Forest Research

Annual Report and Accounts

1998 - 1999

HC801

Forest Research
An agency of the Forestry Commission

Advisory Committee on Forest Research

Membership at 31 March 1999

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Forest Research Organisation

at 31 March 1999

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- **Technical Support (North)** Tony Sharpe (5)
- **Technical Support (South)** Norman Day (2)

Location
1 Northern Research Station
2 Alice Holt Research station
3 Forestry Commission Headquarters
4 Ae Village
5 Newton Field Station
(contact via Northern Research Station)

Forest Research
Annual Report and Accounts 1998-99

Together with the Comptroller and Auditor General's Report on the Accounts

Presented to Parliament in pursuance of Section 45 of the Forestry Act 1967 and Section 5 of the Exchequer and Audit Departments Act 1921

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Contents

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An agency of the Forestry Commission

About Forest Research

Forest Research (FR) is an agency of the Forestry Commission and is the principal organisation in the UK engaged in forestry and tree related research. The Agency was launched on 1 April 1997 and comprises the former Research Division, Technical Development Branch and parts of the former Surveys Branch of the Forestry Commission (FC).

Aims and objectives

Aims

To provide research, development, surveys and related services to the forest industry and to provide authoritative advice in support of the development and implementation of the Government's forestry policies.

Objectives

- To meet customers' needs and respond to changing customer demands.
- To satisfy current standards for the quality of research.
- To increase competitiveness and efficiency and demonstrate value for money.
- To recover the full economic costs of the Agency from charges to customers.

Customers

Most of our work is funded by the Forestry Commission with the Policy and Practice Division of the FC acting as purchaser of research and other services in support of forestry in Britain, including the particular needs of England, Scotland and Wales. Forest Enterprise, the Agency responsible for managing the FC estate, purchases research, development and surveys specifically related to this estate. Other customers include the Ministry of Agriculture, Fisheries and Food, the Department of Trade and Industry, the Department of the Environment, Transport and the Regions, the European Union, commercial organisations, private individuals, landowners and charities. All our customers are free to purchase their research from Forest Research or from other sources.

Activities

FR's research covers a broad range of topics from genetic improvement of trees, through tree seed, tree establishment, stand management and threats to tree health. The species covered include all the main native trees as well as the commercially important introduced conifer species. An increasing proportion of the research effort is directed at increasing the non-market benefits of trees, including biodiversity and recreation, and ensuring compliance with international agreements on the sustainable management of forests. The Agency also carries out method studies, product evaluations, crop inventory, surveys and monitoring.

Resources

The Agency has two main research stations, Alice Holt Lodge in Hampshire and the Northern Research Station on the Bush Estate south of Edinburgh. The main office of Technical Development Branch is located at Ae in Dumfriesshire with a subsidiary office in the Midlands. The Agency also has 10 field stations from which an extensive network of field trials, sample plots and monitoring sites is assessed. A list of addresses and telephone numbers is given on the inside back cover. The Agency employs 280 staff, not including visiting scientists and sandwich students. The Agency has published a Corporate Plan for the period 1998–2003 and a Business Plan for 1999–2000. Copies of these are available from the Library at Alice Holt Lodge.

Chief Executive's Introduction

I am pleased to present the Agency's Annual Report and Accounts for the year ended March 1999. The Agency again had a successful year, achieving all of its key targets and advancing our knowledge and understanding of a wide range of forestry issues. For the first time in many years we were not subjected to major review or organisational change. This has allowed staff to focus on delivering services to our customers, to carry out high quality research and to meet increasingly demanding targets.

Research highlights

Protecting Britain's trees and woodlands from pests and diseases is a major part of our research effort. Research into Phytophthora disease of alder has shown that the causal agent is a new variant of *Phytophthora* arising from hybridisation of two introduced pathogens, *P. cambivora*, a non-pathogen of alder but common on many other hardwood species, and a fungus close to *P. fragaciae*, a pathogen of strawberries; see pages 16–17. There are some parallels with the development of Dutch elm disease and the work has implications for all those concerned with plant pathogens. The investigation of *Phytophthora* on alder is being taken forward in a number of European countries: this process being facilitated by an EU Concerted Action co-ordinated by staff of the Agency.

Fungi which are morphologically similar can have markedly different abilities to cause disease in trees. Following an interest in the gene products of such fungi, like fatty acids and isozymes, current work using DNA analysis is focusing on the source of genetic identity. Initial Forest Research work was on the fungi responsible for vascular wilt of takamaka trees but we are now working on honey fungus and on the most damaging fungus disseminated by *Ips typographus (Ceratocystis polonica)*; see pages 21–25.

Introduced insect pests continue to pose threats to trees in Britain with the latest concern being an Asian longhorn beetle *Anoplophora glabripennis*. A pest risk assessment and surveys to confirm that the species is not established in Britain has led to new emergency legislation allowing quarantine measures to be implemented.

Following the find in 1997 of *Ips typographus* at a major paper mill, surveys have failed to find a breeding population established in Britain, indicating the success of the prompt measures undertaken when the beetles were first discovered; see page 11.

In much of upland Britain windthrow limits rotation length and options for stand management. New Windows-based software has been released for field testing which gives guidance to forest managers on how the risk of windthrow for different crops and site combinations changes through time.

Information on the design of new shelterbelts and on the management and rejuvenation of existing shelterbelts in the uplands has been collated and made available (Forestry Commission Technical Paper 21 *Trees for shelter*). This exercise highlighted the lack of recent relevant information and new measurements have been made to confirm the relationships between shelterbelt characteristics and the provision of shelter. A paper-based decision support system has also been provided for assessing the best location and design of shelter woods on farms (see pages 50–53).

Natural regeneration from seeds produced and germinated *in situ* is the preferred method of restocking semi-natural woodlands, and is also important in continuous cover forestry and uneven-aged silvicultural systems. Natural regeneration can be difficult to achieve and for broadleaved species success depends largely on the size and number of seedlings present within the stand prior to felling. Such advance regeneration is often present in broadleaved woodlands but the seedlings are usually too small and too few for natural regeneration to be successful.

During the past 5 years experiments have been carried out to improve our knowledge of the development and survival of advance regeneration and to investigate the influence of competition with weeds and of deer browsing. These experiments will provide better advice on the use of advance regeneration for restocking; see pages 35–39.

The results of provenance trials of oak, beech, ash and sycamore are now becoming available and will give an indication of the genetic quality and vigour of material from different UK and European sources. A series of similar trials of birch has been established at four sites in Scotland; see pages 27–33.

The impact on water quality and yield has been used as an argument against afforestation in sensitive catchments. Results to date from a six year study of the effects of large-scale tree planting in the upper catchment of the River Halladale show that, using the forestry practices recommended and described in *Forests & water guidelines,* large-scale planting has had a minimal effect on stream water quality and on the salmonid fish and benthic invertebrate populations; see pages 41–47.

Extensive data collection to determine the degree of biodiversity in Britain's plantation forests is now complete and analysis indicates more biodiversity than might have been predicted for a number of plants and animal groups. This work will also contribute to the development of woodland species and habitat action plans.

Experiments using the open-top chamber facility have shown that elevated carbon dioxide results in significant growth enhancement of three oak species (*Quercus petraea, Q. robur* and *Q. rubra*) when trees are well supplied with water. Because of the predictions of increased summer drought in southern Britain, new work will look at drought and CO_2 interactions. New improved scenarios of future climate (UKCIP-DETR and the Met. Office) are allowing us to predict the potential effects on the growth of oak and Sitka spruce stands for the climate which will be experienced by these species during the 21st century.

Commitments to reduce emissions of greenhouse gases and acidifying pollutants have placed new emphasis on biofuel for the generation of energy. Research on short rotation coppice of willow and poplar has confirmed yields as high as 17 dry tonnes of biomass per hectare. This is 70% higher than the yields assumed in the planning of an 8-megawatt wood-fuelled power station being built at Eggborough in North Yorkshire. A publicity day and FRCC seminar were based on the early results of our programme to determine site/yield relationships of willow and poplar clones. These trials allow the planning of new biomass industries and will indicate the best locations within the UK for growing short rotation coppice and the best varieties of willow and poplar to use.

Improved Sitka spruce yield models for unthinned treatments were provided for incorporation into private and Forestry Commission production forecasting systems. Software based on these models has also been made available to industry users. There has been significant progress in the development of models for Sitka spruce with a range of thinning treatments, and the thinning input screens of these models are currently being tested by users.

Initial results from the National Inventory of Woodland and Trees show that the total tree cover in Wales has increased from 11.6% in 1980 to 13.7% in 1998, a faster increase than had been thought. Full results will be published during 2000.

Partnerships with other UK research organisations and in the European Union Concerted Action and Shared Cost programmes have continued to be important with co-operative projects on the development of indicators of biodiversity, dieback of oak, management of Scots pine forests and Phytophthora disease of alder. The changing demands of policy makers have led to the initiation of new research to give advice on integrated crop management with the objectives of reducing the use of chemicals in forests, encouraging the use of native seed origins and ensuring increased genetic conservation.

Advisory Committee on Forest Research

The Advisory Committee provides guidance to the Agency on the quality and direction of its research. The committee met on two occasions and appointed one Visiting Group during the year to assess the work of our Entomology Branch. The group was led by Professor Brian Kerry of the Institute of Arable Crops Research, Rothamsted, supported by Professor Stig Larsson from Sweden and Dr Martin Speight of Oxford University. The group were impressed with the dedication and motivation of the staff and complimentary about the quality of the research and its management. They were concerned that too wide a range of subjects was being tackled with too few resources and recommended greater collaboration with researchers in other organisations both in Britain and elsewhere in Europe. Where topics cannot be resourced adequately, they recommended that work should cease.

Collaboration within Europe is being taken forward through a COST Action on bark and wood boring insects. Given the need to respond to threats as these arise, it is not possible to ignore any insect pest of significance to trees in Britain, but some resources will be released by scaling down the input by entomologists to work on biodiversity research.

We are again grateful to members of the Advisory Committee and of the Visiting Group for their valuable advice.

Performance against targets

The Agency has key targets for customer satisfaction, output of peer-reviewed papers, reductions in unit costs and cost recovery. All four key targets were met, and with the Entomology programme being reviewed by a Visiting Group we are on track to review all the research Branches over a 5-year period.

Performance against key targets

KEY TARGET		TARGETS AND ACHIEVEMENTS 1997/8	1998/9	1999/2000
Efficiency				
Weighted average unit cost/researcher day	Target	98	96	94
1996/7 = 100	Achievement	98	94	
Weighted unit cost of support services	Target	-	-	98
1998/9 = 100	Achievement	-	100	
Output				
Peer reviewed papers	Target	29	35	38
	Achievement	33	40	
Quality				
Customer satisfaction	Target	85%	92%	95%
	Achievement	90%	94%	
Financial performance				
Full cost recovery	Target	100%	100%	100%
	Achievement	101%	103%	

Finance

Income through the Service Level Agreement with Policy and Practice Division declined by 2% on 1997/98 and total income from all parts of the Forestry Commission including Forest Enterprise declined by 0.2%. Income from non-FC sources increased by 6.6%. Total costs declined by 1.5%. During the year our buildings were revalued using open market values resulting in a £2m increase in their value. With other adjustments in the value of equipment and current assets this resulted in our target operating surplus increasing to £496K which compares with an achievement of £878K.

Investing in the future

Because of the depressed state of the timber market, on which the FC in part depends for financing its activities, funds for investment in new equipment and facilities were reduced. Spending was concentrated on replacing obsolete computers, ensuring that our systems are millennium compliant and buying specialist equipment necessary for taking forward new areas of research. New video conferencing facilities now link our main research centres at Alice Holt and the Northern Research Station with other FC offices and with other organisations similarly equipped. As the Agency's two main sites are 400 miles apart, this facility is saving travelling time and costs and allows impromptu meetings to take place which are so important in effective team working.

In preparation for obtaining recognition as an Investor in People a new personnel management system was introduced, a training needs analysis conducted, and we are progressing towards achieving a single status work force.

Use of the Internet continues to grow, with staff increasingly relying on this means of communicating with existing and potential collaborators and users of research findings. However it is clear that, to ensure a reliable, up-to-date and comprehensive service, greater investment in the necessary infrastructure and skills is required. It is intended that, despite the continuing pressures on FC funds, we will increase our investment in the future to ensure staff continue to have access to modern equipment and facilities.

Visitors

During the year the Agency received several hundred visitors seeking information on current forest research activities, management and organisation. From the education sector there were groups of undergraduate and post-graduate students on forestry, woodland management, or environmental science courses. Overseas visitors came from over 40 different countries and included groups from China, Russia, Bolivia, Ghana, Estonia, Latvia, and most countries of the European Union. The Scientific Advisory Board of the European Forestry Institute visited the Northern Research Station, and the Rt. Hon. James Arbuthnot, MP for North Hampshire, visited Alice Holt Lodge. Both research stations hosted annual research updates for members of the Timber Growers' Association and the Institute of Chartered Foresters. Alice Holt was also the venue for a Forestry Research Co-ordination Committee conference on short rotation coppice for energy.

People

Total staff numbers at year end, excluding sandwich students and visiting scientists, was 280, a reduction of 2 on last year.

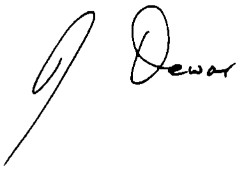
It is with great sadness that I have to report the untimely death of Dick Murray. Dick worked at Alice Holt for nearly 20 years and was Head of Finance. He coped manfully and with customary good humour during his illness and with introducing many changes to our financial systems following establishment of the Agency.

I am pleased to record the award of an OBE to Dr Graham Pyatt for his work on soils and site classification. Dr Pyatt retired in March after 37 years with the Forestry Commission.

New appointments to the Agency include Tony Cornwell, Head of Finance; Norman Day, Head of Technical Support Unit (South); Steven Hendry, forest pathologist; and Richard Thompson, silviculturist for native woodlands. Chris Quine was promoted to Head of Woodland Ecology Branch following the transfer of Simon Hodge to Forest Enterprise.

We value the contribution made by a number of visiting scientists to our work. Dr Mike Menzies from Forest Research New Zealand spent 3 months at our Northern Research Station working on clonal forestry and tree improvement. Dr Euan Mason from Canterbury University, New Zealand spent similar time with our silviculturists working on tree establishment. Dr Mason was assisted by the award of a John Eadie Fellowship from the Scottish Forestry Trust to whom we are most grateful. We currently have with us Dr Franka Bruchert from Freiburg University Germany working on timber quality and Dr Douglas McCreary from the University of California at Berkeley working on the regeneration of oak.

The success of the Agency in meeting financial and non-financial targets and in advancing our scientific knowledge and understanding could not have been achieved without the applied skills, enthusiasm and commitment of the staff of the Agency.



Jim Dewar
Chief Executive
Forest Research

Pests and Diseases

Pests and Diseases
by Hugh Evans and John Gibbs

The roles of Entomology and Pathology Branches in monitoring tree health and developing methods for evaluating and managing problems are demonstrated through the production of annual reports and other publications. As described below, the past year has been a particularly busy period as we have evaluated and reacted to both current and potential pest and disease problems. Pest Risk Assessment (PRA) and contingency planning for a number of organisms have been key elements in the work and have achieved high profiles in the media, particularly for the Asian longhorn beetle (see below) and the subterranean termite, *Reticulitermes lucifugus*. The latter pest species, native to the Mediterranean region, is confined to two houses in Devon and is being dealt with under a joint Department of Environment, Transport and the Regions (DETR), Building Research Establishment (BRE), Imperial College, Natural Resources Institute (NRI) and Forestry Commission programme. A novel method of insecticide baiting, using the insect growth regulator hexaflumuron, is being employed within a programme to eradicate the termite. The PRA carried out on this organism by Forest Research has emphasised that, despite our best efforts to predict which exotic pests are likely to be damaging to Britain, there are inevitably 'surprises' when organisms establish beyond their previous climatic limits. Scientists in the two Branches are, therefore, in regular contact with colleagues throughout the world in order to maintain awareness of potential new threats and to anticipate problems. Such is the case with Asian longhorn beetle and Phytophthora disease of alder, the EU initiatives on the latter organism having been established directly as a result of recognition of the problem by Pathology Branch scientists.

Threats from abroad

Eight-toothed European spruce bark beetle, *Ips typographus*

Surveys were carried out during the year to determine whether the 1997 captures of adult *Ips typographus* in pheromone traps at Shotton Paper Mill, Deeside, north Wales had originated in UK forests. This work involved placement of pheromone traps in over 100 forests and 40 timber yards throughout the country; this was in addition to the normal *c.* 200 traps located at ports and the 40 at the Protected Zone (PZ) survey sites.

No beetles were found at the forest sites. Port interceptions remained low with a total of 26 beetles being found on seven separate occasions. In addition six beetles were trapped at the timber processing yard at Kronospan, Chirk, Shropshire. The origin of these beetles is unclear. They might have been the residue of the population detected at Shotton in the previous autumn and could have been transported to Kronospan in reject wood, or they might have been imported from continental Europe in packaging material. This seems feasible because the Kronospan yard was undergoing a major refit at the time of the captures.

It is gratifying to be able to report that there does not appear to be an established population of *I. typographus* in Britain. The regular PZ surveys and the placement of pheromone traps at ports and timber processing yards will continue.

An Asian longhorn beetle, *Anoplophora glabripennis*

During the past two years Entomology Branch staff, in collaboration with colleagues in the FC Plant Health Service and at the Central Science Laboratory, York, have been assessing the risks arising from a new beetle threat from Asia, an Asian longhorn beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae). This alert arose from the increases in interceptions of *A. glabripennis* in the USA and Canada on wood imported from China and the subsequent establishment of the beetle in both New York and Chicago (Haack *et al.*, 1997). Further details of the US infestations can be found on the USDA APHIS web page (http://www.aphis.usda.gov).

Biology of Asian longhorn beetle

Depending on geographic location and average temperatures the beetle has a life cycle of either one or two years. Temperature conditions in Britain would indicate that a two year life cycle is likely if the beetle was to become established here.

The adult

The adult, which may be up to 50 mm long, is a striking shiny black in colour, with white spots on the wing cases (Plate 1). As the common name implies, the beetle gets its name from the very long antennae that extend forward when the adult is moving and, while at rest, lie along the wings,

1 **Adult Asian longhorn beetle, *Anoplophora glabripennis*. (Courtesy of James E. Appleby, University of Illinois.)**

extending the entire length of the body. Adult emergence generally takes place from May to August, but may extend to October in cooler climates. Signs of emergence are masses of wood shavings at the entrance to the round exit hole (9–11 mm diameter) and on the ground below the tree. Beetles fly to feed in the crowns of trees and to mate. Females lay eggs singly in slits, which they cut in the bark of branches, usually where they join the trunk. Depending on tree species, symptoms of egg laying may include some resin bleeding. Females live up to 66 days and lay around 30 eggs.

Eggs

Egg hatch, which takes from 7 to 17 days depending on time of year and on temperature, occurs in June/July during a one year cycle and in September/October during a two year cycle.

Larvae

The newly hatched larvae feed under the bark, where they pass through two or three moults, eventually boring into the wood in the late third or fourth instar stage. By this time the larvae have grown to approximately 50 mm long. As the larvae grow, damage to the wood increases and eventually galleries up to 10 mm in diameter and several cm long may be formed. Larvae can be found at any time, including the winter months.

Pupae

When fully mature, the larvae moult to the pupal stage within a well-defined pupal chamber, packed at one end with distinctive wood 'shavings' (Plate 2). This usually takes place in the spring.

2 **Pupa of Asian longhorn beetle, *Anoplophora glabripennis*, with characteristic wood shavings in pupal chamber. (Courtesy of USDA.)**

Status abroad

A. glabripennis has become a major pest in China where, as a result of the planting of very susceptible varieties of poplar, populations have increased dramatically during the past 20 years. Although showing preferences for poplars and maples the beetle is capable of infesting and killing many genera of broadleaved trees including alder, willow, cherry, apple, horse chestnut, elm and mulberry. The threat to Britain posed by the beetle has been emphasised by the recent establishment of beetle populations in New York and Chicago where damage to street trees is high and a policy of felling, sanitation and quarantine is being operated.

The risks to Britain

The larval stages of *A. glabripennis* are well protected within untreated wood and, therefore, it is possible for the beetle to be carried in international trade and to emerge in the final destination. This is undoubtedly the route by which the pest arrived and established in the USA, where it was the damage to urban trees that first alerted the authorities to the presence of the beetle. Analysis of climate data by scientists at the Central Science Laboratory suggests that most of England and Wales and some warmer coastal areas of Scotland are suitable for beetle establishment and breeding.

FC plant health inspectors have been on high alert during the past few months and, following the publication of a colour-illustrated Exotic Pest Alert, a number of confirmed interceptions on, or associated with, wooden packaging material from China have been made. For example, adult beetles have emerged from the packaging around flooring slates.

Surveys of trees in the vicinity of warehouses and other storage depots will be carried out during 1999 in order to determine whether the beetle has established itself in Britain. At the same time, new emergency legislation has been put in place that requires wood of broadleaved trees from China to be free from the symptoms of larval feeding – grub holes greater than 3 mm in diameter – which confirms absence of the beetle. These measures were determined on the basis of a full Pest Risk Assessment, which confirmed the quarantine status of *A. glabripennis*.

Established pests and diseases

Fomes root and butt-rot *(Heterobasidion annosum)*

An application to Pesticides Safety Directorate (PSD) for approval of disodium octaborate tetrahydrate (DOT) as a commodity chemical for control of Fomes root and butt rot (caused by *Heterobasidion annosum*) was made in October 1998. This followed a number of successful trials conducted by Pathology Branch over the past few years that have demonstrated the efficacy of this material (Pratt and Quill, 1996; Pratt and Lloyd, 1996), and its environmental acceptability (Pratt, 1996; Pratt *et al.,* 1996). The need to replace urea was established following reports of mechanical problems caused by corrosion from its use in harvesters, and by the publication of comparative trials which showed that urea was not as reliable as DOT in controlling the disease in stumps of our most important species, namely Sitka spruce (Pratt, 1994). Finally, a comprehensive review of the available literature on the effectiveness of urea during the 40 years of its use throughout the world indicated that its effectiveness on spruce was less consistent than on pine (Pratt, Johansson and Hüttermann, 1998).

PSD were notified of eleven trials with DOT, which included Corsican pine, lodgepole pine, Scots pine, European larch and Sitka spruce and involved 2420 stumps. The chemical was applied to the 'point of run-off' to freshly cut stumps and the stumps were then artificially inoculated with spores of *H. annosum,* a technique that provides a more severe test of a control product than occurs from natural infection. The results of this work are summarised in Table 1. It is clear from the results that, when used at concentrations above 4%, DOT greatly reduced both the incidence and degree of stump colonisation by *H. annosum*.

DOT is the most soluble of the manufactured borates. Although it can crystallise out of solution in cool water, its ability to remain super-saturated makes it more stable than published data would

Table 1 *Heterobasidion annosum* colonisation of freshly-cut stumps of various conifers treated with disodium octoborate (DOT).
(Average data from *c.* 20 experiments involving artificial inoculation of the stumps with basidiospores of *H. annosum*)

	DOT CONCENTRATIONS			
	0 (CONTROL)	0.5% – 3%	4% – 5%	6% – 10%
Mean incidence of stump infection (%)	70.0	51.3	10.6	3.9
Mean % stump area colonised	12.8	5.1	0.54	0.12

suggest. To determine whether solutions have the characteristics to make them suitable for use in harvesting machines, a study was carried out in Buchan Forest District, north Scotland from December 1994 to February 1995. No problems of crystallisation in solutions of 5% or 10% occurred in the machines, where constant movement and heat from neighbouring hydraulic pipes maintained solubility even when air temperatures were below freezing. However in bulk storage a significant amount of crystallisation occurred in both 10% and 5% DOT solutions. This means that, before DOT is recommended as a replacement for urea, there is a need to devise a suitable system for preparing solutions from the commercial product (a fine powder) in the forest.

