Forestry Commission

Practice Guide

Choosing stand management methods for restoring planted ancient woodland sites

FOREST SERVICE

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Introduction

The ancient woodlands of the British Isles are a valuable and finite resource. They are important habitats with a high biodiversity value as they can support a wide range of plants and animals. During the mid to late 20th century, many sites that once supported ancient semi-natural woodland were converted to plantation forests to provide a source of timber, a practice that led to the degradation and fragmentation of an already scarce resource. Although these plantations on ancient woodland sites (often referred to as 'PAWS') are usually regarded as forests of non-native conifers, a significant proportion of the 200 000 hectares of PAWS in Britain consists of plantations of broadleaves (of which oak and beech are most common).

Despite the negative impacts of the change in tree species present, PAWS often retain important ecological features of the former woodland. The restoration of such sites to native woodland forms part of the policy to improve the biodiversity and condition of woodlands throughout Great Britain. The UKFS Guidelines on *Forests and biodiversity* recommend that features of ancient woodland remnants are protected, and that progressive restoration to native woodland is considered (Figure 1). This Practice Guide has been produced to support these Guidelines by providing guidance to landowners, managers and practitioners on choosing a method of stand management to restore PAWS. It relates primarily to conifer PAWS, although the general principles will apply to sites planted with broadleaves.

Ancient woodland is woodland which has been in continuous existence since before AD1600 in England, Wales and Northern Ireland, and before AD1750 in Scotland. The term 'ancient woodland site' refers to the site of an ancient woodland, irrespective of its current tree cover. Ancient woodland composed of mainly locally-native trees and shrubs that derive from natural seedfall or coppice (rather than from planting) is known as **ancient semi-natural woodland**. A planted forest of native or non-native tree species that has replaced the original semi-natural tree cover is referred to as a **plantation on an ancient woodland site** – usually abbreviated to **PAWS**.

Figure 1 Ancient woodlands have a high nature conservation value as they are generally more diverse than plantation forests and can support a wide range of plants and animals.

Aims of woodland restoration

Removing or reducing threats to the survival of remnant features is fundamental to the process of restoration. Remnant features are desirable components that have survived from the former ancient semi-natural woodland. They are often considered to be irreplaceable as they may take many years to reappear if they are lost: for example, broadleaved trees (Figure 2a), woodland ground flora species with slow rates of dispersal (Figure 2b) and veteran trees (Figure 2c).

At most sites the aim of restoration will be to create the conditions necessary to secure, enhance and promote development of valuable remnant features by removing introduced species of trees (Box 1). The long-term survival of these features is generally considered to be more secure in a woodland comprising predominantly native tree species, and management should encourage the re-establishment of tree cover (Box 2).

There is the potential for a wide variety of species from the former ancient semi-natural woodland to persist in PAWS, but many of these will be difficult to observe and identify. Examples include invertebrates occurring in deadwood and leaf litter, and the micro-organisms associated with undisturbed ancient woodland soils.

For practical purposes, this Guide concentrates on remnants such as veteran trees and ground flora, which are often the most visible, and assumes these will be associated with the unseen species and features remaining from the previous woodland.

Figure 2 Remnant features such as (a) broadleaved trees, (b) ground flora such as bluebells, and (c) veteran trees often remain from former ancient semi-natural woodland.

Box 1 – What is woodland restoration?

Restoration is a comprehensive term that covers a wide range of subjects and procedures across many habitat types. Within the context of UK forestry, restoration of PAWS is the process by which a plantation of trees that has been established on an ancient woodland site is converted to a woodland comprising native species typical of those that would naturally occur on the site. Typically this is the replacement of non-native conifer plantations with native trees. Naturalised species may be included within this definition if they make a positive contribution to the ecology of the site and do not represent a risk to the native vegetation community.

Restoration is not simply the removal of non-native trees and shrubs. The objective is to re-establish a functioning native woodland ecosystem by:

- Securing and promoting the development of any remnant features from the former ancient semi-natural woodland.
- Removing introduced species of trees and shrubs.
- Providing conditions to allow re-establishment of native species.
- Initiating or enhancing ecological processes which may be missing or damaged.

The ease of achieving these objectives varies. For example, it is often easy to remove introduced species and this can be viewed as an obvious sign of restoration activity. However, it is only one part of the process and felled areas with no non-native species cannot be regarded as restored as many of the species, structures and processes found in native woodlands will be missing.

Restoration is a long-term process and determining when it has been achieved will be problematic. Complete reinstatement of past conditions is unrealistic as at many sites they will be ill-defined, irreversible changes are likely to have occurred and the present environment at the site (including climate and nutrient status) is likely to be different. Woodlands are dynamic, have usually been managed for many centuries and are very variable; a wide range of possible stand structures and species mixtures are possible within the range of native woodland communities.

Box 2 – Case study: Restoring a site underplanted with western hemlock

The woodland shown in the photograph is part of an area in Hampshire, England, which records suggest has been wooded since at least the 11th century. The trees are growing on an argillic brown earth soil, approximately 100 cm deep, that overlays chalk. The overstorey is dominated by oak with some birch, and there are around 90 stems per hectare, which provide around 60% canopy cover. In the 1960s the stand was underplanted with western hemlock, which was clearfelled in 2003. Initially the ground flora was sparse, but a dense thicket of bramble grew quickly. This developed to dominate the site to such an extent that, before the oak could be thinned in 2007, it was necessary to flail some areas to allow access for the chainsaw operator. Natural regeneration of native broadleaved trees and shrubs is insignificant, but approximately 20% of the stand has a developing understorey of western hemlock.

Areas of nearby woodland which have not been converted to plantations comprise neglected hazel coppice with standards, including ash. Similarly, records for the whole woodland from the 18th century indicate that the site was mainly hazel coppice, but oak was also present and there was a small plantation of beech. The stand structure and mixture of species present today is different to that found in the recent past, but the species currently present are characteristic of those found in the NVC W10 oak–bracken–bramble woodland. As the overstorey consists entirely of native species suitable for the site, and the overall woodland community is recognisable, it could be said that the site is restored.

Although the regeneration of western hemlock will need management, has this stand been restored?

However, the site is species-poor, with both the overstorey and ground flora being dominated by few species. Native trees and shrubs are absent from the understorey. An alternative interpretation of the current state of the stand could be that it is still going through the process of restoration, but the trajectory of development is in the expected direction and the site will become more diverse as time passes.

The restoration process could be promoted by operations such as the removal of the developing western hemlock understorey and management of bramble to encourage the regeneration of trees and other ground flora species.

Approaches to woodland restoration

The Forestry Commission Practice Guide on the *Restoration of native woodland on ancient woodland sites*, which deals with the practical processes of restoration, advocates a gradual approach to the removal of plantation trees – with stands being managed using continuous cover systems that maintain canopy cover while the remnant features are secured. Once the remnants are sufficiently robust, options for replacement of the tree canopy can be considered. Although such a method undoubtedly has benefits for some aspects of PAWS management, more rapid removal of canopy cover can provide other opportunities (Table 1 opposite).

The gradual approach to stand management using continuous cover is not well defined and, in practice, the methods lie on a continuum between selection and clearfelling. A commercial thinning regime might be modified to promote the development of any native trees present, or a complicated group or selective felling system used to promote the survival of veteran trees (Table 2 below). Similarly, the process of restocking may also fall on a continuum between conventional establishment using transplants and a system based entirely on natural regeneration. The methods chosen will vary with management objectives.

