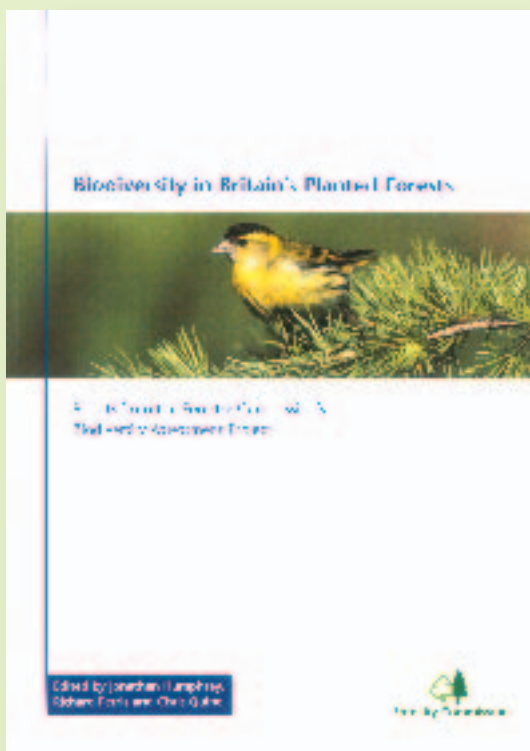


Woodland biodiversity and ecology

Chris Quine

Conserving biodiversity has become one of the most important objectives of sustainable forest management.



Biodiversity assessment in planted forests

Publication of the results of the Biodiversity Assessment programme: *Biodiversity in Britain's planted forests* was a major achievement. Twelve chapters summarise the context, methods and findings of this ambitious programme that investigated 54 plots of one hectare in 16 forests to capture a picture of the biodiversity of Britain's planted forests. The key message to emerge was that these planted forests, even those of non-native tree species, are not 'ecological deserts' as had previously been feared. Much of the biodiversity has benefited from aspects of the habitat that have occurred by chance, but considerable benefits could be obtained if more attention is given to biodiversity during the planning and layout of forests and their subsequent management.

Herbivores as an aid to woodland management

Herbivore impacts are frequently perceived to be negative for forest and woodland development, and as such have been the focus of work on deer populations. However, there has been growing interest in the targeted use of herbivore activity and, in particular, the use of cattle as a way of manipulating vegetation structure. During the year, a survey of cattle-grazing in British woodlands was completed. A database of known sites (over 400 records) was constructed, and a report published summarising the key lessons for managers; a supporting field survey provided insights into relative palatability of elements of the ground layer. In collaboration with local Forest Enterprise staff, work has begun to monitor a trial of cattle-grazing in forests in Glen Garry. The objective is to modify the vegetation composition and encourage regeneration of the native pinewood. Finally on this theme, a trial of a vegetation monitoring method, suitable for use should the European beaver be re-introduced into West Scotland, was developed on contract to Scottish Natural Heritage.

Supporting strategic decision making: whole forest, whole region and whole country

Last year's report highlighted the growing interest in landscape-scale decision-making. In the current year the prototype landscape ecology tool BEETLE was further developed by extending the focal species-based approach to incorporate 'generic species profiles'. These profiles represent the functional characteristics of species groups and allow the impacts of broad-scale decision making to be considered even though the ecological knowledge for individual species is inadequate. We have used the BEETLE model and related analysis to consider options for forest design planning in Clocaenog Forest, for the development of forest habitat networks for West Lothian region, and in the strategic planning of woodland habitat networks for the whole of Wales. In each case, the application of the scientific model has been accompanied by substantial discussion with 'stakeholders' before, during and after the results are obtained.

Ecological studies of Glen Affric

Two PhDs focusing on aspects of the ecology of Glen Affric were successfully completed, one of the case study areas of the landscape ecology project and an important national reserve renowned for its extensive native pinewood. The first developed a challenging dynamic landscape ecology model in the SELES programming language, and demonstrated the integration of a variety of sub-models to consider the expansion and cycling of the pine and birch forests within the Glen over timescales of hundreds of years. Important lessons were learnt over the technical integration of models, and interesting insights gained into potential ecological bottlenecks due to stand dynamics and expansion. The second was a study of the process of broadleaf tree species establishment within the native pinewoods, a component of the stand composition frequently overlooked. The link was examined between inherent shade tolerance and other limiting factors such as soil nutrition and vegetation competition. Strategies of accelerated natural regeneration and enrichment planting were recommended as a result of the findings.

Supporting publications	
Biodiversity assessment	Humphrey, J. W., Ferris, R. and Quine, C. P., eds. (2003). <i>Biodiversity in Britain's planted forests</i> . Forestry Commission, Edinburgh.
Herbivores and woodland management	Armstrong, H. M., Gill, R. M. A., Mayle, B. and Trout, R. C. (2002). Protecting trees from deer: an overview of current knowledge and future work. In: <i>Forest Research annual report and accounts</i> . The Stationery Office, Edinburgh, 28–39. Armstrong, H. M., Poulson, E., Connolly, T. and Peace, A. J. (2003). <i>A survey of cattle-grazed woodlands in Britain</i> . Internet published report. Forestry Commission, Edinburgh.
Supporting strategic decision making	Quine, C. P. (2004). Woodland biodiversity: research highlight. <i>Forest Research annual report and accounts 2002–2003</i> . The Stationery Office, Edinburgh, 16–17.
Glen Affric	Hope, J. C. E. (2003). Modelling forest landscape dynamics in Glen Affric, northern Scotland. PhD, University of Stirling. Ogilvy, T. (2003). Regeneration ecology of broadleaved trees in Caledonian forest. PhD, University of Edinburgh.

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Sustainable forest and woodland management

Bill Mason, Alan Harrison and Bill Jones

The current emphasis on continuous cover forestry, native woodland and natural regeneration have called for new approaches to woodland establishment and management.



Direct seeding by scarifier fitted with New Forest Oy 'Seedgun', identified by the grey box and yellow feed pipes at rear.

Direct seeding of upland restocking sites

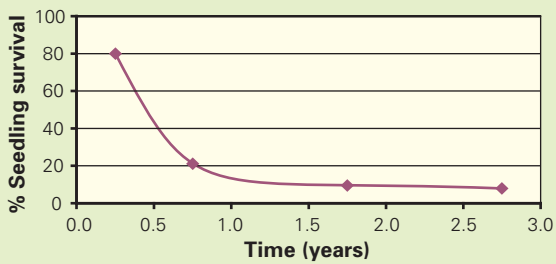
Direct seeding is a potential alternative to the conventional practice of restocking clearfelled sites through planting. Theoretically it is around 50% of the cost of replanting, provided that losses due to poor germination, frost heave, insect and animal browsing, and weed competition can be overcome. The technique is likely to be most applicable on nutritionally poorer, upland sites with limited vegetation competition and where a reduction in establishment costs can offset lower timber values. The method has been successfully used on poorer site types in Scandinavia, which is the source of the sowing technology under trial in the UK.

