Dr. Scott McG. Wilson MICFor

Consultant Forester and Forest Ecologist

Approaches to the retention of timber potential when restoring or enhancing PAWS sites

Technical Report - October 2011

Executive Summary

Restoration of Plantations on Ancient Woodland Sites (PAWS) has been an article of British forestry policy and practice over the past 15-20 years, in response to public pressure and national and international biodiversity commitments. It has been pursued with varying enthusiasm across public, private and charitable woodland ownerships, and has involved a wide range of types of silvicultural intervention and subsequent management approach. Most work has been publicly-funded, either directly, through work on the public forest estate, or indirectly, through grant-in-aid to other owners. A common perception has been that PAWS restoration effectively withdraws a site from the future "production working circle", dedicating it to biodiversity conservation and amenity values. It has therefore failed to command universal support among foresters.

A combination of the current demand and higher prices obtainable for saw-timber and woodfuel, coupled with limitations on available public conservation funding, have challenged the viability and wisdom of recent approaches to PAWS restoration. Experience on some PAWS restoration sites has suggested that typical interventions applied to date, especially the simpler "clearfell-naturally regenerate" approaches frequently applied, often do not achieve effective restocking with productive species. This may compromise conservation, amenity and economic values. Many owners and professional foresters, especially in the private sector, have now become increasingly sceptical of PAWS restoration and reluctant to embark upon it, even if grant-aided. New approaches to PAWS enhancement, where timber value is retained, are sought.

There has been extensive previous research into the biodiversity aspects of PAWS restoration, including the prioritisation of sites for restoration and the selection of the most effective methods for initial intervention. However there has been less work which attempts to follow the longer-term silvicultural development of stands, and a notable deficiency in effective site monitoring. The present independent study sought to draw together relevant professional views, published scientific findings and practical experience of PAWS restoration and enhancement silviculture in Britain, through the research and reportage of a number of short case-studies. These were selected from across Britain to highlight the most common approaches to retention of timber potential within the plantation stand and/ or the successor stand of native trees.

Twenty-seven case-studies highlighted approaches including reduction of coniferous canopy density by regeneration thinning, respacing of natural hardwood/ mixed regeneration, enrichment planting, and tending of young hardwoods (brashing, pruning, thinning). Retained timber potential can be found on all ownership classes. Many successful examples involved "traditional estate" forestry and "continuous-cover" forestry techniques with regular monitoring and interventions. Improved woodfuel prices support earlier respacing/ thinning of hardwoods. Financial considerations, stand instability/ windthrow hazard and perceived biodiversity/ conservation constraints impede retention of timber potential on PAWS restoration/ enhancement sites in some cases, favouring clearfell/ restock working. However the predominant limiting factor is the shortage (and perceived decline) of the practical forestry skills and experience that are necessary to optimise timber potential. Effective enabling actions are likely to include simplification/ relaxation of PAWS restoration prescriptions, under-pinning of the forestry training infrastructure and encouragement of technical information exchange. The insights reported will inform the latter effort.

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Background - PAWS restoration and enhancement in British woodlands

History of Plantations on Ancient Woodland Sites (PAWS)

Ancient Woodland Sites (AWS) are conventionally regarded as those believed from documentary and map records to have been wooded in 1600 (England & Wales) or 1750 (Scotland) and not to have been cleared of woodland since those dates. It is generally assumed that any woodland present at those dates was ancient semi-natural in origin. The possibility that some woodland was planted earlier than this cannot be ignored - while there was probably rather little forestry planting in England before John Evelyn's "*Sylva*" in the late 1600's, there may have been some on ecclesiastical lands during the mediaeval period - for example to supply replacement cathedral oak roofing timbers. In Scotland there was certainly some planting from the 1680's onwards, but it is usually rather easier to recognise as such from historical records.

Plantations on Ancient Woodland Sites (PAWS) are those AW sites replanted subsequent to the above reference dates (with native or non-native trees), either by clearfell-replant approaches or by underplanting/ interplanting through the woodlands. What are termed "classical PAWS" are those AW sites where non-native conifers or hardwoods were established since around 1920 on land still carrying ancient semi-natural woodland until recently (including war time devastation felling sites). A wider "PAWS *sensu lato*" category would include those AW sites replanted with non-native trees earlier - for example in the period during and after the Napoleonic Wars, which have since had more than one forestry rotation since original replanting. PAWS involving site native tree species (e.g. Scots pine, oak, beech) are not usually restored.

Drivers and imperatives for PAWS restoration

The concept of "PAWS restoration" followed on from the publication of the Forestry Commission's Broadleaves Policy (1985). It became increasingly unacceptable to fell native species woodland and replant with non-native conifers after that date. From the late 1980's/ early 1990's onwards there was growing demand for some sites that had previously been coniferised in recent decades ("classical PAWS") to be restored. This was in part a response to public pressure, with a common perception that young, often un-thinned, conifer stands were less aesthetically pleasing than mature broadleaved woodland. There was also mounting scientific evidence that the botanical diversity of ancient woodland sites that had been replanted with shade-casting conifers declined. Due to the long history of woodland clearance and open wood pasture/ coppice-with-standards management of British woodlands, the native woodland flora is less shade-tolerant than that found in continuously-forested provinces of Continental Europe. As time went on through the 1990's, there was further recognition of plantation forestry impacts on less obvious woodland features such as soil biota and deadwood insects. Following the UNCED Rio Conference in 1992, Britain entered into international obligations to protect, enhance and expand native woodland habitats, and restoration of PAWS sites to native species composition was seen as one avenue to achieve that - often thought to be more certain of success, and less expensive, than planting of new woodland habitat on bare land. The expectation of ecological enhancement of PAWS sites subsequently became an article of the UK Forestry Standard and the UK Woodland Assurance Scheme, although full conversion was not always required. PAWS restoration was advocated by public and charitable sector conservation bodies.

Philosophy of and approaches to PAWS restoration

Since the emergence of the concept of PAWS restoration, there has been a dichotomy of approach between those who have seen it as an agenda for "radical ecological restoration" and those who have seen it as an agenda for "gradual silvicultural conversion". The former have tended to place emphasis on the removal of non-native trees from the site and the re-establishment of the site-native woodland composition, whereas the latter have placed emphasis on protection of surviving ancient woodland remnants, retention of woodland conditions (light and micro-climate) and progressive development of the canopy composition to favour native species. Simplistically, these are very often presented as opposing approaches of the "conservationists" and "foresters" camps respectively, despite many conservationists supporting the more gradual approaches on ecological impact grounds and many foresters supporting clearfell-restock working on logistical and economic grounds. In these discussions, some conservationists have "come to the table" with a false urgency to remove the conifer canopy and a lack of understanding of silviculture and woodland economics. On the other hand, some British foresters have adhered over-strongly to the primacy of the even-aged coniferous model and have demonstrated limited knowledge of, and resistance to, adoption of non-clearfell silviculture and the stand tending of quality hardwoods for timber production. It has always been apparent that a more integrated approach, where conservationists and production foresters were the same well-trained individuals, would allow for more effective/ rapid progress with PAWS restoration. Properties where such management has been in place do provide valuable examples.

Adoption of the concept of PAWS restoration in practice

The pattern of adoption of PAWS restoration has been strongly influenced by the fact that is has often responded to "policy push" rather than "practitioner pull" dynamics. Most PAWS restoration has been publicly-funded, and would not have happened without this financial support. It differs markedly from the much more gradual, sporadic pattern of "self-funded and self-motivated" adoption of continuous-cover forestry (CCF) techniques applied to coniferous stands over the past 50-60 years. The pattern of adoption can usefully be considered for three main ownership categories:-

- Forestry Commission - widespread (near complete) mandatory consideration and survey of PAWS sites, with initial interventions to protect remnant ancient woodland features. Earlier preference for rapid, clearfell-regenerate approaches slowly giving way to gradual silvicultural approach. Strong dependency on skills, experience and enthusiasms of key local forestry staff interpreting wider policies.

- Conservation bodies (statutory, Woodland Trust, county wildlife trusts) - enthusiastic adoption on most sites. Many earlier projects involved emergency deconiferisation of woodland reserves and designated sites, but the Woodland Trust is now a leading exemplar of the gradual silvicultural approach to PAWS.

- Private woodlands - generally reluctant, cautious and sceptical response, confining enhancement actions to those required by regulation. Serious concerns over loss of future economic potential. Only a minority of PAWS sites being restored to native species canopy. Some enthusiastic and proficient adoption by atypical individual owners and retained head foresters with the relevant experience and CCF skills.

Development of the concept of PAWS restoration in practice

During the 15-20 year period of PAWS restoration activity there has been significant parallel evolution in the silvicultural context in which it is being conducted and the approaches used. Early examples were usually under-planted woodlands of high previous conservation value where a significant native species canopy component remained and where the work could be characterised as "emergency conifer removal" over a short period. More recent examples are very often sites where remnant ancient woodland features are confined to occasional surviving veteran trees and "hot spots" of ground vegetation. These sites may be dealt with by early action to identify and release/ relieve the remnant ancient woodland features, with a much more gradual subsequent conversion of the canopy using silvicultural techniques adopted from the continuous-cover forestry "manual". Some more recent examples listed for PAWS restoration apparently struggle for tangible evidence, suggesting "mission creep". Early enthusiasm for the "clearfell-regenerate" approach to PAWS restoration has been tempered by disappointing experience, especially on the more fertile lowland sites. Excessive competition from ruderal weeds, including *Calamagrostis epigejos, Pteridium aquilinum* and *Rubus fruticosus* has impeded native tree regeneration in many such cases. Rebound of the soil water table at clearfell is also problematic. The composition of natural regeneration is often dominated by birch and less-desirable conifers such as western hemlock and spruce, limiting future timber potential. Gradual silvicultural transformation is now increasingly preferred in policy and practice, but is seriously impeded by the lack of necessary forestry skills/ experience.

