NSW DPI

SCIENCE & RESEARCH and FORESTS NSW

Research and Development Annual Report 2005–06

NSW DEPARTMENT OF PRIMARY INDUSTRIES

FORESTS NSW

Forests NSW is a public trading enterprise within NSW Department of Primary Industries

NSW DEPARTMENT OF PRIMARY INDUSTRIES

SCIENCE AND RESEARCH

and FORESTS NSW

Research and Development Annual Report 2005–06

Our Mission

Research and development that underpins innovative sustainable forest management systems, adds value to Forests NSW's key objectives and benefits the people of New South Wales.

Research and Development Annual Report 2005–06
is a supplement to *Forests NSW's Annual Report*
and the *Social, Environment and Economic Report 2005–06*.

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

FORESTS NSW

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Front cover: Blackbutt (*Eucalyptus pilularis*) seedlings

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (January 2007). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Primary Industries or the user's independent adviser.

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Foreword

Forests NSW's research and development objectives are delivered through NSW Department of Primary Industries (NSW DPI) Science and Research, as well as through the Plantation and Tree Improvement units of Land Management and Technical Services. These groups provide strategic research support to the organisation's operation and service branches.

The NSW DPI Forest Science Centre of Excellence is co-located with Forests NSW within Cumberland Forest at West Pennant Hills. Tree Improvement has staff at Tumut, Coffs Harbour and the Forest Technical Centre at Grafton. Plantation Improvement has staff at Bathurst, Coffs Harbour, Tumut and West Pennant Hills.

The Forest Science Centre is home to the Forest Resources Research unit of NSW DPI Science and Research. The research focus is on providing science-based outcomes for forest resource development and sustainability within NSW. Research in fields that can add value to the commercial services and planted and native forest businesses of Forests NSW remain a priority. Emphasis includes establishment, management and product quality of sustainable planted forests. Research on the range of important potential benefits to be derived from returning trees to the rural landscape is also an important objective. Benefits include timber, sequestered carbon, enhanced biodiversity and salinity mitigation.

Ross Dickson
ACTING DIRECTOR
LAND MANAGEMENT AND TECHNICAL SERVICES
FORESTS NSW

Robert Eldridge
RESEARCH LEADER / CENTRE DIRECTOR
FOREST RESOURCES RESEARCH
NSW DPI SCIENCE AND RESEARCH

This Annual Report was compiled by Robert Eldridge

Tree Improvement

Manager: **Michael Henson**

Aim: Improved softwood and hardwood genetic material available and in use throughout planted forests.

Objectives:

- Genetically improved planting stock delivered for use across a range of sites of softwood and hardwood plantations.
- Genotypes matched to sites and specific end products.

Hardwood tree improvement

H. Smith

A fitting location for the official opening of the Grafton Forest Technology Centre by the Director-General in August 2005 was the recently established *Eucalyptus pilularis* (Blackbutt) clonal seed orchard on the Grafton site. The opening was held in conjunction with a 3-day training course on "Tree Improvement for Managers" presented by Forests NSW Tree Improvement Program and CSIR South Africa. Twenty-five participants from across Australia, together with Forests NSW managers, attended the course.

One focus of the Tree Improvement team has been the timely delivery of genetically improved material to commercial plantations and the development of economic deployment strategies for this germplasm. While some species may be deployed by vegetative propagules (cuttings, tissue culture plants), others are most efficiently deployed by seedlings grown from improved seed. To this end, clonal seed orchards (CSOs) have been established using elite individuals selected from progeny trials for traits of increased volume, improved form, disease tolerance and wood quality/pulp properties. During 2005–06 one CSO each of *Eucalyptus dunnii* (Dunn's White Gum) and *Corymbia citriodora* subsp. *variegata* (Spotted Gum) were established, and grafting carried out to propagate plants for CSOs of *E. dunnii*, *E. nitens* (Shining Gum), *E. globulus* (Tasmanian Blue Gum) and *Corymbia maculata* (Spotted Gum), as well as to complete plantings in an *E. pilularis* CSO.

The controlled pollination (CP) program for development of new germplasm of pure species and hybrids was continued for its second year. This program aims to produce seed of key commercial species that combines traits from our best performing individuals of these species. In addition, it aims to produce hybrids, crossing the best individuals of the species with alternative species that may impart superior traits or extend the planting range of the key species. A small amount of CP seed was harvested from the Tarkeeth E. pilularis CSO, and this is being grown for field testing. A large number of other crosses were harvested from the potted plants in the breeding arboretum. This seed has been sown and will be tested over a range of sites in collaboration with private forestry companies next season.

The Tree Improvement team has also focused on the assessment of wood properties of the *E. pilularis* breeding population. Standing tree measurements have been completed for growth and form on the progeny trial near Hannam Vale, and novel non-destructive tools used to estimate structural and stability properties. Cores have been taken from the trees to study the effectiveness of cores as a non-destructive predictive tool for measurement of shrinkage and density, as well as for molecular studies. A total of 1200 trees will be destructively harvested in early July for sawing studies and assessment of a number of wood properties and wood chemistry. This is the largest study of its type undertaken in Australia and the work is being carried out in collaboration with Southern Cross University, Ensis-Wood Quality, and Forest Enterprises Australia. Partial funding for the project has been provided by the Australian Centre for International Agricultural Research (ACIAR) in a project commenced in July 2005 entitled "Improving the value chain for plantation-grown eucalypt sawn wood in China, Vietnam and Australia: Genetics and silviculture" and, more recently, by the Forest and Wood Products Research and Development Corporation (FWPRDC) for the project "Improving dimensional stability in plantation-grown *E. pilularis* and *E. dunnii*".

Softwood tree improvement

H Porada

The highlight of the 2005–06 softwood tree improvement program based at Tablelands Research Tumut was the relationship building and collaborative research developed or progressed during the year between Forests NSW and a strikingly broad cross-section of institutions.

Ben Wielinga, a forestry student with Australian National University (ANU) and a casual summer employee with Forests NSW in 2004–05, completed his honours research project with Forests NSW. Mr Wielinga was awarded First Class Honours for his thesis "Timber stiffness of radiata pine at paired breeding trials in Southern NSW". The evolution of the project was due to the relations developed between Forests NSW and ANU in sharing data and providing research trials for the work, with field supervision and resource support directed by Dr Hans Porada. During the summer, Tablelands Research also employed two third-year year forestry students, Hugh MacMurray and Les Dowling, from the School of Forestry, Canterbury University, New Zealand, providing both students with a valuable over-view of Forests NSW and of forestry in southern NSW.

Some 67 ha of tree improvement trials were established between July and October 2005, including 10 ha of clonal blocks covering some 300 radiata clones for CellFor New Zealand. As well, 8 ha of genetic gain trials were established in collaboration with Proseed New Zealand and the Southern Tree Breeding Association (South Australia); 7 ha of radiata pine hybrid family progeny trials in collaboration with Proseed New Zealand, testing families suited to drier environments (looking at solutions to global warming impacts); 11 ha of progeny trials in collaboration with the Radiata Pine Breeding Company; 4 ha of Guadalupe radiate pine hybrid trials established in collaboration with New Zealand; 2 ha of clonal trials with Horizon 2 (New Zealand – United States); and a 5 ha Monterey Provenance planting of some 160 specific radiata pine families within a 25 ha bulk planting of the same provenance. The latter project was a major and singularly important one as it ensured the on-going genetic conservation of this provenance from the impacts of land development and disease

in the United States, and built on collaborative work that has been carried out by Australia, New Zealand, the United States (California) and Mexico since 1977.

Among the trial assessment work undertaken during the past year was the assessment of Forests NSW's first true radiata clonal trial, which was established in 2001 in collaboration with Carter Holt Harvey, New Zealand, and is now managed by Horizon 2. This is a major milestone in radiata tree improvement in Forests NSW, with more clonal trials coming up for assessment over the next 4 years. Early results indicate a very promising gain in growth and form and expected wood quality, with the next critical step being to test the commercial assumptions of such intensive forestry. As well, two important genetic gain trials were measured and the data is currently being analysed; these trials test the assumptions of tree improvement for growth, tree and stem form, as well as wood quality.

The 1980 Radiata Pine Provenance Trial established in Green Hills State Forest was assessed for growth and form and for further testing for wood properties and disease resistance. Findings from this work will be used not only for future breeding work, but also to select new candidates for inclusion in seed production and new plantations. The trial covers some 26 ha and 550 families of radiata from all natural radiata provenances in the United States and Mexico. Although the trial has been managed by Forests NSW since establishment, it has been used extensively by many institutions as part of major genetic and molecular research programs.

New Forests

Program Leader: **Annette Cowie**

Aim: A sound scientific basis established for the use of planted forests to benefit the environment.

Objectives:

- Carbon sequestration quantified in managed forests and forest products.
- Suitable tree species and management systems available for catchment protection and management.
- The use of recycled organics and planted forests for land rehabilitation.
- Contribute to the cost effective management of climate change.

Greenhouse accounting for planted forests

Annette Cowie

Emissions trading is recognised as the most cost-effective mechanism to promote reduction in net greenhouse gas emissions from industry. Emissions trading from reforestation is allowed in NSW through the Greenhouse Gas Abatement Scheme, through which Forests NSW has already benefited. The Australian states and territories have proposed a national emissions trading scheme that, if implemented, will expand the demand for forestry carbon offsets. However, widespread participation in emissions trading from forestry requires cost-effective methods of greenhouse accounting with acceptable levels of accuracy, and an administrative framework that minimises transaction costs.

Accurate assessment of the impacts on greenhouse gas mitigation of forestry and bio energy projects requires a full life cycle approach, with recognition of upstream and downstream factors, indirect emissions, and inclusion of the greenhouse gases methane and nitrous oxide. This project is contributing to the development of greenhouse accounting methods, guidance and standards that aim to balance costs and accuracy. Schemes that find an appropriate balance will encourage wide participation, resulting in expansion of forestry, which has potential to deliver environmental and socio-economic benefits to regional NSW.

Project staff are working with Forests NSW, Enterprise Development, to develop efficient and effective methodology for carbon accounting in Forests NSW's estate, and to promote adoption of appropriate guidelines and standards for greenhouse accounting.

During the year, staff:

- contributed to the Intergovernmental Panel on Climate Change 2006 Guidelines for National Greenhouse Gas Inventories

- responded to the Background Paper for Stakeholder Consultation released by the national Emissions Trading Taskforce

- contributed to the revision of the Australian Standard for Quantification, monitoring and reporting of greenhouse gases in forest projects

- submitted a paper on terminology used in greenhouse accounting for the land use change and forestry sector that clarifies alternative interpretations of key concepts. It uses the example of harvested wood products to demonstrate the impact of different interpretations. The objective is to facilitate clear communication amongst negotiators and practitioners in relation to the terms: emissions, removals, sources and sinks. Confusion and misunderstandings that have arisen in the past are rooted in diverging interpretations of the terms “emissions” and “removals” in the context of land use and wood products. One interpretation sees emissions and removals to be approximated by a change in carbon stocks in a number of selected carbon pools that may include or exclude harvested wood products. Another interpretation views emissions and removals as gross fluxes between the atmosphere and the land/wood products system. Whether emissions/removals are approximated by stock change or from gross fluxes, it is critical that a consistent approach is applied across the whole land-use change, forestry and agriculture sector. Approaches based on stock change are recommended over those based on fluxes

- assessed the impact on greenhouse gas emissions of diverting sawmill residues, currently used for particleboard manufacture, for use in generating bio energy. The study considered a theoretical particleboard plant processing 100 kt feedstock of dry sawmill residues per annum. If the sawmill residues are used instead for bio energy, and the particleboard plant instead utilises fresh plantation biomass, 205 ktCO_2 equivalent (eq) emissions are displaced. However, green house gas emissions for particleboard manufacture increase by about 38 ktCO_2eq, equivalent to 19% of the fossil fuel emissions displaced, due to the higher fossil fuel requirements to harvest, transport, chip and dry the green biomass. Also, plantation carbon stock declines by 147 ktCO_2eq per year until a new equilibrium is reached after 30 years. This result is influenced particularly by the fossil fuel displaced, the relative efficiency of the fossil fuel and bio energy plants, the moisture content of the sawmill residues, and the efficiency of the dryer in the particleboard plant

- published a paper on interpretation of rules and good practice in greenhouse accounting for northern Australian tropical savanna systems. International developments in carbon accounting for the terrestrial biosphere bring a requirement for better attribution of change in carbon stocks and more detailed and spatially explicit data on such characteristics of savanna ecosystems as fire regimes, production and type of fuel for burning, drivers of woody encroachment, rates of woody regrowth, stocking rates, and grazing impacts. The benefits of improved biophysical information and understanding of the impacts on ecosystem function of natural factors and management options will extend beyond greenhouse accounting to better land management for multiple objectives

- submitted a paper describing and assessing alternative methods of greenhouse gas accounting that could overcome deficiencies of the current approaches employed

under the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The alternative methods are for consideration in the negotiation of the second commitment period of the Kyoto Protocol

- assessed the potential for environmental plantings to be included in the NSW Greenhouse Gas Abatement Scheme. This project investigates the institutional barriers to inclusion of environmental plantings, and assesses the suitability of alternative low cost carbon accounting methods that could be used in the Scheme

- drafted a paper on the potential synergies between the objectives of greenhouse gas mitigation and conservation of biodiversity and mitigation of land degradation. Reforestation undertaken to mitigate greenhouse gas emissions can provide multiple benefits including mitigation of dryland salinity, enhancement of biodiversity and improvement in stream water quality through reduction in nutrient runoff and soil erosion. Reforestation projects also offer benefits in regional development and diversification of income for farmers. Carbon credits for reforestation offer an opportunity to promote sustainable development of Australia's rural landscape.

