woodland contractors and forestry profession is based around clearfell and replant. This in turn influences woodland managers' decisions, and hampers adopting silvicultural techniques that are innovative and responsive to the stand
- Concern about wind hazard and an assumption that clearfell is better than allowing windblow
- Target-led PAWS restoration, arising either from Habitat Action Plans and/or interpretation of certification standards pushes for rapid quantifiable forms of restoration
- The payment of WGS grants encourages achieving minimum stocking levels in a short timeframe. This restricts patchy and gradual approaches to restocking and therefore restricts 'innovation' in choice of silvicultural system
- Cash-flow or budgeting constraints favours clearfelling since it produces a large timber income in the same financial year as roading and entrance costs
- Physically difficult extraction conditions or dependence on temporary agreements with neighbours, lead to a view that it is better to get in once and complete the job than have repeated high impact harvesting operations
- A general 'knowledge vacuum' in terms of the potential impacts of different types of silviculture on ancient woodland components. There has been a perception that as long as the canopy is returned to semi-natural species the ancient woodland communities will recover
- 'Restoration silviculture' for degraded forests is an under-developed science. Also a lack of detailed information on ecological impacts and processes, such as the persistence of ground flora seedbanks and how much brash is acceptable for how long
- A sense of urgency arising from seeing dead and dying veteran trees and the last vestiges of woodland ground flora.

Table 2 Summary of the main adverse impacts of clearfell

- Full light conditions and disturbance, which may permit coarse vegetation to effectively oust shade-tolerant ancient woodland species
- Damage from extraction machinery; including direct damage to ancient woodland components, ground disturbance and compaction
- Smothering by deep brash (especially from mid-rotation premature felling)
- Retained veteran trees may be exposed to windthrow or dieback
- Organisms associated with veteran trees may suffer directly from the loss of habitat trees, and indirectly from desiccation when trees are retained but isolated. Some organisms, e.g. bats, may also be affected by disturbance and change to the environment surrounding old trees
- Dead wood communities, fungi and soil invertebrates may be damaged by rapid changes in microclimate and by ground disturbance and compaction
- Slender semi-natural trees, including stems from old coppice stools will be exposed to wind damage
- Habitat provided by maturing plantation trees will be lost
- Ride use, to move the large quantities of timber, can damage some of the most important refuges for ancient woodland flora
- New roading or improvements to existing rides can have a disproportionately high impact in smaller ancient woodland sites
- Successor stands will be even-aged, re-initiating the plantation cycle.

6 Planning PAWS restoration

The analysis of the attributes and sensitivities of the key ancient woodland components suggested that conventional clearfelling and replanting is not likely to be the best way of restoring PAWS, and this was confirmed by the field observations. This section looks at the overall approach to planning and managing restoration and recommends some broader changes in approach. Table 3 at the end of the section suggests many specific ways in which the potential impacts of silvicultural operations may be ameliorated.

6.1 Setting objectives for restoration

'Restoration to native woodland' (UK Biodiversity Group 1995 & 1998) is a straight-forward and attractive objective to adopt, but management is often focused on removing exotic species rather than conservation of ancient woodland communities. One of the key findings of this study is that the potential value of PAWS resides in their extant and *in-situ* ancient woodland components. These remain in all but the most shaded and damaged plantations (section 3.3). Rather than "restoring native woodland cover", the overall aim of restoration should be "to manipulate the canopy to create the conditions in which the remnant ancient woodland communities can recover". It is important that silvicultural operations, such as felling and replanting, are seen as means to an end, not an objective in their own right.

A key implication of this is that maintaining non-native canopy species may be necessary to achieve the primary objective of creating the most appropriate stand conditions for conserving ancient woodland communities. This may mean in the medium to long term that conifers are incorporated into the stand structure, that some unwanted regeneration is tolerated, and certainly that a flexible approach is taken to broadleaves such as beech, sweet chestnut and sycamore.

6.2 Appraisal of PAWS

Restoration operations must take into account the extent, type and distribution of surviving ancient woodland components. This necessitates a site appraisal, to:

- inform the overall restoration strategy
- determine priorities and 'urgencies'
- plan the detail of operations on the ground.
- Most of the ancient woodland components, outlined in Table 1 (section 3.4, page 6), can be assessed readily by non-specialists. A key element of such an appraisal is to identify and map the location of the ancient woodland features and the 'hotspots' of surviving communities. These not only merit particular management and protection, but may also be the focus for more detailed assessment and monitoring.