Information on the extent of PAWS and PAWS restoration works

Information about the amount and location of PAWS sites within Great Britain is based on a combination of the most recent National Inventory of Woodlands and Trees (published 2001-2002, reflecting survey in the 1990's) and the Inventory of Ancient and Semi-Natural Woodlands. The former data source is now rather dated. Pryor and Smith (2002) present useful categorical analyses based on these data, including breakdowns, by country, region, ownership category, plantation species composition and age-class which are worthy of consideration. Some key points - (a) there were thought to be ~220,000-230,000 of PAWS sites across GB; (b) breakdown nationally was England 62%, Scotland 26%, Wales 12%; (c) Scotland and Wales saw roughly 50%/50% public/ private ownership, but England has a majority of private; (d) in Scotland most PAWS sites then carried conifers, but in England and Wales there was a more even division between conifer, hardwood and mixed-wood PAWS; (e) pine and spruce dominated PAWS in Scotland, but in England and Wales there was a more diverse picture with notable amounts of larch, Douglas fir, oak and beech and (f) conifer PAWS were predominantly from the period 1940-1980, but with an older tail of hardwood PAWS sites, reflecting longer rotations for planted oak/ beech. The above data should be significantly updated by the current National Forest Inventory (NFI) round and for Scotland by the Native Woodland Survey of Scotland (NWSS) which is including all PAWS sites. As to information concerning the extent of PAWS restoration/ enhancement work there is no equivalent published data, due to the difficulties in obtaining detailed information on this aspect from the Forestry Commission sub-compartment database and national grant scheme databases. Some indications are available for key UKHAP targets - progress against overall targets for "PAWS fully restored" has been much slower than hoped, but a significant proportion of public/ charitable sector PAWS now receive survey attention/ protective measures.

Objectives of the reported study

The strategic objective of the current project was to attempt to set out a "road map" by which PAWS restoration and enhancement work can become better integrated into the wider body of silvicultural knowledge and practice in British forestry. It is a relatively recent phenomenon in forestry terms (15-20 years accumulated experience) and still tends to suffer from an image of being a counter-intuitive activity, promoted mainly by conservationists and lacking "forestry pedigree". The current financial and timber market conditions differ very markedly from those at the time PAWS restoration was initially promoted. As things stand, there is a perceived risk that PAWS restoration and enhancement work will "run out of steam" or be "sidelined" for implementation only on "special sites" of the highest conservation importance. For that to be avoided, it will need to become an accepted and valued part of mainstream British silviculture.

Within the context of the background environment discussed above, the key intention of the current study was to collect and disseminate useful information that would encourage and enable woodland owners and managers to retain timber potential on sites where PAWS restoration and enhancement is being attempted. This is most likely to be achieved where there is effective silvicultural planning that embraces the desirability of retaining timber potential, and subsequent implementation of targeted silvicultural interventions to achieve a "desired future stand condition". A certain number of experienced foresters, mainly on the established private estates, are confident in their ability to carry out this kind of work, whether they describe it as PAWS restoration or not. Similarly with some examples on the public forest estate and in woods owned by charitable conservation organisations (e.g. Woodland Trust). However in other situations, PAWS restoration interventions are less well-directed, focussing on early deconiferisation, with inadequate subsequent stand tending work. Given that much silvicultural work of this kind tends to be carried out in isolation, it was felt that reporting of successful experiences within short case-studies would be of assistance in alerting less experienced owners and managers to the options available.

Key research questions and practice issues addressed by the work reported were:-

1. To what has extent has future timber potential been retained in PAWS restoration projects conducted to date, given suitable future silviculture?

2. Which approaches to PAWS restoration provide the best opportunity to retain timber potential under the range of climatic, soil and initial stand conditions?

3. Is emphasis best placed on timber potential within partial retentions of mature conifer stands or on the development of quality successor hardwood crops?

4. To what extent, if any, does retention of timber potential conflict with, or impede, the achievement of target biodiversity benefits of PAWS restoration?

5. What are the implications for future selection/ prioritisation of sites for PAWS restoration in terms of site type, soils, existing crop and conservation features?

These matters will be addressed in the relevant sections of the overall technical report and illustrated by many of the short case-studies reported in the Appendix.

Methods of the reported study

The central approach of the present short, independent study was to obtain and report a geographically and silviculturally "inclusive" picture of the range of approaches applied to PAWS restoration and enhancement in British woodlands, and their implications for the retention of future timber potential. This was to be achieved by means of a rapid appraisal (qualitative) investigation, centred on the development and proforma reportage of a portfolio of short, photo- illustrated case-studies. In this it differs markedly from many earlier studies on PAWS restoration practice, which have focussed on detailed (quantitative) plot-based recording of natural regeneration, ground vegetation, veteran trees and other features of conservation significance at a smaller number of research sites. These two approaches should clearly be seen as complementary, but currently available resources may well tend to restrict the future adoption of the more detailed recording approaches in operational forestry contexts.

The work conducted within the project comprised the following elements:-

- Literature review (conventional/ web-based) on UK PAWS restoration policy/ practice and equivalent temperate forest restoration silviculture approaches. Library facilities at the Universities of Aberdeen and Edinburgh were used.

- Technical consultation of relevant experts and researchers, based on invitation to comment and informal discussions during the course of the field research. Response level/ content varied rather due to current conditions in the sector.

- Identification and field examination of case-study examples, involving discussions with owners and forestry agents together with site visits to record salient details for a proforma description and to allow for digital photography. Research time per case-study was generally of the order 0.5-1 working days. A number of potential case-study examples were examined that are not reported.

- Selection and reporting of case-study examples, together with preparation of an overall technical report drawing out the key lessons from the project. An digital appendix to the report will contain the supporting photographic records.

It was considered desirable that future workers should be able to appraise how the sites described in the case-studies have changed over intervening time. In addition to the forestry description forming the basis of the case-studies, an archive of digital photographs was created for each site, which can form a basis for future comparison. In each case, a selection of photographs were either (a) located by 8-figure map reference (obtained from a GPS handset) and compass-bearing or (b) located by 6-figure map reference, cardinal points of the compass and/ or with reference to (sub)-compartments and identified stand types within the case-study site. It was necessary to flexibly adapt the method selected to suite site conditions and in order to avoid a disproportionate allocation of the limited available field visit time to this one aspect.

In terms of dissemination of results, an article will subsequently be prepared for publication in the popular forestry press (likely to be the *Quarterly Journal of Forestry*) and it is likely that future seminar presentations will be given by invitation.

Summary outputs of the literature review and technical consultation

Recognition and definition of PAWS sites

A key issue for PAWS restoration is reliably identifying PAWS sites. Conservation advocates are typically concerned about under-recording of PAWS, adopting the approach that restoration should proceed if there is "a whiff of PAWS about it". Production foresters frequently feel that some PAWS identification is rather "fanciful" and demand unequivocal evidence before agreeing to restore. Such debates can absorb quite some time and energy, with specialist advice often called for. Disputes are increasing as the "obvious" PAWS sites have been worked through, especially on public and charitable estates, and more marginal examples with fewer remnant ancient woodland features are now being tackled. Two basic approaches to recognising PAWS sites are (a) the map-based route, relying on reference to historical estate maps and the First Edition Ordnance Survey series, often indirectly by way of the Ancient Woodland Inventory and (b) the field survey route, relying on recognition of ancient woodland indicator plants, veteran trees, woodbanks, charcoal hearths etc. Both methods carry risks of either false positive or false negative results. There is particular concern about under-recognition of past planting in the Ancient Woodland Inventory and the use of national generic lists of ancient woodland indicator plants at the regional/ local levels. Recent Forestry Commission and Woodland Trust guidance documents have provided useful support for the combination of these methods to produce the most reliable results. Whether it is realistic for these assessments to be carried out by typical operational private foresters is questionable, but realistically the resources are often lacking for routine recourse to the consulting PAWS specialists.

Evaluation of PAWS sites and prioritisation for restoration

Given limited resources, realistically only a part of the PAWS resource is likely to be actively restored during the current rotation - there is a pressing need for effective prioritisation. Both the Forestry Commission (Thompson *et al*, 2003) and the Woodland Trust (Woodland Trust, 2005) have developed guidance on this in recent years, which is used by their own site managers and promulgated to the private sector. This centres on evaluation of the extent and value of remnant ancient woodland features (veteran trees, characteristic ground vegetation), the severity and immediacy of threat to these from plantation conditions and the likelihood of success with any planned restoration work. If based on good quality site appraisal and survey work, these methods work well and remain appropriate. Most often, recommendations will be for modest initial actions to alleviate the threat from shade or competition (e.g. halo thinning or keyhole felling around remnant features), to be followed later by progressive thinning (or now more occasionally single-intervention removal) of the plantation canopy. Where remnant features are limited, the degree of threat small or the likelihood of restoration success remote, restoration may not be prioritised. In the current climate there is a good case for increasing the element in such appraisal that deals with the immediate and long-run costs of restoration and the range of opportunities for the retention of timber potential. Consideration of those aspects is arguably inadequate at the present time, with a degree of resistance to establishing and managing good quality successor forestry crops on PAWS sites. Available financial resources should be devoted to PAWS sites that score highly on all measures - this will probably mean greater emphasis on more accessible, intensively managed sites.