Life cycle analysis of wood products

WD Gardner, F Ximenes

The research into life cycle analysis of wood products was conducted within the Cooperative Research Centre for Greenhouse Accounting (CRCGA) and has demonstrated that wood products are a long-term store of carbon. It demonstrated that the most conservative option for accounting for post-harvest biomass removals—oxidation in the year of harvest—is significantly underestimating the true term of storage of carbon that was sequestered in the trees. Changing the carbon trading accounting methodology to include on-going carbon storage in wood products would significantly increase the returns to Forests NSW from carbon trading and may make other land acquisition and management options viable.

The project aim was to develop data to support an accounting system for carbon that is stored in wood products. The main focus of the project in 2005–06 was on writing papers and reports and involvement with utilisation activities in the last year of the CRCGA. Two papers, a report (Australian Greenhouse Office, National Carbon Accounting System Technical Report) a workshop proceeding, a review and a brochure were prepared and published. Most of the project milestones were met, despite the retirement of the previous project leader, David Gardner.

Landfill project

The proceedings of a workshop on the decomposition of wood and paper products in landfill held in North Carolina in 2005 were finalised and made available on the CRCGA web site in December 2005. Collaboration with Dr Morto Barlaz has continued through the development of work proposals and also through further investigations of the decay of wood products in landfill. A number of samples buried in a North Carolina landfill for approximately 15 years were analysed under a scanning electron microscope by researchers at the Forest Products Laboratory, USA Department of Agriculture, Madison. To our knowledge it was the first time wood products recovered from landfill had been analysed microscopically to characterise any

degradation. The analyses revealed extensive fungal decay in some samples, but no apparent decay caused by bacteria. These results will be valuable in the design of the analysis procedure to be adopted in future landfill research.

Decay of coarse roots

The analysis of coarse roots excavated for a collaborative project with the Australian Greenhouse Office was finalised and decomposition percentages estimated for the species involved. The estimated percentage of the softwood root biomass remaining ranged from 20% for radiata pine 25 years after harvest to 80% for cypress pine 50 years after harvest. For the hardwoods, it was estimated that 10–50% of the root biomass were present up to at least 85 years after harvest, depending on the species and site location. Therefore, it is clear that the current Intergovernmental Panel on Climate Change assumption of total decay of coarse roots in 10 years overestimates the rate and extent of coarse root decay for a range of harvested forest species in Australia.

A series of utilisation activities were conducted in 2005–06 including meetings with stakeholders, demonstration of the use of the model *TimberCAM*, and consultancies. Discussions were held with the Independent Pricing and Regulatory Tribunal (IPART), which regulates the NSW Greenhouse Gas Abatement Scheme, to explore the possibility of including carbon stored in wood products in the accounting rules. There is an opportunity for a case to be made to demonstrate practically how wood products could fit into the accounting framework. This can be most effectively achieved through a combined effort by forest growers and manufacturers of wood products. Discussions have been held between Carter Holt Harvey and Forests NSW to develop a joint proposal for consideration by IPART.

Future directions

Further funding has been obtained that will allow the research on the life cycle of carbon in wood products to continue for another three years. The research will focus on the greenhouse footprint of forest products in NSW. The true greenhouse impact of wood products is measured to a large extent by the energy required in their extraction, manufacture, use and disposal. This project will deliver an energy budget for wood products used for building in NSW and determine the greenhouse impact of waste disposal options. The results will inform energy rating systems, waste disposal strategies and carbon sequestration schemes in NSW.

Key sites for hydrology and salinity measurement and model validation

C Barton

This project aims to collect a range of data from a number of sites to quantify the sub-catchment impacts of land use options, including tree planting. The data will then be used to validate the suite of simulation models currently being developed by Department of Natural Resources that are integral to decision support tools used by Catchment Management Authorities. The project is a collaborative effort between NSW DPI, Department of Natural Resources and the University of New South Wales and is funded by NSW State Government.

The project is an essential input into other current National Action Plan for Salinity and Water Quality / Natural Heritage Trust project areas (TOOLS and Salinity Solutions through Agriculture) and provides information to enable relevant stakeholders (policy makers, Catchment Management Authorities and land managers) to make decisions on best land use to minimise the onset and cost of dryland salinity. Data collected will also be used to the improve tree growth models that are required for economic forecasting and estimating the carbon sequestration potential of tree plantings.

The two field sites operated by the Forest Resources Research unit, one in the Liverpool Plains near Quirindi and the other in the central west between Wellington and Parkes, were re-instrumented and staff were trained to operate the various scientific instruments used to collect the data. A database was developed to manage previous and newly collected data. A number of workshops were held to facilitate communication between the various groups involved in the project. A work plan for data collection and interpretation was devised and is underway.

Dryland salinity trials

C Barton and I Johnson

Trials planted from 2000 to 2003 are designed to provide information about the growth and survival of a number of tree species in the medium rainfall region (500–700 mm) of NSW, and to investigate the effects of various silvicultural regimes (spacing, establishment techniques, thinning) on tree growth.

Dryland salinity species demonstration sites

Forty-four of the original 50 sites are still viable and 5-year growth and form measurements were made in May–June 2005. The data has been analysed to calculate growth rates and investigate species differences. *E. camaldulensis* and the Saltgrow clones showed the best mean diameter and survival over all sites. *P. pinaster* had relatively poor growth and poor survival. *Acacia mearnsii* had poor survival but surviving trees were relatively large. Likely

Six-year-old trial of Eucalyptus sideroxylon *near Wagga Wagga.*

causes of site-to-site variation in growth are also being investigated. Analyses so far mostly indicate only weak associations between single soil and climate factors and mean growth and productivity of species.

Spotted Gum plantation near Quirindi following thinning at age 5 years.

A number of the sites that have adequate growth and survival of one or more species present opportunities to quantify the effects of a commercial thinning and pruning regime on tree growth and development, by comparing the trees with a control group (nil thinning/pruning). Paired first thinned/pruned and control plots have so far been established in four species over six sites. Further plots of this type will be established as the trees reach a suitable mean height for thinning. First thinning aims to retain an equivalent of 500 trees per ha, and the initial pruning is to about 3.0 m. These sites will be monitored to assess the impact of thinning on future growth and survival.

Planting trials in dryland region

Growth measurements of other silvicultural trials have been carried out, including the large spacing trial in the Liverpool plains area. Early growth and survival data from two site preparation methods trials in the Liverpool Plains were analysed. Mean height was considerably greater on the site with more friable, well-drained soil. Across both sites, deep ripping gave superior survival to mounding and to minimum till (shallow ripping). However, there was no significant effect of preparation treatment on height growth.

Tree growth and lateral water movement on hill slopes

A small project with the Cooperative Research Centre for Plant-based Management of Dryland Salinity has been commenced to instrument the ”Planting configuration trial” with new neutron probe access tubes and sap flow gauges. This trial is designed to assess the effect of the width of tree belts on control of lateral flow and tree growth on hill slopes.

The Hawkesbury Forest Experiment: Impacts of precipitation and CO_2 on trees

C. Barton

The Hawkesbury Eucalypt Experiment is being established at the Richmond campus of the University of Western Sydney to investigate how increased CO_2 will affect Australian forests. The results from this project will improve our ability to model and predict the likely effects of climate change on Australian forests in terms of their growth and water use. These effects have implications for carbon sequestration and water resources in both native and planted forests.

The project is a carefully integrated program of experimental and modelling approaches. The centrepiece of the project is a field facility with twelve CO_2 and temperature-controlled whole-tree chambers, valued at over $2million, that have been provided by the Swedish University of Agricultural Sciences.

The field facility at the University of Western Sydney with CO_2 and temperature-controlled whole-tree chambers.

The whole-tree chambers can house entire trees up to 10 m tall and have for the past 8 years been used in a boreal Norway spruce forest in northern Sweden. This unique facility is the first of its type in Australia and the southern hemisphere.

The chambers were carefully dismantled and shipped to Australia, where they are in the final stages of reconstruction. The site infrastructure, which includes power, water, telecommunications and a cabin to house the control systems, has been installed. Initial testing of the temperature control system was successfully carried out on the first ten chambers and testing of CO_2 control and measurement functions will commence shortly. Seedlings have been raised ready for planting in September 2006. The highly visual nature of the whole tree chambers has attracted considerable interest from locals and the media and it is expected that a number of articles will be produced.

The use of biosolids in softwood plantations

G Kelly

Over the past 16 years a series of nine research and 11 demonstration trials, funded by Sydney Water and Forests NSW, has been established to investigate the effects of biosolids on plantation pine. The work began with liquid biosolids (5% solids), which was the most common product at that stage. The product was surface applied to older stands post-thinning. Surface application was necessary to prevent damage to tree roots. Improved growth of 30% over the control was achieved with a rate of 30 dry t/ha. The research then developed to investigate the expanding dewatered biosolids market. Again, with surface application there was significant improvement in growth. The older aged stands were targeted to maximise the benefit on merchantable trees. While silvicultural benefits were encouraging, environmental issues were also addressed.

Re-measuring older demonstration sites in a study of the effects of biosolids on plantation pines.

Biosolids proved an effective fertiliser in pine (both environmentally and silviculturally) but it was important to consider its effectiveness compared to conventional fertiliser protocols. In older age stands, dewatered biosolids at a rate of 30 dry t/ha^{-1} produced highly significant increases in tree volume (which is usually expressed as cubic metres per hectare). This was consistent with the data for liquid biosolids. The response observed in larger scale demonstration trials was also consistent with that found in the research trials: the more fertile sites showed a reduced response and required more biosolids to generate a response. In addition, the higher fertility sites plateau in their response after 3 years, but in the lower fertility sites, the rate of response continued to increase.

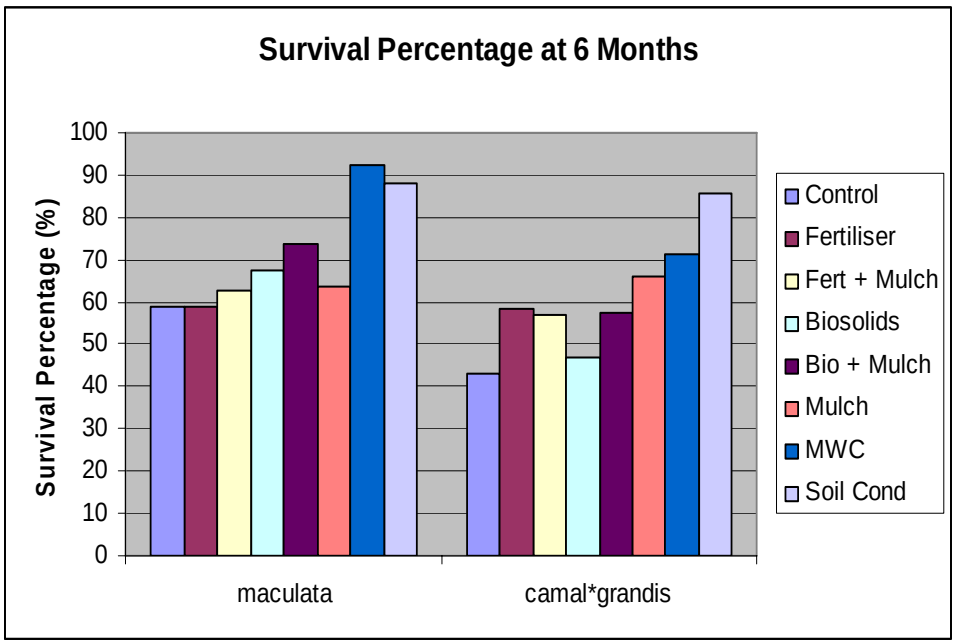
Increases in basal area of up to 30% are not uncommon. Incorporating biosolids prior to establishment gives a greater growth response, but also increases branch thickness, which affects the tree form and merchantability. Surface application to post thinned stands increases growth and does not affect tree form or wood quality, and as most of the treated trees will remain until harvest, this approach is therefore more profitable.