For the past three years, FR has been working in conjunction with FE Wales on the development of direct seeding with Sitka spruce. The site types targeted have been those where Sitka spruce is not expected to exceed YC14 productivity. These are generally above 350 metres elevation with peat or peaty-gley soils, soil nutrient regime (SNR) poor/very poor and soil moisture regime (SMR) moist or wetter, with the vegetation type including one or more of *Calluna*, *Vaccinium*, *Molinia*, *Juncus* or *Eriophorum*.

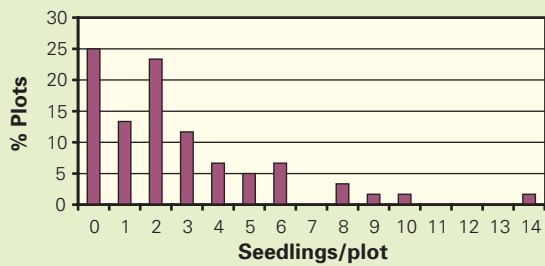
Experiments were set up in 2001 and 2002 to test the efficacy of ground preparation method, sowing method and sowing density on seedling survival and growth. Mechanical mounding, screefing and scarifying were the cultivation types tested. Concurrently with cultivation, seed was sown onto these prepared areas, either by hand or by one of two types of mechanical seeders, at predetermined rates of between 50 000 and 100 000 seeds per hectare.



Mechanical scarification or screening has been found to be the best method of seedbed preparation, with sowing by a pneumatically powered seed-gun mounted on the ground preparation machine. A sowing rate of 50 000 seeds per hectare has been found to be the minimum necessary to ensure a sufficient number of surviving germinants (3500 ha⁻¹) three years after sowing. However, since 1 kg of Sitka spruce seed (about 300 000 seeds) costs around £40, sowing at this rate still costs significantly less than conventional planting stock at around £100 per 1000.



Sitka spruce seedling survival on scarified ground following direct sowing of seed with a tested viability of 80%.



Variation in number of seedlings per 1 m² experiment plot (mean of combined scarified and screef plots).

Most initial seedling loss is thought to be caused by frost heave and wash-out of weakly developed root systems, though seed predation and pine weevil (*Hylobius abietus*) damage are also factors. Weed competition has been slow to develop on these nutritionally poor sites and so far has not been a factor in seedling survival. After three years, average seedling height is >20 cm. A current stocking of around 7000 seedlings per hectare following the highest sowing rate shows the approach to have potential. However, the distribution of seedlings is erratic, indicating that final stocking is likely to be uneven which will have implications for future timber quality. This may necessitate re-spacing or enrichment planting to reach satisfactory tree density.

This year, three new experiments have been established in Wales to check the efficacy of direct seeding on different site types and the success of 300 ha direct sown in 2003–04 will be evaluated. There is increasing interest in this technique in England and Scotland, particularly with pine and birch. Small-scale trials are currently under way in North Scotland and Kielder.

Overall, direct seeding is a promising restocking method but a better understanding of the interactions between site factors, germination and early seedling growth is needed before it can be said to be reliable.

Operational aspects

Following completion of work on developing and evaluating methods of excavator mounding, a Technical Note: *Excavator mound spacing on restocking sites* was published during 2004 giving the results of research, which will assist in the improvement of standards to achieve more consistent and uniform stocking. The results focus specifically on methods of dealing with brash, reducing the amount of spoil required (and therefore the width of the trench) and techniques, which enable better judgement of spacing between mounds. These results have also been disseminated via seminars to forest managers and operators and these will be ongoing during 2004–05. Successful trials have also been completed on a new bucket design, which resolves the problem of clays and peats sticking in the bucket. This problem had slowed the operation and caused extra vibration for the operator. The new design can achieve significant time and cost savings in these particularly difficult soils.



New bucket design shown at left.

Other related work, which will be reported in another Technical Note, is on the construction of brash mats during harvesting. This work identifies the method to achieve best flotation, reduce brash mat repair time and reduce operator vibration when travelling. It also improves subsequent ground preparation.

Woodfuel

There is generally a low level of knowledge in the forestry industry about supplying the new and developing woodfuel market. We have produced a *Woodfuel information pack* with foresters and managers in mind. The pack is a good starting point for all those who need to know more about converting wood into energy. It provides key, basic information about the many aspects of using wood for fuel, including: background on benefits; renewable energy targets and policy; sources; conversion; end users and systems. There are four main sections, starting with background information on the developing industry: the other three cover the types of processes or categories of operations, namely: biomass sources, biomass conversion and biomass users.



Hand winching

A new Technical Guide: *Winching operations in forestry* was published during 2004, giving definitive guidance on the safe use of hand winches for tree takedown and the debogging of forest machinery. The forces developed during winching operations can be considerable and difficult to calculate particularly when pulleys are introduced to multiply pulling forces and/or to deflect the pulling angles. Full understanding of the need for appropriate equipment selection and safe operation is essential. The guide covers four subject areas: Advantages of hand winches, Winching safety, Operational aspects, and Equipment selection.



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Evaluating woodland resources and potentials

Alan Harrison and Graham Bull

There is a wide range of ways in which research, particularly in partnership with the forest industry, can increase the competitiveness of British-grown forest products and their contribution to wealth creation.



A 12-year-old Scots pine, at 450 m asl (DAMS 17), showing needle loss and branch death.

