Research Highlights by Division

Biometrics, Surveys and Statistics

Towards an integrated woodchain model

Ash growth and yield model

Ecology

Habitats and Rare Priority and Protected Species (HaRPPS)

Coning studies establish synchrony between trees species and across regions

Environmental and Human Sciences

Influences of stand age and soil properties on forest biodiversity

Iterative learning from social research

Forest Management

Seed dormancy and climate change

Rhododendron ponticum: planning and implementing a control operation

Rack management in continuous cover forestry

Tree Health

Risks from introduced pathogens

Risks posed by wood packaging materials in international trade

Towards an integrated woodchain model

Tim Randle

Understanding and modelling tree growth and timber output allows researchers to make predictions of timber quality from existing and future forests. Modelling can predict the influence of new sites, climate and management regimes and so indicate the most suitable management techniques to enhance the economic value of forests. Models of forest growth, whether empirical or process-based, tend to finish at 'roadside'. But better descriptions of form and quality are needed to predict the correct market value for trees. The form and quality of wood is associated with several inter-related factors including genetics, forest management and environmental conditions (including site factors such as soil type).

In order to understand the linkages between growth, the physical characteristics of the tree and wood, and the effect on timber and its end-use, FR is developing an integrated model in collaboration with the Building Research Establishment at Watford. To achieve this, researchers have constructed a model or series of linked models to take account of the processes along the woodchain (Figure 1).

The integrated model takes tree-level mensurational descriptions and cuts the bole into log-lengths, accounting for straightness and desired log-length. The logs are cut into battens using a saw-optimising model, which prioritises cuts of batten size. The cut battens are then classified using strength characteristics such as knots and wood density to produce different grades suitable for different purposes. These processes are analagous to some methods used in modern automated sawmills (Figure 2), which are able to use laser and x-ray technologies.

Figure 2

Automatic processing of logs entering a mill.

FR's model demonstrates how environmental conditions and management practices affect both growth rates and the quality of wood produced by a stand, which in turn influences all stages of the woodchain model. The quality and final use of the timber determines its market value but also affects the carbon budget in terms of the length of time the carbon is 'locked up', and energy costs for transportation and production of various products.

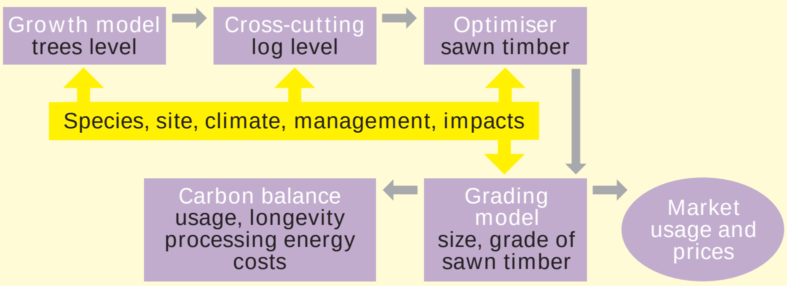

Figure 1

Flow chart of a series of models, linked to create an initial woodchain model.

Ash growth and yield model

Miriam Baldwin

A new stand-level model has been created from data collected from England, Scotland and Wales to predict stand volume of ash (*Fraxinus excelsior* L.). The sampling method allows sufficient data to be collected in a much shorter time frame than previously expected and is already being implemented under the restructuring of the permanent sample plot network.

Approximately 200 plots consisting of a mixture of permanent and temporary sample plots and increment plots were used to build the model. The increment plots were established in the same way as permanent plots, but maintained for a shorter period with more intense monitoring. From a potential 400 sites, 98 were established as increment plots. For this study a 5-year retention was used although 10-20 years is more appropriate. Increment plots were successfully employed for the first time to achieve pseudo-time series data. Annual measurements for diameter were taken, with height and crown measurement recorded every 5 years. A range of environmental data were also collected.

A database was compiled combining selected data taken from FRED (Forest Research Ecological Database), and new measurements taken as part of this work package. The database was built using Microsoft® Access and is suitable for amalgamation with FRED. Software was produced as a tool to aid in stand management decisions. The software is MS-Windows compatible, written in C++ with a ‘point and click’ front end (Figure 1).

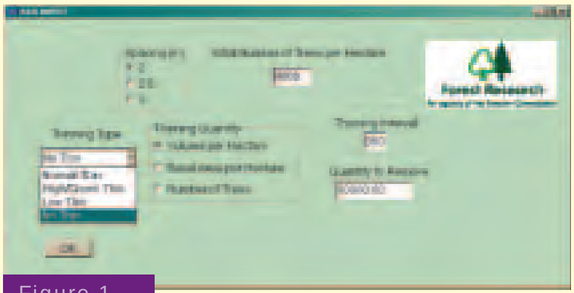

Figure 1

Software input screen.

