Eucalypt Plantation Habitats for Fauna in Rural Landscapes

Enhancing their value with appropriate designs

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Foreword

This report describes how eucalypt plantations can provide habitat for native forest or woodland fauna in rural landscapes of south-eastern Australia, recognizing what they can and cannot do for biodiversity conservation. It shows that they attract many birds and mammals, at higher levels than in open farmland. Some species and groups may be as common in plantations as in native forest, but others are scarce or absent, and need to be conserved in systems of remnant native forest. Some habitat features such as hollows do not form for many decades, though hollows were found to be common in shelterbelt plantations aged 60-80 years. The report recognises that fauna species are mobile and plantations can contribute to the mix of habitats available in the broader landscape. The roles of commercial and other plantations have sometimes been neglected by rural planners and policy makers.

The research identifies variables that contribute to the value of plantations as habitat for groups of fauna, and can be manipulated to help achieve biodiversity conservation goals. Some operate at the scale of sites, e.g. retained old trees, shrub understorey and plantation age or shape. They will be of interest to landholders and plantation managers who wish to consider fauna habitat in their management. Others operate at broader landscape scales, e.g. proximity to remnant forest. They will be of interest to rural planners, policy makers and managers of large plantation estates. The project identifies ways in which the habitat values of plantations can be enhanced through small changes in planning or management.

In dealing with these matters, the report contributes to one of the crucial issues in rural biodiversity conservation: maintaining and restoring fauna habitat in partly cleared rural landscapes. This is a necessary part of our efforts to manage rural landscapes in a sustainable way. The JVAP project has attracted broad interest, and this has led to supplementary projects, with various partners. One of the collaborative studies provides provisional evidence that new plantations can help slow the rate of biodiversity loss in adjacent remnant forest, and this hypothesis will be investigated further. The team has worked closely with landholders, regional organizations and universities, running field days and producing articles for local groups as well as scientific publications. These efforts have helped raise public awareness about the value of different types of plantation or remnant patch as fauna habitat.

This project was funded by the Joint Venture Agroforestry Program (JVAP), which is supported by three R&D Corporations - Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia (L&WA), and Forest and Wood Products Research and Development Corporation (FWPRD). The R&D Corporations are funded principally by the Australian Government. The project was also supported by the Department of Sustainability & Environment and the Department of Primary Industries (Victorian Government), and supplementary studies were supported by a range of regional clients.

This report is an addition to RIRDC’s diverse range of over 1800 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- purchases at www.rirdc.gov.au/eshop

Peter O’Brien
Managing Director
Rural Industries Research and Development Corporation
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Rod Kavanagh and his colleagues in State Forests of New South Wales provided valuable advice in relation to their parallel project on plantations established for amenity or to reduce salinity. Regional staff from DSE, DPI and Parks Victoria have provided support and assistance at many times.

This study was funded by the Joint Venture Agroforestry Program (JVAP) and the Natural Heritage Trust (NHT), along with the Victorian Departments of Sustainability & Environment (DSE) and Primary Industries (DPI), initially as JVAP project DAV 204A and then as DSE1A. JVAP and NHT are initiatives of the Commonwealth Government of Australia, and JVAP is a joint venture between the Rural Industries Research & Development Corporation (RIRDC), Forests & Wood Products Research & Development Corporation and Land & Water Australia (LWA).

Several other organisations subsequently initiated and funded further work in different parts of Victoria and South Australia, allowing us to increase the scope of the program, geographically and in terms of the range of plantation species and ages available for study. The Delatite Arm Reafforestation project near Lake Eildon encouraged us to establish two groups of experimental sites as part of their project: this was facilitated by Catherine Jewell and Catherine Spencer (DSE). The Department of Primary Industries commissioned work in old plantations in the Wimmera through Charles Hajek and Virginia Forrest (DPI, Horsham). DPI and the Port Phillip & Westernport CMA commissioned work on plantations and Landcare revegetation projects near Bacchus Marsh west of Melbourne, through Jennifer Sheridan as part of their “Grow West” initiative: we are also grateful to John Forester and Helena Lindorff (DPI) for their support, and Charles Silveira and Marilyn & Dean Hewish for helping with fieldwork. The Central Victorian Farm Plantations Committee commissioned work in plantations in the Volcanic Plains near Lismore through David Fisken (CVFPC) and Liz Hamilton (DPI): we are also grateful to Bob Hughes for his input to that study. Melbourne Water Corporation commissioned work in plantations at the Western Treatment Plant near Werribee through Will Steele. The Green Triangle Regional Plantations Committee and more recently the Glenelg-Hopkins CMA commissioned work in the Green Triangle of south-western Victoria and south-eastern South Australia: we are grateful to John Kellas (GTRPC), Jody Chinner and Aggie Stephenson (GHCMA) for their support. All these projects have been catalysed by the JVAP project, and benefited from the capacity established through that project.