Application of recycled organics in mine site rehabilitation

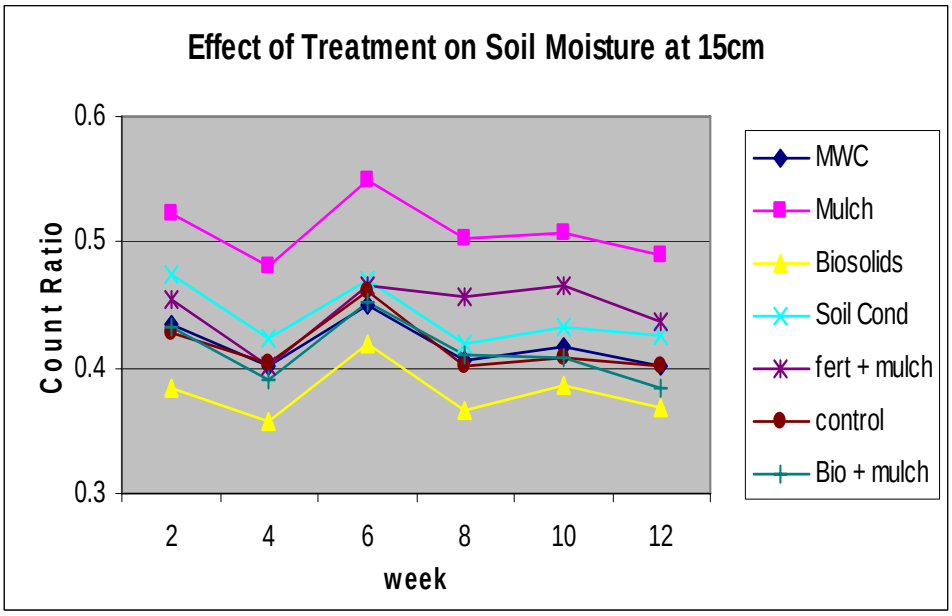
G Kelly

Mine site rehabilitation potentially presents a significant market opportunity for the recycled organics industry, especially for the lower grades of product. Understanding the role of different recycled organics products in maximising the survival and growth of plantation species allows appropriate combinations of recycled organics to be used to overcome site-specific problems.

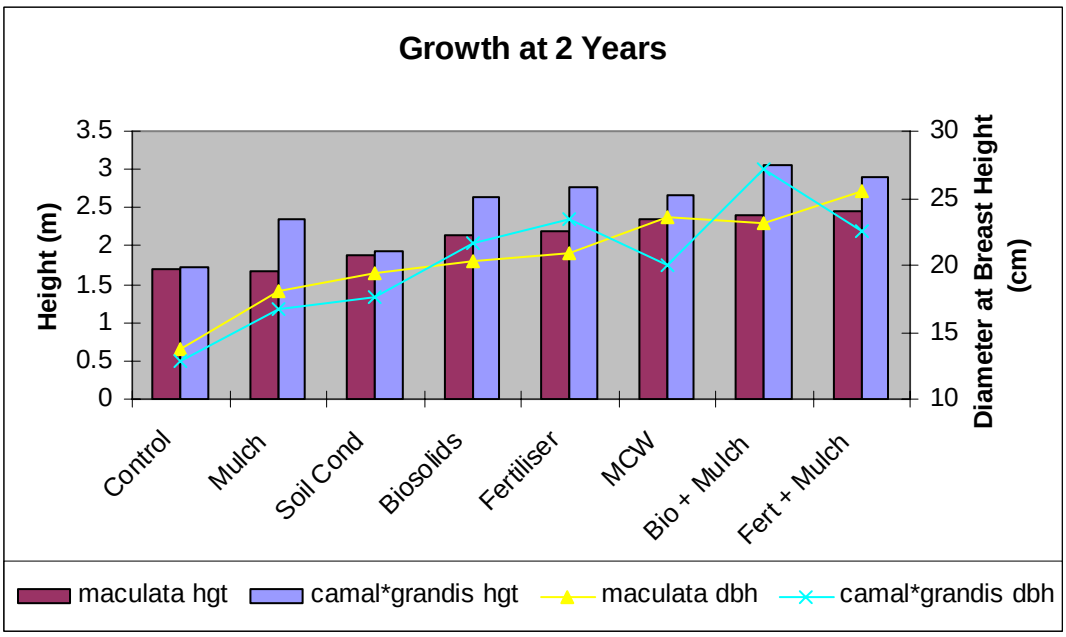
A 5 ha plantation trial was established on Narama mine in March 2004, using a range of recycled organics as soil amendments. These organics included biosolids, mulch, soil conditioner (made from recycled garden organics) and municipal waste compost (MWC—composted curb side garbage collection). The trial was intensively monitored in its first year of growth. Growth assessment was at 3, 6, 12 and 24 months. The critical period for survival is the first 6 months after planting. After 6 months, trees in plots amended with recycled organics had better survival rates than those in plots that had received other treatments.



Amendment of the soil with recycled organics had a significant effect on soil moisture. At this stage in the project we can conclude that mulch has had a significant effect in preserving soil moisture. This is particularly evident in the upper soil profile.



The incorporation of biosolids as a soil amendment induced significant weed growth: over seven times more weed cover than achieved with fertiliser, which produced the next highest percentage of weed growth. The addition of mulch, however, significantly reduced the weed growth and in addition improved soil moisture and moderated soil temperature. These conditions lead to an improvement in tree growth that is superior to that achieved by using biosolids or fertiliser alone. Recycled organics are proving to be very effective amendments for use in the rehabilitation of open cut mine spoil. The use of recycled organics may provide nutrients whilst ameliorating the negative effects of mineral fertiliser.



Soil amendments maximise forest production on mine sites

G Kelly

The Upper Hunter has approximately 20,000 ha of marginal or degraded lands. Much of this land is in the buffer zones of mining leases. This research directly addresses the top two key priorities identified by the Upper Hunter Commercial Forests Steering Committee:

- determining timber yields on a range of sites
- site preparation techniques using ameliorants (such as biosolids), ripping and mounding.

The research program is investigating the processes affecting successful establishment, survival and growth of trees. This includes assessing the role that soil amendments play in improving soil moisture and nutrition. Growth data from trials where bottom ash has been used are very encouraging, with the combination of biosolids and bottom ash resulting in the best early growth and survival. Biosolids in combination with bottom ash have produced significantly better tree growth (diameter and height) than fertiliser and no amendment (the control). The effect of using biosolids alone is statistically equal to that of using fertiliser and significantly better than that of using nothing (the control plot).

Soil chemistry has been analysed throughout the trials. The overburden soils treated with biosolids and biosolids plus bottom ash have higher levels of total phosphorus and available phosphorus (Bray P). Analyses of foliage samples at 3 years post-treatment show phosphorus levels are higher in the leaves of trees in the biosolids and biosolids + bottom ash plots. The trends seen in soil and foliage data for phosphorus mirror the growth trends. The next and final growth, soils and foliage assessment will take place in 2006–07.

Traditional timber species (*C. maculata*) and faster growing clonal material (*E. camaldulensis*grandis)* both respond well to amendment of the soil with biosolids. Nutrition from biosolids (particularly phosphorus), with physical amendment (from bottom ash), seems to be the driving force that is generating superior tree growth. The bottom ash provides better soil structure for root and water penetration.

When the Coal and Allied site was compared to other research sites in the region it was found that biosolids should be applied at a rate of 2 NLBAR (nitrogen limiting application rate) (200 gk)—as determined by the Environment Protection Authority Guidelines. This application rate gives sufficient available nitrogen to establish the plantation and maintain adequate nutrition past the establishment phase. While improved growth is achieved with application rates as low as 0.5 NLBAR, there is inadequate nitrogen and phosphorus to maintain good foliar nutrition.

Bulga mine site plantation trial

G Kelly

Forests NSW established a trial for Tomen Australia Limited on its Bulga Mine to investigate ways of boosting productivity of planted native species on a mine site in the Hunter Valley. Five species and four treatments (including biosolids) were assessed.

The trial, which was designed by the Oji Paper Co. Forestry Research Institute in Japan, has three parts:

1. a breeding test to investigate four suitable tree species (one with two provenances)
2. a silvicultural test to investigate suitable combinations of fertilising and weeding
3. a further silvicultural test to investigate legume pasture additions to the most successful species and most successful silvicultural techniques of the first two tests.

The trial also tests two different land types: reshaped overburden and undisturbed buffer zone land.

The trial is now 6 years old and while the initial contract has concluded, an agreement has been put in place that allows the ongoing monitoring of growth until 2008. The older age growth data is invaluable in determining the viability of plantations in the Hunter Valley.

Hybrid clones on reshaped overburden at Bulga mine

Trees on the buffer land and the overburden site were measured (height and diameter) at 6 years of age. Biosolids is proving to be the most successful treatment on the overburden and the buffer sites. While the clonal hybrids (*E. camaldulensis*grandis*) showed rapid growth in the first few years and were the dominant species, *C. maculata* (Spotted Gum) was the fastest growing species in the last year (in both height and diameter). The clones continue to have good form and grow taller, but the diameter is markedly increasing. *C. maculata* is now surpassing them in annual growth rate (diameter).

Integrated growth and thinning response models for even-aged forests

H Bi

Significant emphasis was given to further model refinement and system development for predicting the growth and yield of regrowth forests in the South-East region. The software Reden is now being used by forest resource managers in the region on a daily basis. It serves as a forest resources management information and decision support system that combines the growth and yield models with inventory data for the regrowth forests in Eden. It has a user-friendly interface for forest managers to obtain growth and yield estimates of the regrowth forests at different levels of resolution. The output from this system has already been linked with a geographic information system (GIS) and used for short-term management planning and long-term strategic yield scheduling of the regrowth forests in the region.

A system of additive equations was developed to predict the aboveground biomass of *Pinus radiata* plantations using data from several countries. The equation system will improve carbon accounting of radiata pine plantations in NSW and elsewhere.

The CRC for Greenhouse Accounting collaboration on the development and application of a generic scaling theory based on the self-thinning phenomenon came to fruition with the publication of an article in the American Ecological Society Journal, *Ecological Applications*. This article showed how the generic theoretical framework can be applied to practical problems in carbon accounting. In addition, collaboration with scientists at the College of Environmental Science and Forestry, State University of New York and the US Department of Agriculture (USDA) Forestry Service focused on a comprehensive comparison of statistical methods for estimating the self-thinning boundary line. This work was published in the *Canadian Journal of Forest Research*.

The potential of *Pinus radiata* for ecological restoration of the Yangtze River catchment in Aba, Sichuan, China. An ACIAR-supported project

H. Bi

The overall objective of this project is to carry out an assessment of the potential of *Pinus radiata* for ecological restoration and so to help ensure the future success of the planned expansion of *P. radiata* in Aba. The results will also be valuable to Forests NSW by:

1. extending the search for dryland provenances of *P. radiata* for the lower rainfall areas of NSW

2. improving assessment of risk of introducing serious pathogens and pests from China

3. increasing understanding of how to manage the pathogens and pests of *P. radiata* in diverse environments.

To evaluate forest health risks to the long-term success of *P. radiata* introduction in Aba, the project team continued to monitor forest health of the young plantations in small patches. They also monitored the newly established provenance experiments following the field inspections and assessments in June and July 2004 by an Australian pathologist and entomologist. A localised outbreak of sawflies was found at one experimental site and was treated by spaying insecticide. A report on the assessment of forest health risks to *P. radiata* introduction in Aba is being written.

Sawfly damage in radiata *pine near Mao Xian, Sichuan, China.*

Work on climate matching has identified areas in Aba as well as other geographic areas in southwest China as suitable for environmental plantings of *P. radiata*. The results show that much of the Min river valley of Aba is climatically suitable for growing *P. radiata*. At the national scale, a climatically suitable area of more than 266,000 km^2 across three provinces in southwest China was identified.

The provenance experiment at three sites along the lower, middle and upper reaches of the Min River valley was re-measured during the last 2 months of 2005. Diameter at ground level and tree height were taken, and mortality was recorded. In addition, individual trees were tagged and mapped at each site. The experimental site at Mao Xian was vandalised and the seedlings heavily browsed by animals in the winter of 2004, but since then many damaged seedlings have recovered and started to grow new shoots.

Radiata *pine in the Min river valley near Li Xian, Sichuan, China.*

A biomass and productivity study was carried out in 5-year-old *Pinus radiata* plantations in the dry river valley area by researchers at Sichuan Forestry Academy as a supporting component to the overall research on the introduction of *P. radiata*. Mean total stand biomass of 5-year-old *P. radiata* plantations were found to be 19.5 t/ha, about 12 times greater than that of plantations of native conifer *P. tabulaeformis* and *C. chengiana* at the same age.

Plantation Improvement

Program Leader: **Ross Dickson**

Aim: Forest management systems developed which meet international benchmarks of productivity and sustainability.

Objectives:

- Robust and cost effective practices developed for stand establishment and management.
- Increased value captured from current and future plantation wood production.

Characterising the pine resource to increase value capture

C Raymond, W Joe, R Dickson

One of the key objectives of the Plantation Improvement research program of Forests NSW is to map the variability in key wood properties across the radiata pine estate, with the longer-term aim of developing predictive models. Wood density and stiffness are the key properties of importance for the manufacture of a range of potential products. The two main forest regions for growing radiata pine are Hume (based around Tumut) and Macquarie (based around Bathurst). These regions differ in both climate and soil types, with the Macquarie region being much more variable than Hume. Major resource mapping projects were conducted in the Hume region over the summer of 2004–5 and in the Macquarie region in 2005–6.