In general the new model is predicting more dense stand populations with thinner and taller trees. The individual growth variable increment is better correlated with observed growth patterns. Direct comparison between old and new models demonstrated an increased flexibility of initial stand and management descriptions for the new model (Figure 2). Describing the full range of thinning scenarios is currently being investigated through the revision of the permanent sample plot network. The model is structured to allow future amendment and refinement. This work demonstrates that incorporation of increment, permanent and temporary plots, within the current sample plot network, sources enough data for much needed refinement of growth and yield models for all species within the *Yield models for forest management* suite of models (Booklet 48 by Edwards and Christie published in 1981).

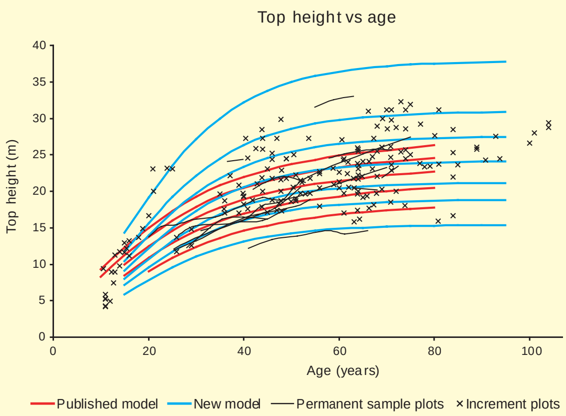

Figure 2

New model predictions.

Habitats and Rare Priority and Protected Species (HaRPPS)

Duncan Ray and Chris Quine

Sustainable forest management places considerable pressures on forest managers (and their stakeholders) to access appropriate information that has a bearing on their decisions. With respect to biodiversity and wildlife conservation, forest managers need up-to-date and concise recommendations for managing a broad range of woodland and open habitats, with a significant number of associated priority, protected and rare species. Last year (*Forest Research annual report and accounts 2003–04*) an article by Broome *et al.* explained the various strands of research being conducted within the Species Action Plan Research Programme to plug some of the key knowledge gaps. However, there is already much existing knowledge and literature describing the autecology of species, impacts of management on species and habitats, guidance on best management practice, and the occurrence of species in particular habitat types and locations. Discussions with conservation managers in each of the countries identified the need for an improved way of accessing these resources.

As a consequence we have been working on a new decision support tool (HaRPPS – Habitats and Rare Priority and Protected Species) that provides managers with quick and easy access to the legal requirements, species-habitat links, forest management impacts and recommended practice for managing species and habitats. The aim is to deliver this tool over the internet – thereby enabling the database to be updated and rapidly made available to all users. Figure 1 illustrates the structure of HaRPPS and its linkages to other databases and sources. Information in the background database comes from a systematic review process, in which individual records have a citation and data quality tag enabling users to assess the authority and impact of information. HaRPPS will provide access to the websites of NBN (National Biodiversity Network) and UKBAP (UK Biodiversity Action Plan) and, importantly, will be accessed directly from GLADE (Grants and Licences Applications Delivered Electronically) and Forester GIS applications. This will enable HaRPPS to deliver spatially explicit species and habitat guidance to private woodland owners, managers and agents, and to FC woodland officers and managers.

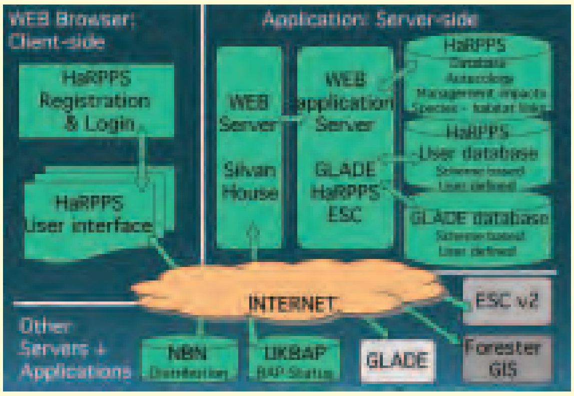

Figure 1

Schematic illustrating the main structure and linkages of HaRPPS.

Considerable progress has been made in developing the structure of the decision support tool – with a user interface structured to reflect the type of likely queries and a supporting database developed for a number of key species. The relative priorities of different options in the development has been guided by a steering group of key practitioners, and the prototype is now being tested by representative users. Results from this beta-testing will focus the subsequent development and roll-out of this system.