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Executive Summary

What the report is about
This report describes a series of studies conducted to assess the contribution that eucalypt plantations can make to achieving biodiversity conservation goals and to test and develop practical modifications to the standard design of commercial eucalypt plantations that will increase their contributions to regional biodiversity conservation goals. This information is important because little is known about the roles that plantations can and cannot perform in contributing to regional biodiversity conservation goals. There may be unrealised opportunities for enhancing these roles with little loss in economic production, through small changes to plantation design or management. The current project takes a two-pronged approach to developing such innovations, with experimental and retrospective components.

Who is the report targeted at?
It is hoped that the report will be useful to rural policy makers and regional planners, who need to know what plantations can and cannot do to contribute to biodiversity conservation. It will also be useful to land managers who may wish or need to consider biodiversity conservation in the mix of outcomes intended from their programs of establishing and managing plantations.

Background
Eucalypt plantations are being established on cleared land in many parts of Australia, to produce wood and income for landholders, and contribute to reversing land degradation. Eucalypt and other hardwood plantations now cover 676,000 ha nationally. Part of the growth is driven by financial incentives for managed investment schemes and prospects for carbon trading, with plantations seen as an effective tool for carbon sequestration as part of efforts to combat global warming. Additional benefits are expected in terms of regional biodiversity conservation, though few studies have provided quantitative assessments. Little attention had been paid to options for increasing the biodiversity benefits of plantations through innovations in plantation design or management.

Aims/Objectives
The main aims were to test and develop practical modifications to the standard design of commercial eucalypt plantations that will increase their contributions to regional biodiversity conservation goals, and to assess the costs and benefits.

Methods used
The studies were conducted in Victoria and adjacent parts of South Australia from 2003-07. Experimental plantations were established in north-east Victoria with shrubs planted among eucalypts in various configurations that proved acceptable to commercial growers. Five groups of sites were established, each with four experimental treatments and nearby benchmark sites in open farmland and forest. The four experimental treatments were as follows:

- Strips: every fifth row a single row of shrubs (3 rows in 1 ha)
- Band: three rows of shrubs together along the middle of the 1 ha site
- Block: the same number of shrubs, planted as a square central block
- Eucalypts only, no shrubs.

Each of the first three treatments involved planting the same number of shrubs among the eucalypts.

Retrospective studies were conducted at 105 sites in north-east and central-west Victoria, including 25 sites in farmland, 58 sites in eucalypt plantations aged 5-10 years and 22 sites in remnant forest. Collaborative work was conducted with Monash University and other organisations, and the project catalysed a number of supplementary projects in varied landscapes in south-west Victoria and adjacent South Australia.
Field methods included timed area-searches for diurnal birds and mammals (10 minutes, 1 ha) in spring/summer and again in winter; spotlighting transects for nocturnal mammals and birds (10 minutes, 1 ha); playback of owl calls at selected sites; ultrasonic detection of bat calls (2 nights per site); hair-tubing for small mammals (10 tubes per site), and habitat assessments.

Results/Key findings
The experimental shrub plantings proved practical, though many shrubs died in the drought and replanting proved necessary. Measurable benefits of shrubs to fauna did not become evident in the first four years, probably because the trees and shrubs had not yet grown enough. The retrospective studies showed that plantations could provide habitat for a wide range of birds and some mammals, making a positive contribution to biodiversity conservation in the landscape. Mean abundance of forest and woodland birds was higher in eucalypt plantations than cleared farmland, and marginally lower than in native forest. Some fauna groups were well represented in plantations but others were very scarce or absent, e.g. treecreepers. Four arboreal mammal species were recorded but in extremely low numbers. Bats were common but less than in forest sites. Modelling showed that various habitat features made positive contributions for different bird guilds, including retained old trees and small shrubs.