Pre-restoration site appraisal should also include adjacent non-ancient woodland. It was often observed during site visits that valuable ancient woodland components are distributed outside the boundaries shown in the Ancient Woodland Inventory.

6.3 Choice of silvicultural system

The choice of silvicultural system should reflect the objectives of restoration and the findings of the site appraisal. Both the theory and the practice suggest that a 'continuous cover' system (Matthews, 1989; Hart, 1995) is likely to suit the majority of woodland specialists, and 'woodland interior species'. This maintains stable woodland conditions to which ancient woodland species are adapted (section 3). This would involve implementing the three restoration operations described in section 5 concurrently: removal, restocking and retention. This makes shelterwood, irregular shelterwood (Kerr, 1999) and group selection systems a reasonable default choice for most PAWS. These 'lower intensity' management systems have recently been shown experimentally to be better at conserving 'late-seral' flora (which would include ancient woodland species) in other forest systems (e.g. North et al., 1996; Fredericksen et al., 1999; Battles et al., 2001). A hypothetical comparison of stand treatments is illustrated in Figure 11 (overleaf).

However, the woodland type, and previous management history must also be taken into account (section 4.1). Some important communities will be adapted to more dynamic conditions, such as coppice with standards. Many important species found in PAWS – such as lepidoptera and thicket stage birds - are dependent on open ground or early successional stages (Greatorex-Davies et al., 1993; Smart & Andrews, 1985). Recreating these habitats through clearfelling may therefore be a priority in certain situations.

The silvicultural system chosen should deliver on the objectives (in the case of PAWS relating to specific woodland conditions, composition and rate of change) rather than dogmatically drive management decisions (O'Hara, 2001). Novel transitional solutions may need to be developed; such as larch or Douglas fir standards over a recovering coppice understorey, or enrichment planting being used to adjust species composition or supplement natural regeneration under continuous cover.

6.4 Potential restrictions on the choice of silvicultural system

Conifer regeneration

Depending on species and site, maintaining continuous cover by retaining conifer canopy has the attendant risk of producing vigorous conifer regeneration. With western hemlock for instance, this can create a dense new thicket stage and in effect, continuous cover conifers. In some cases, for example, where effective removal of such regeneration would entail heavy herbicide use, this risk may justify pre-emptive felling of the parent crop. However, manageable degrees of regeneration should be tolerated, especially if hand pulling, respacing or enrichment planting can be used to favour broadleaves. Any such decisions must be based on an assessment of the level of problem likely on the site, predominantly by assessing advance regeneration, including along rides. In mixed species stands where trees of one species are regenerating most, clearly these should be thinned out first. In pure stands where conditions permit, options such as chemical thinning or girdling while an underplanting is established may be considered.

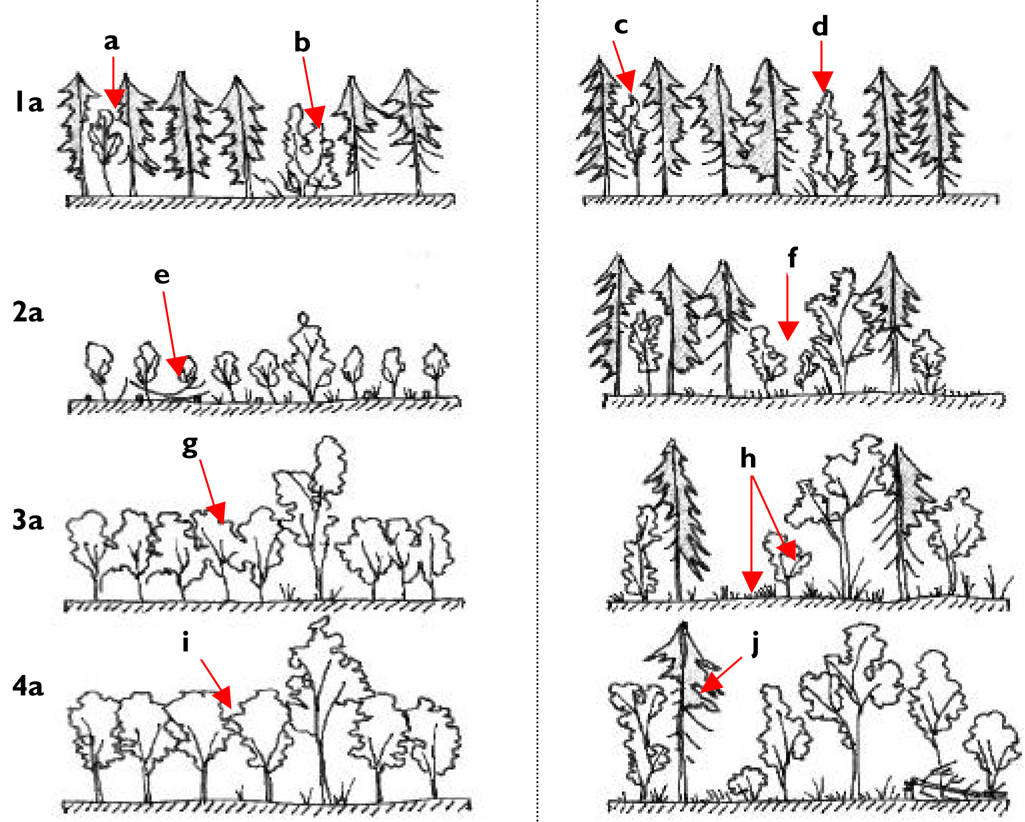
thinning or girdling while an underplanting is established may be considered.