Coning studies establish synchrony between tree species and across regions

Alice Broome, Andrew Peace, Chris Quine and Steven Hendry

Conifer seed is a valuable forest resource which provides reproductive material for forest regeneration, and an important foodstuff for many woodland species. Some of Britain's rarest species depend upon this food resource, for example, the red squirrel (*Sciurus vulgaris* L.) and Scottish crossbill (*Loxia scotica* L.), as described in 'Research in support of the UK Biodiversity Action Plan' (*FR Annual report and accounts 2003–04*). Information on cone and seed production of the main forest species is necessary to implement new forest management systems and to understand the population dynamics within forest ecosystems, but has rarely been the focus of studies. Now a new source of data has been explored and has yielded some fascinating results. Since 1989 coning has been recorded in Norway spruce, Sitka spruce and Scots pine from sites across Britain as part of the Forestry Commission's Forest Condition monitoring programme. Fieldwork has confirmed the relationship between the scoring system and cone counts in the crowns of the sample trees, and an 11-year period of the records has been analysed to establish annual cone production by species and coning synchrony (publication of further details is in preparation). Figure 1 illustrates the geographic and temporal coverage of the analysis.

The results indicate that Norway spruce and Sitka spruce tend to cone sporadically, with a 4-year period between mast crops when cone density (cones per m^2) can be very low or cone production absent. Scots pine produces a good cone crop in most years throughout Britain. In mast years coning in both spruces is in synchrony across Britain; the synchrony occurs over distances of up to 200 km. There is no synchrony between coning in Scots pine and that in the spruces.

These findings have implications in the design of forests for wildlife conservation, and particularly how to mix tree species to ensure a supply of seed in most years. The findings are also of value in considering how to monitor seed production, and contribute to the development of appropriate silvicultural systems for the species involved. The results also raise some intriguing questions about the factors governing the masting and the synchrony and what are the equivalent patterns in other key forest tree species. It is hoped that further work will explore these aspects.

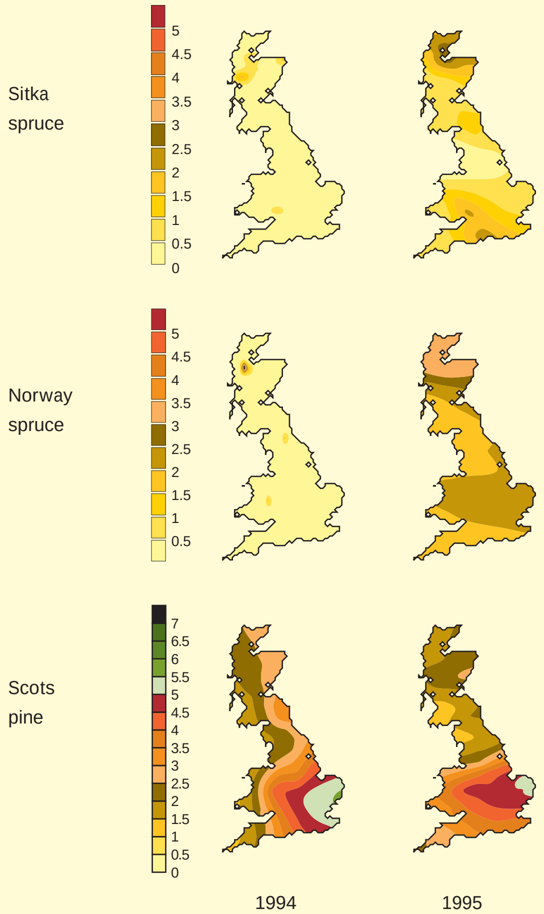

Figure 1

Extract from the coning analysis for three conifer species across Britain in 1994 and 1995. Scale gives average cone density interpolated from point samples (cones per m^2 of canopy: note different scale used for the spruces and Scots pine).

Influences of stand age and soil properties on forest biodiversity

Rona Pitman and Elena Vanguelova

Soil properties and ground flora in a chronosequence of 40 plots in Alice Holt Forest, Hampshire, selected from those in the Environmental Change Network (ECN) surveyed in 2002, were analysed using modified Ellenberg values as an investigative tool. Data were grouped into stand age class (thicket, mid-rotation and mature) to explore the effects of maturing stands on soil and plant properties. A succession of increasing plant diversity under oak was indicated, with Ellenberg values showing significant adaptation to higher levels of nitrogen (N) with age, rising pH and declining water availability. Under Corsican pine stands, similar trends were found from a more limited flora, but with increasing water availability in older stands. The ecological synopsis shown by the Ellenberg values was confirmed by the mineral soil analysis (0–15 cm depth), where nitrogen and pH levels rose with age under both species, and mid-summer moistures declined under old oaks. Significant differences were found in the nature of the plant available N in the soil under each species, with higher levels of nitrate (NO_3–N) under pine stands but higher ammonium (NH_4–N) under the oak (Figure 1a). A comparison of the soil pH under the two forest communities indicates that soil under the pine is significantly more acidic than that under the oak (Figure 1b).