This is the subject of a pilot study being undertaken during 1999 by the Pathology and Technical Development Branches. The study also includes consideration of a number of other issues, which were highlighted at an international workshop on mechanised stump treatment, hosted by Forest Research in May 1998 in East Anglia Forest District (Plate 3). These include the possibility of reducing the volume of liquid applied to stumps (a step that is seen to be desirable if the costs of treatment are to be kept low), and the need for better training if high-quality treatment is to be achieved with minimum inconvenience to harvester operators.

3 **Treatment of a pine stump by harvester head: many issues need to be addressed if this process is to be achieved in an effective and economical way. (41402)**

Oak dieback

At the beginning of 1998, a research project was initiated into the role of *Phytophthora* spp. in the dieback of pedunculate oak, *Quercus robur.* This development occurred in the context of concern over the health of oak in parts of the country, most notably in central and eastern England. Dieback of woodland *Q. robur* was common in this area during the period 1989–1992 and accounts of research conducted during the period up to 1995 have been published (see Greig, 1993; Gibbs and Greig, 1997). During the summer of 1997, continued local anxiety led to the award of a grant from the charity Woodland Heritage for a resurvey of a series of 'dieback plots' that had been assessed annually during the years 1989–1994, but not subsequently. This resurvey showed that there was little sign of improvement in tree condition, with four out of the 10 plots showing some increase in the numbers of trees with significant dieback. At about the same time, the opportunity arose for Forest Research to participate in an EU Shared Cost programme, that also involves France, Germany and Italy, on the pathology of oak. This project has various components. One comprises an analysis of decline and dieback processes and will bring together long-term ecological and short-term physiological studies. However, the principal thrust is an examination of the influence of drought and of an imbalance in nitrogen nutrition on the susceptibility of oaks to root pathogens. The work also includes a study of the root pathogens that are associated with dieback in different areas and this is the topic with which Forest Research is principally involved. Jung *et al.* (1996) in Germany have shown that some previously unrecognised *Phytophthora* species are implicated in the death of oak roots and our work involves an investigation into the status of these and other *Phytophthora* species in UK oak stands showing decline.

It is worth commenting that a reassessment of a number of observation plots of sessile oak, *Q. petraea,* in the Forest of Wyre, Worcestershire, where crown dieback was a significant problem during the 1980s and early 1990s (see Gibbs and Wainhouse, 1995), showed no sign of recent damage. Previously-affected trees had made an almost complete recovery.

Poplar leaf rust

Rust, caused by the fungus *Melampsora larici-populina,* was exceptionally severe on commercial and ornamental plantings of poplar (Plates 4 and 5). Much, if not all, of the damage could be attributed to the widespread occurrence of pathotype E4 of *M. larici-populina.* This pathotype affects all

4 Poplars showing different degrees of defoliation due to poplar leaf rust *(Melampsora allii-populina)*.

5 Close up of foliage affected with *M. allii-populina*.

the relatively new *Populus* x *interamericana* and *P. euramericana* varieties, which were immune to all pathotypes known before 1994. On the very susceptible variety 'Boelare', rust pustules appeared as early as June in some localities, particularly in south-west Britain. Outbreaks which begin so early tend to become very severe by late summer, as the fungus has time to go through several generations and thus to build up considerably. This was indeed the case in 1998, so that total defoliation had occurred at some sites by August. In other sites, particularly in northern and north-eastern Britain, attacks began later and were much less severe.

Even before the 1998 rust outbreaks began, the aftermath of heavy attack in 1997 was observed both in short rotation (SRC) trial plots and in some single-stem plantings. This took the form of dieback, which involved the entire 1997 shoots in severe cases or even entire plants in a few instances. Dieback was mainly confined to the *P.* x *interamericana* varieties 'Boelare' and 'Beaupré', with the former being more severely affected in most cases. Varieties belonging to *P.* x *euramericana*, (e.g. 'Ghoy') and to *P. trichocharpa* (e.g. 'Trichobel') showed little dieback. but were reduced in growth where previous rust attack had been heavy.

Up until 1997 the clones 'Hoogvorst' and 'Hazendans', which are being evaluated for possible registration, were unaffected by *M. larici-populina*. Infections of these clones were, however, found at some sites in 1998, indicating the involvement of a new pathotype of the fungus. Further observations will be needed for an assessment of the susceptibility of these clones, which currently continue to perform well in trials.

Pine looper moth, *Bupalus piniaria*

Entomology Branch staff have been collaborating with colleagues at the Natural Resources Institute (NRI) of the University of Greenwich to identify the female sex pheromone of the pine looper moth, *Bupalus piniaria*. Traps baited with the synthetic pheromone could be used to predict population levels and could therefore replace the laborious counts of pupae in the soil, the only reliable method currently available.

NRI staff collected pheromone from female *B. piniaria* moths by extraction and entrainment methods (Ms Sumathi Chittamuru, personal communication). Analyses of these by gas chromatography (GC) linked directly to electro-antennographic (EAG) recording from a male moth antenna showed a single component eliciting an EAG response. The amounts present were less than 0.1 ng per female, making identification of its chemical structure very difficult. Microchemical reactions and analyses by GC, coupled to mass spectrometry in electron impact and chemical ionisation modes, led to a proposed chemical structure for the active component and this was synthesised.

However, while this work was in progress, Canadian colleagues identified four compounds (I-IV) proposed as pheromone components for *B. piniaria*. During 1998 a collaborative programme to field test the synthetic chemicals was carried out by Forest Research/NRI at Speyside, Scotland, with parallel trials by colleagues in Germany and Hungary. The major pheromone component (I) was attractive to male *B. piniaria* moths by itself, but the other components (II-IV) were not. The attractiveness of (I) was increased by addition of the minor components, with the full, four-component blend being the most attractive of those tested (Figure 1).

Table 2 Summary of data on Phytophthora disease from riparian plots in southern England and east Wales

	DATA FROM 50 PLOTS (ALL PLOTS WITH ALDER)				DATA FROM 31 PLOTS (PLOTS WITH A MINIMUM OF 15 TREES)				
	1994	1995	1996	1997	1994	1995	1996	1997	1998
CATEGORY OF ALDER:									
Number of trees assessed (n)	1704	1741	1744	1746	1679	1716	1717	1720	1712
Number missing since last survey	-	7	53	53	-	5	46	53	37
Number with *Phytophthora* crown symptoms	67	78	97	105	61	71	90	103	117
Number dead (of which number long dead)	21 (7)	27 (13)	40 (24)	44 (23)	22 (7)	28 (14)	40 (23)	44 (24)	54 (30)
Number with *Phytophthora* crown symptoms or dead (d)	88	105	137	149	83	99	130	147	171
Number missing since last survey which had had *Phytophthora* crown symptoms or were dead (m)	-	2	6	9	-	1	4	7	5
Percentage of symptomatic and dead trees	5.2	6.0	7.9	8.5	4.9	5.8	7.6	8.5	10.0
Annual incidence of disease derived from: $\left(\frac{d_i+m_i-d_{i-1}}{n_i+m_i-d_{i-1}}\right) \times 100$	-	1.2	2.3	1.30	-	1.04	2.16	1.50	1.85

where n, m and d refer to the alder categories indicated above and $_i$ is the year for which disease incidence is being calculated

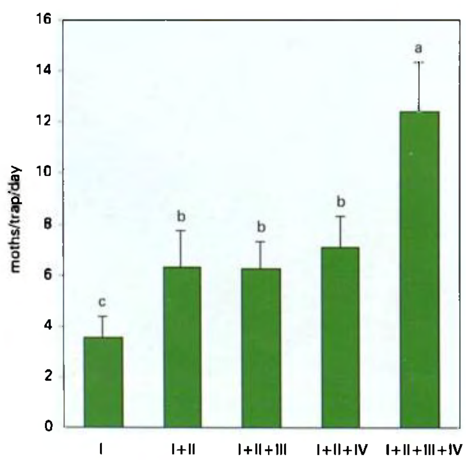


Figure 1 Mean catches (+ SE) of male *B. piniaria* moths per day in traps baited with different combinations of the four synthetic pheromone components, Speyside, July 1998 (10 replicates); bars marked with different letters are significantly different ($P<0.05$) after ANOVAR of log (x+1) transformed data). Data from N. Straw, G. Green (Forest Research), S. Chittamuru and D. Hall (Natural Resources Institute).

With larger amounts of synthetic pheromone available from NRI, the possibility of further work to investigate the extent of correlation between pupal counts and pheromone trap catch is being considered.

Phytophthora disease of alder

An Information Note on the disease was published during the year (Gibbs and Lonsdale, 1998). In addition to work conducted in the UK, the research programme is now able to benefit from information becoming available through a 3-year EU Concerted Action on the disease which began on 1 March 1998. It involves 14 partner organisations in 11 countries and is co-ordinated by staff of the Pathology Branch.

No major changes in the distribution of the disease in England and Wales have been recorded, although it may be noted that it has now been found at two places on the River Spey in north-east Scotland. Surveys of riparian plots across some 70 000 km^2

of southern England and east Wales have now been conducted for 5 years. In 1998 a change in survey methodology to make more efficient use of resources was made, such that only the 31 plots with a minimum of 15 trees were revisited. Table 2 shows the 1994–1998 data from these plots with the 1994–1997 data for the original 50 plots shown for comparison. It can be seen that reducing the number of plots has made very little difference to the data that have been obtained. The 1998 'annual disease incidence' of 1.85% was rather higher than recorded in the previous year but not as high as the peak year of 1996. Symptomatic and dead trees now comprise about 10% of the total population with dead trees making up 32% of these. The rate of 'disappearance' (through disintegration and collapse) of affected trees is lower than might have been expected and indeed has dropped slightly. A detailed analysis of the data for the first 3 years of the survey was published during the year (Gibbs *et al.*, 1999).

Three experiments involving different provenances and species of alder have been established at different riparian sites subject to inundation.

6 Base of stem of 3-year-old *Alnus glutinosa* affected by Phytophthora disease in an experimental planting beside the River Clun in Shropshire.

In July 1998, it was observed that some of the seedlings at a site beside the river Clun in Shropshire, now in their third season of growth, had contracted the disease and, by October, 16 out of 180 saplings were affected (see Plate 6). As yet there are insufficient data to determine if there are significant differences in terms of provenance susceptibility.

Since it was first discovered, there has been considerable speculation as to whether the disease was caused by a new fungus or by a previously unrecognised native fungus, the effects of which had been exacerbated by some particular environmental circumstance. In spring 1999 a paper, resulting from collaboration between Forest Research and the Scottish Horticultural Crops Research Institute, was published in a prestigious American scientific journal to show that the 'alder *Phytophthora*' comprises a range of heteroploid interspecific hybrids between *P. cambivora* and a fungus close to *P. fragariae*. Both these fungi are thought to be introduced to Europe and neither has the capacity to cause disease in alder. The wider significance of these findings for plant health control is discussed by the authors (Brasier *et al.*, 1999).

Weather-related and periodic damage problems

1998 was a year in which there was very little stress to trees arising from extremes of weather. Frost injury was only reported from north-east Scotland, where damage occurred in mid-April to a number of ornamental species, newly-planted Sitka spruce and Scots pine, and established birch of non-native origin. During this period a screen temperature of -6.2°C was recorded at Aviemore and -9.0°C at Altnahara (Sutherland). Cold northerly winds may have exacerbated the damage. A later frost in June injured older Sitka spruce in the same general area. Sufficient rain fell for good growth throughout the season and this was undoubtedly a key factor in the improved crown condition that was recorded in oak and beech plots of the forest condition survey (Redfern *et al.*, 1999). However, the wet weather provided favourable conditions for a number of leaf and shoot diseases. In addition to the poplar rust mentioned above, willow scab, *Pollacia salciperda,* was particularly noticeable on *Salix fragilis.* Mildews were also very conspicuous, although here the link with damp and humid conditions is less clear. The wet soils were favourable for the development of *Phytophthora* spp., and root damage was recorded to recently-planted beech in the Scottish Borders, and to yew at a number of places in Southern England. The species implicated on the yew were principally *P. cinnamomi* and *P. citricola.* During the course of the year there was an unusually large number of cases of damage by root-acting herbicides and in at least one case (a Christmas tree plantation) there appeared to be an interaction with high rainfall and waterlogging.

New or unusual records

A number of reports of damage to poplars, particularly black poplar, by the hornet clearwing moth *(Sesia apiformis* - see photo on page 10*)* drew our attention to the possibility that, in at least a few areas of the country, numbers of this moth may be unusually high at present. Quite large numbers of exit holes, approximately 8 mm in diameter, were reported (more than 30 in some trees 30–40 cm in diameter) with extensive tunnelling under the bark at the level of the root collar and into the upper parts of the root. While some trees appear to be showing no adverse affects, despite having varying degrees of infestation, others have shown signs of crown dieback and foliage deterioration and a few appear to have been killed.

It is unusual for wood-boring insects to be the primary cause of tree death in the UK and a direct causal link between dieback and infestation is still unproven. Predisposing factors, for example drought, are more usually the underlying cause of such a problem. Not all the moth exit holes were made in the current year and it may be that water availability problems during a dry period 2–3 years ago, or even earlier, may have coincided with initial infestations of the moth. Such conditions may have been sufficient to allow the moth population to increase to a level capable of killing trees.

Damage to Leyland cypress hedges was also the cause for concern on numerous occasions throughout the spring and summer. The symptoms of foliage fading to a yellow straw colour, first noticed in May or early June, showed initially at the bases of the affected trees. The discoloration then spread upwards and sideways, often to adjacent plants. Later the foliage turned brown and dieback of the lower branches occurred. When examined at this stage, the presence of sooty moulds on honeydew indicated the prior presence of cypress aphid *(Cinara cupressi)* although live insects were not found easily. Very little information is available on the life cycle of *C. cupressi* in this country, but it is known that the damage occurs very rapidly after colonisation and, thus, any attempt at remedial spraying with insecticide may well prove to be futile. The majority of records of damage were linked to 'golden leylandii' cultivars, particularly 'Castlewellan'.

Phytophthora citricola was found causing a collar rot and basal shoot canker on *Aucuba japonica* used as stock plants. This appears to be the first record of this fungus on *Aucuba* in Europe. A record of *Serpula himantioides* causing decay on *Sequoia sempervirens* is the first for Forest Research and may also be the first record for the UK.

In Scotland, there were two cases of significant killing by *Heterobasidion annosum* in *c.* 40-year-old Scots pine and lodgepole pine on acidic mineral soils (pH <4). It is thought that the hot dry summer of 1995 might have precipitated the death of trees that would otherwise have survived.

Severely distorted leading shoots of thicket stage (8-year-old) Douglas fir were reported from Devon. Some shoots had turned a full circle before resuming their normal upward growth. No cause was found and it appears that similar, though less severe, symptoms had occurred in the same stand in 1997. Herbicide damage could be excluded.

A more comprehensive account of damage to amenity trees in England in 1998 is provided by Gibbs *et al.* (1998) which presents information obtained in the Amenity Tree Health Survey carried out by Forest Research on contract to the Department of the Environment, Transport and the Regions.

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Molecular Pathology

Molecular Methods in Forest Pathology
by Joan Webber

Introduction

Traditionally, most organisms have been identified and classified on the basis of morphological characteristics, in other words 'by how they look'. Organisms that look similar are grouped together and considered closely related, whereas a high degree of difference in appearance indicates only a distant level of genetic relatedness. Unfortunately some organisms, and this applies to many of the fungi that cause diseases of forest trees, do not have enough consistent morphological characters to allow them to be reliably identified. This becomes a serious problem if, for example, two similar species have very different abilities to cause disease, one perhaps being harmless and another highly pathogenic, but they can only be distinguished on morphological grounds with difficulty or not at all.

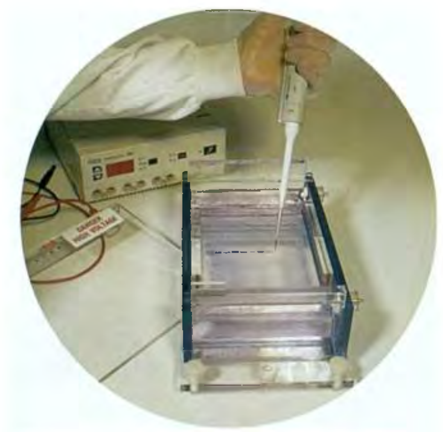
Apart from the requirement to identify organisms reliably, we often need to estimate the extent of natural variation within a species. This gives us a valuable indication of diversity; it may also provide clues on the origins of introduced pathogens and whether they have established as a result of a single introduction or after many such events.

In consequence, in addition to morphological criteria, characters or markers are required which allow us to identify individuals and measure the extent of variation in populations. Ideally, they need to define a species, possibly also provide a unique signature for an individual, and even provide a measure of relatedness between individuals. Examples of biochemical markers commonly used for identifying fungi include gene products such as fatty acids and isozymes. However, in recent years the approach has been to look directly at the source of genetic identity and variation, by analysing the DNA which is the genetic code of every individual.

This switch to examining DNA directly, rather than examining the products that the DNA codes for, became possible in the early 1980s with the development of new recombinant DNA techniques. Having the whole genome available for analysis gives plenty of scope for finding differences between species and individuals. Some segments of DNA are highly variable and therefore likely to yield many distinguishing differences or 'polymorphisms'.

Methods

Two major techniques are now used routinely to analyse variable regions of the genome. The first involves cutting the DNA into fragments, using so called restriction enzymes (originally isolated from bacteria) and assessing the variation in size of the resulting fragments. The second consists of copying or amplifying small segments of DNA using a process called the Polymerase Chain Reaction, or PCR, and looking for differences in fragment size and number. With both these techniques, the DNA fragments are assorted by size as they migrate under the influence of an electric field in a gel matrix, a method known as gel electrophoresis (Plate 1).



1 **Electrophoresis equipment used to separate DNA fragments on a slab of agarose gel.**

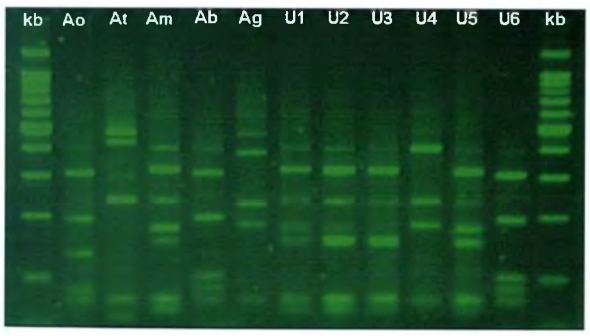
Currently, our work on fungal pathogens employs PCR in combination with short random DNA sequences (called primers) – a method known as Random Amplified Polymorphic DNA or RAPD. Alternatively we use PCR in combination with specific primers which locate the highly variable ITS (Internally Transcribed Spacer) or the IGS (InterGenic Spacer) regions of ribosomal gene sequences; these stretches of DNA can then be compared. Primers are short single strands of DNA which bind to a complementary region of the pathogen's DNA and, with the aid of an enzyme and the building blocks of DNA (nucleotide bases), new fragments of DNA of varying lengths are synthesised during the amplification process. At the end of the process, portions of the DNA selected by the primers have been copied millions of times, and they can be visualised on a gel and different fungal isolates compared.

Honey fungus

The root disease known as honey fungus is one of the commonest diseases of trees and shrubs in the world. It is endemic in broadleaved woodlands and can also cause appreciable damage in conifer plantations. It is a particular concern of gardeners as it is frequently found in long-established gardens, spreading from old decaying stumps and roots through the soil to infect and kill healthy roots (Plate 2). Until the 1970s, honey fungus was considered to be a single species, *Armillaria mellea,* but it is now clear that in Europe alone five genetically and behaviourally distinct species exist. Some are highly pathogenic (e.g. *A. mellea* and *A. ostoyae*), while others (e.g. *A. gallica* and *A. cepistipes*) are largely harmless and grow as saprotrophs on dead wood (Greig, Gregory and Strouts, 1991). However, distinguishing between the harmless and harmful is difficult and time consuming, and involves growing the fungus in culture for mating tests that can take over two months to give a positive identification (Korhonen, 1978).

2 **Toadstools of *Armillaria*.**

In contrast to this, a molecular method devised in North America is proving to be a quick and reliable way of identifying the various species of *Armillaria* (Harrington and Wingfield, 1995) The method allows rapid determination of whether one of the pathogenic species has caused death or whether the tree has been infected or killed by another agent and only later colonised by a saprotrophic *Armillaria.* In this method, a few fragments of mycelium from an *Armillaria* culture are mixed with a specific primer and a portion of the IGS region amplified. The amplified DNA is then cut into smaller fragments using the restriction enzyme Alu I. This results in a characteristic 'fingerprint' pattern for most species (Plate 3), but further restrictions can be carried out with other enzymes for the two species which have the same pattern. Providing, the *Armillaria* species have already been successfully isolated from infected material on to agar medium, the technique can provide a reliable identification within one or two days. In addition, spores collected from fruit bodies can also be successfully amplified and 'fingerprinted' in this way.



3 Stained agarose gel showing DNA profiles of Alu I digest products of the IGS region of known and unknown isolates of *Armillaria.* Known isolates are: Ao, *A. ostoyae;* At, *A. tabescens;* Am, *A. mellea;* Ab, *A. borealis;* Ag, *A. gallica.* Unknown isolates (U1 - U6) correspond to *A. mellea* (U1, U2, U5), *A. gallica* (U4) and *A. borealis* (U6).

Ips typographus associated fungi

Following the suspected outbreak of *Ips typographus* in England in 1997 (Gibbs and Evans, 1998) the risks posed by the beetle and the pathogenic bluestain fungi associated with it are being assessed. The most damaging fungus disseminated by *I. typographus* is *Ceratocystis polonica,* which is a primary pathogen in its own right. As part of their breeding behaviour the bark beetles mass attack trees of Norway spruce. In doing so, they introduce this fungus under the bark and it is then able to penetrate the phloem and sapwood and cause rapid death in affected trees (Plate 4). Because of the threat this combined action of *I. typographus* and *C. polonica* undoubtedly poses to the major home-grown species, Sitka spruce, its exclusion from Britain is vital.

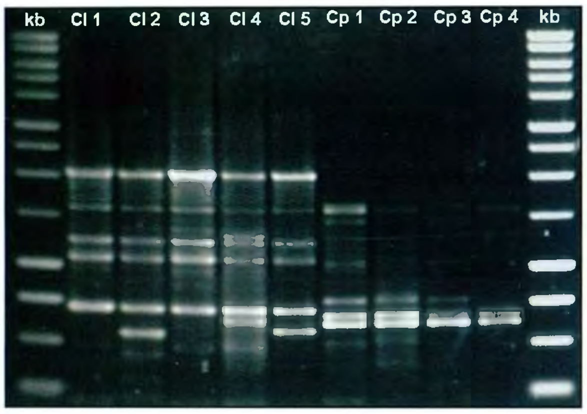
In contrast, there is another bark beetle/*Ceratocystis* association which is well established in Britain:

4 Section through Norway spruce showing the extensive areas of stain caused by *Ceratocystis polonica* invading the sapwood, after the tree has been attacked by *Ips typographus.* (Courtesy of NISK, Norway.)