Supplementary projects confirmed these results and showed that commercial and Landcare plantations were similar in the early years: they differed mainly in the age to which they were allowed to develop. Hollows and some hollow-dependent fauna proved to be common in Sugar Gum plantations aged 60-80 years. Old plantations supported more forest birds when they were planted as blocks rather than strips. Provisional evidence suggests that plantations may help protect patches of nearby remnant forest: this aspect is being investigated further.

Implications for relevant stakeholders
The studies show that plantations can make positive contributions to biodiversity conservation and hence to sustainable landscapes. The contributions can be enhanced through measures such as:
- Retaining patches of remnant forest and individual old trees
- Locating new plantations close to remnant forest
- Locating new plantations in parts of the landscape where there is a need for restoration of wooded habitats
- Planning planting and harvesting cycles to produce or retain as much connectivity as possible in the broader landscape
- Planting blocks not strips where possible, to encourage forest or woodland fauna species
- Including some rough-barked stringybark or box species where possible
- Allowing natural or planted understorey to develop in parts of the plantation
- Encouraging selected special plant species, including mistletoes and Cherry Ballart, where possible
- Adding artificial hollows in the form of nest-boxes
- It is hoped that these recommendations will give useful guidance to plantation managers, rural planners and policy makers, helping them enhance the role of plantations in contributing to biodiversity conservation goals.

Recommendations
The primary recommendation is that results from these and similar studies continue to be conveyed to policy makers, rural planners and land managers as indicated above. The second recommendation is that the details suggested for enhancing biodiversity values of plantations be considered for adoption by plantation managers. The third recommendation is that further research should be conducted to test and refine these suggestions.
Introduction

Loss of habitat (including native forests) is the most crucial process contributing to global losses in biodiversity (Houghton 1994; Bennett 1999; Myers et al. 2000). Remedial action must involve habitat restoration (Saunders and Hobbs 1995; Vesk and Mac Nally 2006), and usually this needs to be targeted to address the needs of particular groups of species. Occasionally, opportunities arise to take advantage of new commercial activities that fortuitously provide new or restored habitat for a wide range of species. In Australia in recent decades, emerging economic, political and social forces have combined to encourage widespread planting of native eucalypt trees to produce timber and income on private farmland. Hardwood plantations now cover 676,000 ha nationally (Parsons et al. 2004). In Victoria, eucalypt plantations cover 170,000 ha, growing by 12,000 ha annually (G. Anderson pers. comm.). Part of the growth is driven by financial incentives for managed investment schemes and prospects for carbon trading, with plantations seen as an effective tool for carbon sequestration as part of efforts to combat global warming.

Plantation establishment is often seen by landholders and others as having multiple benefits, including mitigation of salinity or erosion and restoration of biodiversity values (Reid and Wilson 1985; Hobbs 1993; Hobbs et al. 1993; Bennett et al. 2000; Salt et al. 2004). But until recently, few studies had attempted to assess the benefits of eucalypt plantations for biodiversity conservation (Woinarski 1979; Law and Kavanagh 1998; Ryan 2000; Bennett et al. 2000; Kavanagh et al. 2001, 2005, 2007; Law and Chidel 2002, 2006; Hobbs et al. 2003; Rossi 2003; Scott 2003; Kinross 2004). Many studies have examined roles of remnant native vegetation in southern Australian rural landscapes (e.g. Loyn 1987; Saunders et al. 1991; Barrett et al. 1994; Mac Nally et al. 2000; MacHunter et al. 2006). A common conclusion is that habitat loss and fragmentation have contributed to biodiversity losses, and the corollary is that strategic revegetation is needed to prevent or reverse such losses. Hence it is surprising that the effects of any form of revegetation have received relatively little attention.

The current study was initiated partly to provide basic information on eucalypt plantations as habitat for fauna in Victoria, south-eastern Australia. However, it also had a more specific aim, to develop appropriate designs to increase biodiversity in commercial eucalypt plantations. The study objectives were to test and develop practical modifications to the standard design of eucalypt plantations, that will increase their contributions to regional biodiversity, and to assess the costs and benefits of such modifications. The focus was on birds and mammals as key elements of vertebrate fauna in the rural landscape.