Approaches to PAWS restoration and retention of timber potential

The British silvicultural literature comparing approaches to PAWS restoration and the associated retention of timber potential is rather limited, largely due to the relatively short history of the practice. Much of what there is (e.g. Harmer and Kiewitt, 2006, 2007) inevitably focuses on the early stages of restoration - essentially the choice between clearfell-regenerate and gradual silvicultural conversion. Most comparative work has been undertaken in the lowlands of southern England. The reports for the Woodland Trust prepared by the Oxford Forestry Institute (Pryor et al, 2002; Pryor and Jackson, 2002) are probably the most valuable comparisons on ecological and economic grounds - although now a decade old, recent work has been undertaken towards revisiting their study sites on Woodland Trust land and updating the analyses. The 2002 reports concluded that gradual silvicultural conversion was likely to optimise a combination of ecological benefits and retained timber income, given the market conditions of that time. This applies particularly where the standing value of the conifers is high - for example premium lowland Douglas fir and larch. Upland spruce and pine crops, especially where inaccessible for extraction, may not have the same retention value. Higher prices for conifer timber today are likely to support the overall conclusion, if anything placing greater emphasis on conifer retention. A key problem in this field is the poorly-developed status of British hardwood silviculture. Despite efforts by specialist charitable bodies such as the Northmoor Trust, Woodland Heritage and Future Trees Trust (ex BIHIP), rather too few growers will consider the potential of a future quality hardwood crop seriously, and hence few are willing to invest in effective planting practice, stand tending, thinning and pruning work. For too many, the hardwood element on PAWS sites equates only to biodiversity or woodfuel. At least improved woodfuel prices are likely to promote better hardwood thinnings.

Monitoring and long-term research in relation to PAWS restoration

While the present study and the earlier work by Pryor *et al* (2002) have provided some limited scope for chronosequence study of selected PAWS restoration sites, there remains a serious problem with long-term monitoring and record-keeping in this field. On standard operational PAWS restoration sites, information collected prior to, and at the time of, silvicultural interventions is limited, and is often lost due to "organisational memory" issues. Most of the latter relate to over-dependence on computerised data and image storage and interruptions/ incompatibility of same. Where data is to be stored for more than around 3 years it must be held on paper and held at more than one location to avoid unforeseen physical losses. There should be a more regular practice of recording stand and treatment information for PAWS sites along the lines of the former estate "wood book" or FC "compartment record". The type of quantitative, plot-based, monitoring of CCF/ PAWS restoration work that is advocated by Kerr *et al* (2002) and others is very sound, but appears beyond the reach of many (even more knowledgeable) active forest managers due to time/ cost issues. Development of "rapid visual assessment" protocols for this audience is essential. There is also a need for more detailed quantitative monitoring of PAWS restoration work at a national network of sites, covering the range of conditions and methods. It has become increasingly difficult to pursue such work effectively over the required time period due to the short-term funding arrangements now available for forestry research. Long-term work, along the lines of the transect work at Lady Park Wood, is essential if British PAWS restoration practice is to retain any sound scientific footing.

Overseas experiences with restoration silviculture

Valuable comparisons can usefully be drawn between British PAWS restoration silviculture and experiences of restoration silviculture in forests overseas. Of particular relevance is the experience of restoration of Norway spruce plantations in Germany, France and parts of Central Europe. This has been driven by a combination of landscape amenity, biodiversity and environmental science issues (e.g. soil acidification). Key differences are that the main native species is beech, which is shade tolerant, and that there is better established hardwood silvicultural expertise. Although both clearfell-restock and gradual silvicultural conversion have been attempted, the latter approach is generally preferred. Many countries have instituted effective clearfell bans, mandating "near to nature forestry" approaches. Restoration silviculture following forest exploitation frequently seeks to restore valued light-demanding or medium tolerant species to forests that have become dominated by heavy shade-bearers. Examples include attempts to restore oak to the disturbed forests of eastern North America, and British colonial silviculture for teak in the Western Ghats of India and light *meranti* species in the lowlands of Malaya. Creation of large canopy gaps in such forests has often been found to favour competitive weeds and climbers, requiring intensive manual or chemical clearance to favour desirable trees species regeneration. Selection approaches and enrichment planting are beneficial.

Evolving perspectives - expert views at the present time

Views about PAWS restoration and the retention of timber potential were sought and obtained from knowledgeable people across the forestry sector - public agencies, charitable conservation bodies and private forestry interests. The study coincided with a point in time when there was considerable uncertainty and instability in many public and charitable sector bodies, with knock-on effects on available staff time and enthusiasm to engage with research conducted by an independent party. In addition PAWS restoration has recently become something of a "bone of political contention" between actors in the forestry sector, particularly in England. This tends to encourage reference back to official public policy documents rather than personal commentary. Public agency policy staff generally continue to support the implementation of PAWS restoration in support of UKBAP habitat restoration targets. There is increasing recognition of the merits of more gradual silvicultural approaches and less emphasis on the rapidity of restoration action. Some agency commentary suggested realisation that a more commercial "ecosystem service" ethos may now prevail, with a feeling that PAWS restoration work might risk "going off the boil". Charitable conservation agencies such as the Woodland Trust support increased PAWS restoration activity, and are increasingly seeking to promote this by demonstration and extension work directed at public and private sector growers. The focus is "mainstreaming" of PAWS restoration as part of normal productive silviculture, although production of timber from charity-owned sites after the initial restoration fellings remains the exception. Private growers and forestry agents can see PAWS restoration as an artificial policy imposition and are often reluctant to embrace it, even if marginal cost of operations is defrayed by the public purse. Long-term, autonomous revenue generation potential of quality conifers is usually prioritised. An atypical minority of private growers and foresters undertake PAWS restoration/ enhancement as part of CCF conversion work.

Summary of the case-study examples reported

Case Study 1 - Robson's Spring, North Yorkshire

This is one of the better examples of progressive PAWS restoration on Woodland Trust property. A range of thinning treatments are being used to gradually restore oak-ash-hazel woodland to compartments replanted with western hemlock, European larch, grand fir and Norway spruce in the period 1960-1980. Conifer timber is being harvested for conventional markets. The site is intended to serve as a demonstration example of best-practice in PAWS restoration for private woodland owners locally.

Case Study 2 - Haverthwaite Heights, Cumbria

This example highlights the role of well-tended enrichment plantings and early respacing of natural regeneration of native tree species in producing a quality crop of hardwoods for the future, during PAWS restoration work. The owners (Lake District National Park Authority) have clearfelled compartments of post-war spruce and larch and are restocking these with a view to future quality hardwood timber production. Other fine crops of larch and sycamore on the site are subject to selective thinnings.

Case Study 3 - Assington Thicks, Suffolk

This is an interesting example of different approaches to PAWS restoration within a medium-sized private woodland in lowland England. Crops of grand fir established in the 1960's are being coupe-felled and restocked with planted oak-hazel mixtures. Stands of oak from the 1950's with western red cedar and larch nurses are being gradually thinned, reducing the conifer element and promoting oak stems for veneer. More recently planted oak may need to be pruned in future due to the lack of a nurse.

Case Study 4 - Melbury Estate, Somerset and Rushmore Estate, Wiltshire

These two traditional private estates in the Wessex region are using continuous-cover forestry techniques to manage PAWS plantations of Norway spruce (p1950-71). Specialist forestry adviser Andy Poore of SelectFor is implementing a conversion to permanently irregular structure in both cases. At Melbury the objective is to achieve a predominantly quality hardwood growing stock over the next 30 years (PAWS restoration) while Rushmore aim to enhance PAWS with retained productive conifers.

Case Study 5 - Windsor, Leconfield and Duncombe Park Estates

This case study brings together experience from traditional private estates in Berkshire, Sussex and Yorkshire where quality hardwood timber is being produced on PAWS sites with the continued existence of a coniferous component. At Windsor and Leconfield, variants of the traditional "nursing mixture" approach have been used to establish quality hardwood crops, whereas at Duncombe Park an interspersed mature conifer component is being progressively removed from some areas, with future forestry emphasis being placed on quality hardwoods. These approaches offer a "two stage" strategy to create a productive mature native hardwood resource on PAWS sites, but are strongly dependent on consistent access to silvicultural expertise.

Summary of the case-study examples reported

Case Study 6 - Martinshaw Wood, Leicestershire

This site is an example of the common lowland PAWS situation where wartime clearfells were restocked by the Forestry Commission with a mixture of native hardwoods (in this case oak) and non-native conifers (in this case Scots pine, Corsican pine, western red cedar, western hemlock). The current owners (Woodland Trust) are progressively harvesting the conifer component to standard markets, favouring the oak element, which could be managed for future timber (over a birch-hazel coppice).

Case Study 7 - Rainsbarrow Wood, Cumbria

This Forestry Commission woodland in the Duddon Valley (south-west Lakes) is an excellent example of enhancement of an upland PAWS site previously replanted with beech and some conifers in the 1960's. While conifer compartments are being felled and naturally regenerated with birch-hazel-ash, beech crops have been thinned twice. The beech (along with components of ash and sycamore) are of fine form and will yield valuable firewood and later sawlogs. Veteran oaks and lime are being preserved.