Ips cembrae and *Ceratocystis laricicola* (Redfern *et al.,* 1987). *I. cembrae* attacks larch and occasionally spruce, and its associated pathogen *C. laricicola* causes damage in much the same way as *C. polonica.* However, despite being named as distinct species, *C. laricicola* and *C. polonica* cannot be separated from each other on the basis of morphological criteria (Harrington and Wingfield, 1998) and they also have identical DNA sequences in the ITS region (Witthuhn *et al.,* 1998), suggesting they are conspecific. This question over identification needs to be addressed if the threat posed by *C. polonica* is to properly evaluated.

We have compared the two named species using RAPD technique and by assessing their ability to colonise freshly felled spruce and larch, and found there are consistent differences between them. In contrast to the earlier molecular work which compared ITS sequences (Witthuhn *et al.,* 1998), our study using random primers revealed that *C. polonica* and *C. laricicola* have species specific, characteristic DNA fingerprints (Plate 5). In addition, isolates of *C. laricicola* produced lesions in European larch that were three times greater in size than those of *C. polonica,* whereas *C. polonica* was the more effective coloniser in Norway spruce and Sitka spruce (Figure 1).

Clearly, these fungi are distinct taxa which can be separated on the basis DNA polymorphisms and their response to *Larix* and *Picea*. The extent of their similarity in other respects probably indicates that they have evolved recently, possibly as a result of becoming associated with different species of vector bark beetle and different conifer hosts.



5 DNA profiles of *Ceratocystis laricicola* and *C. polonica* after amplification with random primer OPA9 and separation on an agarose gel. Lanes 1 and 11, Kb marker: Lanes Cl1 to Cl5, different isolates of *C. laricicola;* Cp1 to Cp4 different isolates of *C. polonica.*

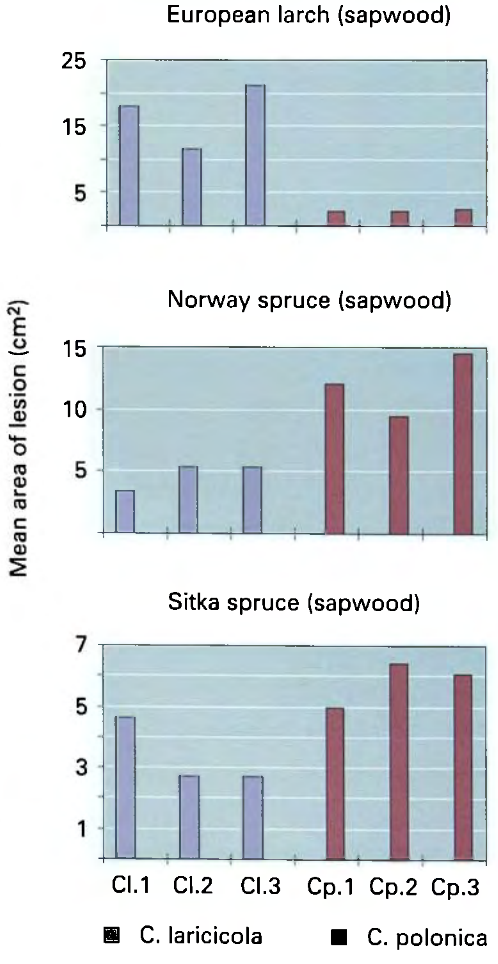
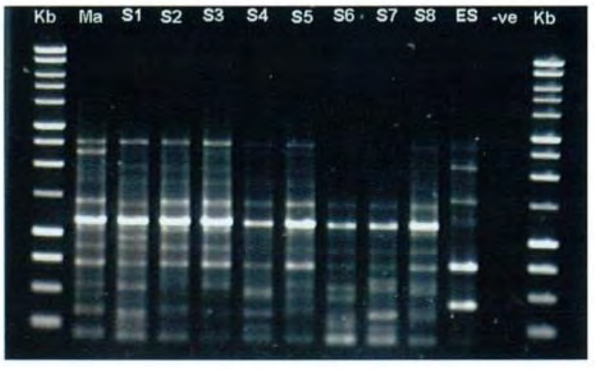


Figure 1 Lesions revealed as stained areas of sapwood produced by isolates of *Ceratocystis polonica* and *C. polonica* after two weeks growth in freshly felled logs of European larch, Norway spruce and Sitka spruce.

Tropical vascular wilt

Following the observations that takamaka trees were dying in large numbers on the islands of the Seychelles, a vascular wilt pathogen was isolated as the causal agent and eventually identified as *Leptographium calophylli* (Webber, Jacobs and Wingfield, 1999). The newly isolated cultures of the pathogen were morphologically similar to forms of the fungus found much earlier this century in Mauritius (Wiehe, 1949) and El Salvador (Crandall, 1949). There was also evidence to suggest that the disease caused by *L. calophylli* in the Seychelles was being disseminated by a bark beetle vector (Wainhouse *et al.*, 1998).

Comparison of more than fifty isolates of the pathogen from the Seychelles using RAPD technique has shown that there is genetic variation between the individuals of *L. calophylli* (Plate 6). This suggests that the outbreak of the disease on the islands has either been introduced on many occasions or that it has been present for some time and natural variation has arisen. Interestingly, in some cases more than one genotype of *L. calophylli* (indicated by unique RAPD patterns) has been found in a single tree, indicating multiple infections have occurred, presumably as a result of the activities of beetle vectors. However, the pathogen is essentially the same as the form of the *L. calophylli* isolated from Mauritius in the late 1930s. In contrast, the RAPD profiles of the fungus from El Salvador is consistently different, suggesting that despite the morphological similarities the latter is a different species, with possibly a different host range.



6 DNA profiles of takamaka wilt fungus after amplification with random primer OPA9 and separation on an agarose gel. Lanes 1 and 13, Kb marker; Ma, isolate from Mauritius; S1–S8, from the Seychelles (with isolates S6 and S7 from the same tree); ES, isolate from El Salvador; Lane 12, negative control.

Conclusions

Molecular methods are now being used widely to tackle a variety of questions related to the identity and behaviour of trees pathogens. Recently, such techniques have allowed the detection of a new hybrid species of *Phytophthora*. This novel fungal pathogen has a new host range and consists of a swarm of hybrids which are still evolving as a consequence of their unstable and highly variable nature (Brasier *et al.*, 1999). International quarantine legislation and the legal specification of organisms emphasise the need for us to understand and define species with increasing precision, so these techniques will need to be a routine tool employed by forest pathogists.

Acknowledgements

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Broadleaved Seed Sources

Evaluation and Selection of Seed Sources in British Broadleaves

by Ned Cundall

Introduction

In the past 7 years broadleaved afforestation in Britain (63,088 ha) has surpassed that of conifers (55,862 ha). However, there has been relatively little attention paid to the genetic quality of the planting stock for most broadleaf species.

1 Ash provenance trial showing genetic differences in leaf-fall (at Hartpury College).

Planting of locally native material may help fulfil genetic conservation objectives (*UK forestry standard,* p.35) but native material may not always be better adapted and more vigorous than alternative planting material. Where a range of hardwood seed sources has been planted in comparative trials in continental Europe local material has not always been the most well-adapted, as measured by vigour. Similarly early results of Forest Research provenance trials for oak, ash and sycamore do not consistently show local sources to be the most vigorous.

Amongst our native high forest broadleaves only oak and beech currently fall under the Forest Reproductive Material Regulations of the European Union which require that seed for commercial use should be collected from Registered Stands. However, there are few years when domestic production from these phenotypically selected stands is sufficient to satisfy demand, and in most years some seed or planting stock is collected from UK stands of lower phenotypic quality or imported from continental Europe. Results of oak provenance trials, outlined below, show the early growth rates of sessile oak from a wide range of sources. For beech a range-wide provenance evaluation has recently been established (Figure 1) (Von Wueschlish *et al.,* 1998) and trials were planted in 1996 in the Chilterns and in 1998 near Oxford.

Other commercially important species such as ash, sycamore, birch, and cherry do not at present fall under the EU Regulations and seed is obtained commercially from many sources both in the British Isles and in continental Europe.

Trials of ash and sycamore provenances were planted under a joint contract between the Forestry Commission and the Ministry of Agriculture, Fisheries and Food from 1992 and 1993 onwards. Ash and sycamore had been chosen as commercially valuable whitewoods which can be grown on relatively short rotations of 60–70 years on farm-forestry sites. Results for early growth for a range of both British and continental seed sources are outlined overleaf.

The form of the tree is important for the final market value of most hardwoods and characteristics such as straightness of the trunk are known to be under relatively strong genetic control (Cornelius, 1994). To date tree form has been assessed and analysed only for the sycamore provenance trials, but will be evaluated for the other species as they grow, and as resources permit.

Birch has not hitherto been considered a commercial hardwood, even in Scotland where it is the predominant broadleaf species, in contrast to its considerable importance in Scandinavia. A series of provenance trials is being established at four sites in Scotland which could be the basis for a programme of genetic improvement (Figure 2).

Cherry and walnut both have high value timbers but were almost entirely neglected in terms of genetic evaluation and improvement, a situation which has recently been addressed by Horticulture Research International and the Northmoor Trust respectively, and reported through meetings of the British Hardwoods Improvement Programme and in the literature.

Oak

A series of provenance trials, mostly of sessile oak *(Quercus petraea),* was established under the auspices of IUFRO in 1990 and 1992 at ten sites. Heights at 6 years have been assessed and summarised.

Table 1 Comparison of oak seed sources for early vigour by country of origin

COUNTRY	NUMBER OF SOURCES	AS PERCENTAGE OF COMMON ENTRIES
English and Welsh	18	109
German	9	95
French	14	92
Scots	3	91
Dutch	1	134
Polish	1	108
Turkish	1	97
Belgian	1	89
Hungarian	1	59

Note: Results are from 6-year heights of IUFRO provenance trials planted in 1990 and 1992 at nine sites in all. Data are as a percentage of the mean for the seed sources which are common to all sites.

Table 1 shows that in this trial series oak seed sources from England and Wales are generally more vigorous than seed sources from France, Germany, or Scotland. A seed source from the Netherlands ranks first for vigour (included at six sites) and eastern sources from Poland and Turkey have grown better than would be expected. (In Tables 1 and 3 heights are given as a percentage of the entries which are common to all sites, as representation of the seed sources is not the same across all sites.)

Table 2 Comparative survival of oak provenance at Inchnacardoch near Loch Ness

STAND	LOCALITY	COUNTRY	SURVIVAL AFTER 9 YEARS (%)
Drummond Castle	Perthshire	Scotland	81
Brecon		Wales	75
Hurst Hill	New Forest	England	67
NL3		Netherlands	64
West Downs	Chiddingfold	England	64
South Oakley	New Forest	England	62
Delgany	Wicklow	Ireland	56
Sutton Bottom	Forest of Dean	England	48
Vinney	New Forest	England	45
Blakeney	Forest of Dean	England	43
Killarney		Ireland	43
Charentes-Poitou		France	40
NE Limons at Argiles		France	34
Dymock	Hereford	England	26
Charentes-Poitou		France	16
Basin superior/Soane		France	15
Mean % survival			50
s.d.			11.6
Statistical significance			$P<0.001$

Note: Survival scored after 9 years.

Nine of the oak provenance trials were established at sites in England and Wales which are suitable for growing oak commercially. A tenth site at Inchnacardoch near Loch Ness was planted to widen the range of climatic conditions. Some survival results from Inchnacardoch are in Table 2. These large and significant ($P< 0.001$) differences in survival percentage are in contrast to the nine other trial sites where survival of all provenances has been good. Survival of all four French provenances has been significantly below average. At the testing frost-prone northern site of Inchnacardoch genetic differences between populations are evident which were not apparent in less stressful conditions.

Ash

Early heights of 18 British and continental seed sources assessed at five sites are summarised by country of origin in Table 3. Differences in vigour between provenances are highly significant at each site. Southern English and Welsh material is on average more vigorous than that from France, which in turn is more vigorous than that from the north-east of Britain (Scotland and Northumberland). Material from the continental climate of eastern Europe (Germany and the Czech Republic) has grown poorly in our more oceanic climate. These eastern seed lots were commercially available for planting in Britain and it is important to note that

Figure 1 International Beech Provenance Trial 1996/98. Trial sites and provenances. (Courtesy Institute for Forest Genetics and Forest Tree Breeding, Grosshandsdorf, Germany.)

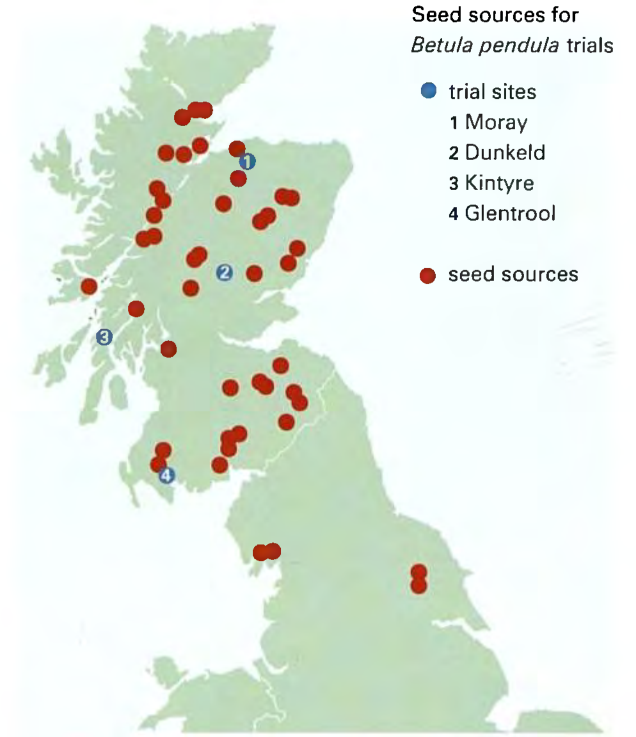

Figure 2 Silver Birch Provenance Trials 1996/99. Trial sites (not including County Cork) and provenances. (Birch Research and Development Co-operative.)

they appear unsuitable for planting in England and Wales. Romanian material has grown particularly slowly to date. On the other hand, the outstanding performance of the Yugoslav material is noteworthy. There is some early evidence that material from northern Britain is growing relatively better at a northern site (Yorkshire) as compared with a southern site (Oxfordshire).

Table 3 Comparison of British and continental European ash seed sources for early vigour

SEED SOURCE	NUMBER OF SOURCES	AS PERCENTAGE OF COMMON ENTRIES
Yugoslavia	1	149
British (provenance zones 30 and 40)	6	124
French	5	115
British (provenance zone 20)	2	108
Czech + German	3	91
Romanian	1	83

Note: Results are from 6-year (4-year, 3-year) heights of trials at four sites. Data are as a percentage of the mean for the seed sources which are common to all sites.

Sycamore

Heights of six British and four continental European seed sources at five sites are shown in Table 4. Heights were assessed at 4 years at Llanrwst and 5 years at the other four sites and are expressed as a percentage of the trial mean at each site. Earlier results have been considered in more detail previously (Cundall *et al.,* 1998). Differences are greatest in percentage terms and statistically significant, at the testing site of Llanrwst which is at an altitude of 200 m in the Snowdonia National Park.

For this naturalised species two of the continental sources, Wedellsborg (Ornsjberg) from Denmark and Pfalz from Germany are more vigorous than material from a range of British seed sources. The British seed sources of Boughton, Chatsworth, Glynliffon and Bolton Estate are similar overall. The French provenance of Picardie is of average height but the German provenance of Bayern,

Table 4 Comparison of British and continental European sycamore seed sources for early vigour

SEED SOURCE		FARM FORESTRY SITES					
		Sparsholt Hampshire	Llanrwst Wales	Hartpury Gloucs.	Riseholme Lincolnshire	North York Moors	Mean % over 5 sites
Pfalz	Germany	113	135				124
Wedellsborg	Denmark	124					124
Bolton Estate	Yorkshire	102	114	98	104	97	103
Boughton	Northants	92	93	104	99	118	101
Glynliffon	Gwynedd	99	88	103	118	97	101
Picardie	France	97	109	104	90	108	101
Chatsworth	Derbyshire	93	86	107	104	107	99
Bayern	Germany	88	101	102	87	104	96
Ampfield	Hampshire	104	72	86	94	100	91
Tehidy	Cornwall	87			89	66	81
Mean height (cm) for provenances common to all sites			209	254	218	211	121
s.d.		32.5	54.2	23.7	28.9	38.7	
Statistical significance		ns	$P<0.05$	ns	ns	ns	

Note: Results are from 5-year heights of trials from five sites expressed as a percentage of the mean for each site.

which is from a relatively high altitude site has grown rather poorly to date. It seems that sycamore is similar to beech (which is considered to be a naturalised species through much of Britain) in that some continental provenances grow better than British provenances at some British sites (Worrell, 1998, 1992). The promising continental material should be tested at a larger number of sites and it has been arranged that commercial nurseries in both Scotland and England will grow seed from Wedellsborg together with Scots and English sycamore seed sources. These sources will later be planted out in simple statistically designed proving trials and managed by interested growers themselves. Further interest may follow publication in trade journals (Cundall, 1999) and this approach of further trialling of promising sources may be applicable to other hardwood species.

Form was scored after 6 years growth for the four sycamore provenance trials planted in 1992. There were, even at this very early stage, highly significant differences in stem straightness. Chatsworth, Pfalz and Glynllifon are the straightest sources overall (Table 5) and the French source of Picardie is the poorest. Differences in branching and forking were not significant.

Table 5 Differences between sycamore seed sources in stem straightness, summing over five sites, as a percentage of the mean at each site

SEED SOURCE	STRAIGHTNESS AS PERCENTAGE OF TRIAL MEAN
Chatsworth	96
Pfalz	98
Glynliffon	98
Ampfield	99
Boughton	99
Bolton Estate	99
Bayern	101
Wedellsborg	101
Tehidy	103
Picardie	105

Note: Scored on a scale from 1–6 where 1 = perfectly straight, 6 = very bent.

Birch

Genetic evaluation of birch is undertaken by the Birch Research and Development Co-operative which brings together the University of Edinburgh, commercial nurseries and Forest Research.

Results of some previous Forestry Commission trials comparing Scandinavian birch with native Scottish sources were reported by Worrell (1998). Survival of Finnish material at Teindland was only 59% compared with 97% for the Scots material. At a more testing site at Speymouth Finnish material had only 36% survival compared to 94% for Scots material. It is clear that although Scandinavian material shows excellent form it is not adapted to Scottish conditions, and improved birch material should almost certainly be selected within Britain.

From 1995 silver birch seed sources were sampled throughout Scotland, with a few representatives also from northern England and these are being compared in provenance trials at four sites in Scotland (Figure 2) and at one site in County Cork, Irish Republic. This is the most intensive sampling of provenances undertaken in a native broadleaf in Britain to date. Analysis of these trials should reveal the extent to which adaptive genetic variation changes within quite small geographic areas. Material which is locally native to a great range of sites is being compared in several contrasting common environments. Results should guide seed transfer rules on the basis of adaptability rather than on the basis of climatic and edaphic zones only.

The first field trial of this material was established at Craigvinean, near Dunkeld, in 1997. Significant differences between provenances in early growth at Dunkeld 21 are not correlated with latitude or longitude of seed source, but Donnelly (1998) found a significant relationship between latitude of seed source and spring flushing with more northerly sources tending to flush later. Brown (1998) used isozyme markers to investigate the genetic structure of eleven of the birch populations which are included in the provenance trials and found relatively high genetic diversity and low genetic differentiation for these sources.

2 A solution of 2,4–dinitrophenylhydrazine is used by Magda Kosmopoulou to distinguish silver birch (orange precipitate) from downy birch (solution remains clear yellow).

Many stands of silver birch in Scotland include a proportion of downy birch trees. The two species can be distinguished morphologically and by chromosome count (*Betula pendula* 2n = 28, *Betula pubescens* 2n = 56) but a chemical test (using a solution of 2,4–dinitrophenylhydrazine) described by Lundgren *et al.* (1995) has been found to be useful to distinguish individual trees in case of doubt (Plate 2).

Future work

In addition to evaluation of provenances there is also the possibility of genetic improvement of commercially important hardwoods through selection of individual trees (plus trees), progeny testing, and production of improved seed from seed orchards (Figure 3). The genetic principles are the same for hardwoods as for commercial conifers such as Sitka spruce, and there have been highly successful hardwood programmes elsewhere, such as that for birch in Finland (Hagqvist and Hahl, 1998). An untested clonal seed orchard for birch at Northern Research Station, based entirely on selected Scottish material, is being re-established, and in future it may be possible to select plus trees from a wider geographic area and establish regionalised seed orchards.

Alternatively improved material could be made available as clones, either as rooted cuttings or through micropropagation. Appropriate means for the rooting of cuttings of both sycamore and ash were investigated (Jinks, 1996) at the same time that provenance trials were established.

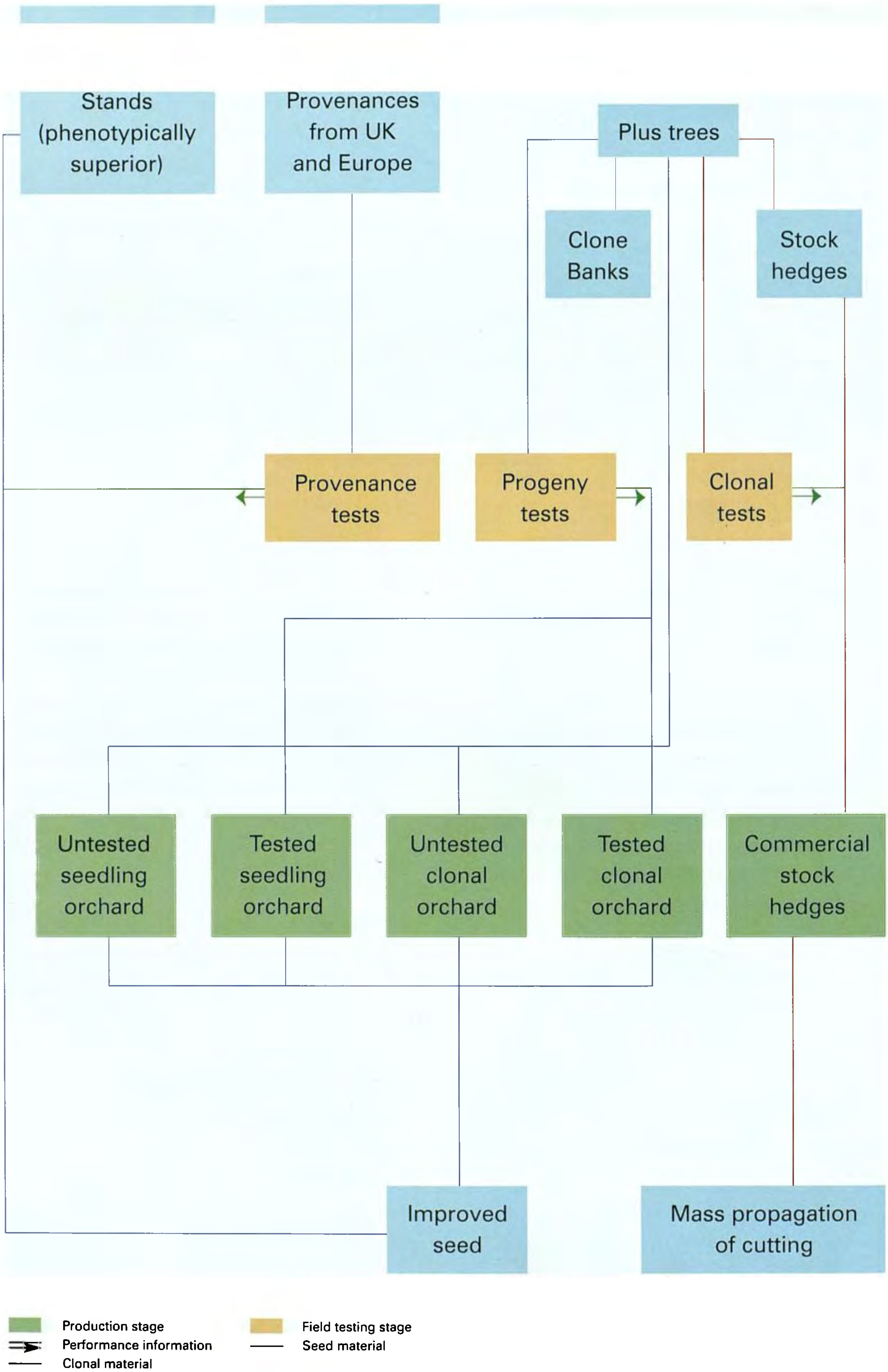

Figure 3 Broadleaved species: breeding strategy.