Figure 3 The rare liverwort *Plagiochila heterophylla* found in woodlands in northwest Britain is sensitive to disturbance.

PAWS vary considerably, not only in the quality and quantity of the features remaining from the ancient semi-natural woodland but also in a number of other aspects. When deciding how restoration should proceed, the location of the stand, climate and soil type, species and condition of the planted trees, native woodland community and species of trees that would naturally occur on the site should all be considered. The restoration methods should depend on the condition of the site and the sensitivity of the remnants present to stand disturbance (Figure 3). The application of standardised procedures to sites that differ widely is unlikely to maximise the potential benefits to woodland biodiversity that PAWS restoration could achieve.

The next sections of the Guide assume that good forestry practice will be used and the relevant *UK Forestry Standard Guidelines* will be followed. They therefore avoid topics that are of general relevance in forest management such as windthrow, archaeology, harvesting and extraction practices, vegetation management and deer browsing. Instead they focus on a range of subjects that can be of special concern when considering stand management during PAWS restoration.

Table 2 Examples of stand management and restocking methods illustrating the continuum between intensive and gradual restoration.

Decreasing intensity of practical management →					
Stand management	Clearfelling of plantation trees without preparatory treatments.	Halo thinning around veteran/ potential parent trees to promote their development, followed by clear-felling of remaining plantation trees.	Initial thinning to secure or promote features, followed by heavier thinning to reduce canopy cover significantly.	Halo thinning to promote veteran/ potential parent trees, followed by premature group felling/small patch clearfelling the remaining plantation trees.	Continuous thinning well beyond plantation economic maturity, followed by small group/ selection felling.
Restocking	Conventional planting of native trees at close spacing for timber production at a clearfelled site, using best practice that could include: ground preparation; repeated vegetation management using herbicides; the use of tree shelters.	Enrichment of natural regeneration by planting small groups of timber species at final crop spacing across a site using best practice.	Enrichment of natural regeneration with species typical of the native community for the site which are unlikely to regenerate as parent trees are absent.	Operations to encourage natural regeneration, e.g. scarification, vegetation management, prevention of excessive browsing damage.	Natural processes only, with no intervention to promote successful restocking or to manipulate species mixture.

Table 1 Comparison of some potential benefits attributed to gradual restoration with those for clearfelling of PAWS (see notes).

Characteristic	Gradual restoration	Clearfelling	Notes
Microclimate	• Maintains more humid and shaded microclimates that favour the survival of veteran trees and their associated species. • Promotes the development of woodland ground flora by maintaining tree cover to provide some control over the development of vigorous competitive ground flora species. Allows robust patches of desirable ground flora to develop sufficiently to withstand competition once the canopy is removed.	• Creates temporary open space and early successional habitat. • Better growing conditions may initially improve growth, flowering and seed set by species which are already growing in the woodland.	• Many important British woodland species depend on the presence of open space or early successional habitat. This includes not only birds and butterflies but also many flowers of ride sides and coppice. • Effects are likely to be site specific. • Epiphytic species associated with ancient woodland are most common in humid oceanic regions. However, some species also occur further east and south where pollution levels are low and there is a long history of limited stand disturbance. Consequently, for epiphytes, retention of some canopy cover may be even more critical in areas which do not have an oceanic climate. • Sudden exposure can have significant adverse effects on trees, including crown dieback and death. • Gradual thinning may also promote spread of shade-tolerant competitive ground flora species such as bramble and bracken that are often present within PAWS, particularly on sites with more fertile soils and warmer climates.
Tree regeneration	• Favours species that can regenerate in shade. This can be positive for target species such as ash and holly, but negative for undesirable species such as western hemlock.	• Allows regeneration of desirable species that require open conditions, such as birch, oak and willow. However, clearfelling can also promote invasive non-native species such as rhododendron if these are not eradicated prior to felling operations. • Stands of troublesome invasive conifers can be removed in one operation.	• Stands should be managed to promote the regeneration of species typical for the native community for the site. The precise species mix will depend on objectives, with a wide tolerance where general native woodland habitat development is wanted, but more specific requirements if future timber production is planned or where there are rare organisms that require particular tree species. • Thinning will promote the development of bigger trees with larger crowns that have the potential to produce more seed. • Felling of trees may not eliminate undesirable species as they may regenerate from seed released by the crop either before or during harvesting. The proximity of adjacent stands of non-native species should be considered as they may also provide a source of seed. The need for repeated management activity to remove seedlings may be reduced if felling takes place after poor seed years.
Stem structure	• Reduces the problems of the stability of weak, suppressed stems on old coppice stools, recently established broadleaves and large veterans.	• Open conditions will allow good growth of coppice.	• Development of the crown is necessary to enhance seed production, but stools and stems are likely to become more unstable. • The regrowth of new shoots from coppice stools can provide structural diversity, but survival of re-cut stools varies with species and age/size of stools. Clearfelling also tends to promote development of epicormic shoots at the expense of crown expansion.

Notes:
Gradual restoration includes the wide variety of procedures that are covered by terms such as 'continuous cover forestry' and 'alternatives to clearfell'. These include selective or group felling, halo thinning and increased intensity of thinning, which can be used over protracted periods of time to secure and develop remnants before final removal of non-native species.
Clearfelling is the removal of undesirable plantation species with little or no use of preparatory treatments specifically used to secure or develop remnants.

Assessing the site

Assessing a site to understand the characteristics of each PAWS is an essential step in the creation of management plans and in deciding which operations will be necessary. Site assessment will:

- provide information on what features are present and where they are located;
- give an indication of the overall condition of the site;
- enable improved prediction of the response to operations;
- provide a basis for deciding the most appropriate method of stand management;
- provide a baseline against which future monitoring information can be compared.

Annotated maps are a good way of recording information.

Understanding the characteristics of a site and predicting how the remnant features are likely to respond to changes within the stand following felling operations will help determine the method of restoration. However, there will be sites where it is not possible to secure some of the remaining features due to stand characteristics (e.g. lack of wind stability) and location (e.g. very poor access). The site characteristics that are of special importance for the restoration of PAWS include features that are remnants of the former stand and environmental factors that are likely to influence the growth and development of woodland. For example:

- Location
- Soil type
- Plantation species
- Veteran trees
- Old stools
- Recently established broadleaves
- Ground flora

Location

The location of a PAWS will influence stand management opportunities in several ways:

- The geographical location of the site will determine the prevailing climate, which will influence a wide range of other factors, including the reproductive potential of trees; growth of competitive ground flora species; the wind stability of the remaining crop and old coppice stools; and the abundance of epiphytic plants.

- The surrounding landscape will be an important consideration as PAWS can have adverse effects on neighbouring vegetation communities. For example, pine can colonise lowland heathland and western hemlock can spread into closed canopy woodland. Where this is likely to occur gradual removal of trees may not be the best approach; thinning can improve growing conditions for remaining plantation trees and increase their potential to produce seed.

- The position of a PAWS within a larger woodland will influence management opportunities as the potential of a small area of PAWS embedded within a large semi-natural woodland is very different to an isolated ancient woodland site. Recolonisation of the stand by species that are missing or scarce is more likely to occur in an 'embedded PAWS' as seed sources are likely to be nearby. Management to ensure the survival of any species present in an isolated PAWS will be more critical, because if such species are lost there is less chance of their recovery.