The study was conducted initially in two regions, the north-east (inland slopes of the Great Dividing Range from Mansfield to Wodonga) and central-west (straddling the Great Dividing Range west of Ballarat) (Figure 1). Part of this work has been published, focusing on diurnal birds (Loyn et al. 2007). Recent work is extending these studies into a range of different environments in southern and western Victoria and South Australia. A number of related studies have been conducted by the authors and colleagues in the valleys and ranges of Gippsland, in south-eastern Victoria. The study also complements work supported by JVAP in plantations established to combat salinity in southern New South Wales and north-east Victoria (Kavanagh et al. 2007).
Figure 1. Locations of study sites in north-east and central-west Victoria, south-eastern Australia, 2003-07.
Methods

The study had two main components, experimental and retrospective. The experimental study examined specific questions about planting shrubs among eucalypts. The retrospective study examined a broader range of questions by assessing the fauna, habitat and context variables associated with large numbers of sites in farmland, plantations and forest.

Experimental Study

Three experimental treatments were developed in consultation with commercial tree growers in north-east Victoria, with shrubs planted among eucalypts in different configurations. A fourth experimental treatment was a eucalypts-only control, with no shrubs planted (as in standard commercial practice). The four treatments were all designed to be feasible in the context of management for commercial purposes, with losses of productivity considered unlikely to exceed acceptable levels. Two further treatments were used as benchmarks: cleared farmland and remnant forest.

Landholders were invited to participate in the work through Farm Forestry of the North East (FFORNE). Three suitable locations were selected in this way, and plantations were established in 2002/03. One location was on public land near Rutherglen; one was on the Norman property near Wangaratta; and one was on the Grimes property near Porepunkah. Each plantation contained four adjacent blocks of 1 ha. The four experimental treatments were assigned at random to those blocks. At one group of sites (Norman property), an additional eucalypts-only control site was available in a paddock nearby. At each group of sites, benchmark sites were selected nearby in open farmland and remnant forest. The project covered the cost of shrubs and provided some help with establishing the plantations. Tree seedlings were supplied under other tree planting initiatives, e.g. to combat salinity or contribute to carbon sequestration. Otherwise, the plantations were all established and managed by the landholders in accord with standard practice. DPI managed the Rutherglen site.

As the region was affected by drought, difficulties were encountered in finding two more suitable properties for plantation establishment as originally planned. Some landholders were keen to participate, but did not have adequate space for the four experimental treatments on comparable parts of the property. A solution was eventually found by collaborating with the Delatite Arm Reafforestation project, run by DSE on former pine plantations near Lake Eildon. Large tracts of pine plantation had been harvested by Hancocks (the plantation owner), and the cleared land was being restored to eucalypt forest through an ambitious program of planting indigenous eucalypts. Two groups of four experimental sites were established according to our design in winter 2004. Benchmark sites were selected in native forest close to each group of sites.

The four experimental treatments were as follows:

- Strips: every fifth row a single row of shrubs (3 rows in 1 ha);
- Band: three rows of shrubs together along the middle of the 1 ha site;
- Block: the same number of shrubs, planted as a square central block;
- Eucalypts only, no shrubs.

Each of the first three treatments involved planting the same number of shrubs among the eucalypts. Shrub species were selected to be locally indigenous species that were readily available in local nurseries, e.g. Silver Wattle *Acacia dealbata*. Shrubs needed replanting in 2005 at two sites (Norman and Rutherglen), because many of the original shrubs died during the drought. At the Delatite Arm, a converse problem arose. There, many indigenous shrubs regenerated naturally on all sites, obscuring the experimental treatments. Consideration was given to removing these unwanted shrubs, but that would have been inconsistent with the objectives of the reafforestation scheme, which was to restore native forest on the area which had produced one commercial crop of pines.
Studies of selected fauna groups were conducted on the experimental sites before establishment and twice a year subsequently (spring/summer and winter). Birds were studied on each visit, and notes were made on other fauna or their signs (scats, diggings, etc.) that were observed.

**Retrospective Study**

Sites were selected in established plantations aged 5-10 years in two broad regions, north-east Victoria and central-west Victoria (Figure 1). Benchmark sites were also selected in open farmland and remnant forest in the vicinity of the plantations (Figure 2). The benchmark sites were intended to represent the sort of farmland (mostly pasture) that is typically selected for conversion to tree plantations, and the sort of forest that would have existed there before clearing for agriculture. Altogether 105 sites were selected, including 25 farmland sites, 58 plantation sites and 22 forest sites. Most of the plantations were of Blue Gum *Eucalyptus globulus*, though some were of River Red Gum *E. camaldulensis* (mainly at lower elevations), Spotted Gum *E. maculata*, Shining Gum *E. nitens* (high elevations) or other species. Most had been established with the aim of producing pulpwood (on projected rotations of 10-15 years) or sawlogs (25-30 years). Two of the forest sites were remnant strips of forest along roads, being the only remaining examples of native forest close to respective plantation sites.