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Natural Regeneration

Natural Regeneration of Broadleaves
by Ralph Harmer

Natural regeneration, the process by which trees and woodlands are established from seeds produced and germinated *in situ,* is the preferred method of restocking semi-natural woodlands, and an important process in continuous cover forestry and uneven-aged silvicultural systems (Plate 1). However, it is unpredictable and successful regeneration can be very difficult to achieve on some sites. Extensive research in the Allegheny hardwood forests of North America has shown that success is closely related to the size and number of seedlings present within the stand prior to regeneration felling (Marquis, Ernst and Stout, 1992). Current advice for British woodlands also suggests that these seedlings, which are called advance regeneration (Plate 2), provide the most likely route to successful natural regeneration (Evans, 1988; Harmer and Kerr, 1995). Although advance regeneration is present in many British woodlands the seedlings are often small and their numbers probably too low to ensure success (Harmer, Kerr and Boswell, 1997).

The growth of seedlings and the dynamics of their populations within woodlands are poorly understood, but it is probable that the lack of suitable advance regeneration is partly due to competition between the seedlings and other vegetation. The increased growth of vegetation in canopy gaps, and trenched plots from which tree roots have been excluded, suggest that plants in the field layer are suppressed by competition with canopy trees for both light and water. However, it is unclear whether the growth of advance regeneration can be improved by reducing the competition from the ground flora (Plate 3).

The establishment of advance regeneration is also influenced by deer browsing. There have been several studies which have observed the influence of browsing intensity and regime on the growth and survival of woody plants and Gill (1992 a and b) concluded that for broadleaves the most damaging effects occur during the summer months. It is well known that established tree seedlings have the potential to survive many years of browsing if they are growing in full sunlight, but their longevity in shaded conditions is not well understood and has been little studied (Plates 4 and 5). During the past 5 years a number of experiments have been carried out to investigate the influence of simulated summer browsing on the growth and survival of broadleaved trees growing under shade. These have taken place both in controlled conditions in the nursery and under natural shade beneath woodland canopies. These aim not only to improve our knowledge on the development and survival of seedlings under shade but also show how these characters are influenced by both competition from weeds and deer browsing. They will also provide information allowing better advice on the use of advance regeneration for restocking.

1 **Uneven-aged stand of beech with well-developed understorey of regenerating trees.**

2 **Dense advance regeneration of sycamore growing beneath an overstorey of beech.**

The following text describes the results from one of these experiments which took place at several woodland sites and was designed to investigate the influence of both weed competition and simulated deer browsing on the growth of seedlings beneath a woodland canopy.

Methods

Sites

Observations were carried out at four sites in the south of England. Seedlings of ash, beech and sycamore were studied at Thetford but there was only one species at the other sites (Table 1). A fifth site with oak was also established but all plants died within 2 years and no useful data were obtained. The sites were established in spring 1994. The seedlings at Thetford and Pixton Park were enclosed by combined deer and rabbit-proof fences, whereas those at Blackwood and Micheldever were protected by individual mesh guards. Overstorey canopy cover was 60–80% at all sites except Micheldever where it was 90–100%.

3 Observation of seedling growth in area of dense bramble treated with herbicide.

The type and amount of vegetation within the ground flora varied between sites, but bramble was not abundant anywhere. The experimental seedlings of all species were initially 30–40 cm tall with root collar diameters of between 3 and 6 mm.

Experiment design

The experiment was factorial combining two levels of weed control and two levels of clipping giving four treatment combinations in total. There were 20 replicates of each treatment combination for each species giving a total of 80 seedlings in the experiment at each site.

Treatments

- **Weed control.** A 1 m diameter weed-free spot was maintained around half of the seedlings using glyphosate when necessary. The remaining seedlings were untreated controls.

- **Clipping to simulate browsing.** Half of the seedlings were treated in both June and August when all new shoot growth longer than 1 cm was cut back to a length of 1 cm. The remaining plants were controls that were never clipped.

Treatments began in summer 1994 and continued until 1998.

Assessments

For individual seedlings the number of shoots clipped and their dry weights were recorded after each clipping treatment. The height, stem diameter and number of branches present on each seedling were assessed every autumn.

Table 1 Site and species studied

SITE	OVERSTOREY	SPECIES	SEEDLINGS HT	SEEDLINGS SD	GROUND FLORA
Thetford	Beech	Ash	35	5	Mixed herbaceous species with some bramble, raspberry, bracken and ivy.
		Beech	35	4	
		Sycamore	30	5	
Micheldever	Beech	Sycamore	40	3	Small amounts of herbs and bramble.
Blackwood	Beech	Ash	40	3	Mixed herbaceous species with some ivy and brambles.
Pixton Park	Oak	Oak	40	6	Bilberry with occasional bramble and bracken.

HT = Initial height (cm) SD = Initial stem diameter (mm)

Results

Weed control

This had little effect on the growth and survival of seedlings which suggests that maintenance of weed-free conditions in woodlands similar to those used will not promote the growth of advance regeneration.

Simulated browsing

The growth of seedlings differed and throughout the experiment not all of the plants produced shoots that were of sufficient length for clipping. The percentage of live plants clipped at each date varied between years and time of clipping (Table 2). In general, for all species, a greater percentage of plants were clipped in June than August: more than 75% of plants were usually clipped in June whereas less than 50% was typical for August. There were some differences between years in the percentage of trees clipped, but the trends were inconsistent: for example, figures for oak showed little change whereas sycamore declined (Table 2). Over all species there was a decline in the proportion of live plants clipped in the 5-year period.

The number of shoots clipped from treated trees varied similarly with month of treatment: more shoots were clipped in June than August. However, in general, the number of shoots clipped from each treated tree did not decline as the experiment progressed. The mean dry weight of shoots clipped from each tree in each year showed no consistent trend across all species (Table 3). The greatest dry weight was clipped from oak. This was probably due not only to the greater stature of the plants, but also their growth habit which is naturally branchy. There were up to 4-fold differences between years, but with the exception of sycamore at Thetford the dry weight of the shoots clipped did not decline consistently with time.

Growth

During the 5 years of the experiment the mean heights of unclipped plants increased by between 20 and 100%. The growth of clipped plants was greatly reduced: height increments were obviously constrained by the treatment, and stem diameter increments were small.

4 **Small yew tree that has survived many years of severe browsing.**

Table 2 **Percentage of live plants clipped at each harvest**

TREATMENT DATE	THETFORD			MICHELDEVER	BLACKWOOD	PIXTON PARK
	ASH	BEECH	SYCAMORE	SYCAMORE	ASH	OAK
June 94	98	90	88	89	97	*
August 94	95	54	83	54	82	80
June 95	95	100	100	100	100	68
August 95	8	16	0	36	18	0
June 96	100	100	100	64	78	82
August 96	6	3	0	40	37	47
June 97	45	66	80	36	59	71
August 97	19	17	20	11	27	53
June 98	51	89	0	17	81	90
August 98	13	21	0	22	32	59

* = *no plants clipped*

Table 3 **Total dry weight (g) of shoot clipped from each tree in each year**

TREATMENT DATE	THETFORD ASH	THETFORD BEECH	THETFORD SYCAMORE	MICHELDEVER SYCAMORE	BLACKWOOD ASH	PIXTON PARK OAK
1994	1.18	0.68	1.48	0.67	0.96	1.71
1995	0.48	0.66	0.56	0.57	0.45	1.54
1996	0.46	0.73	0.32	0.96	1.13	4.17
1997	0.26	0.71	0.30	0.72	0.83	1.26
1998	0.53	0.76	*	0.67	0.79	2.01

Values are means that only include data for trees which were clipped at least once in the year.
* = *no trees clipped*

Survival

Seedling death, which occurred at all sites, was strongly related to treatment (Figure 1). For all species between 80 and 98% of unclipped plants were alive in 1998, whereas only 5–79% of clipped plants survived the 5 years of simulated browsing. Overall sycamore appeared to survive less well than other species. Clipping had no effect on the survival of either beech or oak.

Discussion

The amount of deer browsing that individual seedlings will suffer in a single season is difficult to define, but is probably less severe than the treatment applied in this experiment. As expected, simulated browsing depressed growth and whilst it increased the mortality of some species a high percentage of plants survived the 5-year period of the experiment. The results from this study are consistent with those from another, which took place in the nursery, where it was found that seedlings of ash, beech, oak and sycamore grown under 30, 60 and 80% shade survived repeated severe summer browsing over a 3-year period (Harmer, 1999). Whilst these results do indicate that shaded seedlings can survive severe summer browsing which occurs over several years, this may be related to the initial stature of the seedlings used which were more than 1 year old and well-established.

Survival of the plants may also be related to the species present in the ground flora. Observations of natural regeneration at other sites (part-funded by the EU) have shown that growth of seedlings is influenced by the ground flora and that survival is adversely affected by competitive weeds, especially brambles. The sites used in this clipping experiment had little bramble which may explain the good survival of both clipped and unclipped plants.

Managers will wish to encourage advance regeneration as this represents the most likely route to successful natural regeneration. The results presented show that well established seedlings can survive several years of shade and summer browsing. They also suggest that on sites where bramble is not a problem weed, woodland managers have some flexibility in deciding when to carry out regeneration felling.

5 **Oak seedling that has survived 5 years of severe simulated browsing whilst growing within an oak woodland.**

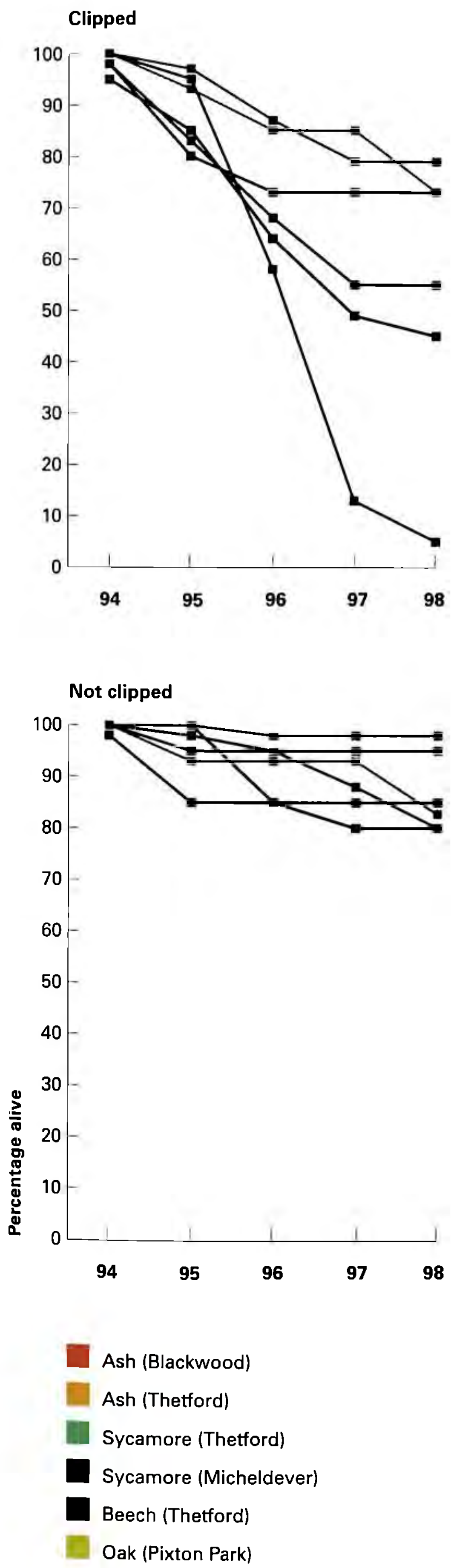

Figure 1 Percentage of live clipped and unclipped trees in different years.

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Forests and Fisheries

The Sustainability of Afforestation within Highland Catchments Supporting Important Salmonid Fisheries – the Upper Halladale River

by Tom Nisbet

Background

The forest industry forms an important part of the rural economy in the Highland Region, with some 12% of the land presently under forest cover. Considerable potential exists for expanding this area, which would bring much needed rural employment and a wide range of other benefits to the region (Highland Regional Council, 1994). A major constraint on forest development, however, is the concern of water and fishery interests about the impact of forest management practices, and forestry in general, on the freshwater environment.

The Highland Region of Scotland has an extensive, high quality freshwater system which supports important commercial and recreational fisheries, as well as containing key sites of conservation interest. This resource is thought to be at risk from: the soil disturbance and hydrological changes that can accompany ploughing, drainage, road building and harvesting operations; nutrient losses following fertiliser applications; and the scavenging of acidic pollutants by the growing tree crop. In order to reduce or eliminate such effects the Forestry Commission published *Forests & water guidelines* in 1988. The guidelines were prepared by a joint forest and water industry working group and give advice to forest managers on best management practices for protecting the freshwater environment. They were revised in 1991 and 1993 to ensure that they continued to reflect recent research and experience.

In 1991, a proposal to afforest around 1000 ha of the headwater catchment of the Upper Halladale River in Sutherland, north Scotland, raised serious concerns by the Halladale District Salmon Fishery Board about the threat to the local salmon fishery. The Halladale River forms a small but productive fishery which makes a significant contribution to the local economy. The upper section of the river above Forsinard, comprising one of the main spawning and nursery areas, was thought to be especially at risk from the planting schemes. An extended period of consultation failed to resolve all of the concerns, particularly the possibility that afforestation might lead to increased stream water acidification and damage to the fishery.

In order to determine the risk to the aquatic environment, the Forestry Commission funded an independent catchment assessment in 1993/94 by a consortium of research organisations. The study used the critical loads approach to calculate the maximum amount of acid pollution that the catchment could receive without any long-term harmful effect on the salmonid fishery. This critical load was then compared with modelled estimates of pollutant deposition, adjusted for the scavenging effect of a future mature forest crop (Figure 1). While the total of wet, dry and occult (cloud) deposition in 1993 was shown to be close to the stream water critical load at high flow, the situation was expected to be greatly improved by 2005, following the reduction of sulphur emissions to which European countries are committed. The proposed afforestation was predicted to have a small effect on pollutant deposition (<10% enhancement at maturity) and therefore posed little threat of surface water acidification. Consequently, approval was finally given in January 1995 for the planting to proceed.

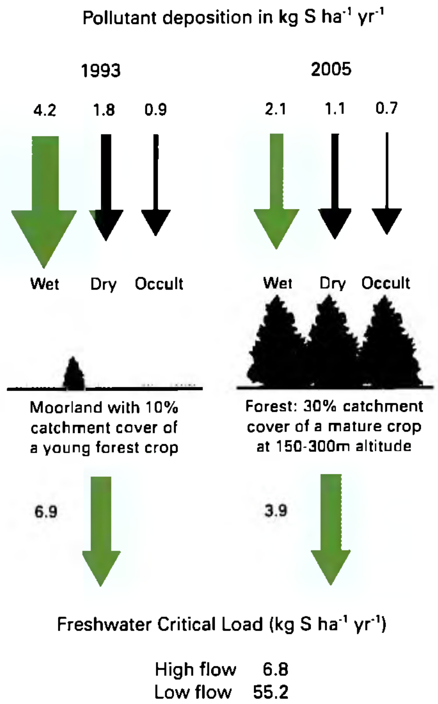


Figure 1 Catchment based critical loads assessment for the upper catchment of the River Halladale in north Scotland.

The planned afforestation of the upper catchment presented an ideal opportunity to assess the efficacy of the *Forests & water guidelines* in protecting a sensitive freshwater environment. A study was therefore set up by the Forestry Commission in 1995 to evaluate the effects of the ploughing, drainage and fertilising operations on stream water quality and on the salmonid population in the Upper Halladale River. A consortium of organisations was involved, including Forest Research (FR), Macaulay Land Use Research Institute (MLURI), Freshwater Fisheries Laboratory (FFL) and the Scottish Environment Protection Agency (SEPA). Funding was by the Forestry Commission, the European Union LIFE Programme, Caithness and Sutherland Enterprise Ltd., Scottish Natural Heritage, and the Scottish Office.

Forest operations

The poorly drained peaty nature of the catchment's soils necessitated cultivation and fertiliser treatments to enable successful forest establishment. Cultivation of the soil prior to planting primarily involved the use of a Caterpillar tractor with a mounted or trailed double-mouldboard plough. Plough depths were kept shallow (30–45 cm) to minimise disturbance to the underlying, potentially erodible, mineral soils. Another important measure to reduce the risk of soil erosion was to restrict the lengths of plough furrows to around 70 m, with consecutive runs on >5° slopes separated by buffer strips of undisturbed ground of 5 to 10 m width (Plate 1).

Wider protective buffer strips of around 50–70 m width were left along all of the main watercourses. Mounding operations were permitted within these areas, involving the use of a Hymac digger to create 2.1 m spaced soil mounds (~30–40 cm in height). Cultivation began on 15 January 1996 following a site inspection by the Forestry Authority to view the planned layout of the cultivation system. Operations were interrupted by thick snow during February and finally completed by 19 April 1996. No cross drains or cut-off drains were initially required, but two small areas of flat, deeper peat required draining in summer 1998. Drain gradients were <2° to minimise the risk of erosion and terminated short of watercourses to provide a buffer of vegetated ground to retain any out-washed sediment. A total area of around 570 ha was planted between March and the end of May 1996. An application of un-ground rock phosphate fertiliser was made by hand to the base of each planted tree between 25 August and 18 October 1996, at a rate of 350 kg ha^{-1}.

1 Northwards view looking across the catchment of the Bealach Burn towards Forsinard. Note the short length of the plough furrows and wide riparian buffer areas.

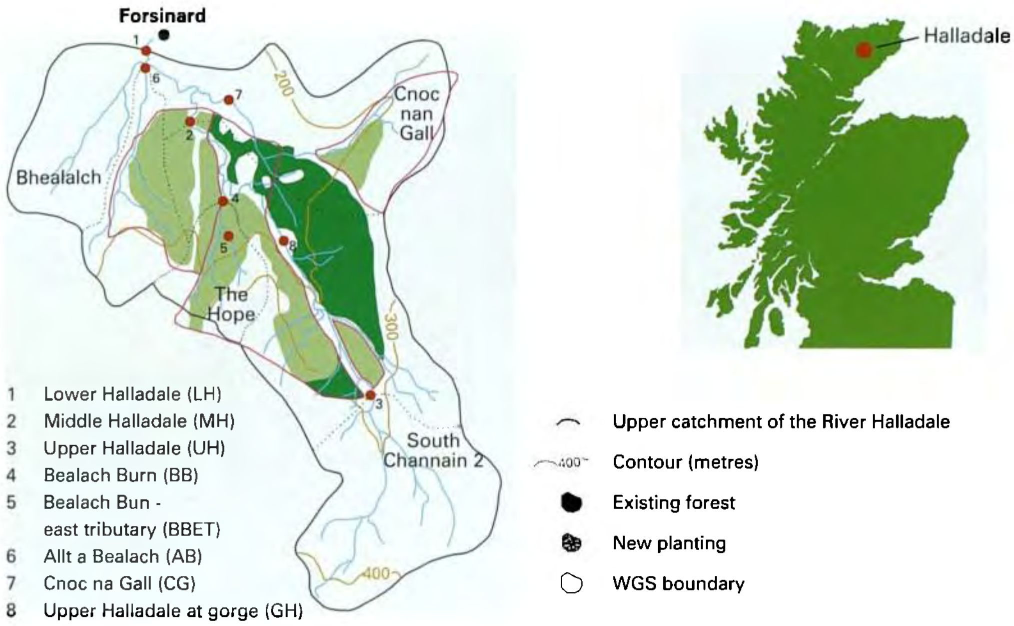


Figure 2 Location of the upper catchment of the River Halladale, showing areas of existing forest and new planting in relation to the main sampling sites.

Sampling methodology

Forest Research began weekly sampling of stream waters on 13 December 1994 at six points on the River Halladale: Lower Halladale (LH), Middle Halladale (MH), Upper Halladale control site (UH), Bealach Burn (BB), Bealach Burn east tributary (BBET), and Allt a Bhealaich (AB), approximately two years before the start of the cultivation operations (Figure 2). These points were selected to form a transect along the main river and to cover the major tributaries. Planting comprised some 17% of the overall catchment above the LH site, 21% of the MH catchment, 51% of the BB, 42% of the BBET and 33% of the AB. Automatic stream water samplers were also installed in April 1995 at the MH and BB sites to collect daily samples for the purpose of monitoring key hydrological events. Rainfall and dry deposition were sampled at weekly intervals at Forsinard. The samples were collected by a local forester and sent to the Agency's laboratories for full chemical analysis, including the main cations and anions, pH, conductivity, turbidity, and colour. The collection of a separate set of weekly stream water samples began at the end of March 1996 for the analysis of total phosphorus concentrations, at SEPA's laboratories in Dingwall.

Biological measurements included: the burial of salmon egg boxes just below the surface of the stream bed gravels in the BB, AB and MH sites by FFL, to assess the effect of the forest operations on spawning success; an annual electro-fishing survey of salmon and trout populations in the LH, MH, AB, BB, Upper Halladale at gorge (GH) and Cnoc nan Gall (CG) sites by SEPA, commencing in 1993; and twice yearly (April and September) surveys of stream invertebrate populations at each of the fish sampling sites, also by SEPA.

MLURI carried out a range of atmospheric deposition, vegetation, soil and hydrological studies within the catchment of the BB stream.

Results

Water quality

Stream water pH and turbidity data are presented in Figures 3 and 4 for three of the sites: the UH control, which is above the afforested area; the MH, which is the most extensively afforested site on the main river; and the BB, which is the most extensively afforested tributary. The pH results show all the streams to be reasonably well buffered at low flow during the summer, but subjected to marked acid episodes at high flows both before and after afforestation (Figure 3).