Soil type

Soil characteristics influence the management of PAWS, but many of the issues these may cause are common to general forestry (e.g. vegetation management related to competitive species, ease of restocking, disturbance during harvesting). Understanding the soil allows the manager to determine which native trees and which woodland community are suitable for the site. Identifying the appropriate trees or community from the soil can be carried out using the guidance in the Forestry Commission handbook on *Managing native broadleaved woodland* and the Ecological Site Classification software produced by Forest Research. Understanding the community and species that will occur on a site will aid stand management. For example, if the site is suitable for oak–birch woodland with bilberry (either NVC W16 or NVC W17) then gradual restoration, where significant amounts of canopy cover are retained, is likely to suppress the regeneration, establishment and growth of the oak or birch that are important tree species in these communities. Similarly, heather and wavy-hair grass, which are frequent ground flora species of these communities, thrive in open conditions. Sites that will support communities including plants that grow beneath moderately dense shade may benefit more from the retention of canopy cover (e.g. those sites with heavy, base-rich clays where ash–field maple–dog's mercury woodlands (NVC W8) would be a suitable community). There may also be more tree species common to W8 communities which could establish in such conditions.

The **National Vegetation Classification (NVC)** is a comprehensive classification and description of the plant communities of Britain used by the nature conservation agencies to describe and assist in the evaluation of habitats. Find out more at: **http://jncc.defra.gov.uk**

Plantation species

The shade cast by the overstorey trees has a significant influence on the quality of the PAWS. Well-managed, regularly thinned stands of light-canopied species such as pine and larch often have better developed ground flora than dense, under-thinned stands, or those of shade-casting species such as spruce and fir. Thinning to reduce levels of shade is generally advised as an initial operation. However, the reproductive characteristics of trees should also be considered. Species such as western hemlock and western red cedar are well known for their ability to regenerate freely and invade new areas. Where natural regeneration of non-native species is likely to be a substantial problem, clearfelling should be considered (Figure 4).

Figure 4 Sitka spruce regenerating with native species in a small felling on an ancient woodland site.

Veteran trees

Veteran trees are obvious relicts from the former woodland and are often derived from the standards remaining from coppice woodland or are ancient trees that grew up in open woodland or wood pasture. Their size and state of decay provide a range of habitat niches that can support a wide variety of animal and epiphytic plant species (Box 3). They can be important features both culturally and biologically and their presence should influence stand management (Figure 5). Clearfelling around veterans is generally inappropriate. Gradual canopy reduction around these trees reduces the risks caused by sudden exposure to open conditions. Non-native species can provide valuable veterans.

PAWS often include large, mature, broadleaved trees that are derived from the former woodland and these trees may also be foci for patches of remnant ground flora. As they are potential parent trees and could provide seed for natural regeneration such trees are probably best managed as veterans.

Box 3 – A simple guide for the identification of veteran trees

A tree may be classified as a veteran if it has at least three of the following four tree attributes or is of large size.

Tree attributes

Tree attributes are measures of the accumulation of deadwood, decay and hollowing that is associated with canopy reduction and death as the tree ages. Veteran tree attributes include:

- Deadwood: either attached or fallen, which must be a minimum of one metre in length and over 25 cm in circumference.
- Rot sites: an area of rot equal to or greater than 300 cm².
- Rot holes: at least one cavity ~10 cm in diameter, i.e. about the size of a clenched fist.
- Hollowing: the trunk or major limbs show signs of hollowing.

Additional features that may be present include: bark loss; crevices in bark; natural water pools; sap runs; fungal fruiting bodies; epiphytic plants; obvious signs of bat roosts.

Tree size

Trees may be considered to be veterans if they significantly exceed the normal size for the species in the locality in which they occur. The following diameters (at 1.3 m) are considered large for the species listed and they indicate minimum diameters for trees that may be regarded as veterans. However, the size classes are only indicative and may be inappropriate for upland areas and other sites with unfavourable growing conditions – or when veteran trees have collapsed but subsequently rejuvenated from fallen limbs. Note that large, old, non-native species can be valuable veterans.

- 75 cm: field maple, rowan, yew, birch, cherry, holly and other smaller tree species;
- 100 cm: oaks (upland), ash, alder, willow;
- 150 cm: oaks (lowland), sycamore, lime, horse chestnut, sweet chestnut, elm species, poplar species, beech.

Adapted from Veteran trees in the landscape: a methodology for assessing landscape features with special reference to two ancient landscapes, Veteran trees: a guide to good management.

Figure 5 Veteran trees from former woodlands growing in planted conifer forests; sudden exposure through clearfelling may result in the death of these trees and halo thinning would be an appropriate management option here.

Old stools

Old stools can comprise both overstorey trees and understorey shrubs. They will often derive from previously coppiced trees but may also have arisen from trees which survived ring-barking. Such trees may be of local genotype. They may have some features in common with veterans (e.g. standing deadwood, epiphytes, niches for rare invertebrates) and the potential to provide seed for regeneration and structural habitat for woodland species. The presence of old coppice stools will influence management. For example, their crowns are often small and careful thinning on several occasions may be needed to promote crown development and seed production. They may be unstable (Figure 6) and collapse if thinning is too heavy, and they may not resprout from the stools if they are felled. Stools and stems can also be very valuable for deadwood invertebrates and epiphytes. Felling of stems should be avoided if possible.

Figure 6 Coppice stools, such as this old ash, may be unstable due to the distribution of stems around the periphery of a central rotting core.

Recently established broadleaves

Small understorey trees or saplings that are clearly of recent origin and have developed by natural regeneration are often common in PAWS (Figure 7). These trees are important because they can form a substantial part of a new broadleaved woodland, but they may require management similar to that for old stools. This category also includes suppressed broadleaves planted in mixture with conifers and coppice stools that are obviously young.

Figure 7 A recently established oak tree in a Douglas fir plantation. This tree should be favoured in future thinning operations.

Ground flora

The abundance and composition of the ground flora in PAWS differs noticeably between sites and is strongly influenced by the overstorey canopy. In many PAWS there are small areas of the forest floor with patches of ground flora that are more diverse than for the site overall. These often occur around veteran trees and old coppice, beside ditches and watercourses, and in wet areas. Such patches can also occur where the plantation species have grown poorly or the canopy has remained less dense, for example along extraction racks and ride sides.

Figure 8 The yellow pimpernel is a desirable woodland plant that responds well to the creation of gaps in the canopy.

These patches provide important sources from which re-establishment of the ground flora will occur and management should ensure their survival and subsequent development. Gradual removal of canopy is thought to benefit patches of woodland flora by maintaining at least some shade, which allows woodland species to develop while the growth of more vigorous competitive species of open habitats remains suppressed. However, a subtle balance of light levels will be required to promote development of desirable species (Figure 8) as there are few species which thrive under deep shade. Also, competitive species such as bracken and bramble grow well under the same conditions as more 'desirable' woodland plants – and such aggressive species may need to be managed during the restoration process.

Management planning

The process of creating a forest or woodland management plan with clearly stated objectives will help clarify which outcomes are realistic and how they can be achieved. It is not possible to re-create the former woodland, but management should encourage the development of a native woodland that incorporates and develops the value of as many of the remaining features as can reasonably be achieved.