![Figure 2](image1.jpg)  
**Figure 2.** Examples of the three broad habitat types studied in north-east and central-west Victoria, south-eastern Australia, 2003-07. a) native forest, b) open farmland, c) plantation, d) plantation (recently pruned)

Each site represented one of the three broad habitats (open farmland, eucalypt plantation or native forest) (Figure 2). Sites of 1 ha were selected within larger tracts of similar habitat where possible. Studies of birds, mammals and habitat were conducted in these sites from spring 2003 to 2005. Birds were assessed in two seasons, spring/summer (September to February) and winter (May to August). Spring/summer assessments were conducted mainly between October and December because that is when most summer migrant species are present and vocal. Bats were assessed between November and March.
Additional studies were conducted in other geographic regions in response to requests from regional agencies, as described briefly below. Reports on these additional studies are appended to this report and it is planned to conduct a meta-analysis using data from all these sources.

**Retrospective Study of Old Plantations in the Wimmera**

This study examined the fauna of old plantations and associated habitats at 28 sites near Wail and the Barrat Reserve in the Wimmera of semi-arid western Victoria, north of Horsham. The plantations had been established over 100 years ago, and there had been several cycles of harvesting and coppice regeneration subsequently. The study examined 16 sites in these plantations, along with benchmark sites in adjacent native forest (6 sites) and farmland (6 sites). The main plantation species were Sugar Gum *Eucalyptus cladocalyx* and Swamp Yate *E. occidentalis*. The study was conducted between January and April 2005 (Attachment A). The study adds new perspectives by considering old plantations (up to 100 years) and a drier environment than we had examined elsewhere.

**Retrospective Study of Plantations in the Volcanic Plains near Lismore**

This study examined the fauna of 32 sites near Lismore in south-western Victoria. These included 5 benchmark sites in open farmland, 9 sites in young plantations, 4 sites in disturbed mature plantations, 7 sites in mature plantations (aged 60-80 years), 5 sites in old plantations (100+ years) and 2 benchmark sites in remnant forest (the latter habitat being rare in this region). Most of the older plantations had been established as roadside shelterbelts of Sugar Gum or Swamp Yate, and young plantations consisted mainly of Sugar Gum and Blue Gum *Eucalyptus globulus*. The study was conducted between March 2006 and February 2007 (Attachment B). The study adds new perspectives by considering old plantations and a more open treeless environment than we had considered previously.

**Retrospective Study of Plantations in the Werribee Plains**

This study examined the fauna of 36 sites on the Western Treatment Plant, an 11,000 ha property managed by Melbourne Water Corporation on the western shores of Port Phillip Bay. The sites included 8 in open grassland, 9 in blocks of young plantations, 9 in old shelterbelt plantations and 2 in patches of remnant forest (the latter habitat being extremely rare on the property). Most of the older plantations had been established as roadside shelterbelts of Sugar Gum, and young plantations consisted mainly of Sugar Gum and Blue Gum. The study was conducted between December 2004 and August 2006. The study adds similar new perspectives to those mentioned for the Lismore study above. An added dimension is that the surrounding land is used for treating half of Melbourne’s sewage: it attracts many water birds and forms an integral part of a Ramsar-listed wetland.

**Benchmark Study of New and Old Plantations near Bacchus Marsh**

This study examined the bird fauna of 78 sites in the foothills west of Bacchus Marsh, between the Volcanic Plains and the Great Dividing Range. The sites consisted of 8 in open farmland, 5 in 0-2 year commercial plantations, 7 in 0-2 year Landcare plantations, 13 in 5 year commercial plantations, 21 in 5 year Landcare plantations, 6 in older Landcare plantations (e.g. some established 50 years earlier to combat soil erosion) and 19 in remnant forest. The study was conducted between November 2005 and June 2006 (Attachment C), and further monitoring has been arranged through Birds Australia. The study adds new perspectives by examining a wide range of age-classes (from very young 0-2 year plantations to 50 year Landcare plantations) and comparing young plantations established for commercial or Landcare purposes.
Retrospective Study of Plantations in the Green Triangle of south-western Victoria and south-eastern South Australia

This study examined the fauna of 92 sites in the Green Triangle of south-western Victoria and south-eastern South Australia. The sites included 13 in open farmland, 22 in eucalypt plantations, 27 in pine plantations and 30 in remnant forest. Most of the eucalypt plantations had been established as commercial plantations of Blue Gum. The study was conducted between October 2006 and July 2007 (Attachment D). The study is being extended to compare the value of embedded patches of remnant forest with comparable patches that remain exposed in nearby farmland. This will test the hypothesis that plantations can help protect patches of remnant native forest, providing an important new perspective on their potential role in helping meet objectives for biodiversity conservation.