Data was collected using a stratified sampling program that aimed to cover differences in climate, soil type, previous land use (ex-forest or ex-farm land) and silvicultural treatments across a range of age classes. The majority of the data was collected from standing trees, taking samples from the lower part of the stem. In addition, data was collected from logs cut along the stem in harvest sites to allow for evaluation of patterns of change in wood properties along the stem and an evaluation of the merit of the standing tree data. This new data base has been used to quantify the degree of variability across each region, determine effects of silvicultural operations such as thinning, determine site effects due to previous land use and/or soil type, identify key driving variables and, where possible, develop predictive models for both density and stiffness.

Overall, Hume and Macquarie have similar average wood density and stiffness but the range is very different within these two areas. The more uniform climate and soil types within Hume region are reflected in a lower degree of variation between forest areas within the region. In particular, no differences were found between forest areas for wood density within the juvenile core of the trees. In contrast, the variability within the Macquarie region is very large,

with large differences in density between forest areas at all ages. The degree of variability in wood density and stiffness is around 50% greater than that within the Hume region.

The Hume region resource survey data was used to develop predictive models for tree diameter, outerwood density and wood stiffness. Multiple regression models containing terms for age, forest area, prior land use (forest or farm) and thinning status were able to reliably predict diameter (R2 of 0.90), density (R2 of 0.79) and stiffness (R2 of 0.88). In a separate but related project for the Hume region, all the age 10 inventory data from across the estate was collated and analysed to determine the potential for prediction age basal area (BA) or total recoverable volume (TRV, an index of potential commercial product recovery). Multiple regression equations fitting rotation number, carbon site quality, stems per hectare and forest area (coded in descending order of average productivity) were able to predict both BA and TRV with R2 of 0.70 or greater. For the Macquarie region such models are still under development.

Results of the resource mapping project are being used operationally to identify areas of either high or low wood quality and to manage wood flow to customers to ensure that peaks or troughs in quality are minimized. The wood quality data is also being included in the forest inventory system and will be used by the planning and harvesting managers for strategic decision-making on future forest management and operations.

Benchmarking wood quality

W Joe, R. Dickson

Wood quality assessment of alpine ash

Wood quality directly impacts on the value of wood products sold, so having an effective set of grading rules that differentiate log quality is crucial to ensuring financial returns to forest growers and processors are maximised. Recent customer concerns about the quality of alpine ash logs supplied led to an investigation into the effectiveness of Forests NSW log specifications for predicting grade recovery of sawn products; of particular interest was the effect of spiral grain on product quality. Logs representing Salvage, Quota and Plantation material were sawn, kiln dried and assessed for recovery of appearance products. Sample material from across the logs was also measured for wood properties including strength, stiffness, hardness, density and spiral grain.

This mill study successfully demonstrated that, although there was considerable variation in basic wood properties between the Salvage, Quota and Plantation logs, the percentage recovery of standard or better grade appearance products was similar. A notable feature of these logs was the very high percentage recovery of Select and Standard grade boards, which accounted for around 96% of all the board graded, with the majority being Select boards. Interestingly, the Plantation logs had the highest recovery of Select boards, whilst the Salvage logs had a slightly greater recovery of Select boards than the Quota logs. This suggests that the current Forests NSW log specifications, particularly in relation to spiral grain, did not have any great effect on grade recovery.

The wood properties for the Salvage and Quota logs were comparable or superior to previously published values, which have been derived principally from tests on mature wood.

On the other hand, the average wood properties of the Plantation logs were quite different and generally inferior to those of more mature wood. Bending strength and stiffness were both about 20% less, whilst hardness was about 10% less than the published values. However, examination of the data revealed that the properties of the Plantation logs were approaching that of mature wood, and that they were low only in the core wood.

Spiral grain, which was a major cause for classifying the logs into Salvage grade, did not appear to have any significant impact on twist in the appearance boards. Boards from all three log types were well within product specifications in respect to twist.

Gum veins were by far the most frequent factor affecting appearance grade for both Salvage and Quota logs and, to a lesser extent, Plantation logs. Knots were prominent in boards from the Plantation and Quota logs, but not from the Salvage logs. Pin holes, gum pockets, chipping out and checking were the other characteristics that affected grade to a lesser degree amongst the logs studied.

Characterising wood quality of pine resource

Information on intrinsic wood properties and product quality of *Pinus radiata* as affected by silviculture, site and genetics is crucial to developing management strategies for the Forests NSW pine resource. A major effort has been made over the past 12 months in providing technical support to Forests NSW's resource assessment of the Macquarie region. This work involved extensive processing and measurement of thousands of increment cores for basic density from in excess of 100 plots from across the region. Clear wood samples from a number of targeted sites are being tested for strength and stiffness properties.

The information gathered will assist with strategic decision-making relating to future land purchases, site selection, silvicultural treatments and forest management and marketing options. The data will also allow for the development of tools and methods for predicting wood quality for new sites, and for identifying and matching the resource to product requirements, resulting in increased revenue to Forests NSW and their clients.

Plantation Blackbutt wood drying optimisation project

This Australian Research Council Linkage Grant PhD project recognises that drying is a key step in the process of processing and adding value to timber. Plantation hardwood timber is increasingly available and has greater variability in its properties than previous resources. This presents an opportunity to take advantage of the development of better mathematical techniques for process optimisation and better drying and mechanical models for timber and timber processing. This collaborative project with the University of Sydney is close to being finalised. The last of a series of drying experiments has been completed and the results are being analysed by PhD student Sherryn Cabardo. Preliminary analysis has identified some key wood properties such as basic density and modulus of elasticity as important drying parameters for plantation Blackbutt sawn boards.

This project is expected to produce optimised drying regimes to effectively dry plantation timber with variable properties, producing timber for high-value and appearance-grade end uses, such as flooring and furniture. This in turn will add value to Forests NSW plantation hardwood resource.

Hardwood plantations—enhancing seedling survival

D Thomas

We have continued our research on increasing the quality of seedling material produced by Forests NSW's nurseries and optimising the management practices of some nursery activities. This impacts on financial performance of the Nursery unit as higher quality seedlings are produced, which can then be sold to third parties. Additionally, this increases staff productivity through improved technology and training, which addresses the key result area of human resources.

We are continuing our research in defining optimal conditions to increase seedling survival during the establishment of new plantations and the use of soil amendments to reduce seedling mortality. High survival promotes good plantation establishment, which not only reduces the financial costs of replanting failed areas, but also ensures more uniform trees at the time of thinning and final harvest, which impacts on a key objective of maximising timber production.

We have confirmed that basic physiological data collected on young seedlings (16 weeks of age) can be used to predict performance of 10-year-old trees, thus assisting the Tree Improvement program in researching their objectives.

We intend pursuing further studies on optimising seedling production such as greater use of direct sown seeds and increasing germination of these seeds, as well as assisting with optimising the nutritional regime of seedling production. Optimising sowing method and germination not only produces better quality seedlings, but also reduces labour costs of production, and there is early evidence that direct sown seeds produce more uniform seedlings.

We will continue our research and monitoring role into longer-term performance of seedlings produced by various nursery regimes to ensure we have achieved both high survival and high productivity. We will evaluate the use of mechanised planting and soil additives in larger operational size trials to best achieve high survival in new plantations.

We will be collaborating with Tree Improvement on evaluating the impact of site factors on volume and quality of timber from desired species and selected improved genotypes.

Hardwood plantation silviculture

G Smith

The hardwood plantation silviculture program aims to improve financial performance through maximising timber production and value using appropriate silviculture. Several projects investigate the wood quality and economic outcomes from stand management regimes designed to produce a variety of products to satisfy market needs.

The modelling of future value of hardwood plantations requires understanding of the effect of silviculture on the wood quality of the products produced. This allows products to be matched to customer requirements. In collaboration with the newly established Cooperative Research

Centre for Forestry, several thinning trials have been established to quantify growth response across species and site qualities within the region. These trials will provide regional data that is currently lacking.

Several 5-year-old trials are beginning to yield information on the effect of pruning and thinning regimes on log quality. The main cause of defects in plantation grown timber is knots. Recent results from thinning and pruning trials show that self pruning in *Eucalyptus dunnii* and *Corymbia variegata* is highly efficient and that pruned and unpruned trees have a very similar sized knotty core. For most species within the plantation program that self-prune well, production of high quality logs should be possible without the expensive practice of pruning.

In a project investigating physiological response to pruning in two contrasting species, early findings indicate that water use is similar but photosynthesis within the crowns of the two species is very different. Another closely related area is spacing at planting. A trial investigating the effect of rectangular plantings has shown that highly rectangular plantings have little effect on branching or growth in the early years after establishment. Wider row spacing can significantly reduce establishment costs.

To maximise the application of data on growth and wood quality, the program will look into the area of simulation modelling of wood quality outcomes. This allows the many possible implications for processing of different products to be explored. Trials will be monitored as they get older and destructive sampling will be undertaken in trials that are old enough to have reached sufficient size for sawing.

Forest Health Management

Program Leader: **Christine Stone**

Aim: Integrated decision support and management systems developed which provide an acceptable level of forest health protection.

Objectives:

- To minimise the introduction or establishment of exotic pests or diseases
- A system of forest health management which minimises pest and disease impacts on managed forests.

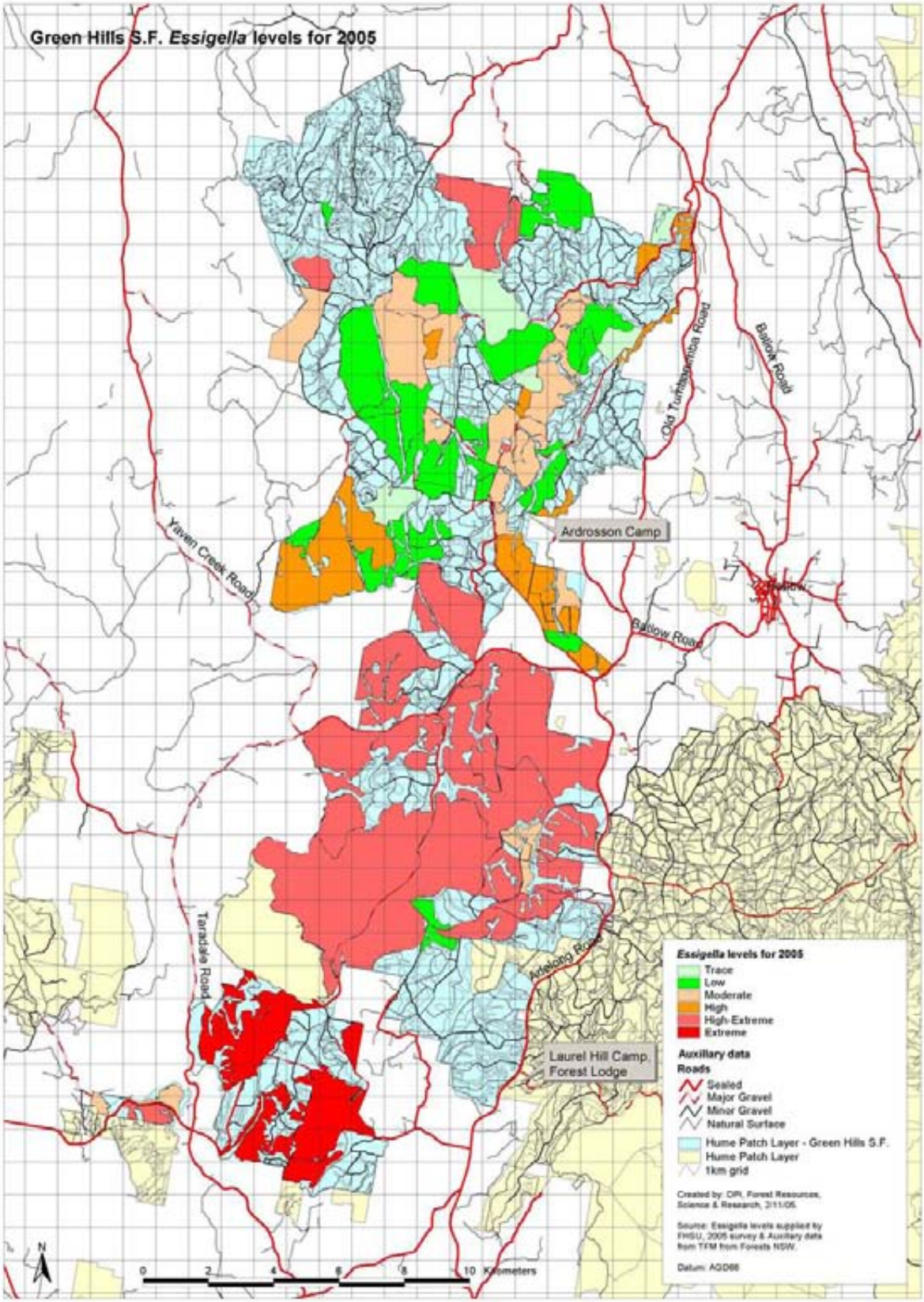
Forest health surveillance of softwood plantations

A Carnegie

Softwood plantations in all regions were surveyed from June to September 2005. Sixty state forests or plantations were surveyed by helicopter, with the majority having follow-up ground surveys. The incidence, severity and extent of the problems in areas where pests, diseases, vertebrates, nutrients and weeds were limiting growth or affecting survival of pines were highlighted by the Forest Health Survey Unit (FHSU). Softwoods management can use this data to: determine correct predictions of pre-harvested wood volume in affected stands; adjust management regimes for "unhealthy" stands (e.g. bring thinning forward in drought-affected stands); apply fertilisers or weed control to improve establishment, growth and survival of young trees; control spray for *Dothistroma*; and increase trap tree plots in *Sirex*-infested areas.