A further collaborative study between FR and Exeter University aims to develop a greater understanding of the relationship between soil nitrogen processes and soil microbial diversity and function. For this study, a representative number of both conifer and broadleaved mature forest plots from the ECN network were selected. Soil microbial diversity associated with nitrification, denitrification and nitrogen fixation were analysed by functional genes (such as those coding from ammonia mono-oxygenase [amoA] for nitrification; NO_2–reductase

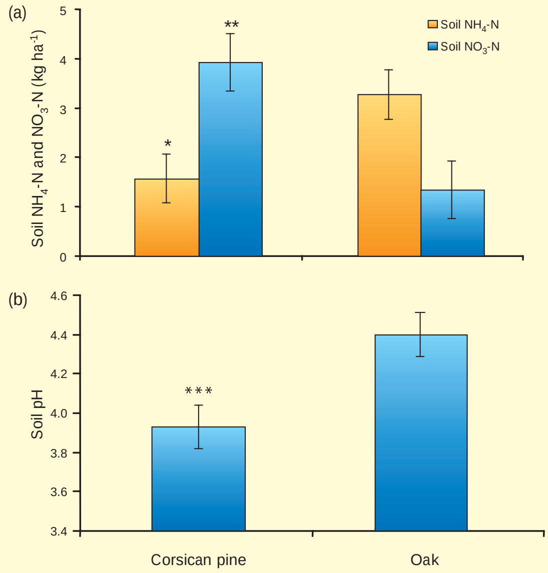

Figure 1

(a) Soil nitrogen species and (b) soil pH under Corsican pine and oak forests. Mean values are from 10 plots with their standard errors.

[*nir*K and *nir*S], N_2O reductase [*nos*Z] for denitrification and [nifH] for nitrogen fixation). The molecular microbiological data corroborated the soil chemical analyses, suggesting that oak forest associated with heavier textured clay soil has higher nitrification and denitrification potentials and thus higher buffering capacity towards N compounds entering the system, compared to the more acidic and sandier textured soils under Corsican pine (Table 1).

Forest type	Presence of gene types in the plots						
	Denitrifiers					Nitrifiers	N-fixers
	narG	*napA*	*nirK*	*nirS*	*nosZ*	*nifH*	*amoA*
Pine	0	6	4	0	0	0	0
Oak	0	10	6	2	0	5	0

Table 1

Presence of the functional gene PCR amplifications from soils in 10 plots under each forest type.

Taken together, the ecological and microbiological studies clearly demonstrate the importance of soil properties and processes, along with nitrogen capital, in determining the complexity of both above-ground and below-ground biodiversity in forests.

Iterative learning from social research

Paul Tabbush and Liz O'Brien

FR's Social Research Group is using the breadth of its work in the UK and Europe to inform its research in the field. A study of consultation and community involvement in forest planning was based on areas in the New Forest, Cranborne Chase and North Dorset (Figure 1). The main recommendations included the need to make a clear distinction between strategic and site-specific issues and then to choose engagement methods suitable for each. It is also important to record and feed back participant views, to stress that they are being listened to, incorporated into the plans and acted upon. Focus group work in Blandford Forum, North Dorset, revealed a clear potential to enhance the public benefit from Forest Enterprise managed woodlands.

Figure 1

Cranborne Chase and North Dorset Forest Design Plan Forum meeting on 24 October 2003.

Inner London woodland study

In 2004 the Group undertook a project looking at trees and their impacts on the emotional well-being of local residents on two inner London social housing estates. The project was a partnership between the Forestry Commission, Peabody Trust (London's largest housing association), Trees for Cities (an environmental charity), with Forest Research carrying out work to explore residents' use of and attitudes towards their local wood called Peabody Hill Wood, situated in Lambeth. Questionnaires, focus groups, a workshop with young people and a walk through the wood were the methods used to gain an understanding of how residents from the two housing estates viewed the woodland. The project also involved residents in a community woodland clearance and a tree planting day (Figure 2). There was a complex mix of perceptions: many valued the wood as an element of nature in their urban environment and as a piece of wild space which provided the opportunity to view wildlife, but residents were also concerned about some of the abuses that took place in the wood and for some this outweighed the potential for using the wood for their everyday enjoyment.