Wind hazard

Wind hazard presents a second potential restriction to the choice of silvicultural system. However it is important that this factor does not encourage a default culture of conventional 'clearfell management'. It has been estimated that alternatives to clearfell may be successful on at least 25 percent of upland sites (Paterson, 1990), and opportunities for continuous cover are likely to be much greater in lowland sites (Kerr, 1999).

On sites where heavy windthrow would clearly result from any attempt at thinning for continuous

Figure 11. Hypothetical comparison of rapid and gradual approaches to conifer removal



	Clearfell approach	Continuous cover approach	
1a	Initial even aged conifer crop with drawn semi-natural tree **a**, and small hotspot **b** in canopy gap.	Same initial stand with semi-natural tree **c**, and small hotspot **d** in canopy gap.	1b
2a	Site is clearfelled and replanted. Hazards include windthrow, **e**, and lack of shade causing excessive weed growth and necessitating herbicide use.	Some thinning around hotspot. Shade is retained but semi-natural tree released **f**. Natural regen and recovery of remnant flora encouraged.	2b
3a	Young even-aged broadleaf stand enters thicket stage, creating unbroken canopy **g** with a slight break near tree retained from before.	As semi-natural component develops more conifers are removed, creating a spreading patch of broadleaves interspersed with open ground and conifers **h**.	3b
4a	Semi-mature even-aged broadleaf crop **i** with single mature tree.	Uneven aged stand with gaps, shade and occasional senescent conifer elements **j**.	4b

cover, and timber production is not an important objective, then 'minimum intervention' should be considered as an alternative to clearfell. Especially in pine and larch stands with a rich surviving flora, this may **sometimes** be the 'lesser of two evils'. With relatively stable high forest conditions, the generation of dead wood, and increased light penetration through the canopy; conditions in plantations retained into the over-mature phase are likely to improve (Kirby 1988) and will produce valuable habitat akin to 'old-growth' stands (Peterken et al., 1992).

Minimal thinning and long-term retention of the conifer canopy carries a risk of windthrow too. However, in natural conifer systems such as those along the Pacific coast of North America, the trees grow dense and even-aged when the stands regenerate after fire or wind disturbance (Hansen et al., 1991). While wind is a major factor in these systems, stands can be stable for centuries as the structure naturally breaks up and diversifies in the 'mature phase' (Mason & Quine, 1995).

6.5 Phasing operations

The rate of removal of the canopy is essentially about striking a balance between the need to halt the adverse impacts and the need to avoid opening up the canopy too rapidly. Phasing operations over many years, if not several decades, is likely to be necessary if natural regeneration is to be utilised successfully. Such phasing also avoids the obvious problem of re-establishing another even-aged stand; that is, it ensures a greater diversity of ages, and hence habitats. It may be that amenity, landscape and short-term economic factors will favour more rapid restoration, but these will need to be balanced against ecological priorities.