Case Study 8 - Duchy of Cornwall/ Bovey Valley/ Eggesford/ Ramscombe

This case-study focuses on gradual PAWS enhancement/ restoration approaches on a range of sites in south-west England where very high-quality mature crops of Douglas fir are present. These are valuable for financial capital and income, long-term carbon sequestration in construction timbers and landscape/ tourist amenity. Growers are generally very reluctant to restore PAWS if this means losing the Douglas fir opportunity, but fortunately it is possible to "bring on" a near complete native hardwood stand "underneath" these very tall, well-spaced conifers. High-level skills in selection silviculture, marking, motor-manual directional felling and sensitive extraction are required to operate such systems effectively, especially on steep slopes.

Case Study 9 - Alice Holt Forest, Hampshire

PAWS restoration within this large Forestry Commission forest in south-east England highlights some of the issues and challenges encountered with such work on the public forest estate. Earlier policy/ technical advice to emphasise the early removal of conifers, followed by patience with regard to natural regeneration, has tended to produce variable stocking, lack of desirable species and reduced standing volume/ capital. Replanting is now in use to produce more certain outcomes on PAWS sites.

Case Study 10 - Stonedown Wood, Wiltshire

This example highlights what is possible on the public forest estate when managers are willing to employ a gradual CCF silvicultural approach to PAWS restoration. Postwar crops of Douglas fir, Norway spruce, larch and western red cedar are being progressively thinned to release existing components of beech, ash and sycamore and to promote natural regeneration of site native species and ground vegetation. A similar stand example from the Forest of Dean is mentioned briefly for comparison.

Summary of the case-study examples reported

Case Study 11 - Bessy Bank, Cumbria and Chopwell Wood, Tyne & Wear

These woodlands represent the situation of conversion from pine-larch dominated plantation forestry to hardwood forestry on the public forest estate in the north of England. This is being undertaken both with the objective of ecological restoration of PAWS sites and also to mitigate the threat to pine and larch from novel pests and diseases. Gradual thinning of post-war larch crops allows for the development of a hardwood understorey that should supply first woodfuel and later quality saw-timber.

Case Study 12 - small private woodlands in Herefordshire/ Oxfordshire/ Perthshire

This case study uses experience from three small private woodlands in different parts of the country to highlight issues affecting the rapidly-expanding new generation of "first-time" private owners of small woodlands with a PAWS history. Such owners generally want to avoid major impacts on visual amenity and wildlife values of their holding and may lack access to capital and forestry machinery. Main crops include Douglas fir, larch and western red cedar, with an aim of gradual partial conversion to well-managed hardwood stands (mainly oak and ash) for woodfuel and carpentry.

Case Study 13 - Glenmore Forest, Inverness-shire

This case-study deals with the large scale restoration of Caledonian pinewood habitats at Glenmore Forest in the Cairngorms, owned and managed by the Forestry Commission. Maturing plantations of spruce and lodgepole pine were coupe-felled over the period 1992-2004, with natural regeneration colonising gaps created. This is being cleaned of non-native seedlings on an ongoing basis, favouring Scots pine. Older plantations of Scots pine are being naturalised by various thinning treatments and will continue to produce saw-timber until regenerating stands are more mature.

Case Study 14 - Dalavich Oakwood, Argyll-shire

This site forms part of a complex of semi-natural oak woodlands along Loch Awe that were traditionally used as industrial coppices, producing charcoal for iron smelting. Following abandonment of coppice working about half of the woodland had been underplanted with spruce and fir during the 1950's. Work has been underway since the mid-1980's to remove conifers, with detailed monitoring of the regeneration of native tree species and ground vegetation. Oak timber production is possible in future, using low-impact silvicultural methods developed for the Sunart/ Morvern oakwoods.

Case Study 15 - Camer Woodlands, Wigtown-shire

This example deals with management of dense birch natural regeneration which often arises during PAWS restoration - in this case in the oakwoods of the Cree Valley in south-west Scotland (FC Scotland and Cree Valley Community Woodlands Trust). Removal of conifers, followed by deer-fencing in some cases, has produced dense birch thickets which are being monitored for species composition. In time these may require respacing to improve the potential of the birch crop, and possibly enrichment planting to increase the proportion of oak and other desirable native hardwood trees.

Summary of the case-study examples reported

Case Study 16 - Strathcashel Wood, Stirling-shire and Callendar Wood, Falkirk

Following on from the previous example, these woodlands illustrate the use of enrichment planting on sites from which conifers have been removed by coupe-felling. In both cases there is adjoining mature semi-natural oak woodland, the intention being for this to extend onto the PAWS site. Widely-spaced initial plantings of oak have been supplemented by subsequent dense natural birch regeneration which will need to be thinned to firewood markets to reduce competition for the planted oak.

Case Study 17 - Moncreiffe Hill and Pressmennan Wood, Eastern Scotland

These examples illustrate gradual silvicultural restoration of comparable PAWS (or PAWS equivalent) sites in eastern Scotland by the Woodland Trust. Both sites have a mix of productive conifers and above-average quality hardwood plantations (mainly ash, beech and sycamore) on sites with significant public visitor attraction. Management combines gradual thinning of the better Douglas fir, larch and hardwood crops with coupe-felling of unstable spruce stands and subsequent replanting with mixed native hardwoods. Future timber production potential is being safeguarded.

Case Study 18 - Bogrie Wood, Drumlanrig Estate

This example highlights a small/ trial-scale PAWS (or PAWS equivalent) restoration project within mature mixed estate woodlands in south-west Scotland. Norway spruce crops are being heavily thinned to release mature oak embedded within the stands and to allow a hazel understorey and native ground vegetation to recover. Most major private estates in Scotland see productive conifers as the mainstay of their forestry economy and are reluctant to embrace a change to quality hardwood silviculture on better PAWS sites - this example illustrates how these objectives might be combined.

Case Study 19 - Shin Forest (Achany and Linsidemore), Invershin, Sutherland

These “lower slope” Forestry Commission PAWS blocks in Sutherland carry crops of Scots pine, spruce, larch and Douglas fir from the late 1950’s. There are adjoining areas of ancient semi-natural birch-hazel-aspen woodland. The Commission are carrying out small coupe fellings of conifers to encourage natural regeneration of these native species, which may later be augmented by enrichment planting of oak. This work is based on a careful procedure for evaluating and mapping PAWS features. In the long run some pine may be retained to support red squirrel populations and produce saw-timber, while birch, hazel and aspen could provide local woodfuel.

Case Study 20 - Lindinny/ Raelees Wood and Glenkinnon Burn, Selkirkshire

This case study contrasts different methods of PAWS restoration working in Forestry Commission woodlands in the Tweed Valley with high landscape amenity, public and community access interest. Lindinny carries mixed woodland with high quality crops of ash, birch and sycamore from which conifers were removed some 10 years ago. Above this area are remaining stands of spruce and fir managed under group systems. At Glenkinnon a conifer crop has been felled and restocked with plantings of oak.

Summary of the case-study examples reported

Case Study 21 - Edistone Ltd., Caeau-gwynedd, Powys

This case-study deals with productive silviculture in a medium-sized woodland (at least partly PAWS) on steep ground in North Wales that was acquired by the present owner in 2001, having previously been leased by FC. Crops of various conifers, beech and oak, planted in 1951 and 1965, have been thinned mainly to supply the owners' innovative firewood enterprise (oak and beech logs, spruce and firs for log-box manufacture). The thinning process is promoting natural regeneration of native trees and ground vegetation from remnant semi-natural woodlands existing on the site.

Case Study 22 - Plas Plower Woods, Coedpoeth, Wrexham

At Plas Plower, the Woodland Trust are managing an ancient woodland site along a sheltered valley that had been largely replanted with various conifers, sycamore and beech over the past 200 years within a designed landscape context. An ongoing process of small coupe felling of conifers shading ancient woodland features and thinning of the remaining conifer matrix has been under-way since 1996. Several species, including Douglas fir, western hemlock, ash, oak and cherry produce very fine timber stems on site, but there are logistical and access problems for extraction.

Case Study 23 - North Wales "Douglas fir o/ ash-hazel" (Denbighshire/ Gwynedd)

This example deals with Forestry Commission woodlands in North Wales where gradual PAWS restoration is being pursued by development of ash-hazel woodlands (with some oak) underneath a high canopy of mature, fine quality Douglas fir. The Douglas fir stands have high timber value and are important aspects of the visual forest landscape that attracts visitors to these areas. Very gradual thinning is all that is needed to allow ash to regenerate beneath. There is every possibility of developing valuable ash timber crops for the future, alongside biodiversity conservation benefits.

Case Study 24 - Ffynone and Cilgwyn Woodlands, Pembrokeshire

These woodlands (partly PAWS) in a steep-sided Pembrokeshire valley were formerly policy woods of the Ffynone Estate, owned by the Lloyd-George family, which was divided up in the 1950's. Extensive areas of mature oak woodland were then felled and replanted with investment crops of Douglas fir, larch, Norway spruce and western hemlock in the early 1960's. The woods have recently been acquired by a workers' cooperative who aim to restore them to native species composition (oak, ash, birch and hazel) by a combination of coupe-fell/ replant and gradual thinning-based methods. Some more valuable and stable crops of Douglas fir, Norway spruce and larch may be retained to produce timber over the longer term, while very dense stands of western hemlock are being clearfelled and restocked with native trees by planting and natural regeneration depending on site conditions and responses. Future coppice management in such areas will yield small pole timber and nuts for local people.