The main health issues in 2005 were:

- *Diplodia pinea* (also called *Sphaeropsis sapinea*) damage affected over 1,500 ha in 2005, mostly related to drought-stress and hail damage. The Hume region had almost 1000 ha affected; in the Northern region, 250 ha were affected. Low levels of damage from *D. pinea* were observed in the Macquarie and Monaro regions. Damage from *D. pinea* was lower than in previous years in all regions.
- *Essigella californica* (California Pine Aphid) caused major damage in 2005, resulting in needle chlorosis and defoliation. Again, older age classes were the worst affected. The Hume region had over 35,500 ha affected to varying levels of severity. In the Macquarie region, almost 25,000 ha were affected, with affected trees in all forests. In the Northern region, moderate to high levels of defoliation were observed in older age classes. Mostly low levels of damage from *Essigella* were observed in the Monaro region, with moderate to high levels in several localised areas.



GIS (geographic information system) map of California Pine Aphid in Green Hills State Forest. The red areas show high infestation.

- *Sirex* Woodwasp caused very low levels of damage in the Macquarie, Northern and Monaro regions. However, up to 2% mortality was observed in several areas in the Hume region. This is a concern as levels of *Sirex* can increase rapidly once tree-mortality rates reach 1–3%. Bark beetles attacked *Sirex* trap trees in the Hume and Northern regions, causing concern over the effectiveness of the plots to assist in the biological control program. The Forest Health Survey Unit is working on a collaborative project with Forestry Tasmania and Queensland Department of Primary Industries and Fisheries, funded by the National Sirex Coordination Committee, investigating the use of insect lures in traps to detect *Sirex* in new areas (such as the Northern region and south-east Queensland).

- *Dothistroma septosporum (*dothistroma needle blight) was again lower this year than in previous years, with only 450 ha affected in the Northern region. No other region had significant levels of dothistroma needle blight.

- Wallaby damage was again severe in young age classes adjacent to native forests in the Northern, Monaro and Macquarie regions. In many instances over 50% of trees had been damaged, and in some cases 90%.

- The bark beetle *Ips grandicolis* had increased populations in the Hume and Northern regions, due most likely to increased logging operations and the resultant slash being left on the ground.

- *Hylastes ater,* another bark beetle, was observed attacking a small patch of replanted stock in Buccleuch State Forest in the Hume region, causing mortality of seedlings.

- Wind had caused damage to recently thinned stands in the Macquarie region, resulting in 5% of retained trees being blown over, and also to young stands, resulting in bent stems as affected trees recovered.

- Possum damage was again lower than in previous years in the Monaro region.

Diagnostics and insect and fungal collection

During surveys, samples of tree damage that could not be diagnosed in the field were taken for laboratory analysis. The samples were analysed for causal agents, including for *Diplodia* (*Sphaeropsis*) and *Sirex*. Insect pests and fungal diseases isolated from these samples were lodged in the collection and entered into the Australian Plant Pest Database system.

Forest health surveillance of hardwood plantations

A Carnegie

Routine forest health surveys of hardwood plantations were conducted during summer-autumn 2006. Over 110 plantations were surveyed from the ground, some twice as part of the *Creiis* Psyllid Monitoring Program. Over 50 plantations were surveyed using the Forests NSW helicopter: in May 2006 as part of the *Creiis* Monitoring Program and again in July. During the aerial survey in May, only *Eucalyptus dunnii* was surveyed, mainly for *Creiis* damage; however, all species were surveyed for all disorders during the aerial survey in July.

Surveys identify important pests and diseases that may be limiting to growth and establishment of eucalypt plantations, and that may need further research, as well as certain sites/areas that may have increased health problems. Continued forest health surveys are essential to increase our knowledge of known pests and diseases and factors influencing damaging outbreaks of these problems, as well as to increase our ability to detect new pests and diseases (including exotic species) early. Forest Health Reports provide managers with a summary of important pests and diseases in their plantations, with recommendations on remedial and control action where appropriate. In most cases these reports are discussed with relevant field staff soon after the survey.

The main forest health issues in the young eucalypt plantations in 2005–06 are listed below:

- The psyllid *Creiis* was not as significant this year, with only one plantation with severe damage. Very low numbers of *Creiis* were observed in many plantations. Plantations that sustained severe damage in 2005 were surveyed again in 2006, with many trees showing poor recovery, resulting in dead topping and mortality.

- Cerambycid stem borers were a continuing problem in the older plantations, especially *E. grandis* and *Corymbia* spp. Some *Corymbia* trees were completely ringbarked by borer damage.

- Cossid stem borers were a continuing problem in older plantations, with *E. grandis* the most susceptible, but stressed *Eucalyptus dunnii* (e.g. after *Creiis* damage) also sustaining high levels of damage from cossids. Cockatoos had caused further damage by feeding on cossid larvae and damaging the stems of trees.

- Stem canker fungi, including *Botryosphaeria* spp., *Cryphonectria eucalypti* and *Caliciopsis* sp., continued to increase in incidence and severity in the older plantations. Severe damage was observed in several plantations. In many cases severe damage appeared to be associated with tree stress, but this needs to be further researched. Some stem fungi in NSW eucalypt plantations are still unidentified, and require detailed taxonomic work.

- Mistletoes were observed in approximately 50 plantations, mostly affecting *Corymbia* spp. Levels of mistletoe were alarmingly high (65%) in several *C. variegata* plantations, and at lower levels in up to 15% of Spotted Gum plantations.

- Ramularia shoot blight (caused by *Quambalaria pitereka*) was more common this year due to good rainfall preceding the surveys. In most cases only low to moderate levels of damage were observed, but some plantations also sustained high to severe damage.

- *Quambalaria eucalypti* was observed for the first time in *E. dunnii* at several plantations; this is the first record of it on *E. dunnii* in Australia. It was associated with small leaf spots and infection of insect damage (e.g. from weevils), and also minor twig cankers.

- Chrysomelid leaf beetles, Christmas beetles, *Amorbus* bugs and flea beetles were observed only at trace to low levels this year.

In March, PhD student Geoff Pegg (Queensland Department of Primary Industries & Forests, Forest Research) joined Dr Angus Carnegie (co-supervisor) to survey a selection of plantations in north-eastern NSW and in south-eastern Queensland. Mr Pegg is investigating various aspects of Ramularia shoot blight, including biology and management of the disease. *Quambalaria eucalypti was* observed on *E. dunnii* for the first time in Queensland during these surveys.

Diagnostics and insect and fungal collection

Samples of damaged trees were collected during surveys where necessary. These were analysed for causal agents, including foliar and stem fungi. Insect pests and fungal diseases isolated from these samples were lodged in the collection and entered into the Australian Plant Pest Database system.

Forest insect collection

D Kent

Forests NSW, through NSW Department of Primary Industries, Science and Research, maintain a significant collection of Australian forest and forest product insects in the Forestry Commission of NSW Insect Collection (FCNI). The collection provides the basis for an important identification service to Forests NSW staff, other government agencies (including Australian Quarantine Inspection Service), the pest control industry and the general public. The FCNI has been improved for future maintenance and management with the adoption of Biolink, a database specifically designed for collections. This enhancement has been made possible by grants of over $60,000 of Commonwealth funding since 2002 from the Australian Plant Pest Database project (APPD). The APPD project was developed by Plant Health Australia and Agriculture, Fisheries and Forestry Australia, as a national, web interfaced tool, linking reference collection databases of pests and diseases of economically important crops and plant-derived commodities in Australia.

The FCNI received another grant from the APPD project for 2005–06 to begin the data capture of an additional section of the wet collection (i.e. insects stored in alcohol rather than pinned). The FCNI's wet collection consists mainly of termites, a group that has already been successfully data captured by earlier funding; however, the wet collection also contains a significant amount of immature insect stages. This important section consists of a wide range of insects including caterpillars and beetle larvae. The majority of the wet collection is closely linked to the pinned adult material, making this current data capture a valuable resource when identifications are required of immature insects such as larval timber borers.

This year saw over 50% of the FCNI collection electronically data captured and available for in-house searches for distribution data and host plant information. The FCNI was also deployed at NSW Department of Primary Industries at Orange in conjunction with the database of the Orange Agricultural Insect collection (part of the Agricultural Scientific Collections Unit). This deployment completes the final funding requirement for the APPD project. The joint hosting arrangement will enable more efficient Internet access of the FCNI collection at the Australian Plant Pest Database website by other participants of the APPD, including Plant Health Australia and Biosecurity Australia.

The FCNI collection is currently being gazetted under the *Agricultural Scientific Collections Trust Act* with other Forestry collections such as the Forest Pathogen Collection and the Wood Collection. Inclusion of the FCNI will recognise this valuable forestry resource and support its long-term maintenance, improvement and management.

Clonal eucalypts resistant to pest and diseases

C Stone

Significant differences between eucalypt species, provenances and individual trees in susceptibility to insect attack have long been recognised. Identification and propagation of clonal material from select resistant trees is an important initial stage in improving the insect resistance of eucalypt plantations. In general, the incorporation of insect-resistant clonal material into plantation stock will reduce the impact of herbivorous insects on tree growth as well as remove any reliance on chemical insecticides and hence reduce the costs of insect pest management.

The Forest Health Surveillance Unit and Hardwood Plantation Officers continue their vigilance for trees that appear to exhibit some degree of resistance to insect herbivory. The Tree Improvement group continues to develop protocols for multiplying clones propagated from the insect-resistant field trees.

A significant contribution to this project has come from two Australian Research Council Linkage Grant PhD projects. Dr Christine Stone is supervising both projects.

Insect resistance traits of *Eucalyptus* for the NSW forest plantation industry

This project is in its third and final year. Mr Martin Henery, the PhD candidate involved, is based in the phytochemistry laboratory managed by Dr Bill Foley, Australian National University, Canberra, and is working towards the following aims:

a) to characterise the chemical and physical parameters (e.g. leaf toughness) of foliage from susceptible and resistant *Eucalyptus grandis* trees

b) to undertake laboratory bioassays and field trials on clonal material propagated from selected resistant trees.

Mr Henery has completed a series of bioassays testing *Paropsis atomaria* larvae (Chrysomelidae) on several *E. grandis* clones progated by the Forests NSW Tree Improvement group and identified two clones presenting significant toxic effects on young feeding *P. atomaria* larvae. Examination of the foliar biochemistry of these two *E. grandis* clones was completed and Mr Henery is preparing his thesis.

Pest status and management of a *Creiis* psyllid in *Eucalyptus* plantations in northern NSW

This project has just been completed. Mr Paul Angel, the PhD candidate involved, has submitted his thesis. As part of his studies Mr Angel obtained *E. dunnii* clonal seedlings from Forests NSW Tree Improvement group, Grafton. The clonal seedlings were propagated either from an individual tree that was exhibiting strong partial resistance to *Creiis* damage

and defoliation or from similar but more susceptible trees. A series of choice experiments were conducted using the propagated seedlings in screened cages. The resistant material was significantly less preferred by ovipositing *Creiis* females, resulting in significantly lower psyllid egg densities on the leaves compared to the susceptible seedlings. Also, the juveniles that subsequently developed on the resistant clonal stock experienced significantly higher levels of mortality in the predator free environment.

Subtropical Forest Health Alliance

C. Stone

In February 2006 hardwood and softwood plantation growers and researchers in south-eastern Queensland and northern NSW formed a Subtropical Forest Health Alliance (SFHA) to maximise forest health research outcomes to industry in the region. The Alliance arose through the recognition that the forest health issues facing plantation growers in north-eastern NSW and south-eastern Queensland are significantly different from those in southern and south-western Australia, where the majority of research effort in plantation forestry has been focussed over the past 30 years. The SFHA was formed to ensure a coordinated and strategic approach to hardwood and softwood plantation health in the subtropics and, through direct grower consultation, to assist in defining, scoping and funding R&D projects. Primary objectives include promoting knowledge transfer to operational staff and maximising forest health R&D investment returns in the region of northern NSW and south-eastern Queensland.

The SFHA includes representatives from the Queensland Department of Primary Industries and Fisheries, Forestry Plantations Queensland, NSW DPI Forests NSW, NSW DPI Science and Research, Ensis, Integrated Tree Cropping Limited, Forest Enterprises Australia Limited, Great Southern Plantations, Queensland University of Technology and Southern Cross University. Membership is also open to other growers or research and development providers that may wish to join the alliance in the future.

Alliance members will consolidate current knowledge of management of pest and disease issues for operational use, standardise surveillance methodologies and provide training to operational staff.