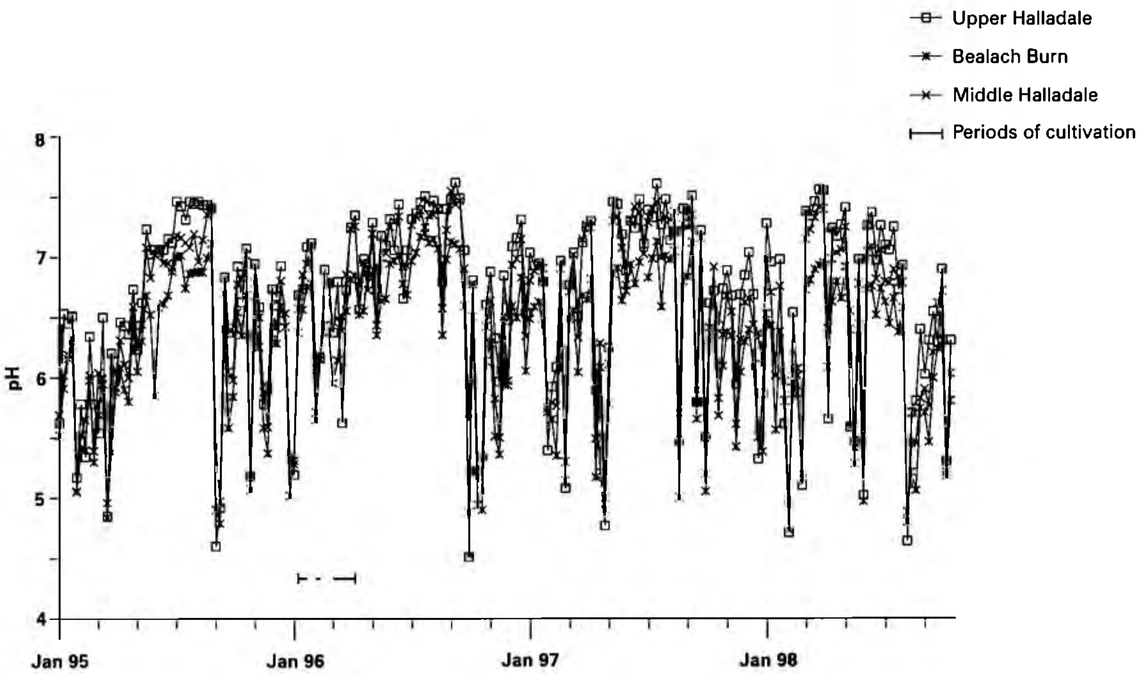


Figure 3 Stream water pH for the Upper Halladale control, Bealach Burn and Middle Halladale between December 1994 and December 1998.

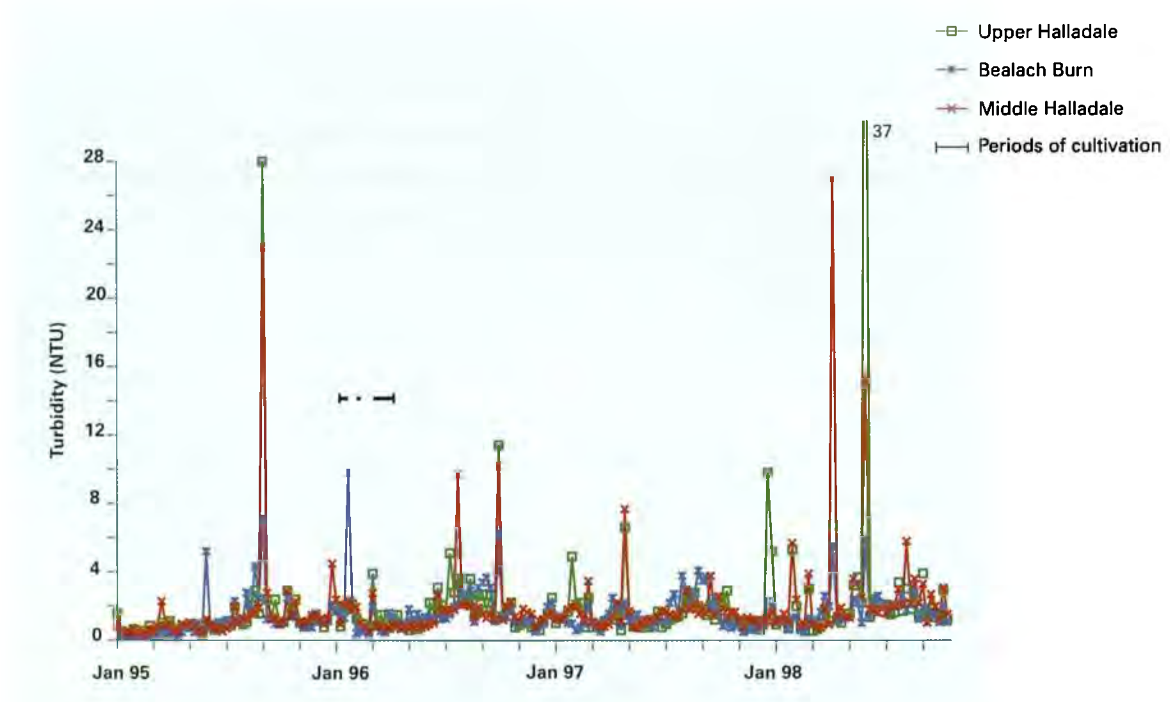


Figure 4 Stream water turbidity for the Upper Halladale control, Bealach Burn and Middle Halladale between December 1994 and December 1998.

Interestingly, the acid episodes were often severest at the end of summer dry periods, when the return of wet weather washed out accumulated acid deposition and organic acidity generated by the mineralisation of the peaty soils. Although the BB was the most acidic site, the UH control experienced the greatest pH range, with a minimum value of 4.5. None of the sites can be classified as significantly acidified, having mean stream water pH above 6.0. There was no evidence that the ploughing operations had affected either the mean or minimum stream water pH to date. This is in line with expectations that the main forest effect on acidification is via the longer-term scavenging of acid deposition, which has been shown to be small at Halladale.

Table 1 Six-monthly mean total phosphate concentrations in the upper catchment of the River Halladale. All concentrations are $\mu g\ P\ l^{-1}$. The fertiliser was applied between 25 August and 18 October 1996

	LOWER HALLADALE	MIDDLE HALLADALE	BEALACH BURN	BEALACH BURN EAST TRIBUTARY	ALLT A BHEALAICH	UPPER HALLADALE
Apr–Sep 96	17.8	15.0	10.1	7.1	17.4	12.5
Oct 96–Mar 97	26.3	29.4	11.2	10.3	19.1	14.2
Apr–Sep 97	22.8	20.3	19.8	6.8	21.9	14.0
Oct 97–Mar 98	25.6	27.5	10.4	5.0	17.8	12.1
Apr–Sep 98	30.4	25.7	16.0	7.0	23.8	16.9

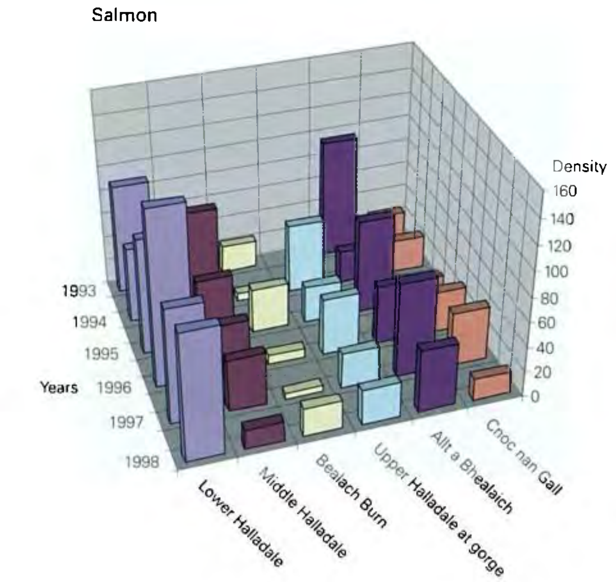
Stream water turbidity, which is a measure of water clarity or the amount of suspended material present, is probably the most sensitive indicator of site disturbance. The weekly turbidity results are presented in Figure 4 and show that the stream waters generally remained very clear throughout the period of measurement (c.f. the drinking water standard of 4 Nephelometric Turbidity Units (NTU) prescribed under the Water Supply (Water Quality) Regulations 1989). Exceedance of the drinking water standard was limited to occasional peaks, particularly during summer storms following extended dry periods, when there was a washout of algal material that had formed on the stream bed. These events appeared to be unrelated to the cultivation treatments, being of a similar order both before and after the cultivation and often reaching highest levels in the UH control. The turbidity data agreed with site inspections, which revealed very little evidence of erosion within plough furrows or the movement of sediment across buffer areas.

Of all the afforestation operations, the hand application of rock phosphate fertiliser in autumn 1996 appeared to have the greatest effect on water quality. The six-monthly mean phosphate concentrations for the LH and MH reached up to double those in the UH control, ranging between 5 and 15 $\mu g\ P\ l^{-1}$ higher than background levels (Table 1). This suggested that there had been a significant wash-off of fertiliser in those parts of the catchment. However, when the concentrations are converted to outputs in kg per hectare, the overall losses are shown to be relatively small, amounting to some 0.3 kg P per fertilised hectare per year or 1% of the total fertiliser applied. The response to the fertiliser application also varied greatly between sites, with the BB and the BBET showing a minimal loss to date, despite the greater scale of the fertiliser applications (33% and 51%, respectively). This can be explained by the thinner peaty soils within these catchments, with the underlying mineral soil having a much greater capacity to fix and retain phosphate.

Biology

The biological results are consistent with the water quality data in showing that the forest operations appear to have had no adverse effect on the freshwater environment. Numbers of salmon and trout fry and older fish fluctuated greatly between individual years in line with natural populations, with little evidence of any link to forestry activity (Figure 5). There were indications of a declining trend in salmon densities at the MH, GH and AB, but most or all of the decline occurred before afforestation in 1996. In contrast, trout densities exhibited a possible rising trend after afforestation at the MH, LH and BB. The results of the egg box studies confirmed the absence of any marked siltation effect on spawning success by showing no significant difference in the number of surviving fry between the control and experimental sites. In terms of the invertebrate populations, all sites had a fauna typical of Sutherland streams, although there were some signs of acid stress in the BB. The data showed no discernable changes in community composition that could be related to afforestation. Site observations also found little evidence of siltation within the sampled stream bed gravels.

A full account of all the results from the studies undertaken at Halladale is available in four unpublished reports (Forestry Commission, 1994, 1997, 1998, 1999).



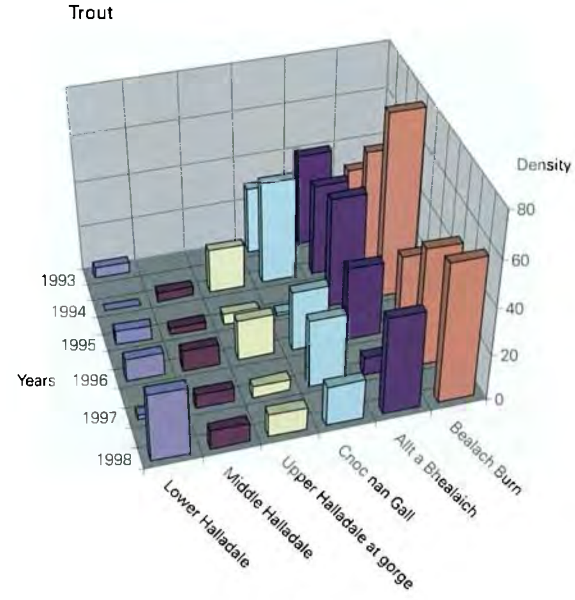


Figure 5 Response in salmon and brown trout densities to the afforestation of the upper catchment of the River Halladale. Densities expressed as number of fish per 100 m^2.

Conclusions

The results of an extensive programme of research have shown that to date large-scale afforestation within the upper catchment of the River Halladale has had a minimal impact on stream water quality and on the salmonid fish and benthic invertebrate populations. The lack of any significant effects showed that forest practice, as recommended in the *Forests & water guidelines,* was effective. in minimising site disturbance and protecting the freshwater environment. This positive result demonstrates the compatibility of forestry and fisheries within sensitive catchments and provides a sound basis for planning woodland and forest operations elsewhere. Monitoring will continue at Halladale to test the prediction that the subsequent growth of the planted forest will not lead to any longer-term acidification.

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Trees for Shelter

The Use of Trees for Shelter

by Max Hislop, Harriet Palmer[1] and Barry Gardiner

Introduction

The benefits of using trees to provide shelter to crops, farm animals and people have been recognised for centuries. The agricultural improvers of the 18th and 19th centuries recognised the importance of shelterbelts in the British climate (Caborn, 1957) and we continue to benefit from their legacy. In other countries such as New Zealand, the United States and the former USSR extensive shelterbelt systems are used and the benefits are well documented (Caborn, 1965; Brandle and Hintz, 1988). Shelterbelts are still used in Britain but often these are old and derelict belts from the last century while new belts are often planted for reasons other than shelter and are consequently poorly designed to provide effective shelter (Palmer *et al.*, 1997a).

In recent years staff of Forest Research have received increasing demands for advice on the management and rejuvenation of existing shelterbelts in the uplands, and on how these woodlands might be sympathetically integrated into the landscape whilst still providing the required shelter. In response to this renewed interest a seminar was arranged jointly by staff of Forest Research, MLURI and SAC in March 1996 entitled 'Trees for Shelter'. A specific aim of the seminar was to identify priorities for future research and development in the use of trees for shelter (Palmer *et al.*, 1997b).

[1] Scottish Agricultural College, Aberdeen.

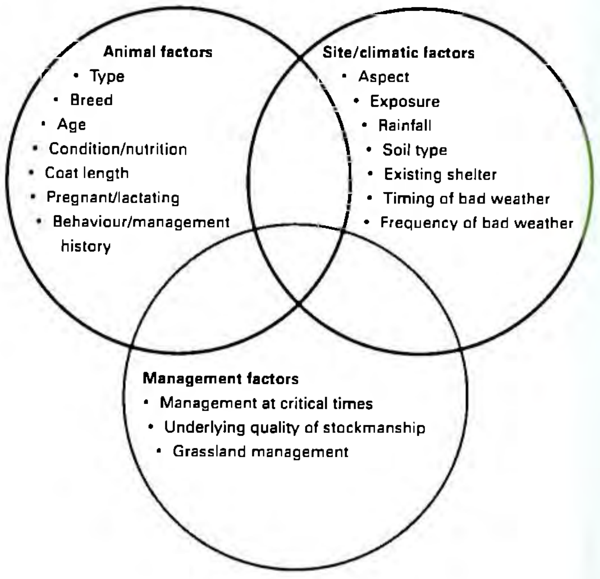

Figure 1 The factors which affect the response of animals to shelter.

The main research priority areas identified by the seminar were:

1. Collation and analysis of information from the many different disciplines with data relevant to the use of trees in rural areas
2. Synthesis of the data to enhance the management of shelter trees
3. Consultation with 'end-users' of the synthesised data to identify important gaps and then design research programmes to address the identified shortfall
4. Development of comprehensive information for practitioners in a flexible and accessible form
5. Provision of recommendations to policy makers, based on proven benefits of shelter trees.

A collaborative Shelter Forestry research project was formed as a result of the seminar. We have been making progress toward achieving these priority research tasks over the last three years. The initial research effort has focused on areas 1 and 2. The work accomplished in these areas is outlined over.

Trees and shelter – a literature review

A review of shelter-related research literature was completed in the summer of 1998 (priority 1). The aims of the review were:

i. to identify whether the potential benefits from shelter in the UK are such that the development of a Decision Support System (DSS) is justified;

ii. to identify whether enough information already exists to enable the development of a comprehensive DSS for practitioners in Britain.

The literature search highlighted the lack of recent information from UK sources, and confirms the low priority given to shelter forestry research in the UK in recent decades. The review showed that the accurate evaluation of shelter benefits and costs to any given farm or farming enterprise is extremely difficult, because of the many inter-related factors. For example, Figure 1 provides a summary of factors that affect the response of animals to shelter.

Added complexity occurs when the long time-scale over which responses to shelter may occur is considered. The review also identified that evaluation of shelter benefits must include consideration of non-woodland shelter alternatives, other objectives (e.g. landscape and environmental impacts) and the timing of financial outputs and returns. However, the evidence did confirm that there is potential for significant positive benefits from the provision of well-designed shelter woods to some farming enterprises. There were enough factual criteria for the project to progress to the first stages of development of a novel decision support mechanism for farmers and their woodland advisers.

Field validation of shelterbelt porosity principles

Four main features can be identified that affect the performance of a shelterbelt:

- porosity
- height
- length
- width

Porosity (or permeability) is the single most important characteristic that determines the performance of any shelterbelt (Bean *et al.*, 1975; Wilson, 1987). The following classification of porosity is generally agreed:

Permeable	Open	>60% porous
Semi-permeable	Medium	60–40% porous
Impermeable	Dense	< 40% porous

There is a close correlation between shelterbelt porosity and optical porosity (i.e. the amount of light that can be seen through a shelterbelt profile).

We have validated these findings in British conditions by taking windflow, temperature, humidity and optical porosity data from three contrasting shelterbelts:

SHELTERBELT NAME	DESCRIPTION	OPTICAL POROSITY
Fagwr Fawr (Mid-Wales)	Open, narrow, spruce/pine	69%
Currieinn (Scottish Borders)	Medium, wide, pine	45%
Blythbank (Scottish Borders)	Dense, wide, spruce	10%

The windflow data for each shelterbelt are shown in Figure 2. The new data are compared with data on the relative windspeed of Swiss shelterbelts of different degrees of permeability (Nägeli, 1946).

The new data confirm the important design factors of shelterbelts identified and show that optical porosity can be used as an estimate of porosity to windflow. These design factors have been incorporated in the decision support system described over.

The development of a farm shelter decision support system (DSS)

The provision of good advice about shelter is complicated, and good decision support, which is capable of incorporating the many inter-related factors involved, is needed. A computer-based DSS is regarded as the most effective way of ensuring that the many factors are logically and objectively assessed. This will be the aim of the Shelter Forestry research programme over the coming years.

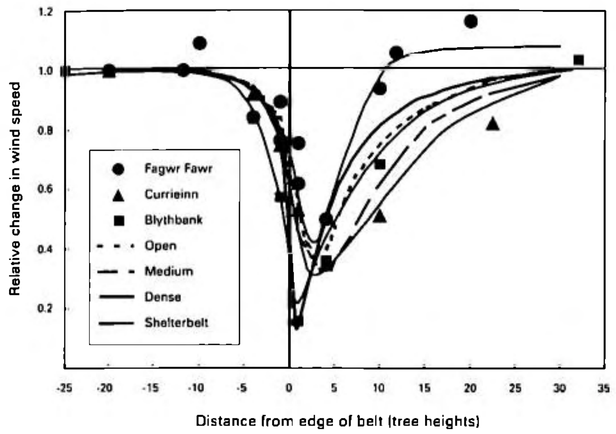

Figure 2 The relative wind velocity in the vicinity of three British shelterbelts compared with Swiss shelterbelts of different degrees of permeability (after Nägeli, 1946).

Initial progress toward this goal has been made by the development of a paper-based DSS for assessing the best location and most appropriate design of shelter woods on farms (Hislop *et al.*, 1999). The 'Farm Shelter Audit' (FSA) method provides, for the first time, an objective means of assessing farmers shelter needs and recommendations for the design of shelter woods to meet that need. We have developed a scoring system for the vulnerability of different farming activities and recommendations for shelter wood design and management. Three types of shelter wood are recommended:

Windbreak	60–40% porosity	
Windshield	<40% porosity	
Hybrid	<40% porosity (lower storey), 60–40% porosity (upper storey).	

There are three stages to the Farm Shelter Audit: gathering the necessary information; establishing the potential benefit to the farming business of shelter woods; and, assessing the effectiveness of existing shelter woods.

1. Gathering information

Knowing the farming activities that need protection from a windy climate is the key to understanding the function of a shelter wood in a particular farm location. Not all activities derive the same benefit from shelter, and a range of activities occurs in each location on a farm. Fundamental to the Farm Shelter Audit is the recognition that a woodland adviser must appreciate the farming activities undertaken in each area of the farm where shelter wood advice is to be given. A straightforward 'Farmer Interview Checklist' has been designed to ensure that the woodland adviser gathers the necessary information from the farmer about all the farming activities and the local climatic conditions in the fields which are being assessed.

2. Establishing the potential benefit of a shelter wood

Having gathered the necessary information on all the fields for assessment, the Farm Shelter Audit method uses a scoring system that allows the woodland adviser to assess the relative potential benefit afforded by a shelter wood to the field. The total score is read-off against a chart, the 'Shelter Woods Matrix' (Figure 3), which indicates the potential benefit to the farm business afforded by shelter woods. The strength of this approach is that all relevant aspects are accounted for, so building up a case for (or against) provision of more shelter.

3. Assessing the effectiveness of existing shelter woods

The final stage of the audit requires the woodland adviser to decide, based on the guidance from the Shelter Woods Matrix, if a shelter wood should be recommended. The 'Shelter Woods Decision Tree' (Figure 4), leads the adviser through a logical sequence of questions that identify management options and the need for new shelter woods.

In using the decision tree the adviser will need to be able to visually assess the porosity of existing woods in the activity area. Pre-assessed porosity photo cards (Figure 5) have been provided for use by the adviser in the field. The photo cards show a range of shelter wood types at varying stages of development that have been digitally assessed for optical porosity. The adviser can select the photo card closest to the wood to be assessed to assist in judging into which of the three porosity categories the woodland should be classed (< 40%, 40–60%, >60%).

Future work

Further development of the shelter woods DSS

The Shelter Forestry team intends to develop the farm shelter audit DSS by expanding the factors which can be assessed in the decision making process (for example the inclusion of the effect of livestock breed on shelter response, and seasonal meteorological information related to farm activity). It is desirable to remove subjective decision making from the process as much as possible. The inclusion of meteorological data about frequency of snow and cold, frosty nights will help in this regard. The inclusion of these additional data means that a paper-based system is not feasible and so the development of a framework for a computer-based DSS is our next priority. The framework will be designed to be able to accept improved data, as these become available.

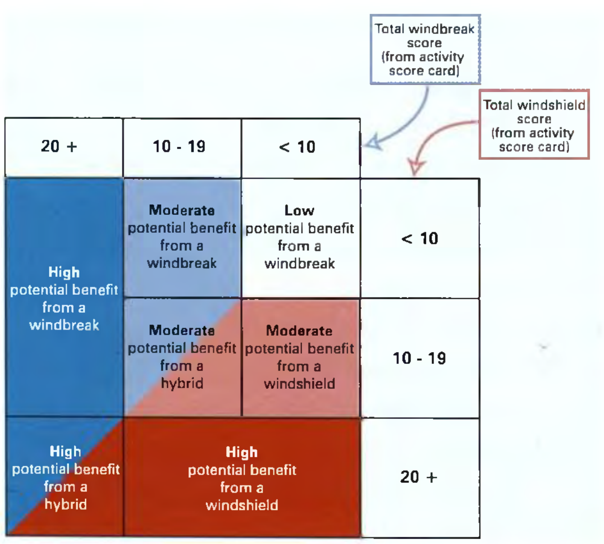

Figure 3 The shelter woods matrix.

Field experimentation

The literature review revealed some areas where there is lack of research data, for example, shelter woodland management techniques to achieve target porosity profiles. This is an area where field experimentation will be focused in the next few years. We anticipate that the process of developing the DSS will identify other areas where field experimentation is a needed.