Figure 2

Residents plant oak trees at Peabody Hill Wood, London, 2005.

The findings suggest that outreach work is needed to encourage those who never use the wood to consider how it might be improved and become usable; this would need to involve all sections of the community. The report of the work is available at: www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/INFD-6C8GNH

The Group also started work on two shared-cost European projects during the year. In both projects, social research methods are being used to help to define the problems and to ensure that solutions take the local social contexts into account.

- SENSOR aims to produce Sustainability Impact Assessment Tools to assess the potential impacts of European policy instruments. Case studies are based on multifunctional landscapes, mainly located in the Accession States.
- RECOAL aims to find solutions to problems caused by pollution with coal ash in Bosnia, based on sites near Tuzla.

Seed dormancy and climate change

Peter Gosling and Mark Broadmeadow[a]

The ‘Seed and seedling biology’ and ‘Climate change impacts’ programmes have collaborated to explore the potential effects of winters that are either warmer, shorter or both on the dormancy breakage process and hence natural regeneration of native trees and shrubs from seeds.

The majority of tree seeds in the UK exhibit one of two sorts of dormancy. A few (alders, birches and Scots pine) have seeds that exhibit ‘shallow dormancy’. In this type of dormancy a varying proportion of seeds germinate at different temperatures – and usually only slowly. However, all seeds respond to a relatively short prechill which stimulates faster germination at all temperatures and improves the maximum germination percentage at most temperatures. These characteristics are illustrated for Scots pine in Figure 1a. If climate change brings longer, warmer autumn temperatures, then the seeds of these species may germinate too soon in autumn. Their highly vulnerable seedlings will be much more likely to be killed by any subsequent freezing temperatures of a later winter (■ - ■). The figure also shows that if the seeds don’t germinate too soon, they require relatively little moist chilling for an even higher percentage to germinate more quickly the following spring (■ - ■).

The native trees that are most likely to be affected by climate change are those with ‘deeply dormant’ seeds – especially if winters are either warmer, shorter or both, and early spring temperatures are higher. Unfortunately, this is the majority of native trees (including the conifers – juniper and yew, and nearly all broadleaves – ash, beech, cherry, dogwood, etc.). Figure 1b shows that freshly shed seeds of these species have a complete metabolic block to germination at any temperature (■ - ■); also that there is an absolute requirement for a relatively lengthy and unbroken period of cold moist conditions to bring about any germination at all. The figure shows that although 15 weeks of prechilling (■ - ■) enables 60% of seeds to germinate at lower spring temperatures (10–15 °C), it requires another month of prechilling to stimulate a similar germination percentage at 20–25 °C (▲-▲). If climate change brings about winters that are warmer or shorter or both, and these are succeeded by faster rising spring and summer temperatures, then many of these species may not be as well suited to natural regeneration in the projected climate of the future.