Remote assessment of native forest dieback in NSW

C. Stone

This collaborative research program commenced in June 2004. The project has been partially funded by the National Heritage Trust. The original research project based in the Richmond range was supported by the Bell Miner Associated Dieback (BMAD) Working Group and recommended by the Northern Rivers Catchment Management Board for federal funding. The research participants secured further funding for the 2005–06 financial year to continue this project.

The overall aim is to identify the acquisition, processing and modelling specifications of cost-effective imagery that will enable the accurate classification and development of a BMAD

hazard-rating model of canopy condition in native eucalypt forests. This will contribute to the development of operational guidelines for the management of BMAD in native forests within NSW.

The key outcomes of this project are:

a) improved ability of forest managers to identify, evaluate and report on the condition of their forests

b) integration of remotely acquired digital imagery with other spatial coverages in the operational GIS data management systems

c) application of spatial models to identify forest areas at risk of particular damaging agents or processes.

Richmond Range Study Site

In the first project a study site of 30,000 ha was selected in the Richmond Range, northern NSW, which contains native forest managed by Forests NSW and Department of Environment and Conservation NSW (DEC) and also forest of private tenure. The ground-based program associated with the intensive assessment of twenty-four 20 m radius plots was undertaken by staff within DEC (John Hunter, Steve King, Tim Perry) and NSW Department of Primary Industries (Christine Stone, Grahame Price, Russell Turner, Peter St Clair, Jamie Churchill). The plots exhibited a range of floristics, stand structure and canopy condition. Both stand and tree-level attributes were measured, including floristic composition and percentage crown cover of both the overstorey and the understorey; Bell miner density; tree crown measurements, soil profile descriptions; and soil chemistry analysis. A complete listing of all of the flora present in the 24 plots was prepared and the floristics data analysed. The visual assessment of canopy condition of a further 99 plots was also completed. This data was examined and preliminary results published.

Analysis of the digital imagery by Russell Turner (Forests NSW) clearly demonstrated the capacity of the 2 m Digital Multi-Spectral Imagery to detect canopy affected by BMAD. Preliminary results associated with the spatial modelling of this Digital Multi-spectral Imagery data with other climatic and terrain-based spatial data sets were published.

Jilliby Catchment Study Site

This is the second phase of this research program with the main study site located in the Jilliby catchment, including parts of Olney and Wyong state forests. This, again, is a collaborative, multi-agency project that is receiving funding from several sources. Department of Environment and Conservation (NSW) and NSW DPI partners are utilising National Heritage Trust funding and are focused on objectives associated with BMAD. The NSW Rural Fire Service is managing a large research project “Assessing Fuel Loads by Remote Sensing”, which now has the same Jilliby area as its primary study site. The research providers for the Rural Fire Service include the University of NSW and the CRC for Spatial Information (Adam Roff, a PhD student) and the Sydney Catchment Authority (Dr Chris Chafer).

The merger of resources associated with these two projects has enabled joint access to an extensive array of ground-based attributes based on the establishment of 130 plots and a

comprehensive set of remotely acquired data covering 12,600 ha of variable Forest Types. The spatial data acquired in May 2006 includes: 1 m Digitial Multi-Spectral Imagery; 3 m HyMap hyperspectral imagery; very high resolution LIDAR (light detection and ranging) as well as SPOT, ASTER and Landsat imagery. This represents approximately $130,000 worth of imagery and provides a unique opportunity for comparing and modelling these different sources of spatial data.

Forestry CRC—The Green Hills State Forest Project

C. Stone

NSW DPI is a Supporting Member of the new CRC Forestry. NSW DPI is making a significant in-kind contribution to Research Program 1, “Managing and Monitoring for Growth and Health”, and in particular to Project 1.2.2, “Measuring and managing forest health”. This project has two components, one based on eucalypt plantations and the second focused on measuring and managing forest health in *Pinus radiata* plantations. The principal study site for the *P. radiata* project is located in Green Hills State Forest, Forests NSW Hume region, with California pine aphid being the principal damaging agent under investigation. Other collaborators in this multi-disciplinary CRC project include the School of Forest and Ecosystem Science, University of Melbourne; ENSIS (formerly CSIRO Forestry and Forest Products); Handcock Victorian Plantations; Forests SA and the University of Tasmania.

A key feature of the Green Hills State Forest study site is that the site will also be utilised by researchers associated with several other Program 1 projects, including “Development of a remote sensing approach to forest condition monitoring based on canopy defoliation and discolouration as key indicators of canopy health”; “Development of a spatial coverage estimating plant available water capacity”; “Utilisation of airborne remote sensing (radiometric data) for spatial prediction of soil variables”; and “Incorporation of data arising from the Green Hills study site into process based models currently being developed” (e.g. CABALA; 3PG).

Soil-applied insecticides for eucalypt plantation establishment

C. Stone

A range of herbivorous insects has been identified as having the potential to significantly affect plantation establishment success and productivity. The effectiveness of the original two insecticides registered for use in NSW eucalypt plantations (dimethoate and alpha cypermethrin) is determined by the timing of spray application with respect to susceptible life stages of the pest insects present in the plantation canopy during insecticide application. Frequent monitoring of the plantations is therefore required to identify the best time to spray. The fragmented nature of the hardwood plantation estate means that Forests NSW is unlikely to have the resource capacity to maintain this level of intensive monitoring. In addition, there are difficulties associated with ground-based application for adequate insecticide coverage to a crop that exceeds 2 m in height within 2 years. The formal protocols (defined by the National Registration Authority) associated with the aerial

application of insecticides to plantations are becoming more demanding and hence more difficult to implement.

Testing imidacloprid against the psyllid *Creiis* in north-eastern NSW

After approximately 5 years of glasshouse and field trials in collaboration with the Forest Resources Research unit, Bayer has announced the registration of their imidacloprid product, Merit FXT, for use in eucalypt plantations. This product registration of a slow-release formulation has the potential to reduce the need for intensive monitoring up to 2 years after planting and provides a viable alternative to the aerial application of dimethoate to control *Creiis* in young eucalypt plantations.

Testing clothianidin against the psyllid *Creiis* in north-eastern NSW

The chemical company Sumitomo has begun trialling a systemic insecticide, clothianidin (an analogue of imidacloprid), in a series of field trials including *E. dunnii* in north-eastern NSW. Unlike the slow release pill formulation of the Bayer product, the clothianidin will be applied into the soil as a liquid formulation in a precise, farrowed strip close to the trees.

Mundulla Yellows—Australian Research Council (ARC) Linkage Project

C. Stone

This ARC Linkage Project, submitted in 2003, is based at the University of Adelaide and partially funded by Forests NSW. Mundulla Yellows is a fatal disease that affects a very wide range of eucalypts, including commercial eucalypt species and other native plants. It is characterised by progressive yellowing and dieback of foliage. It was first observed in the 1970s in South Australia and has been observed spreading, in varying degrees, to other states.

At the time of submission of this project there was debate about whether Mundulla Yellows was caused by a biotic micro-organism or abiotic (environmental) factors. This project is attempting to determine if the causal agent is a viroid-like organism, possibly spread by sap-sucking insects. Another group of researchers, based in Victoria, is concentrating on the identification of possible abiotic factors. They have examined a wide range of environmental factors including soil physical and chemical properties, soil compaction, water availability, increased alkalinity and salinity, and the accumulation of bicarbonate in the soil solution. All symptomatic sites investigated in their study contained alkaline subsoil and higher salt levels compared to asymptomatic sites. These assessments are being replicated at other locations throughout south-eastern Australia.

After 2 years of research the investigators associated with this ARC Linkage project are still convinced that Mundulla Yellows is of biotic origin because they believe they have demonstrated the graft transmissibility of specific symptoms; however, they have not yet identified a biotic agent.

Termite and Power Pole Evaluation Research (TAPPER) Project

M Horwood

The aim of this work is to improve the cost effectiveness and reliability of wood poles relative to alternative materials by identifying effective and acceptable means for protecting poles from termite attack and for eradicating infestations that have occurred. The work is funded by the Electricity Association of NSW and the Forest and Wood Products Research and Development Corporation.

There are two parts to the project:

1. a service trial to evaluate the performance of termiticidal treatments including toxic dusts, chemical soil barriers and a residual timber fumigant for eradicating termite infestations from infested power poles

2. a field trial to evaluate the performance of termiticidal soil barriers and a physical barrier for protecting new poles from termite attack.

Treated hardwood pole attacked by subterranean termites.

The service trial was established between 2000 and 2002. Treatments were applied to over 450 termite-infested poles located throughout urban and rural NSW. Since treatment, poles have been continuously monitored to assess treatment performance.

The field trial was established in 2002 in a state forest near Narrandera. A large number of timber posts were placed in the ground, protected by a range of barrier systems. Posts are being inspected at intervals to determine the effectiveness of the treatments.

This trial has, so far, identified a number of highly effective termite treatments, some of which are not currently used by the power supply industry in Australia. They represent effective alternatives to conventional chemicals such as arsenic trioxide, and could be used should the continued use of this chemical become undesirable. At least two electricity networks in NSW have altered their treatment practices in response to the findings of the research.

Preschem Bioguard Bandage Trial

M. Horwood

In NSW, all of the approximately two million hardwood power poles in service will require remedial ground-line maintenance at some time to protect them from fungal degrade. These procedures cost pole-using authorities approximately $15 million per annum. The most commonly used maintenance treatment is to install a chemical bandage to the underground inspection zone of the pole. This zone extends from the surface to a depth of 35–40cm and is the area most prone to fungal damage.

This industry-funded research project is assessing a range of chemical and delivery system variations to the standard Bioguard® pole bandage to optimise transfer of chemicals into poles and reduce losses of chemicals to the environment. The project was established in the first half of 1999. At specified intervals since then a set number of poles have been inspected. At each inspection, bandages are removed from poles and core samples taken from the bandaged section for analysis.

Inspections have been carried out at 1, 2, 4 and 6 years after treatment. Further inspections are planned for 8 and 10 years post-treatment.

Forest Biodiversity and Ecology

Program Leader: **Rod Kavanagh**

Aim: A scientific basis for maximising biodiversity values in managed forests.

Objectives:

- Enhance understanding of managed forests ecosystems.
- Integrated landscape models of wildlife habitat and timber production.
- Development of species monitoring programs at the regional scale to assist Forests NSW with its environmental management system.

Ecology of birds and non-flying mammals in managed forests

R Kavanagh

These studies reinforce the need for forest managers to carefully plan harvesting operations to minimise adverse impacts on populations of a range of common (and not so common) forest birds and mammals. Many vertebrate species occur so rarely in nature that it is not possible to assess their sensitivity to logging using standard fauna survey techniques. Instead they require species-specific research programs, along the lines of that described for the Barking Owl (below), to obtain information useful for their conservation and management. In the case of the Barking Owl, it was necessary to undertake a radio-tracking study of a number of owls to determine key elements of habitat required by this species and to provide appropriate guidelines for managers.

The greatest task now facing forest managers is the need to implement species monitoring programs at the regional scale so that ecological sustainability of forest management practices can be demonstrated. Particular attention needs to be given to the sampling design of these monitoring projects so that results are informative. The next step will be for managers to establish regional task groups, including community representatives, to implement robust species monitoring programs at the regional scale.

Habitat selection by Barking Owls in the Pilliga

Nine Barking Owls (*Ninox connivens*) from eight territories were trapped, released and radio-tracked for one year in the Pilliga forests of north-western NSW. The study identified important aspects of the ecology of this vulnerable species, enabling the development of guidelines for conserving Barking Owls in timber-producing forests. The research showed that Barking Owl pairs in the Pilliga forests live year-round in non-overlapping home ranges of approximately 2000 ha. The owls used most of the forest vegetation types available in their home ranges, but preferred particular subsets of tree species associations for hunting, nesting and roosting activities.

A feature of the owls in the Pilliga is their diet of native prey species, including sugar gliders, bats, birds and insects, compared to their diet in some other locations where European rabbits form the main component. Perhaps for this reason, forest edges were not as important an element of habitat for Barking Owls in the Pilliga as they appear to be at some other locations. The Pilliga forests have a long history of selective logging, yet there appeared to be no evidence of owls avoiding logged areas within their home ranges. Most pairs of owls attempted to breed during the study but only half were successful, each producing two or three young. Nest predation by goannas appeared to be a significant cause of nest failure for the other pairs. Management guidelines arising from this study are being incorporated into the negotiated outcomes of the recent Brigalow and Nandewar regions land-use decision.

Recovery of large forest owls and arboreal marsupials

Every 3 years, a total of 101 sites distributed throughout several state forests and national parks south of Eden are surveyed to document the recovery of large forest owls and arboreal marsupials following intensive logging during the 1970s and wildfire in 1980. Since the mid 1990s, a large increase has been observed in the number of sites where the Powerful Owl (*Ninox strenua*) and the Sooty Owl (*Tyto tenebricosa*) have been recorded. Both owls are now recorded at rates comparable to those in the best habitat for these species in NSW.