Field Methods

Diurnal birds and mammals (daytime area searches)

Diurnal birds were assessed using an area-search of 1 ha (200 x 50 m) in 10 minutes, modified from Loyn (1986). Numbers of all birds seen or heard were tallied by species while walking slowly through the site. Birds observed outside the 1 ha site were recorded separately, with distinctions made about whether they were in the habitat represented by the site, in another habitat or too distant to tell. Off-site records were not used in numerical analysis. Incidental records of mammals were collected from opportunistic sightings of individuals or other identifiable signs (including scats) during diurnal bird surveys and other daytime visits to the sites.

Nocturnal mammals and birds (spotlight surveys and call playback)

Nocturnal mammals and birds were assessed by spotlight surveys, by one observer carrying a 12V, 55W spotlight and walking slowly along a marked transect of 200 m through the site for a period of 10 minutes. All mammals and birds seen or heard within 25 m either side of the transect (1 ha) were tallied. Mammals and birds observed outside the 1 ha were tallied separately. In open farmland, the method used was the same but the survey was sometimes curtailed before the full 10 minutes, when it was clear that all observable fauna on the site had been detected. Spotlight surveys were carried out once at each site.

Call playback surveys were conducted at selected sites. Calls of five owl species were broadcast at ~110% of natural volume. The species were Powerful Owl *Ninox strenua*, Southern Boobook *N. boobook*, Barking Owl *N. connivens*, Sooty Owl *Tyto tenebricosa* and Masked Owl *T. novaehollandiae*. Any birds and mammals observed during these surveys were recorded, along with information about their distance from the observer and location when first observed. The playback surveys were useful for detecting the presence of owls in the general area, but less useful for determining their use of plantations or other fine-scale habitats because the method can draw owls from a broad catchment.

Bats (ultrasonic call detection)

Anabat detectors (Titley Elecnotics) were used to record microbat echolocation calls. Automated detector units (Anabat detector, Anabat CF Storage ZCAIM, 12V battery) were set for two nights at each site, timed to record from sunset to dawn. Calls were recorded directly onto data loggers, and files downloaded for analysis and determination of the number of bat calls per night. Automated species recognition software AnaScheme (developed by staff from the University of Ballarat and ARI, Gibson and Lumsden 2003; Duffy *et al.* 2000) was then used to assign these calls to species where possible. Results were checked manually and any implausible records removed. Further manual checking is planned as part of a continuing program to refine the method: some of the specific identifications should be considered provisional at this stage.
Small mammals (hair-tube surveys)

Lines of ten hair-tubes were set at each site, baited with a mixture of rolled oats, honey and peanut butter. Two types of hair-tube were used: ground-installed funnels (Faunatech) and small tree-mounted hair-tubes (PVC piping 38mm diameter x 120mm long). Tree-mounted tubes in plantations were attached with PVC tape to avoid damage to trees. The two types of hair-tube were arranged alternately 20m apart. They were left in place for a minimum of ten days, after which the sticky surface at the entrance and inside the tubes were inspected for mammal hair. Hair samples were identified to species level (Brunner and Coman, 1974), where possible (by Barbara Triggs, Dead Finish). This method was not used in open farmland.

Habitat variables

Various habitat features were assessed at each site (Table 1). Total numbers of hollow-bearing trees (live or dead) were counted within plantation and open farmland sites. Hollow-bearing trees in native forest or remnants were counted within the site as a whole or within a certain portion and extrapolated to give a per ha total. Within plantation and open farmland sites numbers of retained old trees (Figure 3) without obvious hollows were also counted. Coarse woody debris within a certain portion of each site was recorded, with separate counts of fallen logs or large branches (>15 cm diameter) and logs or large branches cut during thinning operations. These numbers were later extrapolated to give a count per ha. The cover/density of grass, tall shrubs (>2m), small shrubs (<2m), leaf litter and small branches (including prunings) was assessed as percentages using the following scale: absent, scattered and sparse, <5%, 5-25%, 25-50% and 75-100%. The same scale was used for two groups of plant species known to be of special value to fauna (mistletoes, e.g. Drooping Mistletoe *Amyema pendulum*) or to cause problems for management (introduced Blackberry *Rubus fruticosus*). Grass height was also recorded, and notes were made on the percentage of grass that had been flattened (e.g. by grazing stock).