One of the problems of rapid restoration is that high impact operations and sudden changes are implemented at a time when the 'ancient woodland inheritance' is likely to be at its most vulnerable. As a result of the sensitivity of many woodland specialists to disturbance, populations that have been depleted and weakened under PAWS are likely to be severely threatened by early 'catastrophic events'. With no seed bank and very limited colonisation, any extant remnants in a stand now represent the sole progenitors of recovering populations in the future. A preferable treatment is to create conditions in which surviving pockets of ancient woodland species can recover and spread, and postpone the most disturbing management until the populations are more abundant and resilient.

Whilst a gradual removal of plantations is appropriate in most instances, there will still often be an urgent need to *begin* restoration treatments. Field observations confirmed that most PAWS had remnant ancient woodland communities, but also suggested that often these were still suffering decline (although detailed monitoring to prove or refute this is needed). Some of the most urgent operations are:

- opening up shaded rides
- releasing veteran trees 'drowning' in conifers, and
- thinning around etiolated coppice poles.

The conditions where restoration could be most bold and dramatic, and clearfelling may be justified, is where virtually no ancient woodland communities appear to have survived. This study demonstrates that these conditions are the exception rather than the rule. In such situations restoration is aiming to produce 'new' native woodland, albeit on an ancient woodland site, as rapidly as possible. The dominant aim here is rapidly creating conditions for colonisation, as opposed to favouring recovery of remnant communities.

6.6 Differentiation of treatments

Site appraisal will have established the extent and distribution of surviving ancient woodland components, and management must respond to this variation at two levels:

Differences **between stands** should help determine the overall strategy for restoration of a whole wood, estate or district. This will also help produce structurally diverse successor woodland (Hibberd, 1985).

- **Within stand** treatments need to be responsive to the surviving features. In particular, the 'hotspots' are likely to require different, and more sensitive, treatment than the 'matrix' of the stand. The implication is that there may be a continuous variation of silvicultural system across the site. This requires that silvicultural options be viewed as a 'gradient' from clearfell to single tree selection, rather than being restricted to options selected from the conventional set of 'classical systems' (O'Hara et al., 1994).

To exemplify this differentiated approach, all of the following operations could conceivably occur simultaneously in the same wood, or even in the same stand:

Conventional thinning of dense stands to favour recovery of severely shaded ground flora, combined with halo thinning around veteran trees and heavier thinnings around 'hotspots' located on flushes

Select fellings, incrementally removing conifers, to release some existing 'advanced' natural regeneration

Premature 'small coupe' fellings located on areas of 'matrix' where there is no surviving ancient woodland communities, and restocking predominantly with planting where there is no nearby seed source.

Table 3. Impacts of forestry operations on PAWS and suggested means of amelioration

Impact	Amelioration
Ground vegetation and shrub layer	
Heavy shade from leaving a dense conifer canopy may 'finish off' attenuated woodland herbs and shade out veteran trees	Gradually increase light levels at ground level, prioritising areas where woodland specialist species survive. If none have survived, clear felling may be acceptable. Ensure thinning intensity is sufficient to ensure a sustained reduction in canopy density
Weed competition. Full light conditions resulting from canopy removal or heavy thinning may permit coarse vegetation to oust shade-tolerant ancient woodland species	Maintain shaded woodland conditions by establishing successor stands before totally removing plantation canopy. Make prediction of flora response before deciding on felling intensity. Reduce thinning intensity where competitive species such as bracken and bramble are likely to thrive. Always eradicate any rhododendron present
Dense regeneration of conifers likely to form dense thicket. This may shade out flora components and interfere with the long-term aim of creating a semi-natural canopy	Check for advance regeneration, if it suggests there will be a serious problem, consider complete removal of the parent species in one go. This needs to be weighed against the potential impact on ancient woodland components identified in site assessment. Management of regrowth to reasonable levels may be preferable; see note under herbicide, below
Herbicide use. Direct damage to remnant ancient woodland species, loss of semi-natural regeneration and also reduction in shrub layer habitat	Maintain canopy to avoid excessive weed growth. Pre-empt weeding of conifer regeneration by removing seed sources which might cause particular problems (e.g. western hemlock). Where these need to be partially retained to maintain canopy, consider pulling regrowth by hand. Use natural regeneration, which often comes through with less weed control. Use alternative means of weed control for planted trees, e.g. hand weeding