Consultation and publications

Consultation with practitioners is underway and will ensure that the systems under development meet users' needs. A series of Information Notes on shelter related topics is planned, to provide the practitioner with the latest information in a flexible and accessible form.

Economic analysis

An obvious question which remains is how to evaluate the potential costs and benefits of shelter in financial terms, so providing the farmer with a sound economic justification for expenditure on shelter wood establishment or management. All costs and benefits incurred must be considered including opportunity costs to agricultural production. Each scenario or field should be assessed separately.

While some of the costs of shelter provision can be estimated readily (e.g. actual costs of woodland work, and opportunity costs of land and income foregone), other elements are much harder to quantify (e.g. productivity responses of

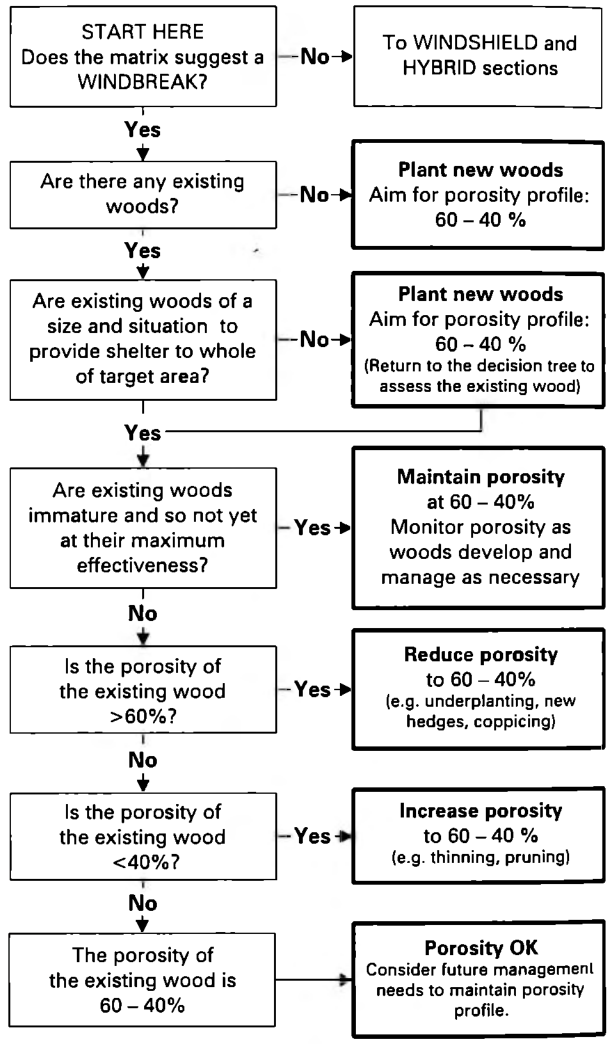

Figure 4 The shelter woods decision tree.

a.
b.
c.

Figure 5 Examples of shelter wood porosity photo cards.
a. Total porosity profile = 55% (winter foliage).
b. Total porosity profile = 10%.
c. Porosity profiles: upper storey = 30%, lower storey = 10% (summer foliage).

livestock to shelter). This is because of the many interactions between the farming system, the site, climatic factors and managerial factors, all of which must be considered over many years for a true analysis. Our initial aim is to develop a user-friendly break-even analysis technique to integrate with the Farm Shelter Audit method.

Acknowledgements

This work is based on research supported by the Policy and Practice Division of the Forestry Commission and by the Scottish Office Agriculture, Environment and Fisheries Department. The Farm Shelter Audit was developed during a project entitled 'The Value of Shelter Woods on Farms' for Cumbria Broadleaves funded by the EU, MAFF, Carlisle City Council and the Countryside Commission.

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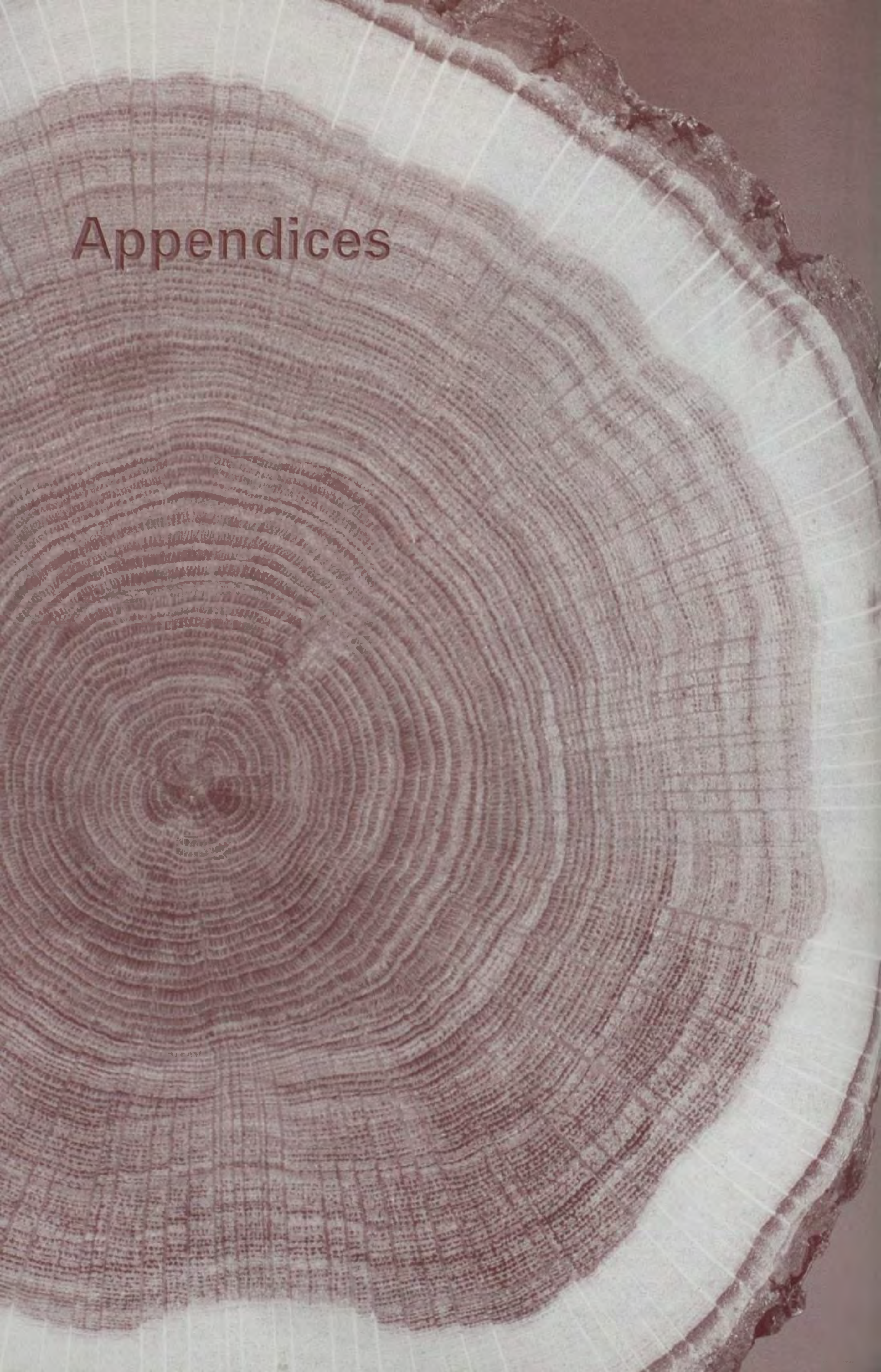
Appendices



Appendix 1
Forestry Commission Technical Publications

The following titles were published
during the year ending 31 March 1999

Report
Forest Research annual report and accounts 1999–98. (£17)

Bulletin
118 Ecology and conservation of raptors in forest, by S. J. Petty. (£14.99)

Information Notes (free)
4 Forest condition 1997, by D.B. Redfern, R.C. Boswell and J.C. Proudfoot.
5 Phytotoxicity of insecticides used to control aphids on Sitka spruce, by N. Straw and N. Fielding.
6 Phytophthora disease of alder, by J. Gibbs and D. Lonsdale.
7 Poplar rust and its recent impact in Great Britain, by D. Lonsdale and P. Tabbush.
8 The national inventory of woodland and trees, by D. Wright.
9 Coniferous standing sales price index (Great Britain).*
10 Timber quality: a pilot study for assessing stem straightness, by J. Methley.
11 Testing plant quality, by C. Edwards.
12 Estimating the age of large and veteran trees in Britain, by J. White.
13 The landscape value of farm woodlands, by S. Bell.*
14 Overwinter physiology and implications for handling and time of planting of Scots and Corsican pine bare-rooted seedlings, by H. McKay, C. McEvoy and A. Hague.
15 Creating new native woodlands: turning ideas into reality, by R. Harmer.
16 Tranquillity mapping as an aid to forest planning, by S. Bell.*
17 Poplar and willow varieties for short rotation coppice, by P. Tabbush and R. Parfitt.

Practice Notes (free)
1 Nearest neighbour method for quantifying wildlife damage to trees in woodland, by H. Pepper.
2 The prevention of rabbit damage to trees in woodland, by H. Pepper.
3 The prevention of mammal damage to trees in woodland, by H. Pepper.
4 Controlling grey squirrel damage to woodlands, by H. Pepper and F. Currie.
5 Red squirrel conservation, by H. Pepper and G. Patterson.

Technical Papers
25 Grazing as a management tool in European forest ecosystems, edited by J. Humphrey, R. Gill and J. Claridge. (£5)
26 Birch in spruce plantations – management for biodiversity, edited by J. Humphrey, K. Hall and A. Broome. (£5)

Book
The living forest: non-market benefits of forestry, edited by C. S. Roper and A. Park. (£80).*

Miscellaneous
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1/98 Slope limits and machine handling characteristics for specific ATCs, by I.R. Murgatroyd.

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27/96 Evaluation of the Keen planting machine, by G.R. Drake-Brockman.
10/97 Log chute extraction of a broadleaved crop, by D.H. Jones.
11/97 Evaluation of the Vimek Minimaster, by D.H. Jones.
13/97 Elmia Wood 1997: review of small-scale forestry equipment, by G.R. Drake-Brockman.
14/97 Evaluation of firewood processors, by D.H. Jones.
15/97 Evaluation of powered CDA knapsack sprayer, by G.R. Drake-Brockman.
16/97 Evaluation of a Valmet 890 forwarder, by J.B. Spencer and C.J. Saunders.

17/97 Clambunk system-residue availability, by D.H. Jones.
18/97 Reipal pusher forestry jack, by C.J. Saunders.
19/97 Flexible fire fighting knapsack, by I.R. Murgatroyd.
21/97 Forwarder fire fighting conversion, by I.R. Murgatroyd.
22/97 Harvesting options in small woodlands: Cottshayne Wood experience, by G.R. Drake-Brockman.
23/97 Review of small fire fighting pumps, by I.R. Murgatroyd.
2/98 The Galmore tree planter, by W.J. Jones.
3/98 Ponsse S10 Caribou forwarder, by C.J. Saunders.
4/98 New planting of farm woodlands: output guidance, by G.R. Drake-Brockman.
5/98 The Jonsered 600+ chainsaw mill, by D.H. Jones.
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13/98 Strategic review of cableway systems, by C.J. Saunders.
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15/98 Planning forest operations, by I.R. Murgatroyd.
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18/98 Clearfell harvesting systems for purpose-built and tracked harvesters, by J.B. Spencer.
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22/98 Review of bracken control methods in the New Forest, by G.R. Drake-Brockman.
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25/98 The ATC Tru-trax systems, by I.R. Murgatroyd.
26/98 Lightweight watergate, by I.R. Murgatroyd.
27/98 Access track construction in small woodlands, by C.B. Reynolds.
28/98 Peelers and pointers, by I.R. Murgatroyd.
29/98 Slope limits for specific ATCs, by I.R. Murgatroyd.
30/98 Total cultivation of compacted soils on reclamation sites, by C.B. Reynolds.
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34/98 Woodfuel production from small undermanaged woodlands, by D.H. Jones.
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36/98 Cleaning and respacing in broadleaved crops, by G.R. Drake-Brockman.
37/98 Farm wood restocking ground preparation techniques – Phase 2, by G.J. Vickers.
38/98 ATC and ATV 'on road' use, by I.R. Murgatroyd.
39/98 Mechanical ground preparation user guide, by J.B. Spencer.
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3/97 Liquid dye for urea stump treatment solutions, by J.B. Spencer.
4/97 Hiller 1.9TDI tracked ATV, by I.R. Murgatroyd.
5/97 Harvester profile: Ponsse HS16 Ergo/H73, by C.J. Saunders.
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4/98 The Grizedale debogging equipment trailer, by J.B. Spencer.
5/98 Mechanical weed control – the eco-puller, by G.R. Drake-Brockman.
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7/98 Modified OSMA flail on a Euromach 6500 walking excavator, by I.R. Murgatroyd.
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Appendix 3
Major Research Programmes funded by the Forestry Commission*

Entomology Branch

Plant health
Hugh Evans, Nick Fielding and Christine Tilbury
Research into the risks from indigenous and non-indigenous forest insect species. The use of Pest Risk Analysis techniques to determine contingency options for potential pests.

Restocking pests
Stuart Heritage and Roger Moore
Research into effective use of chemicals for direct control of restocking pests, notably *Hylobius abietis*, and develop Integrated Pest Management strategies for plant protection. IPM relies on effective monitoring linked to knowledge of population dynamics of *H. abietis*, and the use of insect parasitic nematodes for direct control of larval stages in stumps. The aim is to develop decision support systems for forest managers to avoid or reduce reliance on chemicals.

Impact of insects on tree growth
Nigel Straw
Investigate quantitative relationships between insect population pressure and the growth of trees attacked by those insects. An important aim is to separate the direct effects of damage from other biotic and abiotic variables that might mask the impacts of pest insects. The target species is green spruce aphid, *Elatobium abietinum*, which severely defoliates both Norway and Sitka spruces.

**Note: Further details can be found in the 'Catalogue of Forestry Commission Research' on the Commission's website http://www.forestry.gov.uk*

Mechanisms of tree resistance to insect attack
David Wainhouse
Investigate interactions between genetically determined tree defence mechanisms and site mediated factors. Different seed origins of Sitka spruce analysed for their physical and chemical defences when planted on different sites and when subjected to attack by insects with different feeding strategies (sucking and foliage feeding insects and bark beetles).

Advisory services
Christine Tilbury
Provide identification services for both pest and beneficial insects and provide advice on pest management and control.

Environmental Research Branch

Soil sustainability and site studies
Fiona Kennedy
Investigate the biological sustainability of current UK forest practices (i.e. the ability to grow successive crops without detriment to soil chemistry and physical properties). Specified objectives are also to improve tree growth on lowland sites, in conventional and novel silvicultural systems by establishing practices appropriate to the site factors.

Reclamation of man-made sites for forestry
Andy Moffat
Improve methods of establishing woodland and management practices on disturbed (brown field) sites, taking into account changes in forestry and land-use policy, planting opportunity, environmental impacts, mining practices and technology. Develop best practice guidelines.

Forest hydrology
Tom Nisbet
Study the impacts of forests and forestry management practices on water quality and quantity. Develop and assess guidance on best management practice for the protection of the freshwater environment within forests. Provide expert advice on forestry–water issues.

The effects of air pollution on trees
Andy Moffat and Dave Durrant
Determine the role of air pollution in forest condition and growth through long-term intensive environmental monitoring in forest ecosystems, in compliance with EC regulations. Provide data under the Convention on Transboundary Air Pollution for the calculation and mapping of critical loads.

Climate change
Mark Broadmeadow
Predict and model the impacts of environmental and climate change on tree growth by experimental work in open-top chambers and in forest stands. Identify interactions between forestry and a changing global environment (e.g. exchange of greenhouse gases).

Environmental change network
Sue Benham
Monitor and understand environmental change and its impact on terrestrial ecosystems. Manage one of the national network of terrestrial sites of the ECN network.

Archaeology
Andy Moffat and Peter Crow
Evaluate the impact of tree growth and forest operations on features of archaeological interest. Examine how forest practices can be manipulated to minimise the risk to archaeological features by practical research.

Mensuration Branch

Sample plots
Janet Methley and John Proudfoot
Develop and maintain national reserve of periodic growth and yield data to support measurement, growth and yield studies using a network of permanent and temporary sample plots. Current focus: contemporary silvicultural practices, uneven-aged planting mixtures, modern planting and harvesting systems, long-term environmental change monitoring.

Yield models
Robert Matthews
Improve methods and models for forecasting growth and yield of forests. Current focus: development of interactive stand-level yield model software, site:yield relationships, biomass yield models.

Measurement
Janet Methley
Develop and promote measurement systems and instruments for the accurate and efficient measurement of trees and timber to support industry, national and international standards. Provide independent expert advice in cases of measurement dispute.

Pathology Branch

Tree disease and decay: diagnosis and provision of advice
Derek Redfern, David Rose and David Lonsdale
Diagnose disease in trees and provide advice and information on disease identification, management and control. Provide information on decay in standing trees.

Tree health monitoring
Derek Redfern and John Gibbs
Monitor the health of the nation's trees and raise awareness of tree health issues.

Pathogen risk assessment
Clive Brasier and John Gibbs
Monitor the risks posed by both exotic and established pathogens and investigate changes in pathogen behaviour.

Non-chemical protection
Clive Brasier
Using Dutch elm disease as an example, investigate the value of biocontrol agents and the prospects of producing resistant trees through genetic engineering.

Fomes root and butt rot of conifers
Derek Redfern and Jim Pratt
Conduct research on Fomes root and butt rot of conifers and investigate approaches to management and control.

Phytophthora root disease of trees
Clive Brasier, John Gibbs and David Lonsdale
Investigate pathogenic *Phytophthora* species to determine their impact and the opportunities for management and control.

Stain and decay in forest products
Joan Webber
Identify, investigate and control the fungi that cause deterioration to logs and lumber.

Silviculture North Branch

Forest nutrition and sustainability
Helen McKay
Investigate the influence of site fertility on tree productivity and how forest operations affect sustainability of forest site fertility, including nutrient cycling and tree growth response to fertilizer trials.

Plant quality and establishment
Helen McKay and Steve Smith
Integrated studies of the effect of nursery practice, seedling physiology, plant handling methods, site preparation and maintenance upon plantation establishment.

Silvicultural effects upon timber quality
Elspeth Macdonald
Investigate the impact of silvicultural practices on timber quality in conifers, especially spruce. Main emphasis is impact of site factors (e.g. exposure, fertility) on quality.

Silviculture of upland native woodlands
Richard Thompson
Research into the structure, dynamics and silviculture of native woodland ecosystems in northern and western Britain to support restoration and extension for ecological and economic benefits. Emphasis is on Scots pine forests, birchwoods, and the Atlantic oakwoods.

Conifer natural regeneration and silvicultural systems
Bill Mason and Colin Edwards
Investigate natural regeneration processes in major conifer species to predict and manipulate the timing and density of natural seedling establishment. Evaluate canopy structure manipulation to promote regeneration as an alternative silvicultural system to patch clearfelling.

Stability of stands
Barry Gardiner, Bruce Nicoll and Juan Suarez
Research to reduce wind damage to British forests using a GIS-based windthrow risk model for predicting the probability of windthrow in Sitka spruce forests. Carry out studies of root development and architecture in support of the model.

Shelter forestry
Max Hislop and Barry Gardiner
Research into the design and management of woodlands for shelter and the development of techniques for assessing the potential benefit that they provide.

Social forestry
Max Hislop
Research into the social values of forestry and the development of methodologies for the integration of these values into forest planning.

Silviculture and Seed Research Branch

Social forestry
Gary Kerr
Silviculture as applied to areas with high levels of access; urban and community forests, the National Forest, arboreta.

Poplars
Paul Tabbush
Evaluate poplar clones with potential for timber production.

Vegetation management and woodland creation
Ian Willoughby
Evaluate herbicides for use in forestry, and investigate alternatives to herbicides. Examine establishment techniques in new woodlands.

Coppice
Alan Armstrong
Investigate dry matter yields of willow and poplar coppice grown for renewable energy.

Lowland native woods
Ralph Harmer
Examine methods for managing, regenerating and extending lowland native woodlands.

Silviculture of broadleaves
Gary Kerr
Develop cost-effective methods for establishing and managing the main broadleaved tree species on lowland sites.

Plant production
Peter Gosling and Richard Jinks
Improve the quality and performance of tree seeds, seedlings and vegetatively propagated stock to develop more reliable and economic methods of plant production and establishment.

Statistics and Computing Branch

Process models of forest growth
Tim Randle
Simulate biomass and structural dimensions calculated for foliage, branches, stem, coarse and fine roots using physiological processes. Modelling uses real weather data and parameters appropriate for the site and species and can predict responses to elevated CO_2, drought and temperature changes over 50–100 years.

Technical Development Branch

Large-scale forestry harvesting
Colin Saunders
Evaluate machinery and equipment, produce output guidance and investigate operational techniques relevant to large-scale forestry work in harvesting.

Large-scale ground preparation and planting
Ian Murgatroyd and Bill J. Jones
Evaluate machinery and equipment, produce output guidance and investigate operational techniques relevant to large-scale forestry work in ground preparation and planting.

Environmental aspects of mechanised operations
Ian Murgatroyd
Provide information on techniques to minimise the environmental impact of modern mechanised forestry operations in harvesting, silviculture and related civil engineering.

Farm and small-scale silviculture/harvesting and utilisation of small woodlands
Greg Vickers and David Jones
Develop methods and assess equipment suitable for use in small woodlands, generally broadleaved, having low environmental impact and being suitable for use by farmers and small contracting firms.

Forestry operations on derelict and reclaimed land
Chris Reynolds
Focused research into the cost-effectiveness of restoration techniques, with an emphasis on system and cost advice on techniques recommended by scientists.

Wood for energy
Gordon Wyatt
Develop methods for using short rotation coppice, single-stemmed short rotation forestry, forestry residues and existing under-managed woodlands for small scale heating and small or large scale electricity generation.

Chemical weeding
Chris Reynolds
Evaluation of equipment, application techniques and safety.

Tree Improvement Branch

Selection and testing of conifers
Steve Lee
Plus-tree selection, progeny testing. Breeding/production populations. Demonstration of realised gain. Species: Sitka spruce, Scots pine, Corsican pine, Douglas fir, larch.

Breeding and production
of conifers
Steve Lee
Clonal archives: conservation, advanced breeding material. Improved seed: controlled pollination, seed orchards.

Improvement of broadleaves
Ned Cundall
Selection/testing of selections at population, family and clonal level. Species: oak, ash, sycamore, beech, birch.

Origin and provenance
and conifers
Sam Samuel
Identification of suitable origins of conifer species. Key species: Sitka spruce, Douglas fir.

Biochemical and molecular
study of genetic variation
Ian Forrest and Joan Cottrell
Study of genetic variation in natural and breeding populations. Characterisation of populations, families and clones.

In vitro propagation and phase-change biotechnologies
Allan John
Methods of rejuvenating Sitka spruce and hybrid larch. Tissue culture systems for multiplication.

Forest Reproductive Material
Regulations
Sam Samuel
Inspection of material proposed for registration. Maintenance of National Register of Basic Material.

Woodland Ecology Branch

Assessing biodiversity
in managed forests
Richard Ferris
Determine the biodiversity status of plantation forests, develop practical assessment methodologies and identify potential biodiversity indicators.