Difficult aspects of planning include:

- deciding what degree of management complexity and expenditure are justified, based on the value, abundance and landscape context of remnant ancient woodland features;
- determining what procedures are necessary to secure the future of remnant features and ensure their survival in the restored woodland.

Estimating the value of remnant features can only be done following a thorough assessment of the stand and its surroundings; indicators that can be used for features likely to be present in PAWS are given in Table 3. The extent and quality of each feature will vary, not only between PAWS (e.g. some sites may have veteran trees whereas others have none) but also within a stand (e.g. the remnant ground flora may be good but there are no old coppice stools). If the overall indicators for a remnant feature (Table 3) suggest that it is of high quality then management within the stand should be specifically directed to secure the feature and promote its development. In contrast, if the overall assessment of a remnant feature's indicators suggest that it is of low quality, then specific management to secure the feature may depend on the overall objectives for the site. In some circumstances (e.g. where there are no remnants) clearfelling may provide an appropriate option.

Forest management plans should always include a monitoring scheme, even if only of a very simple kind. This will help determine whether the operations have the expected effects and whether any changes in management are necessary. It will also provide information that will help decision making at other sites.

Table 3 Indicators that can be used to estimate the value of remnant features remaining in a stand (continued on page 12).

Remnant feature	Indicator		Notes
	Higher quality (remnant features will probably benefit from gradual restoration)	Lower quality (clearfelling unlikely to have significant detrimental impacts on remnants)	
Mature trees			
Landscape	• Veteran trees are part of a larger landscape of known importance for cultural and/or biological value. • Few veteran trees with secure future within woodlands in the surrounding area.	• Many mature trees in surrounding woodlands with secure future.	• The probability of finding organisms specifically associated with veteran trees is likely to be greater in areas where numbers of veterans are high than in areas where they are low. • There may be cultural rather than biological reasons ensuring the survival of veteran trees.
Stand	• Veteran and mature trees present.	• Veteran and mature trees not present.	
Individual	• Individual trees with large numbers of attributes and additional features typical of veteran trees. • Mature trees with large crowns.	• Mature trees heavily suppressed by plantation species and unlikely to respond well to thinning. • Species are not site native.	

Table 3 Indicators that can be used to estimate the value of remnant features remaining in a stand (continued from page 11).

Remnant feature	Indicator		Notes
	Higher quality (remnant features will probably benefit from gradual restoration)	Lower quality (clearfelling unlikely to have significant detrimental impacts on remnants)	
Old stools			
Species	• Range of site native species typical of the community that would naturally occur on the site. • Uncommon/rare site native species. • Site native species that are difficult to regenerate.	• Planted native species atypical of the natural community for the site. • Common site native species only. • Site native species that are easy to regenerate.	• The presence of site native species will provide a good basis for the development of a community that is suitable for the site. • Trees with large crowns are likely to produce more seed than those with small crowns. The method of management may have significant influence on the value of the species for restocking. • Species such as oak, birch and willow that require light are unlikely to regenerate satisfactorily in stands where high levels of canopy cover are retained. • Stems on coppice stools should not be felled unless absolutely necessary for safety reasons, particularly where they have features of veteran trees. Species vary in their ability to survive coppicing. Vigorous stools and young stems are more likely to survive felling than those that are old and moribund. Regrowth of coppice shoots will be poor if low light levels remain beneath the canopy.
Condition	• Old stools or stems with some characteristics of veteran trees. • Vigorous stools with robust, stable stems forming part of the overstorey canopy. • Large crowns with the potential to produce seed that will aid restocking by natural regeneration. • Likely to survive and grow vigorously if felled. • Weak stools with suppressed stems that will respond to thinning.	• Young stools and stems.	
Recently established broadleaves			
	• Range of site native species typical of the community that would naturally occur on the site. • Uncommon/rare site native species. • Site native species difficult to regenerate. • Plants with crowns and stems that are sufficiently well developed to respond when canopy is opened.	• Species atypical of the natural community for the site. • Site native species easy to regenerate. • Poor plants with weak stems and poor crowns that are likely to collapse after canopy opening.	• The presence of robust young trees of site native species will provide a good basis for the development of a suitable woodland community. • As young native trees are relatively easy to develop compared with ancient woodland remnants, less effort should be put into securing these features where management is difficult and costly. They will generally have limited biological/cultural value that cannot be replaced over short timescales by natural regeneration or planting.
Ground flora			
	• Large patches of desirable woodland species. • Uncommon species. • Species that disperse slowly within or between woodlands and may be regarded as ancient woodland indicator species. • Many species typical of the natural community suited to the site are frequent throughout the stand. • Plants associated with ancient semi-natural woodlands are suppressed by shade from canopy.	• Only common species are present. • Species present are those which can spread quickly into suitable habitats.	• Desirable species are often small and unable to withstand competition. • The predominant species of some natural communities are vigorous, competitive and can spread quickly even in partial shade (e.g. bramble, bracken). • Rock outcrops can be important sites for lower plants.

Choosing a method of stand management

The method used for restoration should be determined according to the overall characteristics of the site, including the remnant features and their value. Many stand management procedures to promote the survival and development of remnant features of PAWS will be similar to those regarded as good practice for other types of woodland. However, other approaches, such as halo thinning around veterans, will be more specific to PAWS.

A good understanding of the site is needed to help identify what operations are necessary, provide evidence justifying their use, and to establish baseline information against which the success of management will be monitored. Site assessment will often be the first action necessary to determine the site characteristics, including location, soils and potential woodland community, and the type, location and status of remnant features.

Restoration can be regarded as taking place in two phases: the first phase should be to secure remnant features and the second phase should establish a developing cover of native trees and shrubs on the site. However, these phases must not be considered in isolation and at many sites they will take place at the same time.

The conditions created during restoration must be suitable for the regeneration of native trees, whether this is naturally from seed or coppice, or by planting. Management objectives will influence the desired density and species composition of the restored native woodland and the timescale over which regeneration needs to take place.

The restoration process should generally aim to produce a woodland that delivers a range of benefits. Even where remnant features are apparently absent, determined to be of very limited quality or where there has been no response by typical woodland flora to thinning, consideration should be given to features that are difficult to observe. Such features include seed banks, mycorrhizas, and soils, which, due to a relative lack of disturbance, are generally regarded as having a high inherent value.

There are a range of possible management options including:

- A precautionary approach with management to secure the future of any features that are potentially remnants from the former woodland, however insignificant these may be.
- Regular management following good forestry practice until plantation trees reach economic maturity, with targeted thinning to promote desirable features such as veteran trees, patches of woodland flora, and naturally regenerating trees and shrubs.
- Management to create woodland habitats suitable for desirable species that potentially could occur in the wood and are in the locality but are not currently present in the stand.

There may be situations where plantation species are retained for cultural reasons (e.g. retention of mature impressive conifers for aesthetic or historical reasons) or to secure species requiring a proportion of non-native trees (e.g. seed supply for red squirrels). Where this option is chosen, any ancient woodland remnants should still be managed to enhance their condition.

Guidance on selecting methods of stand management is given in the flowcharts on pages 14 and 15. Phase 1 is aimed at securing remnant features, Phase 2 describes the appropriate management techniques to regenerate native woodland. Where there are no remnant features to secure, the Phase 2 flowchart should be used.