Impact	Amelioration
Brash. Excessive and persistent brash smothers vegetation, especially from mid-rotation premature felling, or from repeated thinning to waste. Burning permanently changes soil and vegetation on burn sites and encourages invasion by ruderal species	Remove crop in successive stages, leaving time for brash to rot in-between. Prioritise halo thinning around surviving broadleaves and patches of woodland specialist flora, leave brash under adjoining dense conifer canopy, and delay further thinning until it has decayed Stack or windrow brash to ensure some ground surface is uncovered. Ensure brash is concentrated where there is no pre-existing woodland specialist flora. Extract timber, and possibly brash, if it can be done without undue damage; utilise markets for forest residues if they exist. Consider ring barking or chemical thinning
Extraction damage. Especially in clearfell operations, there can be severe ground disturbance, risking damage to ancient woodland flora. Often most severe at loading areas at the edge of stands, where remnant patches of ancient woodland flora remain. Disturbed soil favours colonisation by ruderal spp, which may then out-compete depleted communities of ancient woodland components	Phase removal, preferring a series of lighter impacts interspersed over years, with recovery periods, to a single major operation. Avoid extraction in adverse conditions. Fell to waste (phasing over a long time period to avoid brash build-up). Locate stacking areas and extraction routes to avoid hot-spots Put in stoned rides if large volumes (1000's tonnes) have to be extracted. Carry out low thinning, felling smaller trees to waste to create brash mat, prior to main felling. Specialist extraction techniques (sky lines, horses) may suit particularly sensitive sites
New roading impacts. Road and ride construction can effectively cause a direct loss of ancient woodland area. This can be disproportionately severe in small ancient woodlands	Phase removal, favouring a series of lighter impact periods on pre-existing rides over years or decades. The decision to use pre-existing rides must be based on an assessment of their relative importance for ancient woodland remnants, compared to adjacent stands, (see notes below). Avoid extracting by felling to waste (see notes on brash, above). Where large volumes of timber have to be removed surfaced rides may be the best option. Route them to avoid surviving ancient woodland features and use local stone
Ride and ride-edge habitat	
Roading impacts along existing rides. Rutting of unstoned old rides damages what can be some of the most important refuges for ancient woodland species	Ensure rides are included in pre-harvesting ecological assessment Avoid extraction along established rides if the ride surface is an important refuge, running new rides within conifer blocks. Close off valuable sections of rides during harvesting contract
Damage from brash. Brash often gets concentrated or dealt with on rides and ride edges, damaging any ancient woodland components present	Do not burn on rides, or chip brash onto ride edges. Ensure snedding is carried out within conifer stand rather than machine delimbing at rideside

Impact	Amelioration
Opening up of canopy along rides may lead to loss of shade tolerant flora	Manage the canopy around ancient woodland component-rich rides in the same way as for the canopy above 'hotspots' in the main stand
Semi-natural trees and underwood	
Wind damage. Exposed after conifer removal, tall slender trees are often vulnerable to blow, snap and bend	More gradual release by removing conifers over time, giving broadleaves time to stabilise. Coppice/fell slender trees with conifers, but only after seeding has occurred if natural regeneration is sought
Browsing of cut stumps and seedlings	Avoid having to cut trees back to stump. Deer control or exclusion
Felling and removal of surviving broadleaves	Do not allow contractors to fell wind stable broadleaves. Ensure extraction routes avoid surviving broadleaves
Veteran trees and deadwood	
Shading of trunk and canopy by conifers – weakening tree and killing epiphytes	Halo thin to allow gradual recovery of veteran tree
Windthrow. Veteran trees are often unstable after rapid removal of surrounding trees (Barwick, 1996)	Avoid clearfelling around old trees, gentle halo thinning only. Halo thin by ring barking where public safety is not an issue. Do not cut up or remove fallen trunks
Branch breakage, collapse of pollards – Neglected large pollards may be inherently unstable. Exposure following thinning results in collapse of large branches or main trunk	The aim should be to retain over-mature and veteran trees for as long as possible. Any tree surgery is better phased over very long time scales using the best arboricultural advice, the older the trees the less surgery at any one time (Read, 2000). Cut branches should be left nearby as dead wood habitat
Scorch and desiccation. Resulting from rapid changes in microclimate following removal of surrounding trees, this can cause die back or tree death	Gradual thinning around retained veterans giving them time to adapt to microclimate changes. Halo thinning by ring barking where public safety is not an issue
Loss of deadwood. PAWS often contain significant coarse woody debris, surviving from the previous semi-natural cover. Its state of decomposition makes it vulnerable to damage by forwarders during extraction of thinnings	Presence of significant coarse woody debris should be identified prior to start of operations and its location avoided during extraction
Damage to associated organisms. Dead wood communities may be damaged by changes in microclimate. Epiphytes may suffer from desiccation and loss of substrate (Rose 1992). Disturbance and change to the environment surrounding old trees may have adverse effects on bat roosts, hole-nesting birds and some invertebrates	Halo thinning around coarse woody debris should be undertaken with care as for post-mature and veteran trees. Maintain sheltered woodland conditions by establishing successor stands before totally removing plantation canopy. Retain and protect younger semi-natural trees as a future replacement substrate source