New native woodland establishment update

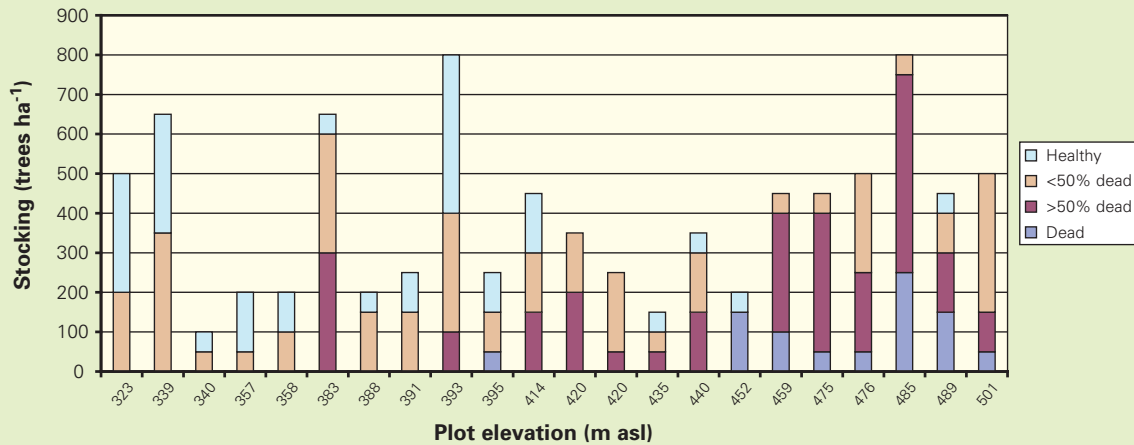
Last year we reported the results of a pilot survey of new native woodland (NNW) schemes in Scotland where low survival and poor establishment appeared to be linked to poor silvicultural practice on exposed sites of very poor nutrient status. In September 2003 the opportunity arose to investigate a ‘problem’ site in more detail. The 300 ha site in Perthshire is a typical NVC W18 pine-birch site with *Calluna* dominated vegetation, growing on freely draining podzols and podzolic brown earth soils. Exposure ranged from DAMS 13 at 300 m asl to DAMS 17 at 480 m asl. It was planted in 1992 with roughly equal amounts of native Scots pine (*Pinus sylvestris*) and downy birch (*Betula pubescens*). The pine and birch were planted at 1500 and 1100 stems ha⁻¹ in line with grant scheme prescriptions. The trees had initially appeared to be establishing well but there had been a recent serious decline in tree health and stocking. We examined site factors in relation to the growth and health (above and below ground) of the trees.

Overall survival was about 60% for the site as a whole with lower survival and poorer health at higher elevations. Mean stocking density for birch was lower than for Scots pine (357 compared to 958 trees ha⁻¹) and thus well below target densities. Exposure appeared to be the major factor affecting tree health, particularly birch, and this effect was exacerbated by poor root growth.

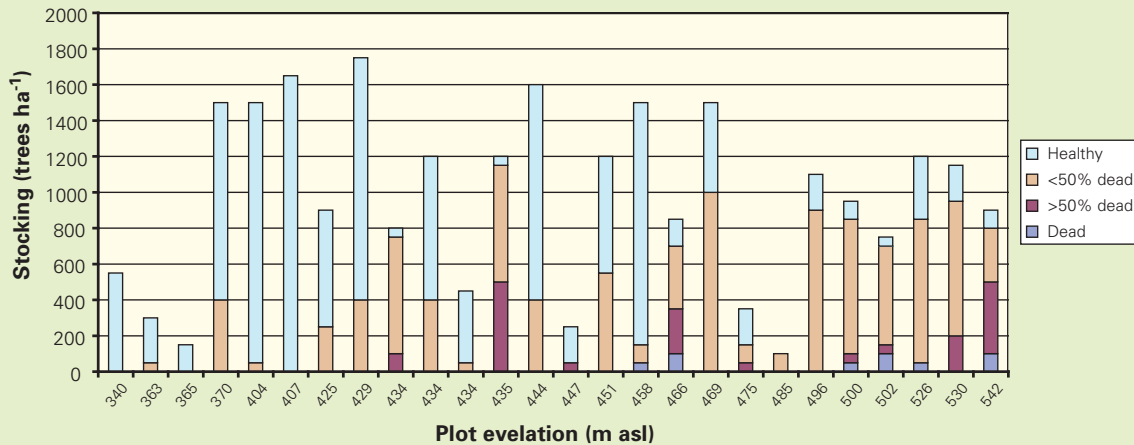
Root investigations showed that many of the live trees were suffering root constriction due to poor planting. This was compounded by the incipient ironpan soil not having been adequately disturbed by the rip cultivation used. Though not statistically linked to exposure due to the small sample size, trees with symptoms of poor health invariably had poor root systems. Approximately 25% of the living trees were likely to become unstable in the near future because of poor root architecture; compare the excellent and poor quality birch root structures.

The poor state of this site is not uncommon since it is thought that up to 30% of NNW schemes are in an unsatisfactory state. This problem seems to be due to establishment prescriptions that ignored or diluted basic

silvicultural practices for exposed infertile sites. A programme of joint FR-FCS seminars with associated publications is under way to advise woodland owners and foresters of these issues.



Downy birch: distribution of stocking density and health score by elevation.



Scots pine: distribution of stocking density and health score by elevation.



Excellent quality birch root structure, showing a high number of structural roots with good radial symmetry. Indicative of good initial planting practice.



Poor quality birch root structure, linear, one-sided and inherently unstable. Indicative of poor planting, i.e. plant was swept into the planting slit with no attempt to arrange the roots more evenly.

Woodland and tree surveys

A key requirement for the formulation and monitoring of forestry policies, forestry standards and forest management strategies is to know the extent and condition of woodland and trees.

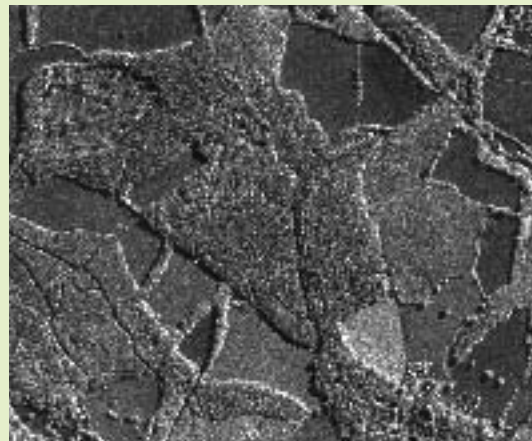
The national woodland inventory, and information derived from it, has been recognised as a major factor in our ability to monitor sustainable forest management and forests. It provides much of the basic data necessary to monitor progress in, and report on, the published UK criteria and indicators, some of which also operate at country level. The next woodland inventory, National Inventory of Woodland and Trees 2 (NIWT2) is scheduled to start in 2005.

During 2003–04, Woodland Surveys with Technical Services Unit carried out field tests in fifty 1 ha sample squares in FE woodland in England, Scotland and Wales in order to establish field methods and information for consultation with the three countries on their requirements to devise the new field data protocol.