Phase 1: Securing remnant features

Use the numbered notes on this page in conjunction with the numbered stages of the Phase 1 flowchart (opposite) to select the appropriate management options that will secure remnant features.

1 The quality and extent of remnant features will affect whether gradual restoration or clearfelling is appropriate. To determine whether the quality and/or extent of remnant features justifies alternative stand management to clearfelling, it is necessary to have a good understanding of the site and its surroundings, and a good evidence base on which to make a decision (e.g. survey records). If valuable features are present then the site should be managed to try to secure their future. Table 3 (pages 11 and 12) provides indicators that can be used to estimate the value of remnant features.

2 The effect of plantation species on remnants is often due to the shade cast by the canopy. Light thinning to reduce threats to remnant features is sometimes recommended but it may not be appropriate in all cases. Thinning will promote the development of the remaining crop trees, and therefore can have economic benefits, but it also has the potential to increase seed production and the natural regeneration of unwanted species. Clearfelling provides important opportunities for creating temporary open space, but the merits of this should be assessed on a site by site basis. If the canopy is casting dense shade that is having adverse effects then the level of shade should be reduced, but the amount of felling can only be decided once all remnant features and site characters have been considered. For sites where regeneration of the current crop will create ongoing problems, clearfelling is appropriate if remnant features are assessed to be relatively unimportant.

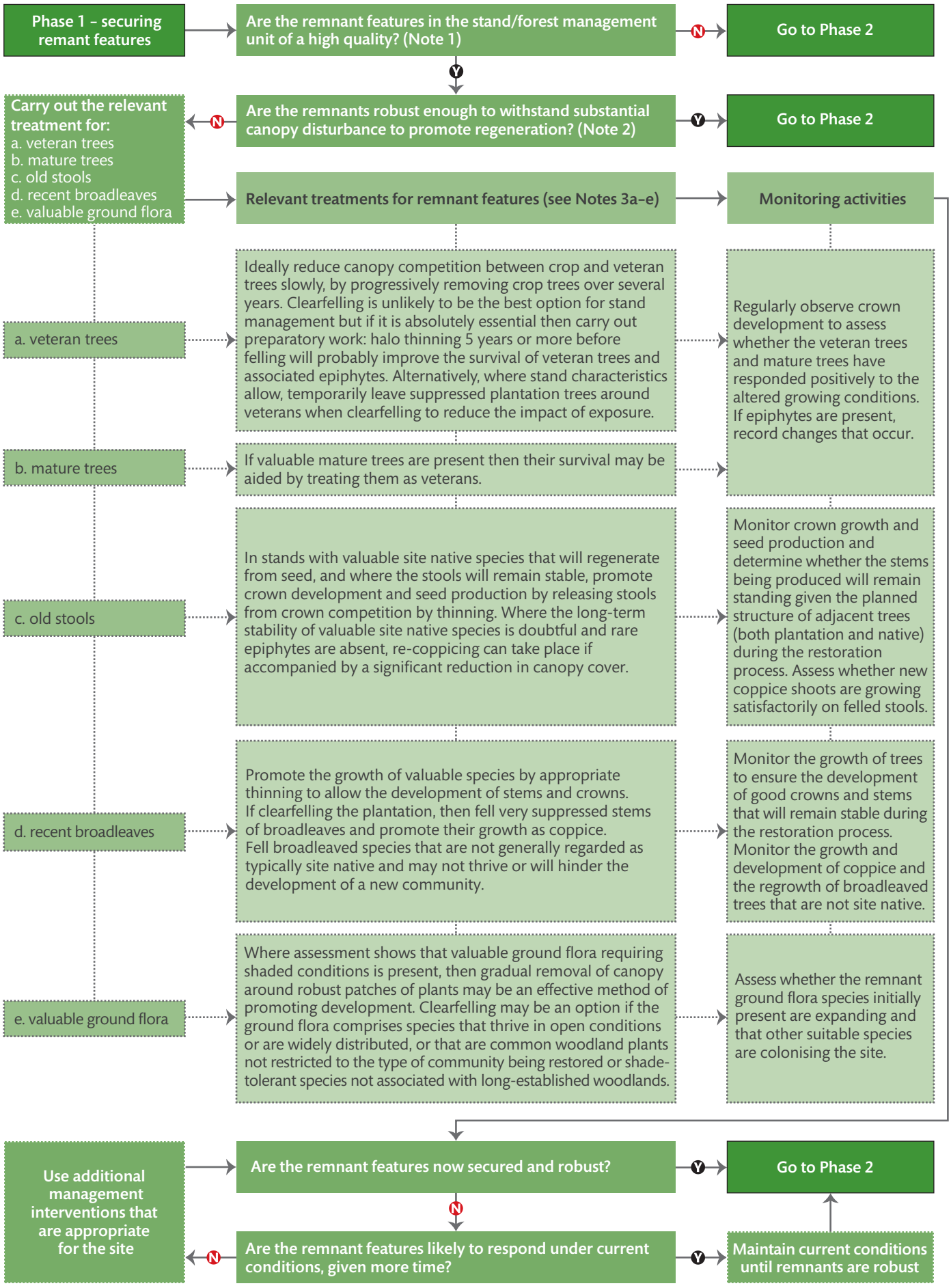
3a Operations should ensure the survival of veteran trees. If veteran trees are clustered together or few in number within a large stand then consider varying treatments across the stand. The risks from exposure will be reduced by gradual removal of the surrounding canopy, but changes in microclimate, light environment and soil moisture availability are inevitable and this will have consequences for the biology and ecology of the tree and its associated organisms. Standing deadwood is also valuable for wildlife.

3b Mature trees older than plantation species originate from the previous woodland. They are likely to form the next generation of veterans and may already be developing some characteristic features.