Forest habitat management
**Jonathan Humphrey
and Russell Anderson**
Understand natural ecosystem processes, and how they are modified by management, to promote characteristics of forest structure and composition that confer ecological and conservation benefits, as well as meeting other management objectives.

Landscape ecology
and forest design
Richard Ferris and Chris Quine
Provide recommendations on the landscape scale design of forests for the conservation and enhancement of biodiversity.

Ecological site classification
and decision support systems
Duncan Ray
Devise and promote an ecologically based site classification as a tool for sustainable forestry in Britain.

Squirrel management
Harry Pepper
Develop cost-effective means of managing the impact of grey squirrels on timber production. Work to secure the future of the red squirrel as a component of the British woodland fauna.

Deer population ecology
and management
Brenda Mayle and Robin Gill
Provide a sustainable basis for deer management in UK woodlands by investigating and developing new techniques and technologies to provide information on deer population dynamics, behaviour and impacts.

Tree protection
Harry Pepper
Develop techniques and materials for cost-effective protection of trees and woodlands from vertebrate damage.

Woodland Surveys Branch

National inventory of woodlands
and trees
Steve Smith
Undertake the FC national survey of woodlands and trees, assessing the woodland cover. Update key statistics on forest type, species, age-class, management and ownership.

Inventory GIS development
Graham Bull
Create the digital woodland map for Britain. Develop the use of GIS for providing spatially referenced data on the woodland cover of Great Britain.

Private sector production forecast
Justin Gilbert
Develop and produce the private sector production forecast incorporating new woodland data from the national inventory.

Appendix 4
Research Contracts Awarded by Forest Research

Abertay University
Genetic engineering of English elm.

Avon Vegetation Research
Forestry herbicide evaluation.

J. Bryce
Habitat use by squirrels, Dunkeld.

Environment Agency (Wales)
Effects of forestry on surface water acidification.

Fountain Forestry
Water monitoring, Halladale.

S. Davey
Lichen survey in semi-natural and plantation oak woodland.

Imperial College, London
Development of a biological control agent for Dutch elm disease.
Biocontrol of sap-staining fungi.

King's College London
Detection and monitoring of the effects of ozone pollution on deciduous forest physiology: remote sensing as a predictive tool.

Scottish Environment Protection Agency
Effects of forestry on freshwater fauna.

University of Aberdeen/ University of Durham
Population dynamics in a predator/ prey system.

University of Birmingham
Woody debris in forest aquatic habitats.

University College London
Effects of forestry on surface water acidification.

University of Durham
Habitat–predator–prey relationships, Kielder.

University of Leeds
Atmospheric boundary layer over forests.
Chemical transport in forests.

University of Newcastle
Squirrel population modelling.

University of Oxford
Flow structures over forests of irregular height.

University of Southampton
Remote sensing of forest canopy gaps.

University of Sussex
Biochemical mechanisms for plants to act as sinks for atmospheric pollutants.
Biodiversity of pine forests.
Drought tolerance in poplars.

University of Ulster
Feeding ecology of the large pine weevil.
Impact of defoliating insects on forests.

University of Wales
Endophytic establishment of wood-degrading fungi.

Appendix 5
Contract Work done by Forest Research for External Customers *(some projects may also be part-funded by FC customers)*

Anglia Woodnet
Evaluation of various construction methods of access trucks.

British Biogen
Gauging the effect of twig breakers and grading plates on chip quality.
Testing the main variables that affect chip quality.
Woodfuel chipping.

Cumbria Broadleaves
Provision of shelter by woodlands.

Deer Commission for Scotland
Assessment of deer damage.

Department for International Development
Virus control of teak defoliator in India.

Department of the Environment, Transport and the Regions
Health monitoring in non-woodland trees.
Potential for woodland establishment on landfill sites.
Research and demonstration in the National Forest.

Department of the Environment, Transport and the Regions/Aspinwall & Company
Effectiveness of provisions for the aftercare of mineral workings.

Department of the Environment, Transport and the Regions/ Loughborough University
Trees and drought in lowland England.

Department of the Environment, Transport and the Regions/Natural Environment Research Council
Cause–effect relationships for pollutant inputs to UK woodland ecosystems.

Department of the Environment, Transport and the Regions/ Wye College
The use of soil-forming materials in the reclamation of older mineral workings and other reclamation schemes.

Department of Trade and Industry
Evaluation of equipment and methods relating to woodfuel supply.
Wood fuel supply for small scale heating from small woodlands.
Yield models for energy coppice of poplar and willow.

English Nature
Development of a self-extracting trailer.

Environment Agency
Best practice guidance for forest operations.
Phytophthora disease of alder.

European Union
Assessment of risks from pinewood nematode.
Control of decay.
Developing somatic embryogenesis in spruce.
Effects of forestry on extreme river flows.
Forest condition surveys.
Larch wood chain.
Intensive monitoring of forest ecosystems.
Native black poplar genetic resources in Europe.
Oak resources in Europe
Phytophthora in European oak decline.
Plant vitality and dormancy.
Silviculture and diversity of Scots pine forests in Europe.
Tree seed dormancy.
Upgrading the Level II protocol for physiological modelling of cause–effect relationships: a pilot study.

EU/AFOCEL
Douglas fir resources in Europe.

EU/Danish Forest and Landscape Research Institute
Tree root architecture.

EU/Finnish Forest Research Institute
Modelling risks to forests.

EU/Highland Birchwoods
Conservation of native oakwoods.

EU/INRA, Nancy
Young oak high forest.

EU/Scottish Natural Heritage
Restoration of wet woods.

EU/SSFRC, Sweden
Natural regeneration of oak.

EU/Swedish University of Agricultural Sciences
The use of excavators and backhoe loaders in forestry.

EU/University of Edinburgh
The likely impact of rising CO_2 and temperature on European forests.

EU/University of Kent
Restoration of environmental diversity by effective ecosymbiont monitoring.

EU/University of Ulster
Improving protection and resistance of forests to the spruce aphid.

EU/University of Wales, Bangor
Poplar for farmers.

FAO
Research design in afforestation, forestry research, planning and development in the three northern regions of the Republic of China.

Friends of the Ochils
Native woodland potential for the Ochils.

Greenwaste
Tree planting on landfill sites.

Griffin (Europe) SA
Root control in container seedlings.

Highways Agency
Stump treatments with herbicides.

Joint Nature Conservation Committee
GIS mapping of constraints
Red squirrel conservation.

Kemira Fertilisers
Slow release fertilisers for cell-grown seedlings.

Leverhulme Trust/ University of Ulster
Novel methods for quantifying the impact of defoliating insects in forests.

Macaulay Land Use Research Institute
Bog management.

Marches Woodland Initiative
Development of a solar kiln.
Evaluation of small-scale forwarders.

Ministry of Agriculture, Fisheries & Food
Provenance testing of broadleaved species in farm forestry.
Development of a site-specific yield model for ash in lowland England and Wales.
Vertebrate repellents (with CSL, ADAS).
Yield models for energy coppice of poplar and willow.

A. Y. Morton
Evaluation of the Galmore tree planter.

Niko Chemical Co Ltd
Animal repellent studies.

Pilkington Trust
Control of *Ophiostoma novo-ulmi* by the 'd-factor'.

Scottish Forestry Trust
Investigations into the stability of irregular forests.

Scottish Natural Heritage
Bog restoration.
Seed vitality in the Mar Lodge pinewoods.

Scottish Office/Scottish Crops Research Institute
Genetic variability in native pinewoods.

Severn Trent Water
Forest survey of Severn Trent Water's area.

Sierra UK
Fertilization of birch.

Appendix 6
Forest Research Staff at 31 March 1999

* denotes part-time staff

Chief Executive
J. Dewar, B.Sc., M.I.C.For.

Personal Secretary
Mrs K. Crocket

Chief Research Officer
P. H. Freer-Smith, B.Sc., Ph.D.

Personal Secretary
Mrs C. A. Holmes*

Branches based at Alice Holt

Administration Branch
K. N. Charles, F.M.S., *Personnel and Administration Officer, Head of Branch*

Central Services Section
Mrs S. J. Hutchings*, *Head of Section*
D. M. Payne
Mrs A. Smith*
M. L. Young

Personnel Section
M. G. Wheeler, *Head of Section*
Miss L. J. Caless
Mrs P. C. Fawcett*
Mrs W. B. Groves
Miss J. R. Lacey

Typing Section
Mrs M. C. Peacock, *Head of Section*
Mrs J. M. Bell*
Mrs S. C. Stiles*

Finance Branch
A. J. Cornwell, FCMA, *Head of Branch*
Mrs M. C. Farm
P. A. Filewood
Mrs T. D. Smalley
Mrs J. M. Turner

Communications Branch
E. J. Parker, Ph.D., C.Biol., M.I.Biol., *Head of Branch*

Library and Information Section
Miss C. A. Oldham, B.A., M.A., Dip.Lib., A.L.A., *Head of Section and Librarian*
Mrs E. M. Harland, M.A., Dip.Lib., *Assistant Librarian*
Mrs K. A. Hutchison, M.A., *(at Northern Research Station)*
Mrs D. Whitehead*

Photography Section
G. L. Gate, *Head of Section*
G.R. Brearley, *(at Northern Research Station)*
Miss M. Trusler *(also with Central Services Section)*
J. Williams

Entomology Branch (with section at Northern Research Station)
H. F. Evans, B.Sc., D.Phil., F.R.E.S., *Head of Branch*
R. Ashburner, B.Sc.
Mrs G. Green, B.Sc.*
M. R. Jukes, C.Biol., M.I.Biol.
N. A. Straw, B.Sc., Ph.D., F.R.E.S.
Mrs S. A. Stephens*
Mrs C. A. Tilbury, B.Sc.
D. Wainhouse, M.Sc., Ph.D., F.R.E.S.

Environmental Research Branch
A. J. Moffat, B.Sc., Ph.D., *Head of Branch*
Mrs S. E. Benham, B.Sc.
M. S. J. Broadmeadow, B.Sc., Ph.D.
Mrs S. R. Cowdry*
P. G. Crow, B.Sc.
J. Davey
D. W. H. Durrant, B.A.
Miss J. N. Edgerton, B.Sc.
T. R. Hutchings
Miss S. B. Jackson, B.Sc., M.Sc.
M. F. Johnston
Miss F. M. Kennedy, B.Sc., Ph.D.
T. R. Nisbet, B.Sc., Ph.D.
Mrs R. M. Pitman, B.Sc., Ph.D.
E. Ward, B.Sc., M.Sc., C.Chem., M.R.S.C.
Mrs C. E. Whitfield*
Miss C. A. Woods *(also with Woodland Ecology Branch)*

Mensuration Branch
Mrs J. M. Methley, B.Sc., *Head of Branch*
I. R. Craig
R. W. Matthews, B.Sc., M.Sc.
J. C. Proudfoot
J. M. Taylor, B.Sc.
Miss M. Taylor*

Pathology Branch (with section at Northern Research Station)
J. N. Gibbs, M.A., Ph.D., Sc.D., *Head of Branch*
Professor C. M. Brasier, B.Sc., Ph.D., D.Sc.
A. Jeeves
Mrs S. A. Kirk
M. A. Lipscombe
Mrs C. A. Lishman*
D. Lonsdale, B.Sc., Ph.D.
D. R. Rose, B.A.
Mrs J. Rose
J. F. Webber, B.Sc., Ph.D.

Silviculture and Seed Research Branch
P. M. Tabbush, B.Sc., M.I.C.For., *Head of Branch*
A. Armstrong, M.I.C.For.
Mrs C. A. Baker, B.Sc.
P. G. Gosling, B.Sc., Ph.D.
R. Harmer, B.Sc., Ph.D.
R. L. Jinks, B.Sc., Ph.D.
G. Kerr, B.Sc., M.I.C.For.
M. J. R. Parratt
Mrs Y. K. Samuel, B.A.
I. Tubby, B.Sc.
M. Robertson, B.Sc.
I. Willoughby, B.Sc., M.I.C.For.
Mrs A. Yeomans *(also with Technical Support Unit South)*

Statistics and Computing Branch (with section at Northern Research Station)
Miss B. J. Smyth, B.Sc., *Head of Branch*
R. C. Boswell, B.Sc., M.I.S.
Mrs C. A. V. Foden*
Miss L. M. Halsall, B.Sc.
Miss T. J. Houston, B.Sc., M.I.S.
Mrs P. E. Newell*
A. J. Peace, B.Sc.
Mrs L. P. Pearce*
T. Porter, B.Sc.
T. J. Randle, B.Sc.
J. M. Robson

Woodland Ecology Section (of branch at the Northern Research Station)
H. W. Pepper, *Head of Section*
A. J. Brunt
R. Ferris, B.Sc., Ph.D.
M. Ferryman
R. M. A. Gill, B.Sc., Ph.D.
Mrs B. A. Mayle, M.Sc.
Miss K. M. Purdy, B.Sc., M.Sc.

Branches based at Northern Research Station

Administration
M. Abrahams
Mrs J. Atkinson
G. T. Cockerell
Miss E. Hall
Mrs M. W. Holmes
Mrs E. E. Ker
Mrs S. F. Lamb*
Mrs R. G. L. Shields*

Entomology Section (of branch at Alice Holt)
S. G. Heritage, M.B.A., C.Biol., M.I.Biol., *Head of Section*
R. Moore, B.Sc., Ph.D.
Miss V. E. Wykes, B.Sc.

Pathology Section (of branch at Alice Holt)
D. B. Redfern, B.Sc., Ph.D., M.I.C.For., *Head of Section*
Miss G. A. MacAskill
J. E. Pratt
Mrs H. Steele*, B.Sc.

Silviculture North Branch
W. L. Mason, B.A., B.Sc., M.I.C.For., *Head of Branch*
C. Edwards
Professor B. A. Gardiner, B.Sc., Ph.D., F.R.Met.S.
Miss S. E. Hale, B.Sc., Ph.D.
A. M. Hislop, M.I.C.For.
Mrs E. Macdonald, B.Sc., M.Sc.
C. McEvoy, B.A.
H. M. McKay, B.Sc., Ph.D.
S. J. Mochan
B. C. Nicoll, B.Sc.
S. A. Smith, B.Sc., M.I.C.For
J. C. Suárez-Minguez, B.Sc., M.Sc.
R. N. Thompson

Statistics and Computing Section (of branch at Alice Holt)
R. W. Blackburn, B.Sc., *Head of Section*
Mrs L. Connolly*
T. Connolly, B.Sc., Ph.D.
A. D. Milner, B.Sc., Ph.D.
Mrs L. Rooney*

Tree Improvement Branch
C. J. A. Samuel, B.Sc., Ph.D., *Head of Branch*
Miss C. M. M. Baldwin
J. E. Cottrell, B.Sc., Ph.D.
E. P. Cundall, B.Sc., Ph.D.
G. I. Forrest, B.Sc., Ph.D.
A. John, B.Sc., Ph.D.
S. J. Lee, B.Sc., Ph.D., M.I.C.For
Mrs M. A. O'Donnell*
R. J. Sykes
Miss H. E. Tabbener, B.Sc.

Woodland Ecology Branch (with section at Alice Holt)
C. P. Quine, M.A., M.Sc., M.I.C.For., *Head of Branch*
A. R. Anderson
Miss A. C. Broome, B.Sc.
Miss J. Fletcher, B.Sc., MSc.
J. W. Humphrey, B.Sc., Ph.D.
Mrs M. Plews *(also with Technical Support Unit North)*
D. Ray, B.Sc.

Branch based at Ae Village

Technical Development Branch
W. M. Jones, *Head of Branch*
Mrs Y. Butler
Mrs C. Harkness*
W. J. Jones
I. R. Murgatroyd
J. D. Neil
Mrs N. Nicholson*
Mrs B. J. Rammell*
C. J. Saunders
Mrs A. Wallace*

Midlands
G. R. Drake-Brockman
C. B. Reynolds
G. J. Vickers
G. Wyatt

Wales
Mrs V. Edwards*
D. H. Jones, Eng.Tech., A.M.I.Agr.E.

Branch based at Edinburgh H.Q.

Woodland Surveys Branch

S. Smith, B.Sc., B.A., M.B.A., *Head of Branch*
R. H. Beck
G. D. Bull
Mrs C. Brown
J. R. Gilbert, B.Sc.
Miss S. Macintosh
Mrs E. S. Whitton

Field Station Staff

Technical Support Unit (North)

A. L. Sharpe, *Head of Branch*

Cairnbaan

D. R. Tracy, B.Sc., *Head of Station*
J. McCuish
Mrs J M McDonald*
R. L. Preston
Mrs P. M. Simpson, B.Sc.
Mrs E. M. Wilson, B.Sc.

Inverness

P. J. Walling

Kielder

P. W. Gough, *Head of Station*
R. J. Brown
T. C. O. Gray
M. Ryan
L. Thornton
I. J. Yoxall

Lairg

A. J. Bowran
C. M. Murray
D. Williams

Mabie

D. M. Watterson, *Head of Station*
L. R. Carson
J. M. Duff
Miss H. Russell
Miss J. Sneddon*
H. Watson
J. White
D. Wilson

Newton

A. W. MacLeod, *Head of Station*
Miss L. A. Bradbury, B.Sc.
Miss A. R. Cowie
Miss A. J. Craig
H. MacKay
F. McBirnie
S. T. Murphy, B.Sc., M.Sc.
M. Park
C. Smart

Northern Research Station

D. R. Anderson
J. H. Armstrong
D. J. Brooks
D. C. Clark
G. M. Crozier
C. D. Gordon
A. J. Harrison, B.Sc.
J. T. Howell
M. Hunter
N. R. Innes
P. J. Love
G. W. Mackie
G. Mercer
J. A. Nicholl
S. P. Osborne, B.Sc.
A. Purves
S. Sloan
J. E. Strachan

Perth

A. Herd, *Head of Station*
N. C. Evans
W. F. Rayner

Wykeham

D. Kerr, *Head of Station*
I. F. Blair
L. S. Cooper
Mrs N Cooper*
R. Horridge
Mrs P. A. Jackson*
W. J. Riddick
D. R. Wharton

Technical Support Unit (South)

N. C. Day, *Head of Branch*

Alice Holt

M. J. Awdry
R. I. Bellis
Mrs S. N. Bellis
A. Bright
R. Brooker
J. L. Budd
S. M. Coventry
A. R. Dowell, B.Sc., M.I.C.For.
I. L. Green
Miss L. M. Haydon
A. Martin
R. A. Nickerson
J. E. Page
W. Page
R. M. Panton

Exeter

D. G. Rogers, *Head of Station*
S. A. Minton
D. J. Parker
A. M. Reeves
P. Wooton

Fineshade

D. A. West, *Head of Station*
J. Laing, B.Sc., M.I.C.For.
J. Lakey
Mrs E. M. Richardson
P. Turner
D. S. Watts
A. Whybrow

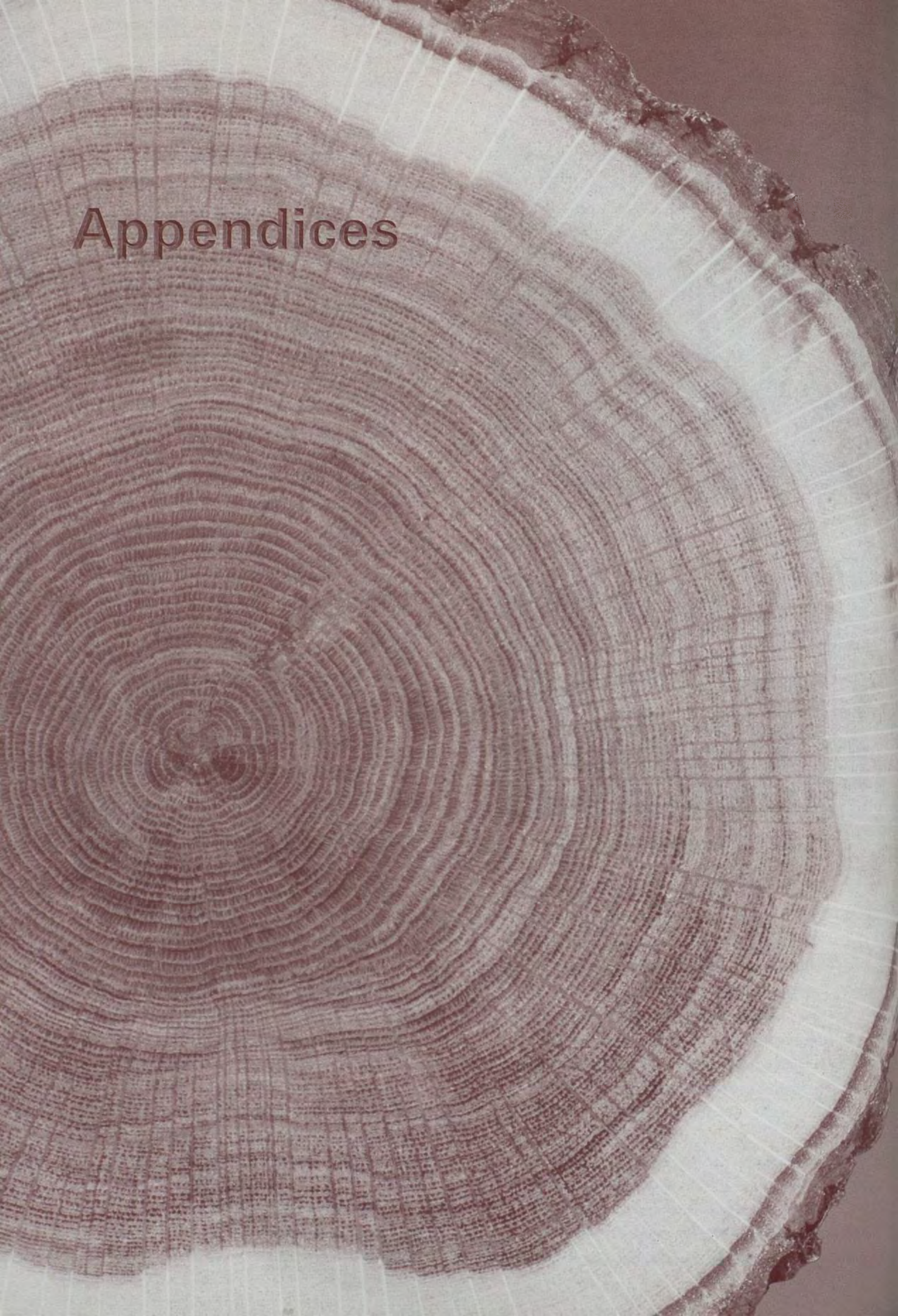
Shobdon

N. J. Fielding, *Head of Station*
B. J. Hanwell, B.Sc.
Mrs S.A. Hardiman
D. M. Jones
J. P. Jones, B.Sc.
Miss E. Maddocks
J. J. Price

Talybont

C. D. Jones, B.Sc., *Head of Station*
Mrs L. Ackroyd*
M. J. Chappell
D. M. Evans
A. Hoppit
B. Jones
R. J. Keddle
T. A. Price
Ms R. Sparks
D. J. Thomas
G. K. Williams

Appendices



Contents

Foreword

1. Status

Forest Research became an Executive Agency of the Forestry Commission with effect from 1 April 1997.

Forest Research remains part of the Forestry Commission which is the Government Department responsible for forestry throughout Great Britain. The relationship between Forest Research, the Forestry Commissioners and Forestry Ministers is described in the Framework Document published February 1997.