Summary of the case-study examples reported

Case Study 25 - Wentwood, Monmouthshire

This is a large area of PAWS woodland where productive post-war crops, mainly of Norway spruce, larch and Douglas fir are being managed by Forestry Commission Wales and the Woodland Trust using varied silvicultural approaches. The FC had earlier used some coupe-fell and naturally regenerate methods, but are now tending to emphasise gradual conversion by progressive thinning. The Woodland Trust are using gradual silvicultural conversion techniques, with Wentwood acting as a valuable test-bed for the optimum methods and their economic implications. There is a strong emphasis on visitor amenity and recreation potential within this forest as a whole.

Case Study 26 - Coed Dol-Fawr, Cardiganshire

This case-study deals with productive silviculture in a medium-sized woodland on very steep ground in West Wales that is owned by an adjoining hydro-electric power concern and managed by a local forestry consultant, Phil Morgan, who specialises in continuous-cover forestry techniques. Landscape amenity and slope stability are key management issues alongside ecological restoration and biodiversity conservation. Crops of various conifers (inc Douglas fir, larch and noble fir) are being thinned, serving local timber markets and providing income to support forest management. Western hemlock stands are being chemically thinned. The thinning process is now allowing natural regeneration of native trees and ground vegetation from extensive remnant semi-natural oak woodlands existing on the site and around its perimeter.

Case Study 27 - Mostyn Estate, Flintshire

This case study deals with the situation of Sitka spruce plantations on a fairly exposed site which contain ancient woodland remnants (veteran oak) from a historic deer park. As with many PAWS examples involving Sitka spruce, the managers are seeking to retain the productive conifer crop while embarking on some PAWS enhancement work. Veteran oak are being released through halo-thinning, while the matrix of the crop is regularly thinned for woodfuel. Selection forestry is more difficult in this situation than on sheltered sites where Douglas fir and larch are the primary conifers.

Generic Case Study - upland Sitka spruce (locally with lodgepole pine and/or larch)

Examples of PAWS restoration involving former/ retained Sitka spruce crops within this project have generally been restricted to the more lowland/ foothills examples (e.g. Haverthwaite, Dalavich, Strathcashel and Callendar) or the rather specialised case of the Caledonian pinewood restoration work at Glenmore/ Glen Garry. Above the 200m contour in Wales, Cumbria and Southern/ Eastern Scotland and from lower elevations in the Scottish Highlands, PAWS restoration from Sitka spruce plantations by gradual selective conversion is still uncommon. Windthrow hazard, poor soils, lack of previous thinning and difficult extraction logistics have generally rendered such attempts problematic and uneconomic. Current PAWS restoration work on such sites on both public and private ownerships is still being undertaken by more extensive patch clearfelling, with either deer-fenced replanting or natural regeneration to follow. In some cases the regeneration contains a significant component of conifer species and in most cases it has not yet been tended to develop its future timber potential. Due to the slower rates of growth, it was felt to be too soon to judge the latent timber / woodfuel potential in these young hardwood stands or to single-out examples fairly.

Visual assessments of stand composition and floristics

The tables on the succeeding pages present indicative information about the principle tree species and ground flora present within each case-study example at the time of this study. For composite case-studies, these are aggregated to a common format. This information is derived from a fairly rapid "forester's walk" through these sites and not on detailed plot recording. As such, minor components of the stand and vegetation may not be fully described. The information is presented here to inform the reader as to the main resources that are being managed and should not be used in future for any other PAWS management or assessment purpose. Planning of PAWS restoration or enhancement works should be based on more detailed surveys conducted at the time.

In some cases, more detailed stocking information, derived from owner management plans and compartment records, is presented within the Electronic Appendix pockets. Similarly there is a large resource of digital photography (some located) for each site.

Legend to these tables

Fd = felled
V/O - veteran/ over-mature
M = mature timber (usually >20cm dbh for conifers, >30cm for hardwoods) [saw-log]
ST = small timber (usually <20cm dbh, but >7cm dbh) [woodfuel/ small-roundwood]
Rg = regeneration (planted or self-sown) [may be saleable for biomass/ craft uses]

neg = negligible proportion
1 = 0-20% cover
2= 20-40% cover
3= 40-60% cover
4= 60-80% cover
5= 80-100%

D = Dominant
Co-D = Co-Dominant
A = Abundant
F = Frequent
O = Occasional
R = Rare
LO, LF, LA, LD = Locally (Occasional, Frequent, Abundant, Dominant)

Opportunities for and approaches to retention of timber potential

Silvicultural planning and monitoring

One essential pre-requisite of retention of timber potential on PAWS restoration sites is effective silvicultural planning and monitoring. This should be carried out by a competent and experienced person, preferably a professional forester, and should be based on an effective appraisal of initial stand conditions. Owner objectives, including the potential for future timber production, should be properly considered alongside biodiversity and conservation aspects. Available financial resources, equipment and expertise should be realistically evaluated. An adequate, but not over-laborious, approach to subsequent stand monitoring should be selected and implemented, with effective record-keeping. There should be a clearly-defined "desired future condition" for each stand, avoiding the "we'll wait and see what happens" paradigm, especially to natural regeneration dynamics. It has to be remarked that many previous schemes have proceeded on an "emergency deconiferisation" basis without adequate appraisal of the initial stand conditions, management planning or monitoring protocols. Research priority should focus on developing simple semi-quantitative monitoring protocols that are within the reach of operational foresters, as opposed to researchers.

Clearfell-replant and clearfell-regenerate approaches

In some situations, approaches to PAWS restoration based on a single-intervention removal of the coniferous canopy may be preferred or unavoidable. These are most common in the uplands where physical access and exposure/ stand instability constrain the adoption of more gradual approaches. Some lowland situations, such as dense, un-thinned western hemlock or grand fir stands may also require clearfell. To recover maximum timber value from the conifer plantation, felling should be as close to maximum MAI as possible, unless conservation imperatives dictate otherwise. Interim measures to protect ancient woodland features (e.g. halo-thinning, keyhole felling) can be used to reduce the pressure for premature clear-felling of the conifer matrix on more sheltered sites. After felling, timber potential emphasis should be placed on the promotion of a quality crop of desirable native hardwood trees. A key problem with clearfell restoration is the promotion of competitive weed growth. An excessive reliance on natural regeneration should be guarded against, with appropriate consideration being given to supplementary planting and use of "nursing mixtures".

Continuous-cover forestry approaches

Wherever possible PAWS restoration and enhancement should be carried out using gradual "continuous-cover forestry" approaches that "manage down" the non-native conifer element and "manage up" the productive/ desirable native hardwood element over a suitable period. Such approaches avoid an undesirable hiatus in forest micro-climate, carbon storage and timber income. They also allow better control of potentially competitive ground vegetation, fostering more sustainable natural regeneration of desirable native species. Again, effective management planning and monitoring is essential. False urgency to complete the restoration/ conversion within the current coniferous rotation should be avoided - it may well be appropriate for a coniferous component (including natural/ artificial regeneration) to be carried forward into the next rotation period and beyond, if well-managed. A variety of shelterwood and selection forestry approaches are available, depending on whether the successor crop is to be promoted "under" or "in mixture with" the retained conifer component.

Timber production from retained mature native trees (inc Caledonian pine)

A sub-set of PAWS restoration and enhancement projects involve the potential to retain and realise timber potential in mature native hardwoods (or Caledonian pine). This was true of some of the earlier projects where the priority was seen to be removal of introduced conifers from relatively well-preserved ancient woodland habitats. Good examples are found within the Caledonian pinewood habitats of the Scottish Highlands and the Atlantic oakwood habitats of Scotland, Cumbria and Wales. Some more lowland examples are also found in under-planted oak, ash and beech woodlands. Timber from such native trees can often support local wood-using businesses and generally enters long-life carbon sequestering applications. Appropriate and sensitive silvicultural approaches have been developed for these sites, but there can still be perceived conflicts with biodiversity/ conservation objectives, including the protection of sensitive bird, invertebrate and lower plant populations. An automatic "conservation lock-down" approach, following the initial removal of conifers, should be resisted, as this will risk loss of timber potential and may deter future owners and managers from agreeing to PAWS restoration work.

Timber production from retained mature conifers

Other than in clearfell situations, there should be retained timber potential in non-native conifers on PAWS sites undergoing restoration/ enhancement. This potential should be partitioned between that in conifers which are eventually to be removed, and those which have been accepted as a permanent stand component. The latter element should generally not exceed 20-30% cover and should be well distributed across the site, avoiding local perpetuation of heavily-shaded plantation conditions. Where possible the retained conifer component should avoid those areas with concentrations of ancient woodland features to limit shading and harvesting impacts. Usually, part of the standing conifer element will be removed at or before MAI under PAWS restoration scenarios, but the retained element may be allowed to persist to greater timber sizes and ages under variants of the "continuous-cover forestry" approach. This can produce timber of high individual stem value which is particularly suitable for building construction applications - beamwork, decking and cladding. The most commonly retained conifer species are Scots pine, larch and Douglas fir which cast less shade, but spruce, hemlock, red cedar and *Abies* firs can be retained where they can be well managed silviculturally and their regeneration properly regulated.

Natural regeneration and selective respacing

Very many PAWS restoration projects, especially those using patch clearfell, result in a subsequent successor crop dominated by spindly birch at variable density. Some sites will also regenerate ash, sycamore, rowan, willow or alder. Oak is less common. Where natural regeneration is inadequate (or does not contain sufficient desirable species - good birch, ash, oak, beech, sycamore, cherry) supplementary or enrichment planting may be required. Where the natural birch regeneration is dense it should be appraised early for inherent stem quality. Where there are sufficient good stems, there should be a selective respacing operation prior to firewood thinning diameter to favour the better stems and minority species such as oak, ash and cherry. Local markets for birch rods - e.g. aluminium pokers, horse-jumps and traditional besoms - can help to offset the costs of what would otherwise be a pre-commercial intervention at a stand age of 8-12 years, with dbh below 7cm. Where the form of the birch is poor it may be better taken on to firewood diameters prior to thinning or clearfelling.