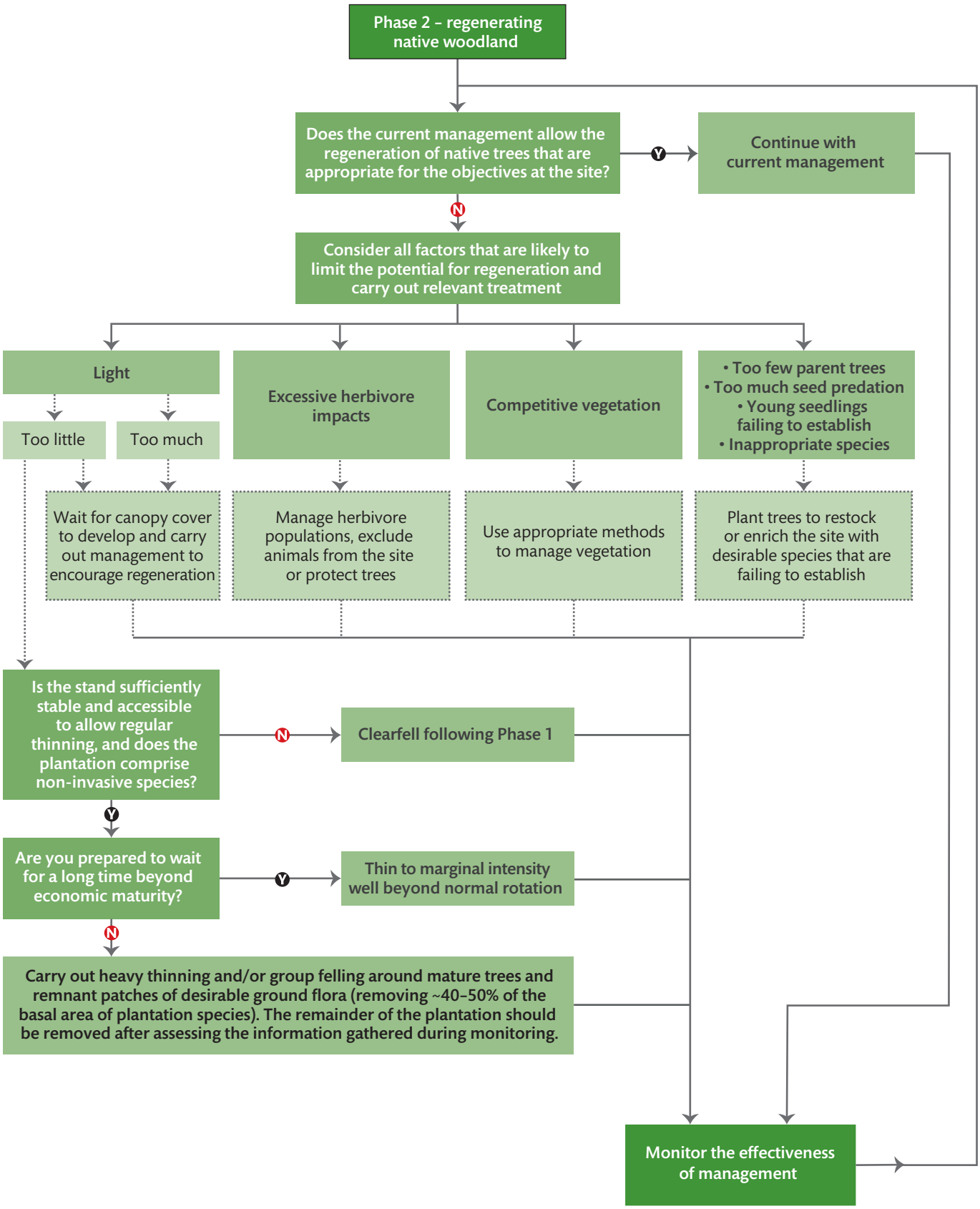
3c The old coppice stools found within PAWS are often in poor condition; the risks from instability are high and will increase if thinning is very heavy or clearfelling takes place. Although stability can be increased by re-coppicing, the regrowth of coppice shoots is worse beneath tree canopies than in the open. Felling may delay seed production but good vegetative growth will provide structural habitat for other species.

3d These are obviously of recent origin and should be managed according to their site-nativeness and biological characteristics. Broadleaves planted in mixed plantations with conifers can probably be treated as recent broadleaves but at some sites inappropriate species were used.

3e Woodland ground floras are very variable and not all woodland communities have a ground flora that requires shaded conditions. Careful control of canopy cover is often regarded as a useful method to manage the ground flora vegetation. However, tree canopies that are sufficiently dense to restrict the growth of undesirable, competitive, shade-intolerant ground flora species may create conditions that are too dark to allow the satisfactory natural regeneration of many native tree species which will perform better after heavy thinning/clearfelling. Management may be needed to control the growth of vigorous competitive species if many small desirable species are to survive. Where large amounts of brash are created then it should not be piled or burned in areas where there are desirable ground flora communities.


Phase 1 – securing remant features
Are the remnant features in the stand/forest management unit of a high quality? (Note 1)
N
Go to Phase 2
Y
Carry out the relevant treatment for:
a. veteran trees
b. mature trees
c. old stools
d. recent broadleaves
e. valuable ground flora
N
Are the remnants robust enough to withstand substantial canopy disturbance to promote regeneration? (Note 2)
Y
Go to Phase 2
Relevant treatments for remnant features (see Notes 3a–e)
Monitoring activities
a. veteran trees
Ideally reduce canopy competition between crop and veteran trees slowly, by progressively removing crop trees over several years. Clearfelling is unlikely to be the best option for stand management but if it is absolutely essential then carry out preparatory work: halo thinning 5 years or more before felling will probably improve the survival of veteran trees and associated epiphytes. Alternatively, where stand characteristics allow, temporarily leave suppressed plantation trees around veterans when clearfelling to reduce the impact of exposure.
b. mature trees
If valuable mature trees are present then their survival may be aided by treating them as veterans.
Regularly observe crown development to assess whether the veteran trees and mature trees have responded positively to the altered growing conditions. If epiphytes are present, record changes that occur.
c. old stools
In stands with valuable site native species that will regenerate from seed, and where the stools will remain stable, promote crown development and seed production by releasing stools from crown competition by thinning. Where the long-term stability of valuable site native species is doubtful and rare epiphytes are absent, re-coppicing can take place if accompanied by a significant reduction in canopy cover.
Monitor crown growth and seed production and determine whether the stems being produced will remain standing given the planned structure of adjacent trees (both plantation and native) during the restoration process. Assess whether new coppice shoots are growing satisfactorily on felled stools.
d. recent broadleaves
Promote the growth of valuable species by appropriate thinning to allow the development of stems and crowns.
If clearfelling the plantation, then fell very suppressed stems of broadleaves and promote their growth as coppice.
Fell broadleaved species that are not generally regarded as typically site native and may not thrive or will hinder the development of a new community.
Monitor the growth of trees to ensure the development of good crowns and stems that will remain stable during the restoration process.
Monitor the growth and development of coppice and the regrowth of broadleaved trees that are not site native.
e. valuable ground flora
Where assessment shows that valuable ground flora requiring shaded conditions is present, then gradual removal of canopy around robust patches of plants may be an effective method of promoting development. Clearfelling may be an option if the ground flora comprises species that thrive in open conditions or are widely distributed, or that are common woodland plants not restricted to the type of community being restored or shade-tolerant species not associated with long-established woodlands.
Assess whether the remnant ground flora species initially present are expanding and that other suitable species are colonising the site.
Use additional management interventions that are appropriate for the site
Are the remnant features now secured and robust?
Y
Go to Phase 2
N
N
Are the remnant features likely to respond under current conditions, given more time?
Y
Maintain current conditions until remnants are robust

Phase 2: Regenerating native woodland



Note that any operations to regenerate a native woodland must not have an adverse effect on the ancient woodland remnants.

Case studies

The following case studies are examples taken from across Britain. Restoration options differ according to site type, climate, terrain and landscape setting as well as the nature of ancient woodland remnants. Where appropriate, alternative silvicultural approaches to restoration are described in the case studies.

Case study 1 – Restoring a stand of Corsican pine in the lowlands

Case study 2 – Restoring an extensive PAWS on a challenging upland site

Case study 3 – Gradually restoring of a site with shade-casting conifers

Case study 4 – Managing a Douglas fir PAWS

Case study 1 – Restoring a stand of Corsican pine in the lowlands

Site description

This 40-year-old stand is located within a 200 hectare block of woodland in Surrey that is managed by the Forestry Commission. Much of the woodland comprises PAWS of various conifer species on a site of old mixed coppice. It is an important area for butterflies, which influences ongoing management.The stand is dominated by an overstorey of Corsican pine, but sub-dominant trees including oak, chestnut, willow and ash derived from old coppice stools are scattered irregularly throughout. There are no veteran trees in the stand. There are remnant hazel stools of varying size within the understorey but the most frequent species is hawthorn. Most of the naturally regenerating tree seedlings are ash but these are few in number and are only establishing slowly. Bramble is the predominant species in the ground flora, but about 100 other species have been recorded.