Impact	Amelioration
Soils and small-scale topographical features	
Ground disturbance, rutting and compaction	Avoid heavy and protracted extraction operations. Mark features and sensitive (wet) areas and ensure they are not crossed by extraction routes If large volumes to extract put in permanent stoned rides along route of least impact Careful use of brash mats
Windthrow post-harvest, up-turning features	Avoid retaining trees in a vulnerable state (see above)
General habitat issues	
Habitat loss. Habitat provided by maturing planted trees, particularly for birds, may be lost when they are removed	Retain some conifers to senescence
Even-aged successor stands. PAWS restored by clearfell and replant will essentially again be even-aged plantations, albeit broadleaved	Phase restocking over long time-scales, in conjunction with phased felling. Vary thinning intensity, encouraging advance regeneration in places, and allowing some small scale gap creation Allow long time scales for natural regeneration and minimise re-planting. Retain thin canopy including any seed trees sufficient to avoid obligation to re-plant
Planting patterns and species composition may not reflect natural site variation	Retain all broadleaved trees to enable a greater use of natural regeneration, supplementing by planting in order to diversify species mixture and guarantee establishment of successor stand
Extensive windthrow possible post-thinning in some areas	Consider minimal or no thinning and long-term retention of conifer canopy so that stands may senesce and break up gradually in the mature phase. This carries an attendant risk of windthrow, but may be worthwhile for example in flora rich pine or larch stands. Consider clear felling where no significant ancient woodland components are likely to be destroyed. Avoid similar hazards in the future by developing uneven-aged and wind-firm successor stands

6.7 Monitoring progress

The HAP targets are expressed in terms of area 'fully restored', which is perceived by some as being virtual absence of exotic canopy species. This is in danger of encouraging rapid and complete conversion of PAWS. Monitoring progress through silvicultural indices such as percentage of conifers removed is preferable, as it facilitates an incremental approach. The original expression of certification targets was a 10% reduction of conifers each decade (FSC, 1998), and this is more suitable to gradual restoration and enhancement of PAWS in general than the current HAP targets. However, although such indices reflect the condition of the stand, they are closer to outputs or activities than to outcomes. If monitoring is to be closely linked to objectives then it must focus on a wider range of structural features, and ideally on the state of the ancient woodland communities and components

(as listed in Table 1, section 3.4). Monitoring and milestones based on the following characteristics would reflect the success of restoration in providing the right conditions for recovery of ancient woodland components:

- Canopy species composition and cover

- Age structure, regeneration and under-storey regrowth
- Abundance of 'woodland specialists' in the ground flora
- Health and growth of veteran trees and old coppice stools
- Recovery and expansion of 'hotspots'.

The last three of these might be best done via fixed-point photographic records.

7 Summary of conclusions

7.1 Survival of ancient woodland communities

It appears from this study that most PAWS (over 80% of this sample) will contain **significant survival** of ancient woodland communities and species.

Ancient woodland species are, almost by definition, **slow colonisers** and adapted to stable woodland conditions; they will not readily recolonise PAWS from which they have been lost; the surviving remnants, albeit sparse, are thus crucial.

Ancient woodland species **do not have long-lived seed** generally, and will thus not rise, phoenix-like from the soil once the conifers are removed. In terms of woodland specialist plants "what you see is what you get".