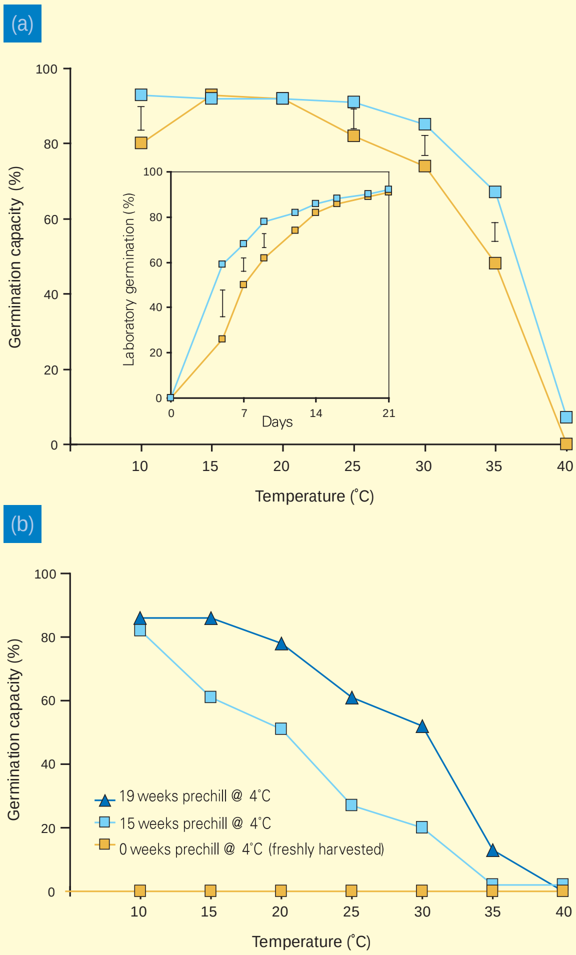

Figure 1

(a) Maximum germination percentage of Scots pine seeds at constant temperatures following 0 and 3 weeks moist prechill at 4°C (inset shows course of germination at 20°C, with and without a 3 week moist prechill).
(b) Maximum germination percentage of beech seeds at constant temperatures following 0, 15 and 19 weeks moist prechill at 4°C. Bars signify statistically significant confidence limits at 95% level.

There are currently a number of groups encouraging the collection and propagation of ‘native-trees’ from ‘local seed sources’ – the laudable aim being to preserve locally adapted genotypes. However, if the UK climate is likely to significantly change in the next 50–100 years then perhaps seed sources adapted to local environmental conditions may not be so appropriate after all.

[a] EHS Division.

Rhododendron ponticum: planning and implementing a control operation

Colin Edwards

Despite its attractive flowers, *Rhododendron ponticum* (Figure 1) only has a negative impact on areas it colonises, reducing the numbers of earthworms, birds and plants and the regenerative capacity of such sites, and impairing physical access which pushes up management costs. A long-term challenge, researchers have recently developed techniques and guidance for the sustainable control of *R. ponticum*. A forthcoming Forestry Commission Practice Guide: *The management and control of invasive R. ponticum* takes the forest manager through a series of steps partly formulated as a decision chart.

Figure 1

R. ponticum – an introduced, woody, ornamental species that is now a major invasive weed of forests and heathland habitats.

The first step is a detailed site survey describing *R. ponticum* in the target woodland area. The safest and most efficient method of control then depends on the size, life stage and accessibility of the bush. Although stem treatment is generally the most effective and efficient method of killing bushes, where there is no access to stems, a foliar spray can be used. Small bushes can be easily treated, but foliar sprays cannot be applied safely to larger bushes so they must be reduced in size with a mechanical flail or manual cutting before application of the herbicide.

The Guide gives details of how to plan a control operation, including information on approved methods of application and herbicides for effective control of *R. ponticum*. Sections on prioritising areas for control and monitoring the success of operations aid managers in making the most effective use of the resources available to them. The Guide is due for publication early in 2006 and should be used in conjunction with FC Practice Guide *Reducing pesticide use in forestry* and the FC pesticides resource website.

Research is still under way – stem treatment is a relatively new technique for controlling bushes where each stem is > 3 cm diameter and can be individually accessed (Table 1). While the basic technique has been found to be effective in Scotland and North Wales, some aspects of the technique, such as the best time of year for application, are still being investigated. The techniques described in the Guide are effective: treatments early in the growing season prevent flowering, reduce seed dispersal and potential colonisation of other sites while mature bushes should be dead within 6 months of application.

Table 1

Kintyre 21: health score of treated stems 6 and 12 months after application. Health scored 1–6, where 1 = healthy, 6 = dead.

Treatment	Health score 6 months	Health score 12 months
Control	1.40	1.20
Stem girdling	1.80	3.60
Water	2.60	1.60
Undiluted Glyphosate	6.0	6.0
50% solution Glyphosate	6.0	6.0
25% solution Glyphosate	6.0	6.0

Rack management in continuous cover forestry

Duncan Ireland

Racks are simple corridors through the standing tree crop that allow access for harvesting and management operations. When forwarding, racks should be spaced as far apart as machine reach will allow. This reduces the area subject to compaction, the loss of potentially productive land, and potential wind blow risk when opening up the canopy. The long-term sustainability of timber harvesting and extraction in continuous cover forestry (CCF) is closely connected with rack management.

Methods of reinforcing racks against disturbance include redistributing brash, adding biodegradable materials and adding stone to selected sections. The cost of reinforcement should be considered against the loss in productive time during timber extraction due to reduced/restricted access as a result of degraded racks. The useable life of the rack network can also be increased through operational controls including alternate racks in later thinnings (Figure 1) and reducing loading by forwarding partial loads.

Rack layout should be designed to minimise the number of watercourse crossings. Where required, efficient crossings can be provided using a range of techniques; the simplest comprises a polypropylene pipe, transported by harvester, placed into the drainage channel and covered by brash. The pipe can be transported by harvester and removed for reuse when felling is complete.