Gradual restoration

The presence of a developing understorey and the mixture of broadleaved canopy trees indicate that gradual restoration by repeated thinning could be successful in this stand, but would the method necessarily produce the most appropriate woodland for the site? Birch and oak, which perform well in the heavy clay soils found at this site, are unlikely to regenerate satisfactorily beneath the shade of a stand which is gradually thinned. Their successful regeneration will probably be further hampered by the expansion of the bramble thicket, which is likely also to have an effect on the growth, development and survival of the smaller species in the ground flora. Woodland conditions would be maintained during the process, which would be of benefit to an unknown range of species. The stand produced would comprise native species, but scrub species may predominate and forest trees may be present in relatively small amounts initially, with the possibility of forest trees regenerating within scrub patches in future decades.

Clearfelling

Rapid removal of the conifers would cause a significant change to the environmental conditions at the site; this may have adverse effects on some species but be beneficial for others. The remaining broadleaved trees may suffer from stress, but the increased amounts of light would improve conditions for the growth of the understorey and coppice and allow establishment of light-demanding species by natural regeneration. Birch would probably be the dominant species. Inevitably the amount of bramble will increase, but initially the growing conditions will be improved for other species in the ground flora including violets, which are important for some of the butterflies in the woodland. While shaded woodland conditions would be lost in this stand during the early phase of regeneration, the development of birch scrub is often fast on this type of site and the stand is located within a large area of woodland. The temporary open space and early successional habitat will benefit a wide range of species including butterflies, which are important at this site. In addition, until relatively recently, the stand was part of a woodland that was traditionally managed as coppice in which patches of open space would have been typical.

Case study 2 – Restoring an extensive PAWS on a challenging upland site

Site description

This PAWS occupies an area of around 350 hectares on the southeast side of Loch Shiel in the Highlands of Scotland that is managed by the Forestry Commission. Most of the plantation is Sitka spruce established in the 1960/70s. There are extensive remnant patches of ancient woodland, typically upland oakwood (NVC W11) where soils are well-drained and mildly acidic to neutral. There are also wetter areas with patches of alder–ash woodland (NVC W7) or birch/Molinia woodland (NVC W4). The areas of birch/Molinia appear generally of the same age as the plantation trees. There is limited access for wheeled machines, with only one forest road along the lochside. A small proportion of the site has been thinned, but due to limited access and poor stability most remains unthinned. Some existing patches of windblow illustrate that, despite years of dense shade, ground flora can quickly respond to canopy gaps. While many mature and veteran trees do occur within the plantation, most ancient woodland remnants are associated with watercourses. Many of the oak and hazel trees, and open rock outcrops and boulders, support nationally scarce lichens and bryophytes typical of Atlantic oakwoods. Extensive native woodland restoration is proposed but there are several practical constraints to consider.

Gradual restoration

Some alternative management options have been explored at this site (thinning rather than clearfelling), but sporadic windblow was a problem. Given the lack of previous thinning, extensive windblow would be inevitable if further thinning takes place. Additionally, cable crane systems would be required to extract timber from much of the site and repeated thinning operations would be expensive.

Clearfelling

The presence of important lower plants and fragile veteran trees means that clearfelling is undesirable as remnants may suffer from sudden exposure due to loss of shelter from the plantation. However, to avoid large-scale loss of plantation as it increases in height and becomes susceptible to catastrophic windblow, some felling has started and more is needed shortly. Careful forest planning is needed to ensure that the less stable areas are selected initially for felling and those with less remnants are prioritised for felling so that intermediate options could be used elsewhere (see below). There may also be scope to cut a number of smaller areas rather than one large coupe during each operational phase.

Intermediate option

Operations elsewhere have shown that halo thinning around remnants helps surviving trees, ground flora and epiphytes to develop into more robust communities. Although there is poor access for wheeled machines at this site, it is possible to manually fell plantation trees around remnants to allow them to become more robust before clearfelling. Where larger gaps are created, regeneration of native trees can take place and help provide shelter when remnants are otherwise exposed through clearfelling. In sites similar to this a rapid response to halo thinning has been seen and it appears that such treatment is worthwhile if there is a window of 5 years or more prior to the time when clearfelling will be necessary due to reducing plantation stability.

Case study 3 – Gradually restoring a site with shade-casting conifers

Site description

This 1300 hectare woodland at Wentwood, one of the largest ancient woodland sites in Wales, has a long history of management which dates back more than 1000 years. At present a small area of the woodland is in private ownership, but the majority is managed by Natural Resources Wales (formerly Forestry Commission Wales) and the Woodland Trust. The site is at an altitude of 250 m, has a southwesterly aspect and has an annual rainfall of 1000 mm. The soils are generally light-textured and well-drained overlaying sandstone, but there are some patches with less permeable soils. At present the majority of the site comprises 20th century conifer plantations and The Woodland Trust's long-term aim is to restore the site to stands dominated by native broadleaves using appropriate continuous cover methods to maintain a tree canopy throughout the process wherever possible. The area owned by the Woodland Trust mainly comprises stands of well-managed mid- to late-rotation conifers – mostly Japanese larch, Norway spruce and Douglas fir that have been well cleaned. Native broadleaves are rare and consist mostly of suppressed birch with some oak and ash often in the wetter areas of the stands. The initial survey found that ground flora species were well distributed throughout the site, but there were few large mature trees and only one ancient oak that could be regarded as a true veteran.

Initial management

A general thinning was carried out throughout the stands to remove about 20–25% of basal area to improve growing conditions for the ground flora, with some additional thinning around broadleaved trees to aid crown development and enhance growth to improve the stability of stems. The thinning operations were carried out using a harvester and the main difficulty encountered was ensuring that the operator removed sufficient conifers from around the remaining broadleaves. Thinning around the one veteran tree has been very light with the removal of a few trees to create a small canopy gap.

Monitoring and future management

Stands are formally monitored at 5-year intervals but intermediate observations have already suggested that, although the ground flora has improved, further thinning to improve its quality should be carried out. This will once again remove about 25% of conifer basal area, improving stand quality by removing the largest stems and those of poorest form. Extra thinning will take place around broadleaved trees if it is thought necessary. Once again the area around the veteran tree will be treated differently and the single tree interfering with the oak's crown will be felled. More intensive thinning to allow tree establishment will only take place once the ground flora is considered to be secure and capable of surviving the conditions necessary for the good growth and establishment of trees. However, at present there is very little natural regeneration of broadleaved trees and the paucity of potential broadleaved parent trees throughout the stand is of concern. A variety of trial plots to investigate methods and costs of enrichment planting have been established.

Case study 4 – Managing a Douglas fir PAWS

Site description

Nash Wood, on the Welsh–English border, is managed by Natural Resources Wales (formerly Forestry Commission Wales). It has high visual amenity value and is important for recreation. The woodland is around 250 hectares in area and comprises mainly non-native conifers including Douglas fir, Japanese larch and grand fir. Most of the site is at an altitude of 200–300 m and the upper slopes have a heathy vegetation (including bilberry and heather) which is characteristic of acidic oak–birch woodlands of NVC W16/W17 communities. The lower parts of the site have more fertile lowland brown earth soils where the native woodland community would probably be oak–birch–bramble woodland (W10) and include ash. Current plans are to use continuous cover silviculture to restore the woodland to predominantly native broadleaved species over the next few decades.