During 2004, we also tested production of a new NIWT2 updated digital woodland map for woodland of 0.5 ha and over using colour orthorectified aerial imagery and Intermap Technologies NextMap ORI (Orthorectified Radar Imagery) product within a 20 x 20 km tile in Southeast England.

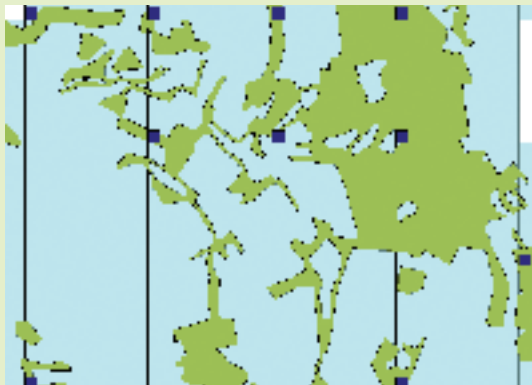


Example of coloured aerial imagery used to create woodland map.



Example of NextMap ORI product.

Once the digital woodland map has been created Woodland Surveys Unit will be able to combine it with an Ordnance Survey 1x1 km grid and select out the 1 ha samples for the field survey. The current estimate is between 40 000 and 45 000 1 ha samples throughout GB, with approximately 20 000 in England, 18 000 in Scotland and 5000 in Wales.



1 ha samples generated over woodland map.

Based on Ordnance Survey mapping with the permission of the controller of Her Majesty's Stationery Office. © Crown Copyright Forestry Commission Licence No 100025498

The overall NIWT2 programme is to be made up of two, complementary surveys: the Woodland survey (woodland of 0.5 ha and over) and the Survey of tree features (to include all tree features less than 0.5 ha, i.e. small woodland, groups of trees, linear features and single trees). The Survey of tree features will be a sampling exercise, and will use the same set of approximately 2400 1 km² sample squares selected for NIWT1. Using the same digital imagery as for the Woodland survey map, an API exercise will identify the features required and map and record digitally within each 1 km² sample square.

The aim of the NIWT2 is to provide up to date information on the extent, size and composition of our woodlands. In particular the aim is to provide an accurate assessment of woodland location, area and composition, and to provide estimates of a set of woodland parameters. The survey data will provide information for:

- decisions on land use and woodland expansion
- forecasting wood production
- targeting advice and grant aid

- assessing woodlands as a wildlife and conservation resource
- studies on biomass production and carbon storage
- monitoring the sustainability of forest management, and contributing to the monitoring of sustainable development of land use
- other more specialised woodland surveys.

Forest Research will be working closely with FC Scotland making use of the NIWT2 woodland map to assist selection of sample woodlands for the Scottish Native Woodland Survey (SNWS) which is scheduled to start in summer 2005.



NIWT2 field survey test sites in Scotland.

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People, trees and woods

Paul Tabbush and Liz O'Brien

Links between trees and woodland and the environmental, economic and social aspects of our lives are wide-ranging. Woods can contribute to human well-being by providing natural restorative spaces.



Forest School at Whitestone Woods in the Wye Valley.

During 2003, social researchers became involved in a number of EC funded projects. This reflected international will to include social issues in research aimed at defining good practice in sustainable forest management.

Project work included 'Leisure landscapes', and a final report on 'Social and cultural values of woodlands and trees in northwest and southeast England'. In addition, a number of projects were undertaken working with external contractors. Some key examples are described below.

Forest School evaluation

The New Economics Foundation (NEF) was contracted to evaluate two Forest School projects in Wales as phase one of a two-phase project. The Forest School idea is attracting a great deal of excitement among education professionals and there is anecdotal evidence from teachers and others that it has a profound positive effect on the way children relate to each other and the world around them. NEF applied a qualitative approach to evaluation, including participatory appraisal, and the development of a self-appraisal toolkit was a major product of the research. The report identifies and describes the development of major positive outcomes from the forest school process. These outcomes include increased self-confidence and self-esteem in the children who get involved, as well as a better understanding of the environment and a sense of ownership of the woodland they visit on a regular basis.

Phase two of the project involves NEF working in partnership with Forest Research to evaluate Forest School in England. The self-appraisal toolkit developed in phase one will be used to track changes for a small group of children over a seven-month period. A final report is due in August 2005.

The phase one report is available at:
<http://www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/INFD-5Z3JVZ>

Woodland owner's attitudes

The Social Research Group (with sponsorship from Forestry Commission England) contracted the University of Brighton to research ownership patterns and woodland owners' attitudes and perceptions of public access provision in the southeast of England. The findings of the report distinguished a typology of three distinct views. 'Dutyists' who feel they have a duty to supply public access, often because they have received management and planting grants from the Forestry Commission. 'Marketeters' who will provide access if the incentive is right; these are generally private woodland owners who view access as a market phenomenon and many are not interested in permitting public access if it interferes with current market and non-market benefits obtained from the woodland. Finally, 'Reluctants', who are unlikely to be attracted by incentives to provide access. The work led to a recommendation for a menu-driven approach to providing incentives, so that woodland officers can tailor incentives for access to the wider management objectives of woodland owners.

Social enterprise and community woodland

The Social Research Group undertook work for Forestry Commission England to explore a case study of a woodland social enterprise in Lincolnshire called Hill Holt Wood. The work explored and described how the woodland has developed to provide vocational training for young people excluded from school and for young unemployed people. Interviews with staff, members of the local community and key staff from organisations contracting work to Hill Holt Wood explored Hill Holt's role as a social enterprise, the community involvement and control of what takes place in the wood and its delivery of education and vocational training to young people. The woodland habitat provided a number of advantages:

- Ability to absorb activity without seeming crowded.
- Calming and therapeutic effects of trees and woodlands on the young people being trained, some of whom have emotional and behavioural difficulties.
- Opportunities for a variety of different training activities such as coppicing and making wood products as well as recreational activities.



Young person carrying out a demonstration at Hill Holt Wood in Lincolnshire.

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Woodlands and the environment: hydrology, archaeology and environmental change

Andy Moffat

Climate change, pollutant depositions and other anthropogenic factors can have a major influence on forest condition and thus on terrestrial and aquatic ecosystems. The merits of effective co-ordinated monitoring and research have become clear.