Thinning and woodfuel markets

While conditions vary, a useful distinction may be made between selective respacing (<7cm dbh) and first thinnings (>7cm dbh). Whereas only the better hardwood regeneration may justify earlier respacing, thinning should generally be applied to all stands once they reach the saleable diameter for woodfuel (usually above 10-15cm). This includes young growing stock in clearfell coupes and within CCF forestry stands. Age at first thinning varies depending on species and site productivity, but should generally be before 15 years. Prior to the recent rise in woodfuel prices, first entry to such stands was often undesirably delayed, reducing longer-term productivity. The current strong prices for regular hardwood woodfuel mean that such operations should usually cover their costs or make a surplus, unless very inaccessible. Alternative markets for small-diameter roundwood include hardwood pulp. Respacing may be done by manual methods (loppers, clearing saws) or chainsaw. Thinning will be by chainsaw or occasionally harvesting machines to create racks. Thinning should almost always be selective on form and should also be used as the first major opportunity to modify species composition, preferably based on some form of quantitative pre-assessment of stocking. Almost all other species should be preferred over the birch matrix to promote diversity and develop silvicultural options. Some undesirable non-natives such as western hemlock, Sitka spruce etc may be completely removed at this stage if desired. More controversial is the decision on "desirable" conifer regeneration such as Scots pine, larch and Douglas fir - these species may be retained at regulated density to form part of the future stand.

Supplementary or "enrichment" planting (including use of "nursing mixtures")

The PAWS restoration/ enhancement process in Britain has placed excessive reliance on natural regeneration to date, and this has been associated with a reduced attention to the retention of timber potential. While natural regeneration can sometimes deliver a successor stand of desirable species and high quality, more often than not this is not the case, especially on clearfell sites. Lack of seed supply, stiff weed competition, rebound of the soil water table and excessive browsing are the common causes. Where natural regeneration is prolific it often contains only a small proportion of desirable species (oak, ash, sycamore, beech, cherry, Douglas fir and larch), rather being dominated by birch of poor form and sporadic spruce and hemlock stems. Supplementary planting can be used either prior to natural regeneration arising, or in natural or artificially-created planting gaps within it, to improve the species mix. Planted trees should be properly defended from weed competition and browsing. In some situations, "nursing mixtures" with pine, red cedar or another conifer can be used to establish a quality crop of native oak or ash, prior to planned removal. Although controversial on PAWS sites, they have a place in closely-managed woods.

Pruning and tending aimed at future quality timber crops

Rather few British PAWS restoration projects relying on natural regeneration have reached the stage where pruning and other mid-rotation silvicultural interventions have been contemplated. In those fewer cases where an investment has been made in establishing quality hardwoods by planting, some pruning and cleaning work has been carried out. It can also be relevant to quality conifers such as Douglas fir or red cedar. There should probably be greater attention to the potential value of pruning better hardwood stems in natural regeneration, and expansion of that to public and charitable land ownerships - at present almost all such work is pursued on the private estates.

Constraints on and challenges to the retention of timber potential

Abiotic site factors - exposure, soils and terrain

Especially in upland areas of Scotland, Wales and the North of England a combination of steep slopes, poor physical access/ soils and climatic exposure act as significant constraints on the co-location of PAWS restoration and timber production. In these situations it may be impractical to carry out multiple-intervention removal of the existing coniferous canopy due to costs of accessing the site and the higher risks of wind-throw of conifers retained under attempted continuous-cover systems. It may also be more difficult to justify the costs of establishing and tending a quality crop of young native hardwoods, given the likely low rates of growth and inferior stem form typically achieved in existing upland hardwoods. It proved difficult within the present study to identify examples where upland Sitka spruce was retained as a productive component on PAWS restoration sites - almost all Sitka spruce crops were either retained with only PAWS "hotspot" release or clearfelled with untended mixed species regeneration. Careful appraisal of such situations is required to discriminate between those where the physical constraints are actually binding and those where a "preference for simplicity" among operational forestry staff leads to over-caution. PAWS restoration in the uplands remains essentially an experimental activity, but opportunities for quality timber and woodfuel production from Caledonian Scots pine, silver birch and aspen are increasingly being recognised, especially within Scotland.

Silvicultural and past management factors

A considerable proportion of contexts in which PAWS restoration or enhancement is being contemplated or conducted are un-thinned or poorly-thinned post-war conifer stands that have effectively been neglected since their original establishment. In many cases, it it this neglect, rather than the original selection of coniferous species, that places remnant ancient woodland features under current threat. Despite recent adversarial commentary in the press, examples of such deficient management can be found in woodlands under all ownership categories. In the uplands it may often have resulted from poor access or concerns over wind-throw risk, whereas in the lowlands poor prices for small-diameter roundwood or competing woodland uses (e.g. sporting) are cited. In some cases the opportunity to restore or convert such stands by application of gradual approaches, along the lines of continuous-cover forestry, may well have been lost. This applies particularly in over-dense stands of shade-casting species such as spruce or western hemlock. There is often a need to carry out early work (e.g. halo-thinning, patch felling) to release or protect remnant ancient woodland features (e.g. veteran trees, ground vegetation hotspots). The conifer matrix may then have to be removed by a single-intervention felling to forestall extensive conifer regeneration or to reduce the risk of progressive wind-throw resulting from the instability of the stand. In some cases, chemical-thinning or girdling may represent a viable alternative, extending the period of woodland shelter to regeneration. Again, careful appraisal of such situations is required to discriminate between those where silvicultural constraints are real and those where unfamiliarity leads to over-caution. Numerous convertible conifer stands have been prematurely felled off PAWS sites.

Skills, familiarity and experience

One of the most frequently encountered explanations for the lack of endeavour to retain timber potential on PAWS sites is lack of available skills and experience. This

applies both at the professional forester/ forestry agent level and at the forest technician level. There is a perception that this problem is growing worse, with fewer estates replacing a traditional head forester/ retained agent following retirement of the incumbent and with suitably qualified staff in the public and charitable sectors either retiring early or having to spread their efforts across an unrealistically wide land base. Increased rates of turnover of staff/ advisers across all three ownership categories makes it more difficult to accumulate silvicultural experience and detailed knowledge of the long-term development of any given woodland. This is often combined with inadequate record-keeping of the initial silvicultural condition of PAWS restoration sites and of subsequent removals/ silvicultural treatments. These factors taken together make it more difficult to pursue a consistent course of silviculture, whether that is continuous-cover transformation, gradual PAWS restoration or any other. Parallel declines (mainly due to retirement) in the number of contractors with motor-manual/ directional felling skills and the relevant types of light, flexible extraction equipment also impose constraints on the implementation of sensitive thinning and CCF harvesting operations, especially on steep terrain in the uplands. There is a noticeable regional variation in this problem, with the greatest difficulties encountered in the remoter uplands of Scotland and Wales, where clearfell operations using heavy harvesting and forwarding equipment have become the industry norm. Mixed woodland areas in parts of southern England, the Marches etc have usually retained a more diverse and flexible contractor and equipment base, which is of considerable value when approaching the gradual PAWS restoration and enhancement ambition.

Economic considerations

Economic and financial considerations play an important role in influencing owner/ land manager decisions regarding PAWS restoration and the retention of timber potential. The priority given to the process of PAWS restoration in the allocation of public funding for forestry was one of the major driving forces in the earlier adoption of the concept. This applied both to direct cost-support for work on the public forest estate and to grant-in-aid for work on other ownerships, across the three home countries. However at present, economic considerations are tending to slow down the rate at which PAWS restoration work can be pursued, and in some cases mitigate against the selection of the optimal methods for retaining future timber potential. On the public forests, public spending constraints risk increasing the need to realise short-run timber revenue from the harvest of standing crops and enticing managers to minimise the subsequent costs of restocking and young-growth tending. This favours the "clearfell-regenerate" approach, and can lead to adverse perceptions of recourse to "low-input, low-output" management of the public forest resource in the future. It can be subject to critique as a "selling the family silver" approach that cannot be repeated. On the private estates, improved prices for timber and woodfuel are making owners and agents more reluctant to embark upon PAWS restoration/ enhancement where this is seen to close-off future options for long-term productive coniferous forestry. As there is limited (in some cases no) remaining grant-in-aid for restocking PAWS sites with conifers, some owners/ managers, especially in the lowlands, are tending to prefer approaches that preserve coniferous or mixed-coniferous stands by means of progressive thinning and natural regeneration under variants of the continuous-cover forestry approach. This can be consistent with either PAWS restoration or PAWS enhancement depending on the degree of conifer cover retained over the longer-term. In the uplands, however, economic considerations tend to push owners/ managers towards selecting between either (a) "low input, low output" PAWS restoration by the

"clearfell-regenerate" approach (where future timber potential is foregone) or (b) resistance to PAWS restoration, with stands replanted with improved Sitka spruce. There is a perception that forestry grant schemes are too complex/ bureaucratic and to be avoided if possible, promoting an approach that minimises management costs. By contrast, improved prices for small-diameter woodfuel may help to offset some of the costs of otherwise pre-commercial respacing and thinning operations. This will encourage the more knowledgeable/ innovative owners/ managers to see the economic potential of successor hardwood crops on PAWS sites, favouring stand improvement. Overall there is a trend away from "grant-driven" approaches to the management of existing woodlands, towards a "self-funded" or commercial approach - this will probably support (albeit gradual) PAWS enhancement in the lowlands, but will reinforce intensive spruce plantation forestry in more accessible parts of the uplands. "Clearfell-regenerate" PAWS restoration approaches will appeal on inaccessible sites. Establishment of new woodland remains an almost entirely "grant-driven" activity.