The best explanation for this result is the relative abundance of the two major prey species for these owls in these forests: the Common Ringtail Possum (*Pseudocheirus peregrinus*) and the Sugar Glider (*Petaurus breviceps*). Numbers of the Common Ringtail Possum may now be declining, partly in response to predation by these owls. The occurrences of two other arboreal marsupials, the Yellow-bellied Glider (*Petaurus australis*) and the Mountain Brushtail Possum (*Trichosurus caninus*), appear to be stable or increasing. Core habitat for all of these species is located on lower slopes and near minor drainage lines and riparian zones. Most species require old hollow trees for nesting and shelter and also hold strong relationships with the composition and structure of the forest understorey. It is important for managers to ensure that adequate numbers of old hollow trees and their recruits are retained in logged areas.

Towards an integrated landscape model of wildlife habitat availability and wood supply in south-eastern NSW

Forest managers require decision-support tools to understand the consequences of alternative management scenarios in terms of their effects on wildlife habitat availability and wood supply projections into the future. In the past, wildlife management for sensitive species in Australian forests has focussed on the provision of core habitat or limiting resources without fully recognising the contributions to wildlife habitat provided by the mosaic of “disturbed” areas within the commercial forest landscape. Recent studies of the spatial and temporal responses to intensive logging of large forest owls and their arboreal marsupial prey show that both logged and unlogged forests contribute significantly to the habitat requirements and hence the population status of these conservation-priority species in commercial forest environments.

As part of other work, significant efforts have been made to apply spatially explicit scheduling of wood supply (yield) in the forests of south-eastern NSW. The tasks of developing and then successfully integrating these spatial and temporal models of wildlife habitat availability and

wood supply are daunting and will require considerable investment. Important issues that need to be addressed include the identification of goals and constraints so that conservation and production objectives can be optimised. Current work has outlined some of the key steps required and established collaborations to work towards developing a decision-support tool for forest management in south-eastern NSW.

Detectability of large forest owls and arboreal marsupials

Surveys that record the presence or absence of fauna are used widely in wildlife management and research. A false absence occurs when an observer fails to record a resident species. There is a growing appreciation of the importance of false absences in wildlife surveys and its influence on impact assessment, monitoring, habitat analyses, and population modelling. Very few studies explicitly quantify the rate of these errors. Quantifying the rate of false absences provides a basis for estimating the survey effort necessary to assert that a species is absent with a pre-specified degree of confidence and allows uncertainty arising from false absences to be incorporated in inference.

In this study, we estimated the rate of false absences for two species of large forest owl and four species of arboreal marsupial based on eight repeat visits to 50 survey locations in the Eden region. Detectability curves were derived for each species to convey the number of visits required to achieve a specified level of confidence that resident species will be detected. The observation error rates calculated were substantial but varied between species. For the least detectable species, the Powerful Owl (*Ninox strenua*), standard surveys returned false absences on 87% of visits. However, surveys of the more detectable Sugar Glider (*Petaurus breviceps*) returned a 45% false absence rate. Thus, up to 18 visits may be required to be 90% sure of detecting resident owls and up to five visits may be required to provide 90% confidence of detecting resident Sugar Gliders. Temperature, rainfall, wind, and habitat quality influenced the detectability of most species. These results have important implications for the design and implementation of programs that monitor regional species.

Impact of forest management strategies on plant species diversity and richness

R Kavanagh

Prescribed burning and logging operations affect understorey plants differently. However, the typically patchy nature of these management procedures, at least in the dry sclerophyll forests in south-eastern NSW, means that some refuges are likely to be available for species that are more sensitive to fire and logging. The final product of this research will be a decision-support tool for managers to determine the impact of various management strategies on plant communities. It is envisaged that this management tool will be applicable on a regional scale.

The project examines the effects of the two primary forest disturbances, fire and logging, on both understorey and overstorey vegetation. Data has been collected within the Eden Burning Study Area over a 20-year period. Funding has been provided by the Bushfire CRC to analyse and publish the results of this study.

Eden Burning Study Area

Assessment of fire patchiness

Data has been collected from 25 prescribed burns over the 20 years of this study. This data has been analysed and will be submitted for publication. In summary, the prescribed burns were found to be extremely patchy. Such burns are likely to have significantly lower ecological impacts than homogenous burns because refuges are provided for fire-sensitive species and newly burnt areas for colonizing species.

Effects on understorey vegetation

Understorey data has been collected during the study approximately every 5 years. Logging resulted in higher species richness for the shrub understorey, with no obvious effect of fire. In contrast, fire had a significant impact upon ground vegetation diversity and richness, with no obvious effect of logging. The results of this study will allow the identification of species or groups of species that are more susceptible to logging and fire disturbances. This data has been analysed and will be submitted for publication.

Effects on overstorey vegetation

Logging extended over about 85% of the planned area, felling or knocking down 49% of overstorey trees and 61% of their basal area. About 34% of logged forest was burnt in the post-logging burn. The area burnt by prescribed burns ranged from nil to 33% in logged forest and from nil to 59% in unlogged forest. Logging reduced the density of potential habitat trees (trees larger than 50 cm diameter at breast height (DBH)) by 65% to about 15 trees/ha, but did not substantially change the proportions of species. Thirteen years after logging, sufficient trees had grown larger than 10 cm DBH to replace those removed by logging and those that had died. Eucalypts regenerated effectively after logging, exceeding the minimum standard of 30% of 4m^2 plots stocked. In logged forest, frequent prescribed burning (four burns) over a 13-year period had little effect on initial establishment and development of overstorey species.

Soil seed bank study

The Bushfire CRC provided funding for a student scholarship to assist in the establishment of a study of the soil seed bank in the Eden Burning Study Area. Soil samples were collected from the site in April 2006 and will be germinated over a 12-month period. The data will be analysed to determine whether the history of prescribed burning and logging in the study has influenced the composition of the soil seed bank.

Biodiversity in eucalypt plantations established to reduce salinity

R Kavanagh

Eucalypt plantings play an important role in improving the quality of the habitat for wildlife in agricultural landscapes. Opportunities exist for Forests NSW to become a supplier of seedlings and a manager of commercial eucalypt plantings on farms in non-traditional forestry regions.

We conducted a large-scale study to guide future planting schemes for biodiversity recovery. Our study was located near Albury-Wodonga, where re-planting of native vegetation began in the 1970s. Eucalypt plantings were found to provide considerable biodiversity benefits over cleared paddocks, but the different fauna displayed a range of responses. Birds and bats made the most extensive use of plantings, particularly favouring the older plantings. Birds were strongly affected by the size of the area covered by the patch of trees, both in new plantings and in remnants of forest, whereas bats were widespread throughout the area, even in paddocks, although they were much more common in remnant vegetation. Remnant forest and woodland were most important for arboreal mammals and nocturnal birds and reptiles, but older aged plantings were also contributing to the habitat of these species. Ground mammals were virtually absent from the study area due to the impact of grazing and introduced predators.

This study showed that the absence of shrub cover and logs on the ground was an important factor limiting the availability of habitat for many species. Plantings of native trees and shrubs larger than 5 ha clearly have an important role to play in providing habitat *in situ* for many species and they may also contribute significantly to increasing the effective size of remnants in agricultural landscapes. Young plantings of native vegetation are used by more species of woodland-dependent birds if they are situated in landscapes having greater amounts of remnant forest and woodland. New work is planned to calibrate the biodiversity values of these environmental plantings with commercial forestry plantings in similar environments.

Ground-truthing Biodiversity Benefits Toolkits

R. Kavanagh

The NSW government is exploring the potential for market-based solutions to reverse the effects of habitat loss and land degradation on private land. The aim is to provide financial incentives to landholders to undertake changes in land use or land management that will improve the status of environmental services (e.g. the provision of clean water, healthy soils, biodiversity conservation). As part of this process, several biodiversity toolkits are being developed by other agencies to quantify the value of this environmental service, and rank improvements to biodiversity under different management actions employed by landholders. These toolkits use a combination of attributes of ”vegetation structure” and ”landscape context” as surrogates for the perceived habitat requirements of a broad range of animals and plants. This project, funded primarily by a grant from the NSW Environmental Trust, aims to verify the assumption that these surrogates closely reflect the observed biodiversity at a site.

Knowledge of the relative importance of toolkit components, including vegetation structure, species composition, landscape context and connectivity, and the weightings given to each component, will provide an assessment of the rigour of the assumptions underpinning biodiversity toolkits. In particular, the habitat value of eucalypt plantings versus forest remnants and cleared paddocks will be calibrated. Subsequent toolkit enhancements will enable greater accuracy and efficiency in predicting likely changes to biodiversity as a result of land management practices. This information will help to underpin national and state government efforts to place biodiversity values within an economic context.

Habitat data were collected from 120 eucalypt plantations, remnant forest and farmland sites previously surveyed for birds, mammals, reptiles and amphibians in the Albury-Wodonga region. These habitat variables were recorded and ranked according to the procedures specified by each of the three main biodiversity toolkits currently under development. Analyses are underway to assess the performance of the toolkits across a range of different vegetation types. This is being done by relating the toolkit scores, and overall toolkit predictions, to the existing survey data for terrestrial vertebrates collected at the same sites in 2002.

Bat ecology in managed forests

B Law

The improving knowledge of forest bat ecology is allowing predictions to be made about changes in bat communities resulting from changes in forest management practices, and thus will be integral to demonstrating ecological sustainability. Studies on the “biological width” of streams (the minimum undisturbed corridor width necessary for biological conservation, in this case of bats) can provide a scientific basis for setting buffer widths, most likely at widths considerably less than those suggested by external regulators.

Publication of research on threatened bats (e.g. Large-footed Myotis and Golden-tipped Bats) has provided a major contribution to 5-year Regional Forest Agreement reviews of threatened species licences. Pre-logging survey guidelines and associated prescriptions for these species are currently under review and it has been argued that management emphasis should shift from pre-logging surveys to post-logging monitoring.

Improved tools have been produced for surveying bats, such as identification keys that can be used with software for automated bat call identification, as well as monitoring bats using novel methods such as banding and infra-red counters at known roosts. The information gathered from long-term monitoring is extremely valuable; for example it has shown that riparian buffers are effective in mitigating the immediate effects of logging on the Large-footed Myotis. The data can be used in annual Environmental Audit Reports.

Response of bats to disturbance

Bats in the Pilliga

A major study of bats (and other fauna) in the Pilliga region was initiated in spring 2004. The aim of the study is to establish the “biological width” of streams in the Pilliga, so that there is a scientific basis for buffer widths surrounding streams. The study sampled three different-sized streams replicated across the region. Ultrasonic detectors were used to record bat calls at four distances from the stream—over the stream bed (0 m), and at 50 m, 100 m and 200 m from the stream. Many thousands of calls were collected in the study, and as part of the process of identifying these calls, an identification key has been developed for the Pilliga region that is compatible with software designed to automate the process of bat call identification. Both the key and software will be a valuable tool for the Western region, allowing rapid and reliable identification of bat calls collected as part of the planned Western region monitoring. Call identification from the stream width study was completed, preliminary data analyses were run and a progress report was provided to the regional ecologist.

Bats in the Karuah Research Area

An eighth consecutive year of banding bats was completed in March 2006, with 93 banded and 54 recaptured from previous years. The study will provide the first estimates of bat population sizes and survival rates in forests, which we will be able to use in comparisons between regrowth and unlogged catchments. To maximise the precision of our estimates data will continue to be collected for this comparison until regrowth catchments are thinned, which is expected to occur in the next year. Annual banding is also providing extensive pre-thinning data on bat populations that will allow comparison with post-thinning data in years to come. In preparation for thinning, additional Anabat surveys were conducted concurrently with trapping in the catchments, which will allow comparison of bat activity between thinned, unthinned and mature forest.

A Greater Broad-nosed Bat and an Eastern Falsistrelle caught during a long-term study of bats occurring under different forest treatments in research catchments on the upper Karuah River, Chichester State Forest.

Improved tools for monitoring and surveying bats

The Large-footed Myotis, a waterway-dependent bat, was banded for the tenth consecutive year at Kerewong SF. Seventy-four of these bats, including 56 recaptures, were caught at Kerewong State Forest in 2005. In January 2006, half of the bridge under which this colony of bats roosts, collapsed. An inspection was undertaken early in February to assess whether the colony of bats had perished with the collapse, but a large colony was still visible. A large number of bats have tolerated this disturbance. However, until more detailed data analysis is undertaken, it will be unclear whether the number of bats in the local population has declined through direct mortality due to the collapse or through associated disturbance at the roost. A full analysis of population trends over 10 years will assess changes both before and after

logging in surrounding catchments from 2000 to 2003 and over changing weather conditions. This data will provide a strong test for the effectiveness of riparian buffers in mitigating any potential short-term effects of logging.

Monitoring also continued at two key subterranean roost sites, using an infra-red gate and data-logger. At Mumbulla mine near Eden, 763 bats (over four nights) were counted in November 2005. In December 2005, the fifth annual population census was carried out at Ourimbah bat cave on the central coast (the largest known roost of Horseshoe Bats in Australia). An uncorrected count of 5,391 bats (over four nights) was made as they exited their cave. Calibration of this count by two correction factors for bats that fly over the infrared gate and those that simultaneously fly through (both estimated using a video) is yet to be made. Counts at both Mumbulla and Ourimbah were similar to previous years and a stable population pattern, with no large fluctuations, is beginning to appear. Continued monitoring of these important bat populations will allow Forests NSW to track the changing status of these bats and to assess changes due to forest management practices imposed on the surrounding environment.