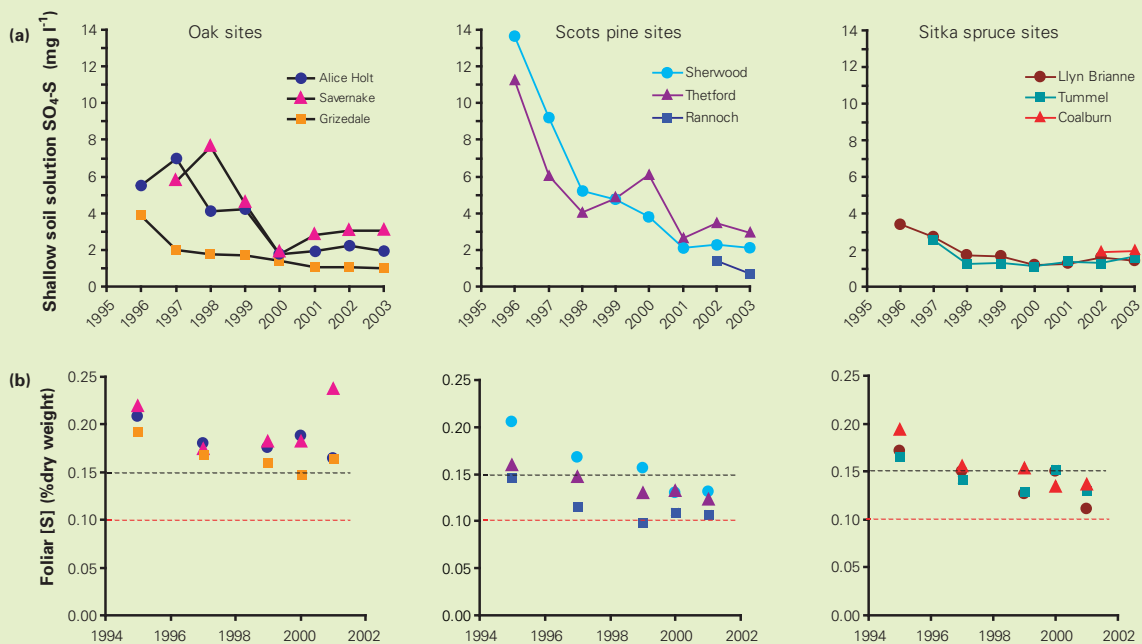
Hydraulic models are being used to assess the ability of trees and woody debris to slow down flood flows.

Forest hydrology

The role of forestry in flooding is an issue of increasing interest, and work on this subject was strengthened with the appointment of a new forest hydrologist at the Research Field Station at Talybont in Wales. The work will focus on modelling the hydraulic impact of floodplain woodland. A significant output in 2003–04 was the completion of a study examining opportunities for planting floodplain woodland for flood alleviation in the River Parrett catchment in SW England. Staff were closely involved with the publication of the 4th edition of the Forestry Commission's *Forests and Water Guidelines*, and the final conference and report on the EU LIFE Demonstration Project: Sustainable Forestry to Protect Aquatic Biodiversity. Forest Research has joined the National Board of Forestry in Sweden and the Office National des Forêts in France as partners in a new EU LIFE project: Forests for Water.

Remote sensing for archaeological surveys of woodlands

A review of remote sensing methods showed that with large image resolutions and the application of multispectral and thermal analysis, some archaeological features can be detected below the canopy. Developments in canopy penetrating methods such as Light Detection and Ranging (LiDAR) and Radio Detection and Ranging (RADAR), and the computer processing of their data, allow earthworks to be mapped with considerable accuracy and precision. The potential of LiDAR led to a commissioned survey specifically designed to assess the ability of the method to model earthwork topography below forest canopy cover. Preliminary results are very encouraging and suggest a large potential for this form of survey.



Trends in (a) soil solution sulphate sulphur and (b) foliar sulphur at UK Level II sites.

Environmental change

The use of Ecological Site Classification (ESC) to predict the likely effects of climate change on species suitability for timber production has been extended to include a wider range of tree species and to assess suitability of NVC woodland types for semi-natural woodland regeneration. These assessments provide a basis for climate change adaptation strategies for woodland management. The role of seed origin in climate change adaptation has also been addressed through the re-interpretation of existing provenance trials, together with an analysis matching current climates in Europe with those predicted for the UK over the coming century.

A national ozone visible injury monitoring scheme was established in 2003, making a significant contribution to the derivation and adoption of new Critical Levels for ozone for forest trees within the Gothenburg Protocol. The summer of 2003 saw the highest ozone levels for over a decade and visible injury was reported at two of the 13 assessment sites. An experiment investigating the interacting effects of elevated carbon dioxide and ozone levels on tree growth and function in the open top chambers at Headley Nursery has been completed. The data will be analysed to develop the flux-based approach to critical load assessments for ozone.

A protocol for preparing a carbon inventory for UK woodland is being implemented in two pilot areas. The carbon inventory is based on a range of FC monitoring networks, together with a modelling component and an assessment of inter-annual variation in carbon fluxes derived from CO₂ flux stations.

Analysis of the macro-moth data collected at the Environmental Change Network (ECN) site at Alice Holt since 1966 has shown a decline in the number and diversity of moths. Vegetation data have been used to produce chronosequenced plots, and changes to understorey related to age of stand have been examined. The environmental status of ground flora in different woodland types has been studied using Ellenberg indicator values. Provisional results show a significant difference between the young, mid rotation and mature woodland nutrient status of the ground flora.

Some recovery from high pollution loading in the past and the successful implementation of emission control policies is evident in some Level II plots. There is a general downward trend in foliar sulphur concentrations at most sites, and sulphur deficiency may become more widespread if the downward trend continues. Recovery from soil acidification at previously polluted sites is also evident, with reduction in foliar aluminium levels.

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Land regeneration and urban greening

Tony Hutchings and Danielle Sinnett

Woodland and other greenspace can provide a wide range of socio-economic, health and environmental benefits, including amenity, recreation and economic regeneration of deprived areas.

Recent work incorporates:

- Integrating site remediation and greening ■
- Utilising wastes in greenspace establishment ■
- Assessing site fitness for greening ■
- Testing new cultivation technologies ■



Example of community woodland following brownfield restoration in a residential area.

Integrating site remediation and greening

Existing sites where integrated remediation and greening solutions have been employed provide a vital vehicle for investigating the sustainability of remediation and greening systems, and for securing the development of robust, reliable, cost-effective and sustainable design methods for the future.