Movement of machinery over dry ditches can be facilitated by temporarily inserting logs into the channel and laying brash over the top, followed by regular checks during felling to ensure the channel remains dry and that produce is removed after use. To allow machinery to cross wider channels, bundles of pipes, secured with chains can be used to form a ‘fascine’. Different numbers and gauges of pipes can be used to span a range of watercourse widths.

Low value, small dimension roundwood can be used to construct sections of ‘corduroy’ rack (lengths of timber placed side by side along the extraction route covered with brash) to prevent ground damage where the soil is locally wet.

The ongoing mechanised harvesting access required for successful CCF transformation and management will only be achieved through the use of appropriate rack construction and maintenance techniques throughout the development of the stand. Some of these aspects are being investigated at demonstration sites, including Coed Trawlim in Wales in collaboration with the School of Agricultural and Forest Sciences of the University of Wales, Bangor.

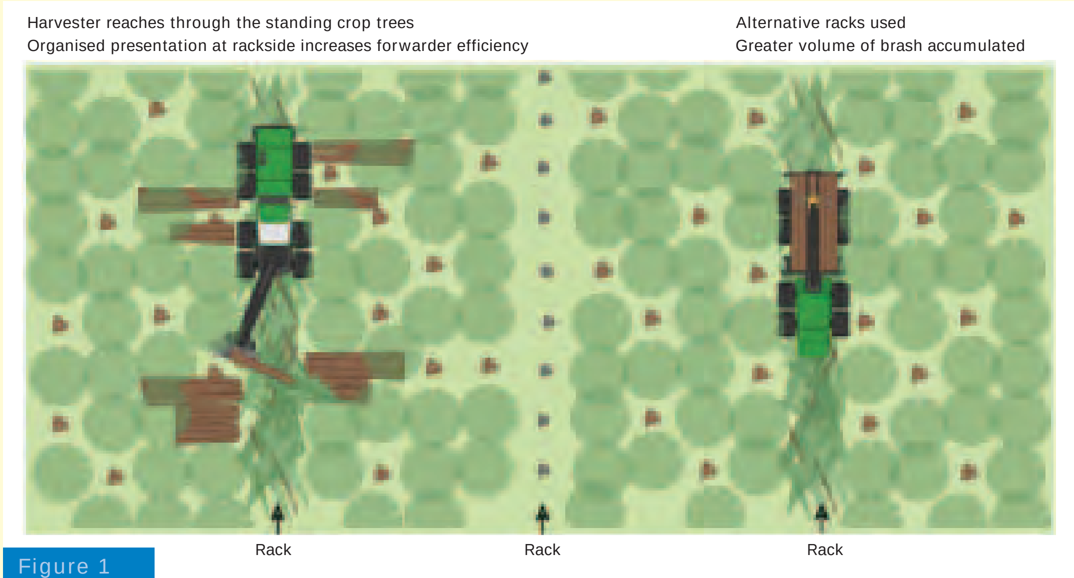

Figure 1

Using alternate racks for extraction maximises available quantities of brash and reduces the compacted area.

Risks from introduced pathogens

Joan Webber

Phytophthora ramorum, the cause of Sudden Oak Death in western USA, has been found at approximately 400 nurseries and garden centres and at a smaller number of parks and historic gardens across southern England.

Collaborative research between FR pathologists and colleagues at the Central Science Laboratory shows that *P. ramorum* is remarkably adaptable, affecting a large range of hosts and causing a variety of symptoms. Some trees have susceptible bark and can develop lethal, bleeding bark infections. Other trees or shrubs suffer only foliage infections or shoot death and though rarely seriously affected, provide the source of inoculum for bark infections on trees. Trees suffering from ramorum bleeding bark cankers have always been found close to infected rhododendrons (mainly *Rhododendron ponticum*), usually within 2–5 m.

Initial research work:

- tested UK tree species to assess which are most at risk of developing lethal bark infections;
- assessed which foliar hosts could be significant sources of spore inoculum.

Trees with susceptible bark include beech, American northern red oak, turkey oak and horse chestnut. Trees with susceptible foliage include holm oak, sweet chestnut and ash. These tests have proved to be very good predictors of susceptible hosts in the field, although the total number of infected trees is small. Currently only around 40 affected trees have been found and all, except one, are in Cornwall.

It is important to understand how *P. ramorum* reproduces, spreads, infects and survives under UK conditions in order to predict risk. Infective spores are probably produced on foliar hosts and natural dispersal can be local and limited through rain-splash and mists. Human activities may move the pathogen further afield through contaminated leaf litter or soil on shoes.