Many of the stands within the woodland comprise less than 20% native species but there is considerable variation between stands, which may require different management during restoration. Two examples are given below:

Stand 1: 35-year-old Douglas fir. This stand has been under-thinned and the canopy has been very dense resulting in a sparse ground flora with few species. However, broadleaved trees including oak, birch and rowan are abundant throughout the stand, but most are strongly suppressed. The most important aim of the initial restoration treatment was to improve the conditions for growth and survival of suppressed broadleaved trees. The stand was thinned by a contractor under a standing sale agreement and prior to operations the better broadleaved trees were identified and conifers in the immediate surrounding area were marked for removal. The thinning was generally successful and there is more light within the stand with many, but not all, of the marked broadleaves being released.

Stand 2: 49-year-old Douglas fir. This stand has been thinned more regularly than Stand 1. The trees have well-developed crowns and naturally regenerating Douglas fir seedlings are present within the stand. Remnant broadleaved trees are rare, but those present are old, of large diameter and have relatively small crowns. A few seedlings of holly, ash and hazel are growing among the ground flora, which includes mixed grasses and herbs, with bramble and raspberry developing. The recent thinning will allow continued development of the ground flora, but open areas within the stand suggest that development of a bramble thicket could create future problems for tree regeneration. Although there are some broadleaved seedlings, the paucity of parents within the stand suggests that the most likely species to regenerate and restock the stand will be Douglas fir.

Although these stands differ, their recent treatment is likely to promote the development of the remnant broadleaves and ground flora within the stand. However, the current absence of suitable seed sources is likely to mean that restoration of a woodland dominated by native tree species will take many decades using continuous cover and natural processes for restocking.

Further reading and useful sources of information

forestry.gov.uk/publications
forestry.gov.uk/ukfs

Forestry Commission publications

- The UK Forestry Standard (FCFC001)
- UKFS Guidelines on Forests and biodiversity (FCGL001)

Guidance and good practice

- Restoration of native woodland on ancient woodland sites. (FCPG014)
- Managing ancient and native woodland in England (FCPG201)

Research

- An Ecological Site Classification for forestry in Great Britain. (FCBU124)
- The restoration of wooded landscapes. (FCRP001)
- Natural regeneration in western hemlock plantations on ancient woodland sites (FCRN011)

Other publications

- British plant communities. Volume 1: Woodlands and scrub (Cambridge University Press)
- Guidance on dealing with the changing distribution of tree species (Natural England)
- Managing native broadleaved woodland (TSO)
- National vegetation classification: field guide to woodland (JNCC)
- Native woodland definitions and guidance (Northern Ireland Native Woodland Group)
- Restoration of PAWS – testing some of the advice (Quarterly Journal of Forestry 101)
- Restoring ancient woodland. Park Place estate – a case study (Quarterly Journal of Forestry 98)
- The area and composition of plantations on ancient sites (Woodland Trust)
- The conservation and restoration of plantations on ancient woodland sites (Woodland Trust)
- The potential for native woodland in Scotland: the native woodland model (SNH)
- Veteran trees: a guide to good management (English Nature)
- Veteran trees in the landscape: a methodology for assessing landscape features with special reference to two ancient landscapes (In Landscape Ecology of Trees and Forests. Proceedings of the 12th annual IALE (UK) conference)

Websites

- Forest Research – www.forestry.gov.uk/forestresearch
- Native Woodland Survey of Scotland – www.forestry.gov.uk/nwss
- Felling licences (Great Britain) – www.forestry.gov.uk/felling
- Felling licences (Northern Ireland) – www.dardni.gov.uk/forestry
- Northern Ireland Forest Service – www.forestserviceni.gov.uk
- Scottish Natural Heritage – www.snh.gov.uk
- Natural England – www.naturalengland.org.uk
- Natural Resources Wales – www.naturalresourceswales.gov.uk
- Northern Ireland Environment Agency – www.ni-environment.gov.uk
- Inventory of ancient woodland in Northern Ireland – www.backonthemap.org.uk
- Woodland Trust – www.woodlandtrust.org.uk

Glossary

Ancient semi-natural woodland Ancient woodland composed of mainly locally-native trees and shrubs that derive from natural seedfall or coppice (rather than from planting).

Ancient woodland Woodland which has been in continuous existence since before AD1600 in England, Wales and Northern Ireland, and before AD1750 in Scotland. The term 'ancient woodland site' refers to the site of an ancient woodland, irrespective of its current tree cover.

Continuous cover forestry A silvicultural system whereby the forest canopy is maintained at one or more levels without clearfelling.

Coppice Management based on regeneration by regrowth from cut stumps (coppice stools). The same stool is used through several cycles of cutting and regrowth and it can contain considerable deadwood if ancient.

Coupe An area of woodland that has been clearfelled or is planned for clearfelling.

Enrichment planting A technique of planting trees of desirable species into existing regeneration or an understorey to improve the chances of achieving management objectives.

Epicormic (of a shoot or branch) Growing from a previously dormant bud on the trunk or limb of a tree.

Epiphytic plants Plants growing on other plants, especially those that are not parasitic.

Genotype The genetic constitution of an individual organism.

Halo thinning Thinning in a circle around veteran or ancient trees to open up their crowns.

Marginal intensity (of thinning) The maximum rate at which volume can be removed without causing a loss of cumulative volume production. Current Forestry Commission growth models are based on the assumption that marginal thinning intensity is 70% of yield class.

Mycorrhiza A fungus which grows in association with the roots of a tree or plant in a symbiotic relationship.

NVC (National Vegetation Classification) A comprehensive classification and description of the plant communities of Britain used by the nature conservation agencies and other bodies to describe and assist in the evaluation of habitats.

PAWS (Plantation on an ancient woodland site) A planted forest of native or non-native tree species that has replaced the original semi-natural woodland on sites with a long history of woodland cover.

Remnant feature(s) Are features that have survived from the former ancient semi-natural woodland. They are often irreplaceable components of a PAWS, having originated in a complex woodland ecosystem that has evolved over centuries. Remnant features include: veteran/mature trees, standing and fallen deadwood and specialist woodland flora. Features may also include historic artefacts such as charcoal hearth and saw pits.

Scarification A method of cultivation used to break up the ground and mix the organic and mineral layers of soil to improve conditions for the growth of trees on a site.

Seed bank A natural store of seeds, often dormant, within the soil of most ecosystems.

Standard(s) A large tree or trees growing within an area of coppice.

Veteran tree A tree that is of biological, cultural or aesthetic interest because of its great age, size or condition – including the presence of deadwood micro-habitats (see also Box 3 on page 8).

Wood pasture An area of historical, cultural and ecological interest, where grazing is managed in combination with a proportion of open tree canopy cover.

The restoration of plantations on ancient woodland sites (PAWS) to native woodland communities is a challenging objective that requires more management input than simply re-creating a stand of site native species. All sites differ, and optimising the choice of methods thorough site assessment is necessary before restoration starts. Where there is evidence of valuable remnants of the former ancient semi-natural woodland within the stand, management should secure their future, and promote their development and subsequent contribution to the future native woodland. This Guide provides a framework for selecting a method of stand management and advice on good practice that is appropriate for a particular site and related to the quality of the remnant features present.

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