Experimental research is also necessary to test the interaction of different types of vegetation with engineered systems, the ability of materials remediated *in situ* to support vegetation, and the re-use of materials within the creation of green landscapes. In 2003 we began conducting a project through the Engineering and Physical Sciences Research Council SUBR:IM (Sustainable Urban Brownfield Regeneration: Integrated Management) consortium. This project is designed to review existing information on integrated remediation and greening systems; to assess the sustainability of a number of greening systems and their design methods; to develop environmental, economic and social sustainability criteria for greening; and to develop improved and new integrated remediation and greening solutions designed to meet the existing sustainability criteria.

Utilising wastes in greenspace establishment

Also within the SUBR:IM consortium, we began a project examining how the remedial capabilities of composts derived from wastes could be enhanced through amendment with naturally occurring minerals. Soil remediation using compost is an emerging technology that is gaining considerable acceptance due to its success for the treatment of various contaminants and its environmentally friendly principles. The relatively high success of this technique strongly suggests that particular activities of compost can be enhanced, thereby increasing its effectiveness. We are particularly interested in the improvement of contaminant

binding capacity of composts by the addition of inorganic materials. Research indicates that some naturally occurring minerals such as clays and zeolites interact with metals to form a matrix in which the bioavailability of the metals is remarkably decreased. This attribute, coupled with the biodegradation capability of the compost, could provide a unique and novel remediation technique. It is thought that novel composts could facilitate plant growth, providing soil conditioning and nutrients to a wide variety of vegetation, as well as reducing contaminant availability.

Assessing site fitness for greening

Currently no technique exists to determine the ecotoxicological impact of soil-borne contaminants to trees or landscape flora. This means that a significant proportion of expenditure from a reclamation budget is used to clean up contamination to generic levels. This is often unnecessary, environmentally and financially costly, and may lead to a reduced quality of the final landscape. In addition, traditional methods of assessing the phytoavailability of potentially toxic elements in soils are difficult to interpret and are often contradictory. Forest Research, in collaboration with ARUP, began a research programme in 2003 which aims to develop a biological indicator methodology for assessing the feasibility and risk-benefit of direct vegetation establishment on contaminated land. The project is being supported by CL:AIRE (Contaminated Land: Applications In Real Environments) and the Forestry Commission.

Although still in its preliminary stages, early results have already yielded significant findings. For example, we have found that Field Portable X-Ray Fluorescence (FPXRF) technology can give a good indication of total metal contaminants in soils. We have also found that the biological indicators tested are responsive to metal contaminant levels. We have yet to gather all of the data necessary to determine whether the

indicators are responsive enough to ascertain how other landscaping trees and shrub species will perform. Our continuing work on this project aims to develop such links over the coming three years.

Testing new cultivation technologies

Tree roots are frequently unable to penetrate highly compact, restored substrates. Current cultivation treatments are either considered to be too expensive by developers or are not effective in the long term. We have been conducting research on methods of achieving deep cultivation of compacted soils that is both sustainable and cost effective. The research focus has been: to examine the effectiveness of different deep cultivation methods in creating a uniform and loose soil condition; to assess the longevity of the treatments and their impact on long-term tree growth and rooting; and to provide indicative costs and output rates for all cultivation methods.

Treatments included total cultivation, industrial ripping and the 'Maxilift' prototype ripper which were tested against uncultivated controls. A long-term tree growth and rooting trial is ongoing at a former sand and gravel quarry site near Reading. Results so far indicate that both the Maxilift prototype ripper and the total cultivation methods achieve full 1 metre profile loosening. The loosening effects of both methods have been retained for at least three years following the cultivations. The 'Maxilift' has the advantage that it can be operated at a quarter of the cost and a quarter of the time input of the total cultivation system. The 'Maxilift' has since been used to successfully establish new community woodlands in The National Forest on a wide range of sites over the past two years. With the continued support of the Forestry Commission, we aim to monitor the longer term effects of the different cultivation treatments on tree performance.

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Protection of trees, woodlands and forests

Hugh Evans and Joan Webber

The management of woodlands to provide a wide range of public benefits places even greater priority on their protection. Risks to trees and woodlands need to be properly understood; in many instances new threats need to be excluded or established pests and pathogens managed.



Longhorn beetle *Monochamus galloprovincialis*, native to Portugal.

Plant health

Research has started under the new EU Framework Programme 5 topic PHRAME (Plant Health Risk and Monitoring Evaluation) on improved Pest Risk Analysis of the threat posed by pinewood nematode, *Bursaphelenchus xylophilus*, in Portugal as a model system. This programme involves Entomology and Mensuration, includes partners from Austria, France, Germany, Portugal and Spain. Significant progress has already been made by the consortium, particularly in providing new information on the interactions of the nematode and vector insects, which in this case are *Monochamus galloprovincialis*, longhorn beetles native to Portugal. Forest Research scientists are concentrating on development of improved PRA models by integrating new biological and eco-climatic information gathered by the consortium with existing tree growth models that have been produced by FR staff. This phase of the work will have increasing impact as new data are gathered during the course of the programme. Meetings have been held in Portugal, Germany and UK in order to exchange information and plan new work. The Consortium website can be accessed through the Forestry Commission website at <http://www.forestry.gov.uk/forestry/ggae-5rhgfr>.

Insect impacts

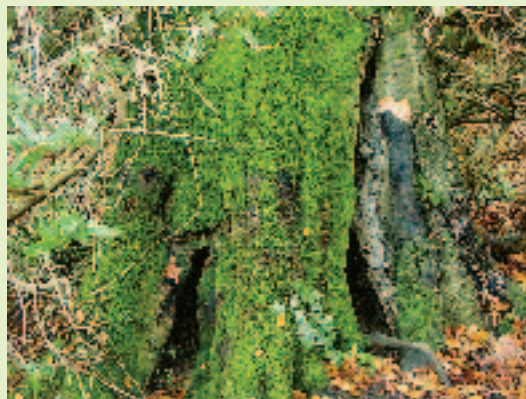
An unusual problem requiring attention during 2003 was the reported death of young poplar trees caused by the stem aphid *Pterocomma populeum* at a site in Cornwall. The poplars had been planted in early 2001, and following initial reports of *P. populeum* in the second year, large numbers of the aphids were present in 2003 and were associated with shoot dieback and the death of several hundred trees. Field surveys during the summer revealed that most of the aphids and damage was restricted to the poplar varieties 'Gibecq', 'Gaver' and 'Ghoy', especially the former which appeared generally less suited to the site, and was growing poorly even where the aphid was not present.