Figure 1

Phytophthora kernoviae causing (a) rhododendron wilt and (b) bleeding stem lesions on beech.

Recently another exotic *Phytophthora* species has been discovered and named *P. kernoviae* (after Kernow, the Cornish name for Cornwall). So far it has only been found in woodlands and gardens in Cornwall, one area of south Wales and in one nursery. It also infects rhododendron (Figure 1a) and in the past year has been found causing bleeding bark cankers on 40 beech trees (Figure 1b) and two native oaks close to *P. kernoviae* infected rhododendrons.

Assessing the risk from *P. kernoviae* is in its early stages, but it is clear that both *P. ramorum* and *P. kernoviae* represent a potentially serious threat to trees in the UK. Currently the Forestry Commission and Defra are putting measures in place to contain and eradicate this pathogen while the risks are evaluated more fully.

Risks posed by wood packaging materials in international trade

Hugh Evans

For many years, scientists in Tree Health Division have carried out research into the threats posed by exotic pests and diseases, most recent of which is the emerald ash borer beetle *(Agrilus planipennis),* shown in Figure 1. For most of the damaging organisms already established in the UK, the pathway for invasion has been associated with wood, either as a product or as wood packaging material.

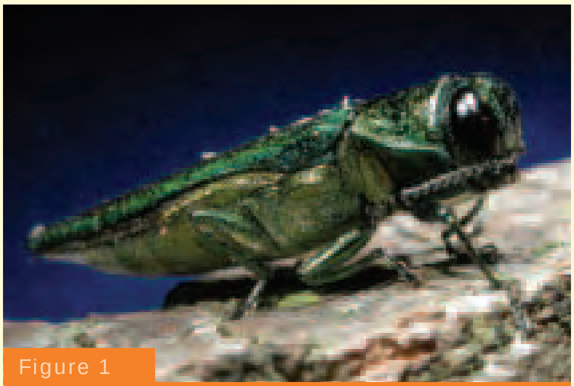

Figure 1

Adult emerald ash borer: *Agrilus planipennis* (David Cappaert: www.insectimages.org).

Rules to reduce the risks from these pathways have been developed and these are reasonably effective in well-regulated wooden products. However, wood packaging material is much more difficult to regulate because it ranges from fully manufactured materials such as pallets, through to completely raw wood used as dunnage. It has also been recognised by the International Plant Protection Convention that rules were needed specifically for wood packaging and these have been promulgated through the newly introduced International Standard on Phytosanitary Measures (ISPM) Number 15. This requires that wood is treated to kill any pest or disease organisms present before shipment. Currently the two methods of choice are heat treatment (HT) to reach a wood core temperature of 56 °C for 30 minutes or to carry out methyl bromide fumigation to an agreed standard.

With part funding by the Carbon Trust, FR has been working with BHR Group at Cranfield to assess methods for verifying that HT has been carried out to the required standard and also to develop procedures that minimise the treatment time and, consequently, energy required to heat the wood. This research has used a combination of mathematical modelling of heat penetration into the wood, using an Elasteq model developed by BHR scientists and both laboratory and industrial heating chamber experiments and tests by FR and BHR to test and verify heat penetration predictions.

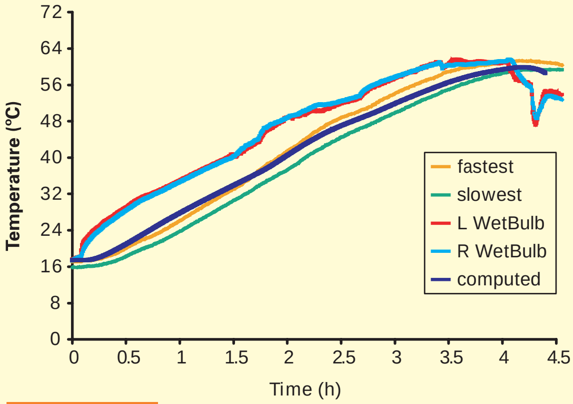

Figure 2

Heating profiles of pine with moisture content of > 35 %. The two chamber wet bulb profiles, the slowest and fastest heating wood pieces and the TimberTherm computed line are shown.

The work has now developed a beta version of the software, named TimberTherm, which has proved accurate for a range of timber species and dimensions. For example, Figure 2 shows the actual and predicted heat penetration curves for pine in an industrial heating chamber under standard loading. Verification was carried out using thermocouples placed in a number of pieces of wood within the chamber and the curves show the slowest and fastest heating pieces as well as the two chamber wet bulb curve profiles and the TimberTherm predicted curve.