Conservation imperatives

In some situations, there is a perception of potential conflict between retention of timber potential (and management for timber) on PAWS sites and biodiversity/ conservation objectives of the restoration process. Those concerns are most often expressed by those with biodiversity/ conservation policy remits, in both public-sector and charitable conservation agencies. Some native woodland advocates would appear to equate PAWS restoration with the adoption of future non-intervention management as an article of principle, whereas others approach the discussion on a more pragmatic "case-by-case" basis. There is no question that these differences of perception can serve to engender highly counter-productive "stand-offs" between the conservation and production "branches" of the forestry sector. There is some sense that such divisions, which had faded out following the "Flow Country" debate, have been rejuvenated in recent months as an aspect of the economic situation. There is very limited published scientific evidence to shed light on these discussions either way, particularly if one looks for material based on British domestic experience. There is slightly more deriving from the Continental European "Norway spruce v beech" controversy, but even there, detailed research and monitoring have been quite limited.

The issue is best divided between (a) concerns over potential adverse effects of retained conifers and (b) concerns over potential adverse effects of forestry operations. The latter issue is closely allied with the problem of shortage of operational skills and experience highlighted above, and can best be tackled by a combination of training and technical exchange. The need for sensitive harvesting and extraction practices, coupled with soil protection and fostering of the deadwood resource, are now better recognised and are increasingly being realised on the ground. Given those prerequisites, it should rarely be necessary for woodland management for timber production to be avoided for conservation/ biodiversity imperatives - it just needs to be better planned/ conducted. Those conservationists proposing such operational constraints - for example, by arguing against well-tended planting of native hardwoods or sensitive hardwood silviculture on priority PAWS restoration sites - must be asked to produce better justification for their positions. On the issue of retained conifers, there is considerable variation and inconsistency between policy and guidance extended by different agencies and sub-divisions thereof, over time. Some will argue that a PAWS site can be considered to be "restored" when more than 50% of the canopy is of native species, whereas others are concerned on principle by

the permanent retention of even 10% of non-native conifers. Such differences, especially in the absence of sound under-pinning science, confuse practitioners. It would seem that a compromise position of permitting long-term retention of 20-30% of well-managed non-native conifers, well distributed on the site, will minimise the risk of shade-related impacts to native trees/ vegetation or of soil acidification. This will offer considerably greater opportunities for retained timber potential than a minimalist 5-10% "conifer limit", while encouraging appropriate thinning works. Further research is needed on the potential long-term effects of conifer retention at the 20-30% level on biodiversity/ conservation features. This applies especially in upland situations where shade-tolerance of those features may be thought to be lower. It may be appropriate to calibrate the permissible retained conifer cover fraction according to the conifer species involved, stand structure and biodiversity composition, but realistically we simply do not have the level of scientific data required for that. The precautionary principle must be applied in the interim, but not to an excessive degree.

Carbon storage implications

There is an emerging debate over the carbon sequestration and storage implications of silvicultural operations, including those aimed at PAWS restoration/ enhancement. This needs to be considered alongside differential effects of PAWS restoration on woodfuel availability. There is little doubt that initial silvicultural interventions, particularly under "clearfell-regenerate" and "clearfell-replant" approaches, noticeably reduce the carbon stored on site. The fate of the carbon transported off-site in the form of timber products will be partitioned between woodfuel, short-life products such as paper and longer-life products such as construction timber. The proportion of the latter will usually increase as the conifer stand being thinned or felled matures. On balance, PAWS restoration approaches that minimise or avoid the "standing volume gap" following initial intervention might be favoured, while trees continue to add increment. Where possible, felling in advance of annual increment should be avoided unless the initial condition of the stand is markedly over-stocked. The longer-term carbon balance on PAWS sites is much more complex and uncertain. In some situations there is likely to be a long-term reduction in overall annual increment (GYC), as the native species favoured will usually have a lower yield than conifer crops such as Douglas fir and Sitka spruce. The difference will be less pronounced on good hardwood sites currently stocked with less productive conifers such as pine and larch, especially where the latter display reduced yield due to climate and pest/ disease factors. However the yield reduction may be counter-acted by an increased "rotational mean" standing volume in well-managed hardwood or mixed-hardwood stands on PAWS sites - this will depend on species choice and silvicultural systems selected. Removals by harvesting from such mature mixed stands are more likely to enter predominantly longer-service applications such as furniture or construction timber or to be used as woodfuel, offsetting fossil fuel consumption. As compared with regular conifer plantations, rather less of the harvested material will be used for short-life products such as pulp and paper which decay during service or soon after service completion. However there is usually a greater deliberate retention, and subsequent natural forest decay, of deadwood on restored PAWS sites as an article of conservation policy - a balance is required in this area. Some management on restored PAWS sites, such as hardwood coppice and early thinning, may be well-suited to the production of industrial woodfuel, rather than pulpwood. Due to the complexity and variation involved in PAWS restoration practices, thorough carbon life-cycle analyses, incorporating woodfuel production, are to be advised.

Reconciling perceived conflicts between conservation and timber production

There a number of frequently-cited areas of perceived conflict between biodiversity conservation and timber-production on PAWS sites (especially those of higher value), which can constrain management innovation. Below are some thoughts on these, based on observations during case-study research and study of the existing literature:-

Shading and soil acidification by retained conifers - these effects can very likely be mitigated by reduction of the conifer canopy cover to 20-30%, well distributed, and avoiding PAWS "hotspots". There is limited evidence that reduction to 10% cover (probably below the productive conifer "critical mass") has significant advantages for biodiversity or soil amelioration, but more research may be justified on that point. Soil effects are very strongly dependent on the conifer species involved and the initial soil conditions. A hardwood component in the litterfall will usually avoid significant problems in mixed woodlands. Sensitivity to retained conifer shading is likely to be much greater on upland sites where the biodiversity is less shade-tolerant - for example acid ground vegetation, butterfly food-plants and some moss/ lichen species.

Conifer natural regeneration - this can certainly be an issue with western hemlock, *Abies* firs, western red cedar and to some extent with Sitka spruce. Douglas fir, larch, pine and Norway spruce regeneration presents a much more localised challenge. "Propagule pressure" increases with stand age and its effects are strongly differential depending on soil type - the risks are highest on freely-draining soils of low to moderate fertility. The regeneration of these species can be effectively controlled and managed on estates and forests where there is a high-quality silvicultural input with regular interventions, but becomes much more difficult to deal with in poorly-tended woodlands. A risk-based approach to decisions on conifer removal is still appropriate.

Disturbance of biodiversity during establishment and tending operations - in almost all situations this can be mitigated by appropriate silvicultural practice, well-planned and conducted by experienced personnel. Most problems arise from non-expert implementation of "prescription-based" establishment models. Lowland sites present fewer live issues. Any need for mounding on upland re-planting sites (especially following clearfell of conifers) is more of a concern and should be avoided where remnant PAWS features are of higher biodiversity/ conservation value. Natural regeneration, perhaps with some enrichment planting, is the preferable approach, but further research into effective restocking, developing the FR EMIS tool, is desirable.

Disturbance of biodiversity during harvesting operations - again, such issues can most often be mitigated by appropriate silvicultural practice, well-planned and conducted by experienced personnel. Many problems arise from the use of unsuitable (over-weight) harvesting and forwarding plant, where more flexible and traditional motor-manual and light-weight skidding/ forwarding systems would be more relevant. This is accompanied by a need for skills development and technical training inputs. Careful planning of PAWS restoration sites, such that biological reserve areas are positioned "behind" rather than "in front of" timber working circle areas is essential. Careful scheduling of harvesting work on a seasonal basis to reduce biodiversity impacts (e.g. on ground vegetation and nesting birds) is also a pre-requisite. Special considerations may apply to situations such as old oak and hazel stools that support a diversity of lichens - for example restoring coppice working may be inappropriate.

Reduction of genetic, age and structural diversity through management - issues such as the reduction of veteran/ over-mature trees and deadwood components in stands managed for timber production are not unavoidable. In woods worked on the permanently irregular systems these can be retained as a distributed component throughout the production working circle, but in many situations the "biological reserve" approach is probably more realistic, focussing on the less accessible parts of the site and being positioned to avoid their disturbance *en route* to the production working circle areas. It is not essential that the biological reserve is put onto a "non-intervention" prescription - that may be relevant in some cases, but elsewhere a low-impact silvicultural system (LISS) approach may allow the continued production of high-quality conifer or hardwood timber on a long-rotation, selective forestry basis. This is typically the case in the Riparian Buffer Zone (RBZ) along broader streams.