Horse chestnut leafminer, *Cameraria ohridella*, a small leafmining moth, was first reported in Britain in 2002, when it was discovered attacking horse chestnut trees in the Wimbledon area of London (*Forest Research Annual Report and Accounts 2002–03*). During 2003 FR Entomology scientists began a programme to monitor the spread and impact of the moth, which had already established in several London Boroughs, and had spread to Ashstead, Leatherhead, Weybridge, Tonbridge, Sevenoaks, Medenham in Buckinghamshire, and Oxford. This pattern of spread is similar to the two-phase process of dispersal seen on the continent, with movement away from the centre of infestation on a broad front, presumably by adult flight assisted by the wind, and the separate, sudden appearance of the moth in towns and cities some distance from the known area of infestation, apparently because of transport inside or on cars or other vehicles. The expectation is that *C. ohridella* will colonise most of the UK during the next few years.

Pathogens

Phytophthora ramorum

The new pathogen *Phytophthora ramorum* which causes sudden oak death in the USA, was first found in the UK in 2002. For eighteen months infected plants were mainly limited to nurseries and consisted of ornamental species such as *Rhododendron* and *Viburnum*. However, in October 2003 Forest Research pathologists found *P. ramorum* infecting mature trees in the south of England. The groundwork of host susceptibility tests had predicted that tree species such as red oak and beech would be the most susceptible to *P. ramorum*, and the field findings confirmed this. The first infected tree, a *Quercus falacata* (southern red oak), had extensive bleeding and bark necrosis around the trunk; similar symptoms were then found on beech trees (*Fagus sylvaticata*). Around ten *P. ramorum* infected trees have now been found at a total of three sites, with all but one of the infected trees located in Cornwall.



Extensive bleeding on the root flares of a mature beech caused by *Phytophthora ramorum*.



Foliage of holm oak (*Quercus ilex*) infected by *Phytophthora ramorum*.

It has also become clear that while some tree species are susceptible to lethal trunk infections caused by *P. ramorum*, other species (holm oak and sweet chestnut) suffer only foliar infection. These foliar infections are not lethal to the tree but do give the pathogen the opportunity to sporulate, and the spores may then go on to infect other plants.

To discover how widespread *P. ramorum* was beyond known outbreaks, the Forestry Commission tasked Forest Research Technical Support Units to carry out a survey in areas of the UK considered to be at high risk from the disease. These were regions with a climate that was predicted to favour infection and symptom expression by *P. ramorum*, and where woodlands with susceptible tree hosts were mixed with rhododendron. Following training in disease recognition on trees and ornamental plants such as rhododendron, a total of 1217 sites were surveyed in the high risk area. As a result, 335 samples were collected from rhododendrons that had symptoms that could indicate infection with *P. ramorum*. However, all proved negative. On this basis, the distribution of *P. ramorum* is considered to be very limited: further details of the survey are available at www.forestry.gov/pramorom.

Concerns about the potential impact of sudden oak death has generated intense interest from many sectors: the public, tree wardens,

arboriculturists, local councils and the media. Forest Research pathologists, working with Defra scientists, have participated in five stakeholder meetings with interested parties to provide information about *P. ramorum* and the extent of disease development in the UK compared with the parts of the USA where the disease is extremely damaging. In addition, a number of television programmes and publications (Country File, BBC news, *New Scientist* and *Tree News*) have featured the potential threat posed by *P. ramorum* and the work of Forest Research.

In January 2004, a new EU funded project started on 'Risk Analysis of *Phytophthora ramorum*'. Involving six countries and nine research institutes, the project consortium is led by Forest Research pathologists and the aim is to develop a European Pest Risk Analysis (PRA) for American and European isolates of *P. ramorum* (see <http://rapra.csl.gov.uk>). It will assess the potential for pathogen establishment, the environmental and socio-economic impacts, and also develop risk management strategies and contingency plans for areas where the pathogen is found. The PRA will draw on information and data that is already available, but a major part of the project will consist of research to provide data for PRA.

Dothistroma pini

Red band needle blight caused by the fungus *Dothistroma pini*, another quarantine listed pathogen, is also a matter of concern in the UK particularly in commercial forestry plantations. Corsican pine (*Pinus nigra* var. *laricina*) is highly susceptible to this pathogen, and the incidence of the disease has increased markedly over the past five years. We know that *D. pini* is active in a number of locations in England, Scotland and Wales but the disease is particularly severe in East Anglia.



Corsican pine shoot showing typical symptoms caused by red band needle blight (*Dothistroma pini*).

A survey of pine in the East Anglia Forest District has indicated that 75% of the compartments of Corsican pine (covering around 10,500ha) have *D. pini* infected trees. On average about a third of the crown displays symptoms on infected trees, but in some stands up to 95% of the crown of each affected tree has symptoms of needle loss and discoloured needles. All age classes of trees can suffer from the disease, but the most seriously affected tend to be in the 10-30 year age class. When the past three years growth (2000–03) were compared with previously ten years (1990–2000) in severely affected stands, the annual height and diameter increments were halved, with serious implications for productivity.

So far only the asexual stage of the fungus has been found, so we conclude from this that only low levels of variation occur in pathogen population. Work planned for the immediate future includes a comparison of *D. pini* populations from the UK with those from France and Germany where the disease has also become much more severe in recent years.

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Enhancing economic value

Barry Gardiner and Sam Samuel

There is a wide range of ways in which research, particularly in partnership with the forest industry, can increase the competitiveness of British-grown forest products and their contribution to wealth creation.



Off loading pine logs at a sawmill in Aboyne, Aberdeenshire.

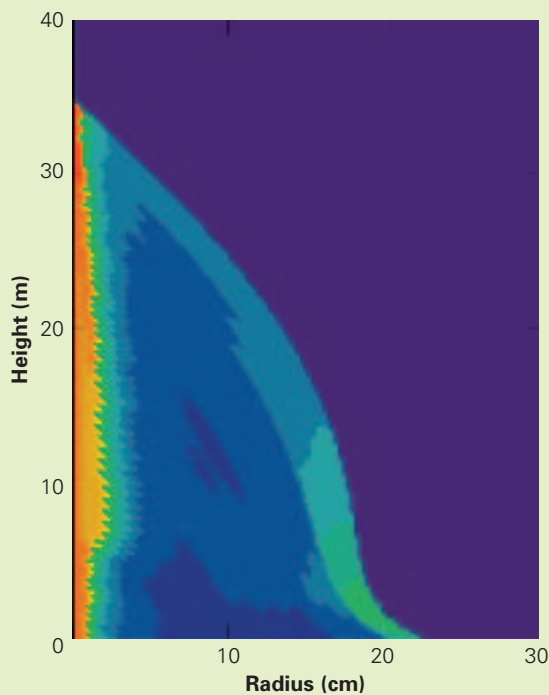
Modelling the effects of site factors and silviculture on Sitka spruce timber properties

A model predicting Sitka spruce wood properties is being developed with three main aims:

- To predict the timber properties of the existing Sitka spruce resource, on the basis of inventory data.
- To quantify the interaction between timber quality, site factors and silvicultural regime, which will enable forest managers to evaluate the effects of different management options.
- To estimate the impact on timber utilisation of changes in wood properties brought about by selection and breeding programmes.