Ground flora is just one component likely to survive, and should not be given undue weight. **Other key components** are: canopy trees and understorey, veteran trees and deadwood, soils, and topographical or cultural features. The value of fallen deadwood and decaying coppice stools surviving from the pre-existing ASNW appears to have been overlooked in PAWS.

The **distribution** of ancient woodland components within a stand is non-uniform, with distinct 'hotspots' often associated with irregularities in the canopy.

Assessments of the survival of such components in PAWS are crucial before restoration is initiated, but this need only focus on readily identifiable features.

The **survival of ground flora** appeared to be better under lightly shading species (pine and larch), and worst under spruce and hemlock, with Douglas fir being intermediate.

However, assuming that certain plantation species or types of PAWS will have high levels of ancient woodland inheritance is not robust as there will be a wide variety of other **factors affecting survival**. A strategy for restoration, whether it is at a woodland or regional scale, must be based on field assessments not on simple categorisation of current crops.

7.2 Restoration of PAWS

- Restoration of PAWS is currently focused on "restoring native woodland cover and removing exotic tree species". A better **overall aim** would be "to manipulate the canopy to create the conditions in which the remnant ancient woodland communities can recover".
- Restoration typically involves three distinct operations: **removal, restocking and retention**. These need to be seen as closely integrated. It is important that silvicultural operations, such as felling and restocking, are seen as means to an end, not an objective in their own right.
- Design and planning of these operations should always be based on the results of a **pre-restoration field assessment** of the nature and distribution of remnant ancient woodland components.
- If gradual restoration is to be promoted, **monitoring and targets** will be needed which focus on changes in the composition

across all PAWS, rather than being based on achieving full restoration on a small proportion.

- Targets and monitoring of restoration should not focus, as they do at the moment, solely on 'activity/output' parameters such as 'complete removal of exotic species'. Site level monitoring should ideally be based on **outcomes** related to recovery of ancient woodland communities.
- While it is often **urgent to commence restoration**, many of the ancient woodland components share attributes that make them vulnerable to conditions created by rapid canopy removal. The urgency to start should not extend to an urgency to complete. Phasing restoration over many years, or even several decades, will generate greater age diversity, reduce rates of change, and better protect ancient woodland components.
- **Currently, clearfelling** is a dominant method of removing the canopy but this is likely to create exactly the conditions to which many ancient woodland species are not well adapted. Far from assisting recovery, clearfelling may be the final blow to many ancient woodland communities.
- Specific **impacts of clearfelling** that were observed include: a high risk of wind blow of retained veterans, creation of a deep brash layer, soil disturbance and compaction and dominance by coarse vegetation.
- It appears that silvicultural systems that **maintain continuous cover** create conditions that are more conducive to the survival and recovery of ancient woodland components.
- We need to learn more about the **effect of different treatments**, for example thinning thresholds, different continuous cover systems, and techniques such as 'halo' thinning around retained veteran trees.
- **Replanting** is the dominant method of restocking and this is often associated with use of herbicides and inadequate deer control or exclusion, both of which could be causing further losses.
- **Clearfell may still be appropriate** for patches where there is no survival of ancient woodland components, or where open habitat or early stage habitats are critical.
- On some sites where heavy **windthrow** would result from any attempt at thinning, the option to retain the stand, unthinned, into senescence rather than felling and replanting, may be 'the lesser of two evils'.
- The **conservation of 'hotspots'** within a stand will often only be achieved if treatments are applied differentially within a stand so that they receive appropriate and sensitive treatment.
- **Novel approaches** to conventional silvicultural systems may be called for, combining and adjusting operations and varying them spatially in order to create optimum stand conditions for remnant ancient woodland components.

8 Research needs and opportunities

This study has drawn many provisional conclusions, and identified other areas where our understanding is lacking. Whilst carrying out the fieldwork sites which would provide opportunities for more detailed investigation were identified. Such work is necessary for two purposes: (i) to test the hypotheses and provisional conclusions derived from this observational study; and (ii) to investigate and resolve areas of uncertainty. The proposed research programme includes a major study of silvicultural trials, and several related studies on key ecological and management issues. Several of these could take place on the same sites simultaneously, thereby giving economy of effort and interlinking of results. (Full details are given in Curtis & Pryor, unpublished 2002).