Planting of non-native trees on PAWS sites - a particularly controversial aspect of PAWS restoration practice is whether there is any situation where re-planting of non-native species can be justified as a part of restoration/ enhancement silviculture. It is essentially proscribed on the public forest estate and would rarely be considered under most charitable conservation ownerships. Some private forest managers wish to have the option to re-plant conifers such as pine, larch and Norway spruce, following coupe-felling, as an element of nursing mixtures, primarily with oak. The Windsor case-study highlights a situation where that approach has been endorsed. In other situations there may be a desire to plant small amounts of desirable conifer species such as Douglas fir or western red cedar as an enrichment intervention, for example in mature stands of pine or larch likely to become vulnerable to pest and disease impacts. The intention would be to create a valuable native hardwood stand with a minority ongoing component of high-value conifers. Although some commentators will disagree, the author feels that these options should remain open, as an element of PAWS enhancement works, where there is a track record of proficient estate silviculture, regulating stocking to maintain diverse woodlands. Future climatic change and pest and disease pressures militate in favour of maintaining flexibility in the selection of tree species for productive forestry, including on PAWS sites.

Wildlife management issues - grey squirrel damage on young stands (and more occasionally deer, rabbit and vole impacts) can deter many forest managers from tending promising hardwood crops towards a crop of timber. This in turn may persuade them to favour retention of a predominantly coniferous forestry model and only limited efforts in the direction of PAWS restoration. Such views can be heard frequently on both the public and private forest estates. More effective control of these pest species would be of mutual benefit to both biodiversity conservation and timber production aspects of management following PAWS restoration, not least in areas where the protection and expansion of red squirrel populations is an objective. There is a need for the re-assertion of the production of quality hardwood timber on both public and private estates as being an article of public benefit, with a concomitant re-introduction of effective grant-in-aid for crop protection/ pest control.

Conclusions and recommendations

In terms of the research questions proposed, the conclusions of the work were:-

1. The case-study examples reported here represent atypically superior practice. Retention of timber potential in PAWS restoration work conducted to date has frequently been disappointing, with many projects involving single-intervention removal of the coniferous canopy, with untended and patchy regeneration. Only a small minority of projects have embraced adequate subsequent stand tending. More recently there has been wider adoption of more gradual silvicultural conversion of stands, which, if followed through on, may retain timber potential.

2. For timber potential to be retained, there must be effective and relevant pre-intervention silvicultural planning and subsequent adequate monitoring. Planning and execution of the PAWS restoration/ enhancement silviculture must be carried out by proficient and experienced professional foresters and operational staff. Shortages of such personnel and skills remain the most serious impediment to high-quality PAWS silviculture and a major effort on training and extension is called for. There remain situations (especially in the exposed uplands) where single-intervention (clearfell-replant/ clearfell-regenerate) approaches are relevant. However in the vast majority of situations gradual silvicultural restoration/ conversion using variants of the continuous-cover forestry approach are to be preferred, as they help retain/ realise value in the coniferous crop and provide more favourable conditions for the establishment of a successor crop of timber.

3. The balance between retention of a minor proportion of high quality conifers in the stand and development of quality successor hardwood crops will vary between sites, depending on biophysical conditions, owner objectives and conservation features/ priorities. Both aspects should be given adequate consideration from the outset and no timber opportunities should be foregone unless this is unavoidable on conservation grounds. The most successful examples tend to combine early protection of surviving ancient woodland features, continued selective thinning of the coniferous matrix/ overstorey and the subsequent promotion, enrichment, selective respacing and pruning of the hardwood (or mixed-wood) successor crop.

4. There is little evidence that retention of timber potential in native hardwood species conflicts with biodiversity/ conservation objectives as long as silviculture is well-planned, sensitive and properly conducted (including deadwood retention). Retention of a coniferous component in the long-term is more controversial, but should often be consistent with biodiversity/ conservation objectives as long as the canopy fraction is moderate (max 20-30%), conifers are kept well spaced and coniferous advance regeneration (e.g. western hemlock) is appropriately managed. Harvesting and extraction must be carefully planned and conducted. Some more light-demanding upland vegetation, lower plant assemblages etc may conceivably require complete conifer removal, but that assertion requires firmer evidence.

5. Current approaches to the evaluation of sites for PAWS restoration/ enhancement on conservation grounds remain appropriate, but should be supported by more realistic appraisals of economic timber opportunities and available silvicultural skills. Work should not be embarked upon where there are inadequate resources to see it through to completion. Sites where surviving ancient woodland features are very limited should be much more critically evaluated for relevance to PAWS.

Conclusions and recommendations

There were also several policy and practice areas where attention is clearly needed:-

Grants

It became apparent during the course of the study that the current regime of forestry grants for the management of existing woodlands (annual management grants, woodland improvement and restructuring grants etc, differing between the countries) are not fully meeting expectations and requirements in terms of flexible PAWS silviculture on the private estates. The main problems appear to be excessive bureaucracy, uncertainty as to outcome of applications, adverse timing of payments and restrictive management prescriptions (re use of conifer nurses on PAWS etc.). As a result, many woodland owners and managers are eschewing grants in favour of self-financing forest management approaches, emphasising low-cost regeneration. Uptake of grants is tending to concentrate on "organisational ownerships" (both larger private estates and charitable holdings) where there is (a) a "back office function" to assist with handling the application process and (b) access to significant working capital/ bank finance to deal with payment delays. For smaller growers, it is likely that a simple annual area payment for competent forest management, based on a suitable woodland management plan, would secure greater uptake and activity on PAWS. The concept of a "Single Forest Payment" akin to the "Single Farm Payment" is germane. There may be a need to involve ICF and others to certify "competent manager status".

Education and training

As in the related silvicultural fields of Continuous Cover Forestry (CCF) adoption and diversification of the conifer species portfolio, there remain frequently encountered concerns over the level of silvicultural skills being imparted in modern-day forestry training and expressed by some entering the forestry profession at the present time. This reflects the content/ ethos of the training programmes provided at all levels, reducing numbers of traditional estate/ retained head foresters/ forest workers and changes in the recruitment approach of public/ charitable sector bodies, away from routine insistence on a forestry background. This is of potential significance to PAWS restoration with retained timber potential, both in terms of the actual availability of the skills required to implement it and in terms of the essential ability of well-trained foresters (in all three ownership classes) to "plough their own furrow", "set their own course" and question/ resist any misguided management prescriptions impinging on them. There is still seen to be an unsustainable dependence on a small cohort of head foresters, forestry consultants and independent-minded FC staff, who are often nearing retirement. Younger staff, especially those with a more generalist training, are more likely to become dependent on formulaic guidance and decision-support tools, with variable results. These problems are of course not new, and are not amenable to solution by short-run actions and initiatives. A combination of wider sectoral support for the continuity of forestry training at academic and operational levels, together with annual commitments to recruitment of young, well-trained foresters, is required, but would need to be sustained over the next 20-30 years to provide a sound platform.

Forestry engineering and equipment

Alongside the education and training issue, another frequently encountered problem is the concentration of the forestry contracting base on heavy equipment designed for "Scandinavian style" conifer clearfell harvest. This is most limiting in areas such as

the Scottish Highlands and upland Wales where there is little recent history of more "intimate" forestry approaches including PAWS CCF thinning and quality hardwood silviculture. There is a need for increased availability of "Continental style" light and medium weight forestry equipment and techniques - e.g. motor manual felling, small-scale forwarders and skidders, horse extraction, sky-line/ cable-crane and in-forest wood processing. These are essentially pre-requisites for competent and effective management on PAWS sites that will retain timber potential and biodiversity value. Availability of these is currently better in those parts of the country (e.g. SW England, Marches) with a more mixed forestry composition, a greater number of small private woodland owners and increased interest in community-managed forestry. It may now be possible to use rural business development grant schemes, together with intelligent public procurement strategies, to foster the required contractor base elsewhere.

Research

The current research work undertaken in the field of PAWS restoration, mainly by Forest Research and the Oxford Forestry Institute (OFI) is generally held in very high regard and it is essential that the critical mass of silvicultural research work is upheld. However there are concerns over the ease-of-adoption of some silvicultural research recommendations by the smaller private owners and the community woodland sector. Issues of time consumption, technical complexity and inherent costs are often cited. In the field of work examined by this report, the area of natural regeneration monitoring, frame-tree selection and permanent/ temporary plot recording are the most tenacious. There is also some unease about the current emphasis on computer-aided decision-support as opposed to conventional field guide and bulletin materials. There is perhaps a tension between the very high standards of statistical rigour set for scientific research journals/ certification protocols and the lower "technical absorption potential" of the smaller, non-specialist growers. Researchers may struggle to address both audiences when reporting the same body of work, but it is essential do so. There may be a role for an uncharged "forestry extension service" to carry the results of the latest research out to smaller practitioners, expanding on the "research update days".

Guidance and regulations

There is now a large body of valuable technical guidance on PAWS restoration available, particularly from the Forestry Commission and the Woodland Trust. Some commentary tended to suggest that this was stronger on PAWS identification, evaluation and prioritisation for initial intervention and rather weaker on long-term silvicultural planning and retention of timber potential. Clear and simple guidance on the implementation of ATC/ CCF in mixed hardwood stands was a perceived lack. In reality this information is already available from specialist bodies such as the Continuous-Cover Forestry Group, Pro Silva and AFI in France, but hard-pressed British practitioners may be less familiar with those sources. Whether this is best dealt with by producing yet more GB guidance or by expansion of the extension effort through a specialist silvicultural touring corps approach is open to discussion. Another aspect that arises is perceived indecisiveness or, by contrast, "gold plating" of PAWS restoration prescriptions, both in FC internal guidance and grant scheme requirements. The three key aspects are (a) allowable retention percentages/ distribution of conifers, (b) permissibility of use of conifer nurses/ enrichment conifer planting on PAWS and (c) management of volunteer conifer regeneration. Practitioners favour guidance which is clear as to why and where it does set standards/ benchmarks, but which sets them in as few areas as possible and "errs on the side of grower/ manager autonomy".

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