Effect of logging on nectar production in eucalypts

B Law

Outcomes from measuring eucalypt nectar in logged forests will have relevance for managing the nectar resource for both native wildlife and beekeepers using state forests. This research will vastly improve our understanding of nectar production after logging and will be used to make recommendations to ensure the continuing supply of this valuable resource.

Supported by external funding from the Honey Board (Rural Industries Research and Development Corporation), this project is measuring nectar production in two tree species—Spotted Gum and Grey Ironbark. Both species are key nectar producers for beekeepers and native wildlife as well as being important timber producing species.

Researchers Brad Law and Mark Chidel are lifted by a crane into the canopy of Spotted Gum forest on the south coast of NSW to measure nectar in flowers and assess logging impacts.

Spotted Gum flowers are often loaded with nectar and thus provide a large food resource for honeybees and a diverse array of native wildlife.

Spotted Gum that had been well budded since 2003 burst into flower in 2005. Over the course of winter we measured nectar at three replicate sites from each of three logging histories. At each site eight trees were measured—four large and four small. Nectar was measured in flowers bagged over-night to determine nectar production and on unbagged flowers in the late afternoon and early morning to determine nectar availability at each of these times of day. This will provide us with excellent data to address the project's objectives, including comparisons in nectar production between a poor flowering year (2003) and a prolific one (2005). Nectar measurements from over 2000 flowers have been databased and are currently being analysed.

Grey Ironbark also flowered moderately well in spring. We completed one trip to measure nectar in unbagged and bagged flowers from three sites, each with a different logging history. This gives us data for this species from 2004, 2005 with 2006 to follow.

We also collected data on honey production from beekeepers with site permits surrounding our study areas. Survey forms were designed and distributed to 38 beekeepers.

Nectar maps for flying foxes

B Law

This project aims to improve our understanding of, and provide mapping tools for describing, the distribution of food resources of Grey-headed Flying Foxes, a recently listed threatened species. It is fully funded by Department of Environment and Conservation (DEC) for a collaborative role in preparing digital maps of the distribution of flying fox food (i.e. nectar and fruit). Significant progress has been made in devising a method to rank the diet species of Grey-headed Flying Foxes for their productivity and reliability. Vegetation associations in different geographic regions are allocated a nectar score based on the presence and abundance of diet species. Where possible, local experts have been consulted to score the diet species for flowering phenology, productivity and reliability. Vegetation associations are then mapped by region using Geographic Information Systems (primarily that of Forests NSW). Draft maps have been completed for Victoria, south-eastern Queensland, Eden,

southern NSW, Sydney and northern NSW. Final refinements to the maps are needed and a final report to DEC is expected by December 2006.

Research on this threatened species will ultimately provide a scientific underpinning for its management by aiding the development of sensible and effective wildlife prescriptions in forests subject to timber harvesting. The project's outcome will have relevance to Forests NSW in that it will identify areas that provide food for flying foxes during annual bottleneck periods and thus identify the areas that are most sensitive to the species.

Ecology of pygmy possums in managed forests

B Law

This research aims to provide a scientific basis for the management of Pygmy Possums by aiding the development of sensible and effective wildlife prescriptions in forests.

The project is investigating the ecology of the Eastern Pygmy Possum and the impact on this creature of logging in forests. The species has recently been listed as threatened and little is known about its ecology in forests. Routine surveys for the species are problematic as Pygmy Possums are notoriously difficult to catch in Elliott traps, although labour intensive pitfall traps have moderate success. Rather than focusing on surveys of this cryptic species, targeted research should be more effective for the species conservation by identifying its key habitat requirements in forests subject to timber harvesting and then using this data to inform management.

An Eastern Pygmy Possum with a radio-collar fitted. This small marsupial is the subject of a study investigating the impacts of logging its forest habitat at McPherson State Forest.

Over the past year most effort has gone into trapping and radio-tracking possums at the McPherson State Forest sites (Hunter region). The project is in the before-logging phase and is collecting valuable information on home range and den use of this small marsupial. In the past 12 months over 5000 pit-trap nights and almost 1000 Elliott trap nights have resulted in the capture of 40 possums. Of these, 18 have been large enough to radio-track and a further 18 have been spooled with a fine cotton thread to reveal microhabitat use. Two sites were included in the experiment because they were logged 5 years ago and thus they provide us with a picture of how pygmy possums use habitat in the early stages of regrowth after logging, rather than in the immediate post-logging period. One of these sites has had the greatest capture rate of all sites, with 21 recorded there. This preliminary result, together with data on den use and foraging movements in the regenerating zone, suggests that these possums can survive in the thick understorey regenerating after logging.

Managing frogs and reptiles in the forest environment

F Lemckert

Threatened frog species have different habitat requirements and habitat use patterns, hence no one set of protective prescriptions or monitoring strategies adequately covers all species. Stream-side buffer strips remain critical in protecting both calling sites and the water quality of the tadpole habitat. Giant Burrowing Frogs are being managed in south-east NSW through a diverse strategy that encompasses all land tenures. Such an approach should be applicable to a wide range of species.

Monitoring of frog populations continued to be hampered by the major drought. Numbers for some frogs appeared to remain relatively high, but several species were very difficult to locate. However, this may simply have been due to a lack of activity by these frogs rather than a decrease in their numbers. A wet winter/spring will provide interesting data on overall drought effects.

Development of an effective monitoring strategy for Corroboree Frogs around Tumut using their long-term count data is progressing. This work will determine the most appropriate number of sites to monitor and the sensitivity of the program to detect real changes in abundances. Current monitoring strategies for Northern Corroboree frogs are likely to detect only coarse changes in numbers and only after several years. More sites are required to provide the data needed to detect more subtle changes between consecutive years.

A PhD student, Harko Werkman (Newcastle University) is completing analysis of data for his study into the impacts of logging on stream breeding frogs in areas between Gosford and Coffs Harbour in NSW. He has data on the growth and survival of frogs on streams with differing disturbance histories and is comparing them to assess whether there are differences that correlate with management history.

In collaboration with the Federal Department of Environment and Heritage, work has begun on looking at the species richness and endemism patterns of frogs in Australia and the patterns of frog records in Australia. The former provides information on the regions of Australia with higher conservation values and places that may provide the maximum

conservation return with their protection. The latter is providing specific information on the actual rarity of Australia's frogs, and particularly of those in south-eastern Australia. A first task is to determine which frogs have relatively few records and how their biology and range influence the numbers of records, and then to develop *a* new system of ranking the relative rarity of frogs that are detected, taking into consideration how easy they should be to detect and the range and habitats over which they are found. This will provide a better understanding as to whether some of our rare species really are rare, or just hard to find, and should be applicable to other taxonomic groups.

We were successful in tendering to write the Giant Burrowing Frog recovery plan and for funds to survey the Giant Burrowing Frog in the Jervis Bay area. Both will provide for better management of this frog.

Pond requirements of frogs and effects of disturbance on frogs

F Lemckert

Monitoring of numbers of permanent pond-breeding frog species appears to be an effective strategy to assess long-term impacts of disturbances. These populations are resilient to drought and most are relatively stable.

A study has been completed comparing the attributes of 45 ponds in the Watagan Ranges, just north of Sydney, and the frog communities breeding at them. No single factor was of outstanding importance to the overall number of frogs and number of species using ponds and different factors were important to different species, both in being present and in their abundance. Larger, more complex ponds are, overall, likely to better maximise their potential as a frog breeding habitat, but rare species need specific attributes of a pond before they will use it. This may exclude many other species from using the pond. This work has now been expanded to include ponds from the Dorrigo, Wauchope and Bulahdelah areas and further frog population data has been collected from these areas in the past year. This work will look for general patterns of correlation between pond attributes and frogs that can be applied across northern NSW.

An additional area of work has been to measure the pH, salinity, dissolved oxygen levels, dissolved solid levels, temperature and turbidity of ponds in the Watagan Mountains to assess if water chemistry also has a role in determining pond use. The preliminary information from 40 ponds has failed to identify any factor of great importance. However, ongoing drought conditions may be confounding the results to some degree as pond levels have dropped to very low levels and frog numbers have also declined recently. Over the coming summer, assessment will be made of invertebrate predator numbers at the same ponds to determine if predation may have a relationship with frog presence and numbers.

Amplexing Red-eyed Tree Frogs in Olney State Forest: part of the frog pond studies in the Watagan ranges.

Over 300 frogs have been micro-chipped for long-term monitoring of population size, health and mortality. Some data are now available to indicate that recruitment to calling populations of males is relatively high each year, but that overall population sizes remains similar. Populations overall appear to be very stable, as do community structures. That is, there is not a high population turnover as is the case in many northern hemisphere systems and the typical metapopulation structure believed to drive populations in that hemisphere are not very relevant here. This is important as it may make eastern Australian pond frogs less prone to localised extinction events through disturbances. However, this may also mean that populations that do go extinct locally are likely to take longer to be replaced at breeding sites.

Thirty-two new ponds have been constructed in the Watagans and are being monitored to determine colonisation rates and test predictions as to the species that will colonise them. All sites have already been colonised by at least one species and four sites are being used by the rare Heath Frog, providing a good demonstration of the potential for constructing ponds to assist rare species. Half of these sites are to be disturbed with fire to see how this changes the frog communities present at them.

Wildlife schools

F Lemckert

Wildlife schools, open to Forest NSW and staff from other agencies, provide continuing training to enable staff to carry out pre-logging survey programs as efficiently as possible. They also promote communication and understanding between Forests NSW and other agencies regarding current forest practices and management knowledge. Providing regulatory agency staff with training promotes efficient communication and collaboration between the agencies and Forests NSW.

Two courses were held over the past year. Both were frog, bat and reptile schools with one held in September in Dorrigo and the other in March at Kioloa. Both were attended by a number of Forests NSW staff as well as by consultants, students and people from Department of Environment and Conservation, Department of the Environment and Heritage, and Department of Natural Resources.

Water Quality Monitoring

A Webb

Forests NSW conducts water quality monitoring and applied hydrological research programs to determine if there is an identifiable impact on water quality or quantity from licensed forestry activities and, if so, to quantify the level of that impact. Forests NSW conducts river gauging and water quality monitoring at a number of sites in both native hardwood forests and softwoods plantations.

Cadiangullong Creek in flood, Canobolas State Forest, November 2005.

This year, one major water quality monitoring project was concluded. The multi-catchment Canobolas water quality monitoring program was conducted to assess the effects of clearfall harvesting of Pinus radiata plantations on water quality and quantity near Orange. Results of the 7-year study confirmed that while forestry activities have the potential to impact upon water quality, best management practices greatly reduce the magnitude of any impacts on suspended sediment concentrations and turbidity. In the two catchments subjected to harvesting treatments, small but statistically non-significant increases were detected in Event Mean Turbidity values and event mean concentrations (EMCs) of suspended sediment in the immediate post-harvest period and declined thereafter to pre-treatment levels. Another measured effect of the harvesting was to reduce evapotranspiration levels within the harvested catchments. This resulted in statistically significant increases in streamflows in the two catchments, most of which was contributed by baseflows.

Snow in the Canobolas 7 catchment, winter 2005

Monitoring continues post-harvest in the Bago softwoods water quality monitoring program, while preparations are being made for harvesting to commence next financial year in the Yambulla and Kangaroo River replicated native forest water quality monitoring programs.

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List of Shortened Forms used in the Report

ACIAR	Australian Centre for International Agricultural Research
ANU	Australian National University
APPD	Australian Plant Pest Database
ARC	Australian Research Council
ASCU	Agricultural Scientific Collections Unit
BA	basal area
BMAD	Bell Miner associated dieback
CP	controlled pollination
CRC	Cooperative Research Centre
CRCGA	Cooperative Research Centre for Greenhouse Accounting
CSOs	clonal seed orchards
DBH	diameter at breast height
DEC	Department of Environment and Conservation (New South Wales)
FCNI	Forestry Commission of NSW Insect Collection
FHSU	Forest Health Survey Unit
FWPRDC	Forest and Wood Products Research and Development Corporation
GIS	geographic information system
IPART	Independent Pricing and Regulatory Tribunal
MWC	municipal waste compost
NLBAR	nitrogen limiting application rate
NSW DPI	New South Wales Department of Primary Industries
SFHA	Subtropical Forest Health Alliance
TAPPER	Termite and Power Pole Evaluation Research Project
TRV	total recoverable volume
USDA	United States Department of Agriculture

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The Forest Resources Research Unit is based at the DPI Forests Science Centre, located within Cumberland Forest at West Pennant Hills. Tree Improvement for hardwoods is based at Coffs Harbour and the Forest Technical Centre at Grafton, while softwood tree improvement is based in Tumut. Plantation Improvement has staff at Tumut, Coffs Harbour and Bathurst as well as Cumberland Forest.