8.1 Trials of restoration silviculture

These trials are designed to investigate experimentally the actual impact of different PAWS restoration approaches on ancient woodland components. Similar trials on previously logged old growth stands in North America have shown that such experimental approaches are realistic (e.g. Battles et al 2001). It is proposed that three standard treatments would be applied at a range of sites, selected to cover variation in soil base status and canopy density in a factorial design. The treatments would be: (1) premature clearfell and replant; (2) regular thin with felling at rotation age and (3) irregular shelterwood or group selection system. Indices of species richness and species quality, relating to different taxa (e.g. ground flora, deadwood invertebrates and fungi) would be used to assess treatment effect. Monitoring would be required annually for an initial three years, repeated at year five and then subsequently at five-yearly intervals in order to ascertain long-term response.

8.2 Other studies

The other studies need to focus on three distinct aspects of ancient woodland conservation and restoration:

Factors affecting survival of ancient woodland communities, focusing on two aspects: (i) the influence of stand factors on the distribution of 'hotspots' in PAWS, and (ii) the composition of PAWS seed banks

Ecological responses to restoration treatments, which is essentially the next level of monitoring for the restoration trials. Three key aspects, all relating to ground flora response, were identified as being investigated readily:

Rates of flora recolonisation on PAWS (as distinct from on secondary woodland sites)

The long-term impact of coarse vegetation on the recovery of ancient woodland flora

Canopy thresholds to prevent domination by different types of coarse vegetation

The impacts of restoration operations: two of these relate to ground flora, firstly, the impact of extraction damage, and secondly the effects of brash depth. Two other studies relate to veteran trees and deadwood: one on the impact of canopy removal on deadwood communities and a second on the effects of different felling and halo thinning intensities on veteran tree health and stability.

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Appendix

Explanation of ancient woodland component survival scores

1. Flora survival

Flora survival was assessed by giving a subjective score ranging from 1 to 4 depending on the DAFOR score of the 'woodland specialist' species recorded during the stand assessment (referring to the lists in Kirby et al., 2001). Each score represents an interval along a continuous scale of variation in survival. A guide to the scores is given below:

Definition of flora survival scores	
1	Rare or absent woodland specialists
2	Specialists Rare to Occasional, (flora tending to be dominated by course vegetation if anything)
3	Frequent specialists, (vegetation overall tending to be abundant).
4	Abundant to Dominant woodland specialists

2. Dead wood

Dead wood was given a simple subjective score based on the following categories:

Definition of dead wood scores	
1	Absent
2	Mainly softwood or under 15cm diameter
3	Some Coarse woody debris
4	Much Coarse woody debris

3. Veteran trees

Veteran trees were given a score based on their frequency per hectare. Veteran trees were identified as trees of semi-natural origin, that clearly pre-date the plantation crop. They would usually be showing signs of senescence (dead wood, rot holes etc) and often showed evidence of former management (i.e. formerly coppiced or pollarded).

Definition of veteran tree scores	
1	Absent
2	Rare (<1/ha)
3	Occasional (2-5 / ha)
4	Frequent (> 5 / ha)

WOODLAND TRUST

The Woodland Trust was founded in 1972 and is the UK's leading woodland conservation organisation. The Trust achieves its aims through a combination of acquiring woodland and sites for planting and through advocacy of the importance of protecting ancient woodland, enhancing its biodiversity, expanding native woodland cover and increasing public enjoyment of woodland.

The Trust relies on the generosity of the public, industry, commerce and agencies to carry out its work. To find out how you can help, and about membership details, please contact one of the addresses below.

The Woodland Trust (Registered Office)
Autumn Park, Dysart Road
Grantham
Lincolnshire NG31 6LL

Telephone: 01476 581111
Facsimile: 01476 590808

The Woodland Trust Wales/Coed Cadw
Uned K, Yr Hen Orsaf
Llanidloes
Powys SY18 6EB

Telephone: 01686 412508
Facsimile: 01686 412176

The Woodland Trust Scotland
Glenruthven Mill, Abbey Road
Auchterarder
Perthshire PH3 1DP

Telephone: 01764 662554
Facsimile: 01764 662553

The Woodland Trust in Northern Ireland
1 Dufferin Court, Dufferin Avenue
Bangor
County Down BT20 3BX

Telephone: 028 9127 5787
Facsimile: 028 9127 5942

Website: www.woodland-trust.org.uk

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