During 2003 Dr Jean-Michel Leban of INRA (Institut National de la Recherche Agronomique), Nancy in France was awarded a John Eadie fellowship by the Scottish Forestry Trust to adapt an existing Norway spruce timber quality model to Sitka spruce. Data collected by staff of Forest Research and Bangor University from a range of Sitka spruce stands throughout Britain were used to develop models predicting wood density and branching characteristics on the basis of tree height, diameter and age.

A prototype computer software programme was developed which integrates the density and branching model relationships with growth models for Sitka spruce to enable simulations to be run for a range of scenarios. The yield class, thinning treatment, initial spacing and age of the stand to be modelled can be selected from drop-down lists. The model then gives estimates of ring widths up the entire stem, i.e. taper on an annual basis, wood density distribution within the stem and number, size and insertion angle of branches at different heights up the tree.



Predicted wood density distribution in the stem of an 80-year-old Sitka spruce growing at Yield Class 20, after planting at 2.6 m spacing and with no thinning. In relative terms green is the highest wood density with dark blue lowest and other shades intermediate. Note the comparatively large area of low density timber towards the base of the stem as a consequence of having been grown at wide spacing on a fertile site.

At present the growth models available enable predictions to be made for the average tree in an even-aged stand. As more complex growth models are developed, these will be incorporated to allow for the different diameter classes present in a stand. This will enable a more realistic assessment of the wood properties of various types of potential products, such as sawlogs and pulpwood, and will facilitate the modelling of uneven-aged stands. Plans are also in place to extend the model to include predictions of grain angle and compression wood. The next important step will be to link the timber quality model with sawing simulation software and batten performance models developed by the Building Research Establishment. This will allow estimates of batten mechanical properties and drying behaviour to be made for different silvicultural scenarios.

Planting stock derived from family mixtures and seed orchards can give gains of 20 to 30% in final volume

Analysis of 38-year-old volume data collected from one of the first Sitka spruce progeny tests ever planted has confirmed that significant volume gains can be obtained by planting selected stock. The test, growing in Clocaenog forest, involved the measurement of diameter and top-height amongst open-pollinated Sitka spruce families collected from highly-selected plus trees growing in forests around the country. Some individual families had 35 to 42% additional standing volume relative to the control plots of direct import material from the Queen Charlotte Islands. Conifer breeders have used these data to predict likely final-rotation volume gains from currently available tested clonal seed orchards and family mixtures as around 20 to 30%. Further economic gains from the selected planting stock can be expected due to additional improvements in stem straightness and branching quality which will be the subject of another study in 2004–05.

Family forestry - the promise of improved crop uniformity

Mass vegetative propagation by cuttings now makes a major contribution to the flow of genetically improved Sitka spruce into commercial planting, combining advantageous gains across a range of selection traits. To date, this has been based on superior half-sib families in which a number of plus trees are used to provide a pollen mixture for the male parent. The number of parents involved in such pollinations means that despite often high predictions of gain, the resultant crop is very variable in stem size and quality. However, the testing of families deriving from two specific parents (full-sib families) has indicated that further enhancements, particularly to quality characteristics, can be achieved. Artificial

pollination work to re-create such families is now proceeding. The resultant seed will provide full-sib families with enhanced gain and advantageous combinations of selection traits for propagation by cuttings. Deployment of this material can be in family mixtures or individual family blocks, which will provide a more homogenous and uniform product.

Selections completed for the hybrid larch breeding population

Ten-year height and stem straightness data collected from over 43 progeny tests were brought together and analysed during the year. As a result of this, the very best European (EL) and Japanese larch (JL) plus trees selected over the last 30-years will be re-selected to form the Hybrid Larch breeding programme. The genetic testing of JL and EL plus trees selected in forests around Britain proved to be time-consuming due to incompatible flowering times across the two species, early spring flowering leading to many losses from frost damage, low viability of stored pollen and low numbers of seed per cone. True hybrid families involving the best parents from each species should result in genetic gains of between 15 to 20% for 10-year height and 20 to 25% for stem straightness relative to a JL seed stand. Grafted copies of re-selected EL and JL plus trees will now be retained in two geographically separate clone banks.

Understanding the genetic structure of native black poplar in Britain

More detailed knowledge of the genetic structure of black poplar (*Populus nigra* var. *betulifolia*), one of Britain's rarest native trees is emerging. This is contributing to the development of a conservation policy for the species. As a result of cooperation under EUROPOP, an EU funded Europe-wide partnership, analysis of molecular data has revealed that genetic diversity was greatest in countries from southern Europe (France, Italy and Spain) and lowest in Britain. The results confirmed a contrasting situation in the British population which contained widespread duplication of genotypes as a result of extensive vegetative propagation. There is also a serious imbalance in Britain between male and female trees, males outnumbering females to a large extent.



A specimen of a black poplar growing in an urban setting. Black poplars were commonly used in amenity plantings because of their attractive form.



The project also addressed the question of introgression of introduced *Populus x euramericana* hybrids into the native black poplar gene pool. Results from several different sites showed that where a female black poplar was within pollinating distance of both hybrid and non-hybrid male trees there was no introgression. However, introgression did occur in situations in which there were no male non-hybrid trees within pollinating distance of a female tree which was surrounded by male hybrids. It appears therefore that female black poplars preferentially breed with non-hybrid males if they are available but in situations where non-hybrid males are not available the females can breed with hybrid males. It becomes clear, therefore, that new planting of the species should aim for a balance of male and female trees.

Results based on chloroplast DNA demonstrated that there were both eastern and western refugia of black poplar in Europe during the last glacial period. The majority of British samples originated from an eastern refugium, which is in contrast to results obtained in an earlier project showing that oak in Britain originated from Spanish refugia. Some British samples of black poplar showed cpDNA variation typical of material originating from Spain, but this may have reached Britain through human mediated movement.

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