Prior to April 1997, Forest Research was managed as a Division of the Forestry Commission and its assets and financial transactions were included in the departmental accounts presented in the Forestry Commission Annual Report and Accounts.

From 1 April 1997, the Agency assumed ownership of and responsibility for the assets and liabilities appropriate to the research activity which were included in the Forestry Commission Statement of Assets and Liabilities as at 31 March 1997. It also assumed ownership of the building assets it occupies, which were previously owned and managed on behalf of the Forestry Commission by the Forest Enterprise agency, with appropriate intra-departmental charges made, and recorded on the Forest Enterprise balance sheet as at 31 March 1997.

Under the Framework Document, Forest Research is funded from the sale of its services to both the Forestry Commission and external customers. Any annual surplus or deficit is counted in the Forestry Commission's net Grant-in-Aid drawn down from Class XIII, Vote 10 into the Forestry Fund.

2. Aims and Objectives

The aims of Forest Research are set out in the Framework Document. They are to provide:

a capability to conduct research and development, surveys and related services relevant to the forest industry;
authoritative advice to support the development and implementation of the Government's forestry policy.

The objectives of Forest Research are listed on page 3 of the Report.

3. Review of Activities

This is Forest Research's second year of operation as an agency. Forest Research produced a net operating surplus of £878,000 on its Income and Expenditure Account, excluding the notional cost of capital. A comparison of income and expenditure with the previous year shows that:

- staff costs were reduced by £43,000;
- other management costs were reduced by £118,000 (10%) mainly due to a reduction in depreciation costs of office equipment;
- materials and service costs were reduced by £9,000; and
- income from external customers increased by £81,000 (6.4%).

The net surplus for the year after cost of capital of £496,000 was £382,000.

After adjusting the total surplus for items not involving the movement of cash and for capital expenditure and income, the net cash surplus paid into the Forestry Fund was £1,262,000.

4. Financial Objective

Forest Research's financial objective set out in the Framework Document is to recover the full economic costs, including cost of capital, of its operations from the sale of services to customers.

5. Employment Policies

Forest Research is committed to the principle of equality of opportunity for employment and advancement for all eligible people on the basis of their ability, qualifications and fitness for the work. The operation of this policy is set out in a series of Forestry Commission Action Programmes which are monitored by an Equal Opportunities Committee. Forest Research has systems to ensure that all permanent appointments are made on the basis of fair and open competition and in accordance with the guidance laid down by the Civil Service Commissioners. Further information on the employment of persons with disabilities, the provision of information to, and consultation with, employees, and the promotion of equal opportunities is available on request.

6. Year 2000

The Agency has reviewed all its IT systems to ensure that each is capable of operating after the year 2000.

7. Management Board

Members of the Management Board of Forest Research during the year were:

Jim Dewar	*Chief Executive*
Peter Freer-Smith	*Chief Research Officer*
Ken Charles	*Personnel and Administration Officer*
Tony Cornwell	*Finance Officer*

8. Auditors

These accounts are prepared in accordance with a direction given by the Treasury in pursuance of Section 5(1) of the Exchequer and Audit Departments Act 1921. They are audited by the Comptroller and Auditor General.

J Dewar
Chief Executive and Agency Accounting Officer
11 October 1999

Income and Expenditure Account

For the year ended 31 March 1999

	Notes	1999 £000	1998 £000
INCOME			
Income from research, development and survey services			
Forestry Commission customers	2	**11,015**	11,037
Non-Forestry Commission customers		**1,347**	1,266
Total income		**12,362**	12,303
EXPENDITURE			
Staff costs	3	**7,414**	7,457
Other management costs	4	**1,118**	1,236
Materials and services	5	**2,952**	2,961
Total expenditure		**11,484**	11,654
Net operating surplus/(deficit)		**878**	649
Cost of capital	7	**(496)**	(459)
Net surplus/(deficit) for the year		**382**	190
Transferred to General Fund		**382**	190

Statement of Total Recognised Gains and Losses

For the year ended 31 March 1999

	1999 £000	1998 £000
Net surplus/(deficit) for the year	**382**	190
Revaluation surplus for the year	**1,959**	179
Total recognised gains/(losses)	**2,341**	369

There have been no discontinued operations during the year.

The notes on pages 80 to 85 form part of these accounts.

Balance Sheet

For the year ended 31 March 1999

	Notes	1999 £000	1998 £000
FIXED ASSETS			
Tangible fixed assets	6	**8,175**	6,898
CURRENT ASSETS			
Stocks		**56**	112
Debtors	8	**850**	922
Cash at banks and in hand		**1**	1
		907	1,035
CURRENT LIABILITIES			
Creditors - amounts falling due within one year	9	**248**	199
Net current assets		**659**	836
Total assets less current liabilities		**8,834**	7,734
CAPITAL AND RESERVES			
General Fund	10	**6,393**	7,252
Revaluation Reserve	11	**2,441**	482
Total capital and reserves		**8,834**	7,734

J Dewar
Chief Executive and Agency Accounting Officer
11 October 1999

The notes on pages 80 to 85 form part of these accounts.

Cash Flow Statement

For the year ended 31 March 1999

	Notes	1999 £000	1998 £000
RECONCILIATION OF NET SURPLUS TO NET CASH FLOW FROM OPERATING ACTIVITIES			
Net surplus for the year		**382**	190
Notional cost of capital	7	**496**	459
Depreciation	4	**344**	515
Loss on sale of assets		**24**	19
Decrease in stocks		**56**	3
Increase in debtors		**72**	(291)
Increase in creditors		**49**	41
Net cash inflow from operating activities		**1,423**	936
CAPITAL EXPENDITURE			
Payments to acquire tangible fixed assets		**(161)**	(285)
Receipts from sale or transfer of tangible fixed assets		**-**	4
Total net cash inflow		**1,262**	655
Financing			
Cash surplus transferred to Forestry Fund		**1,262**	655
Increase in cash		**-**	-
RECONCILIATION OF NET CASH FLOW TO MOVEMENT IN NET FUNDS			
Increase in cash		**-**	-
Net funds at 1 April 1998		**1**	1
Net funds at 31 March 1999		**1**	1

The notes on pages 80 to 85 form part of these accounts.

Notes to the Accounts

Note 1. Accounting Policies

1.1 Form of Accounts

In accordance with Section 5(1) of the Exchequer and Audit Departments Act 1921, the accounts are drawn up in a format agreed and approved by Treasury. They are prepared under the historical cost convention modified by the inclusion of the valuation of assets. Without limiting the information given, the accounts meet the requirements of the Companies Acts and of the Financial Reporting Standards where relevant.

1.2 Accounting for Fixed Assets

Where the Agency is the principal beneficial user of assets of the Forestry Commission estate they are treated as a fixed asset of the Agency although legal ownership is vested in the Forestry Ministers.

1.3 Valuation of Assets

Land and buildings are revalued every three years by professionally-qualified staff employed by the Forestry Commission. Research and office equipment is revalued every three years using prevailing current prices for replacement items. Between revaluations, tangible fixed asset values are updated annually using a general price index. All revaluation surpluses and deficits are taken to the Revaluation Reserve.

1.4 Depreciation

Depreciation is provided on all tangible fixed assets - except land - at rates calculated to write off the valuation, less estimated residual value, of each asset evenly over its expected useful life.
Buildings - over 20 to 80 years
Research and office equipment - over 2 to 20 years

1.5 Stocks

Consumable materials and supplies are valued at current replacement cost.

1.6 Corporation Tax

Forest Research is not subject to corporation tax.

1.7 Provision for bad and doubtful debts

Specific provisions for bad and doubtful debts are set aside on the basis of a review of individual debts at the end of the year.

1.8 Employer's Superannuation Contributions

The Agency's staff are covered by the Forestry Commission Pension Scheme which is a defined benefit pension scheme. Employer's superannuation contributions, calculated as percentages of pensionable pay, are paid to the Forestry Commission Pension Scheme and are included in the Income and Expenditure Account. The rates of employer's contributions were from 15 to 22 per cent according to grade. Actual pension payments are met by the Forestry Commission. The receipts and payments of the pension scheme, its status and how it operates, and the valuation of unfunded past service liabilities, are shown in the accounts of the Forestry Commission published in its Annual Report and Accounts.

Note 2. Income from Forestry Commission and Forest Enterprise

The Agency undertakes a significant proportion of the Forestry Commission's overall annual research programme in the form of specifically commissioned projects to deliver agreed outputs. A separate annual charge is agreed for each project based on full cost recovery. The total of such charges, originally assessed at £10.0 million on the basis of the Agency's expected operational costs, were later reduced to a total of £9.8 million in the light of cost savings achieved, as reflected elsewhere in these accounts. The costs now established will be used to determine firm project charges for future years. The Agency also provides research and survey services for Forest Enterprise on a full cost recovery basis.

Total income from Forestry Commission customers consisted of:

	1999 £000	1998 £000
Research development and survey services to:		
Forestry Commission	**9,969**	10,000
Forest Enterprise	**1,046**	1,037
	11,015	11,037

Note 3. Staff Costs and Numbers

3.1 Employee costs during the year amounted to:

	1999 £000	1998 £000
Wages and Salaries	**5,555**	5,532
Social Security Costs	**410**	403
Employer's Superannuation Costs	**892**	872
Travel and Subsistence	**474**	585
Training	**83**	65
	7,414	7,457

3.2 The total remuneration, excluding pension contributions, of the Chief Executive, the highest paid member of the Management Board was £55,194. The Chief Executive is an ordinary member of the Forestry Commission Pension Scheme.

3.3 The range of salaries of Management Board members, excluding the Chief Executive, and other higher paid employees over £40,000 is shown below. Management Board members are senior staff and are ordinary members of the Forestry Commission Pension Scheme.

Management Board Members	1999 Number	1998 Number
£30,000 - £34,999	**2**	1
£40,000 - £44,999	**1**	1
Other higher paid employees		
£40,000 - £49,999	**5**	1

3.4 The average number of employees during the year was as follows:

	1999 Number	1998 Number
Permanent staff	**257**	271
Staff on fixed-term appointments	**16**	8
Casual staff	**17**	12
	290	291

Note 4. Other Management Costs

Other management costs are stated after charging:

	1999 £000	1998 £000
Exchange rate losses on EC contracts	**28**	-
Auditors' remuneration	**12**	10
Depreciation of Fixed Assets	**344**	515
Loss on disposal of fixed assets	**24**	-

Note 5. Materials and Services

The cost of materials and services includes service charges from the Forestry Commission and Forest Enterprise amounting to £1,235,801.

Charges are made to Forest Research from the Forestry Commission and Forest Enterprise, as appropriate, for assistance with field experiments, hire of machinery and equipment and for personnel, business management, financial and other support services at Headquarters.

Note 6. Fixed Assets

	Land and Buildings £000	Machinery and Equipment £000	Total £000
VALUATION:			
At 1 April 1998	6,083	4,170	10,253
Additions	50	111	161
Disposals and transfers	(512)	(307)	(819)
Revaluation adjustment	1,510	(95)	1,415
At 31 March 1999	**7,131**	**3,879**	**11,010**
DEPRECIATION:			
At 1 April 1998	301	3,054	3,355
Provided in year	141	203	344
Disposals and transfers	(37)	(283)	(320)
Revaluation to current prices	(405)	(139)	(544)
At 31 March 1999	**-**	**2,835**	**2,835**
NET BOOK VALUE:			
At 31 March 1999	7,131	1,044	8,175
At 31 March 1998	**5,782**	**1,116**	**6,898**

Land and Buildings were revalued as at 31 March 1999 in accordance with accounting policies. The valuation includes the principal research stations at Alice Holt Lodge near Farnham, Surrey, and the Northern Research Station, Roslin near Edinburgh, valued at £5.0 million and £1.6 million respectively at 31 March 1999. The valuation of the Alice Holt buildings increased by £2.0 million.

Note 7. Cost of Capital

Notional cost of capital based on 6% of average total assets less current liabilities employed in 1998-99 amounted to £496,000.

Note 8. Debtors

	1999 £000	1998 £000
Trade debtors	**803**	852
Other debtors	**47**	70
	850	922

Note 9. Creditors: amounts falling due within one year

	1999 £000	1998 £000
Payments received on account	**49**	33
Trade creditors	**151**	33
Other creditors including taxation and social security costs	**48**	133
	248	199

Note 10. General Fund

	1999 £000	1998 £000
Balance brought forward	**7,252**	7,258
Movement in year		
net surplus for year	**382**	190
disposal and transfer of fixed assets	**(475)**	-
cash surplus transferred to Forestry Fund	**(1,262)**	(655)
notional cost of capital	**496**	459
Balance carried forward	**6,393**	7,252

Note 11. Revaluation Reserve

	1999 £000	1998 £000
Balance brought forward	**482**	303
Revaluation surplus for the year ended 31 March 1999		
Land and Buildings	**1,915**	150
Machinery and Equipment	**44**	29
Balance carried forward	**2,441**	482

Note 12. Contingent Liabilities

There were no contingent liabilities at 31 March 1999 for damages caused to other persons' property or for compensation for personal injury to employees.

Note 13. Related Party Transactions

During the year, Forest Research has had a significant number of material transactions with the Forestry Commission and Forest Enterprise agency who are regarded as related parties.

In addition, Forest Research has had various material transactions with other Government Departments and other central Government bodies. Most of these transactions have been with the Department for Environment, Transport and the Regions, the Department of Trade and Industry and the Ministry of Agriculture, Fisheries and Food.

Note 14. Financial Performance Measures

The target to recover full resource costs, including capital, from internal and external customers was achieved. The Agency achieved an operating surplus of £878,000 which, after allowing for the cost of capital (£496,000) represented a cost recovery of 103%.

Statement of Forestry Commission's and Accounting Officer's Responsibilities

Under Section 5 of the Exchequer and Audit Departments Act 1921 the Treasury has directed the Forestry Commission to prepare a statement of accounts for Forest Research for each financial year in the form and on the basis set out in the accounts direction. The accounts are prepared on an accruals basis and must give a true and fair view of the Forest Research state of affairs at the year end and of its income and expenditure and cash flows for the financial year.

In preparing the accounts the Forestry Commission is required to:

- observe the accounts direction, including the relevant accounting and disclosure requirements, and apply suitable accounting policies on a consistent basis;
- make judgements and estimates on a reasonable basis;
- state whether applicable accounting standards have been followed, and disclose and explain any material departures in the financial statements; and
- prepare the financial statements on the going concern basis, unless it is inappropriate to assume that Forest Research will continue in operation.

The Director General of the Forestry Commission, as departmental Accounting Officer, has designated the Chief Executive of Forest Research as the Accounting Officer for the Agency. His relevant responsibilities as Accounting Officer, including his responsibility for the propriety and regularity of the public finances and for the keeping of proper records, are set out in the Accounting Officers' Memorandum, issued by the Treasury and published in "Government Accounting" (HMSO).

Statement on the System of Internal Financial Control

As Accounting Officer, I acknowledge my responsibility for ensuring that an effective system of internal financial control is maintained and operated by Forest Research.

The system can provide only reasonable and not absolute assurance that assets are safeguarded, transactions authorised and properly recorded, and that material errors or irregularities are either prevented or would be detected within a timely period.

The system of internal financial control is based on a framework of regular management information, administrative procedures including the segregation of duties, and a system of delegation and accountability. In particular, it includes:

- comprehensive budgeting systems with an annual budget which is reviewed and agreed by the Management Board of Forest Research;
- regular reviews by the Management Board of periodic and annual financial reports which indicate financial performance against the forecasts;
- setting targets to measure financial and other performance;
- clearly defined capital investment control guidelines;
- as appropriate, formal project management disciplines;
- a programme of accounting inspections.

The Forestry Commission has an internal audit unit, which operates to standards defined in the Government Internal Audit Manual. The work of the internal audit unit is informed by an analysis of the risk to which the body is exposed, and annual internal audit plans are based on this analysis. The analysis of risk and the internal audit plans are endorsed by the Forest Research Audit Committee and approved by me. At least annually, the Head of Internal Audit (HIA) provides me with a report on internal audit activity in Forest Research. The report includes the HIA's independent opinion on the adequacy and effectiveness of the body's system of internal financial control.

My review of the effectiveness of the system of internal financial control is informed by the work of the internal auditors, the Audit Committee which oversees the work of the internal auditor, the executive managers within the body who have responsibility for the development and maintenance of the financial control framework, and comments made by the external auditors in their management letter and other reports.

J Dewar
Chief Executive and Agency Accounting Officer
11 October 1999

The Certificate and Report of the Comptroller and Auditor General to the House of Commons

I certify that I have audited the financial statements on pages 77 to 79 under the Exchequer and Audit Departments Act 1921. These financial statements have been prepared under the historical cost convention as modified by the revaluation of certain fixed assets and the accounting policies set out on pages 80 to 81.

Respective Responsibilities of the Commission, Accounting Officer and Auditor

As described above, the Commission and Accounting Officer are responsible for the preparation of the financial statements and for ensuring the regularity of financial transactions. The Commission and Accounting Officer are also responsible for the preparation of the other contents of the Annual Report. My responsibilities, as independent auditor, are established by statute and guided by the Auditing Practices Board and the auditing profession's ethical guidance.

I report my opinion as to whether the financial statements give a true and fair view and are properly prepared in accordance with the Exchequer and Audit Departments Act 1921 and Treasury directions made thereunder, and whether in all material respects the expenditure and income have been applied to the purposes intended by Parliament and the financial transactions conform to the authorities which govern them. I also report if, in my opinion, the Foreword is not consistent with the financial statements, if the Agency has not kept proper accounting records, or if I have not received all the information and explanations I require for my audit.

I read the other information contained in the Annual Report, and consider whether it is consistent with the audited financial statements. I consider the implications for my certificate if I become aware of any apparent misstatements or material inconsistencies with the financial statements.

I review whether the statement on page 87 reflects Forest Research's compliance with Treasury's guidance 'Corporate governance: statement on the system of internal financial control'. I report if it does not meet the requirements specified by the Treasury, or if the statement is misleading or inconsistent with other information I am aware of from my audit of the financial statements.

Basis of Opinion

I conducted my audit in accordance with Auditing Standards issued by the Auditing Practices Board. An audit includes examination, on a test basis, of evidence relevant to the amounts, disclosures and regularity of financial transactions included in the financial statements. It also includes an assessment of the significant estimates and judgements made by the Commission and Accounting Officer in the preparation of the financial statements, and of whether the accounting policies are appropriate to Forest Research's circumstances, consistently applied and adequately disclosed.

I planned and performed my audit so as to obtain all the information and explanations which I considered necessary in order to provide me with sufficient evidence to give reasonable assurance that the financial statements are free from material misstatement, whether caused by error, or by fraud or other irregularity and that, in all material respects, the expenditure and income have been applied to the purposes intended by Parliament and the financial transactions conform to the authorities that govern them. In forming my opinion, I have also evaluated the overall adequacy of the presentation of information in the financial statements.

Opinion

In my opinion:

the financial statements give a true and fair view of the state of affairs of Forest Research at 31 March 1999 and of the surplus, total recognised gains and losses and cash flows for the year then ended and have been properly prepared in accordance with the Exchequer and Audit Departments Act 1921 and directions made thereunder by Treasury; and

in all material respects the expenditure and income have been applied to the purposes intended by Parliament and the financial transactions conform to the authorities which govern them.

I have no observations to make on these financial statements.

John Bourn
Comptroller and Auditor General
15 October 1999

National Audit Office
22 Melville Street
Edinburgh EH3 7NS

Accounts Direction given by the Treasury in accordance with Section 5(1) of the Exchequer and Audit Departments Act 1921

1. Forest Research shall prepare accounts for the financial year ended 31 March 1999 and subsequent financial years comprising:
   (a) a foreword;
   (b) an income and expenditure account;
   (c) a balance sheet;
   (d) a cash flow statement; and
   (e) a statement of total recognised gains and losses

   including such notes as may be necessary for the purposes referred to in the following paragraphs.

2. The accounts shall give a true and fair view of the income and expenditure, and cash flows for the financial year, and the state of affairs as at the end of the financial year.

3. Subject to this requirement, the accounts shall be prepared in accordance with:
   (a) generally accepted accounting practice in the United Kingdom (UK GAAP);
   (b) the disclosure and accounting requirements contained in "The Fees and Charges Guide" (in particular those relating to the need for segmental information for the services or forms of service provided) and in any other guidance which the Treasury may issue from time to time in respect of accounts which are required to give a true and fair view;
   (c) the accounting and disclosure requirements of "Government Accounting" (in particular Chapter 16) and the Treasury's guidance paper "Next Steps Agencies - Annual Reports and Accounts" (February 1993), as amended or augmented from time to time, insofar as these are appropriate to Forest Research and are in force for the financial year for which the accounts are to be prepared.

4. Clarification of the application of the accounting and disclosure requirements of the Companies Act and accounting standards is given in Schedule 1 attached. Additional disclosure requirements are set out in Schedule 2 attached.

5. The income and expenditure account and balance sheet shall be prepared under the historical cost convention modified by the inclusion of:
   (a) land and buildings at their existing use value where a market exists, otherwise at depreciated replacement cost;
   (b) machinery, plant and equipment at current replacement cost; and
   (c) stocks of consumable materials and supplies at net current replacement cost.
6. This direction shall be reproduced as an appendix to the accounts.

J Mortimer
Treasury Officer of Accounts
3 July 1998

Schedule 1

Application of the Accounting and Disclosure Requirements of the Companies Act and Accounting Standards

Companies Act

1. The disclosure exemptions permitted by the Companies Act shall not apply to Forest Research unless specifically approved by the Treasury.

2. The Companies Act requires certain information to be disclosed in the Directors' Report. To the extent that it is appropriate, such information relating to Forest Research shall be contained in the foreword.

3. The income and expenditure account shall be in a form which discloses the information described in paragraph 2 of Schedule 2, as neither of the recommended formats prescribed in Schedule 4 to the Companies Act is appropriate to Forest Research.

4. When preparing its balance sheet, Forest Research shall have regard to the balance sheet format 1 prescribed in Schedule 4 to the Companies Act. The balance sheet totals shall be struck at "total assets less current liabilities".

5. Forest Research is not required to provide the historical cost information described in paragraph 33(3) of Schedule 4 to the Companies Act.

6. The foreword and balance sheet shall be signed by the Accounting Officer and dated.

Accounting standards

7. Forest Research is not required to include a note showing historical cost profits and losses as described in FRS 3.

8. The cash flow statement shall be constructed using the indirect method as described in FRS 1.

Schedule 2

Additional Disclosure Requirements

1. The foreword shall, inter alia:
   (a) state that the accounts have been prepared in accordance with a direction given by the Treasury in accordance with Section 5(1) of the Exchequer and Audit Departments Act 1921;
   (b) include a brief history of Forest Research and its statutory background.

2. The income and expenditure account shall show, inter alia:
   (a) income:
   income from the Forestry Commission customers
   income from the non-Forestry Commission customers
   (b) expenditure:
   staff costs
   other management costs
   materials and services
   (c) the resulting operating surplus shall be adjusted by the notional cost of capital to give the 'net surplus/(deficit) for the year' which shall be transferred to the general fund.

3. Notional insurance premiums shall not be charged in the income and expenditure account. Instead, expenditure in connection with uninsured risks shall be charged.

4. The notes to the accounts shall include details of the key corporate financial targets set by the responsible Minister together with an indication of the performance achieved.

5. The notes will also show an analysis of the total staff costs and numbers of employees engaged on Forest Research activities.

6. Minor drafting changes may be made to the headings without seeking the approval of Treasury.

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