<table>
<thead>
<tr>
<th>Habitat features</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
<th>SE</th>
<th>SE</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cleared</td>
<td>Plantation</td>
<td>Forest</td>
<td>Cleared</td>
<td>Plantation</td>
<td>Forest</td>
</tr>
<tr>
<td>Number of sites</td>
<td>25</td>
<td>58</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live hollow-bearing trees (number/ha)</td>
<td>0.25</td>
<td>0.21</td>
<td>15.44</td>
<td>0.03</td>
<td>0.01</td>
<td>0.20</td>
</tr>
<tr>
<td>Dead hollow-bearing trees/ha</td>
<td>0.08</td>
<td>0.12</td>
<td>5.75</td>
<td>0.02</td>
<td>0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>Retained live trees (no hollows)/ha</td>
<td>0.00</td>
<td>0.76</td>
<td>N/A</td>
<td>0.00</td>
<td>0.03</td>
<td>N/A</td>
</tr>
<tr>
<td>Retained dead trees (no hollows)/ha</td>
<td>0.00</td>
<td>0.02</td>
<td>N/A</td>
<td>0.00</td>
<td>0.01</td>
<td>N/A</td>
</tr>
<tr>
<td>Tall shrubs (&gt;2m) index</td>
<td>0.19</td>
<td>0.19</td>
<td>1.25</td>
<td>0.03</td>
<td>0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>Small shrubs (&lt;2m) index</td>
<td>0.23</td>
<td>0.12</td>
<td>0.97</td>
<td>0.03</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Logs/ha (natural &gt;15cm diameter)</td>
<td>1.23</td>
<td>1.09</td>
<td>242</td>
<td>0.07</td>
<td>0.03</td>
<td>0.81</td>
</tr>
<tr>
<td>Small branches (inc prunings) index</td>
<td>0.08</td>
<td>1.25</td>
<td>1.57</td>
<td>0.02</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Blackberry index</td>
<td>0.00</td>
<td>0.41</td>
<td>0.41</td>
<td>0.00</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Mistletoe index</td>
<td>0.00</td>
<td>0.03</td>
<td>0.44</td>
<td>0.00</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Elevation (m above sea level)</td>
<td>302</td>
<td>337</td>
<td>345</td>
<td>40.3</td>
<td>19.9</td>
<td>60.4</td>
</tr>
</tbody>
</table>

Table 1. Mean values of selected habitat variables in farmland, plantation and forest at 105 retrospective sites in north-east and central-west Victoria, 2003-06. Indices are on a scale from 0 (absent) to 5 (abundant). Standard errors are also shown, and the number of sites in each habitat.
Landscape context variables

Landscape-scale metrics were obtained for each site from concurrent satellite image interpretation (P. Griffioen, pers. comm.). They included the amount of forest cover, native grassland, cleared farmland and wetland or water bodies in areas of different size centred on each site. The scales chosen were based on the site itself (pixel of 25m square) and squares of 100m, 500m, 1km and 5km. The site metric was used to confirm grid references but was not useful for further analysis. For plantation sites, the 100m metric helped distinguish small plantations from those that formed parts of larger plantations (sometimes under multiple ownership). The broader metrics helped characterise the landscape at the different spatial scales for different groups of fauna.

Analysis

Some bird and mammal species were grouped as guilds for statistical analysis. Data on bats were analysed in terms of total bat calls per night used as an index of overall activity level, with data on individual species or groups being examined descriptively at this stage. Diurnal birds were assigned to overlapping groups relating to the main habitats used by each species (forest or woodland birds, open-country birds, generalists and water birds), 12 guilds for feeding and other groups for nesting, migration and status (Appendix 1). Mammals were considered as native or introduced, with native species further divided into those that rely on tree hollows and those that do not (Appendix 1). Relative abundances of these guilds and individual species were considered as dependent variables in subsequent analysis. Generally, data were adequate for analysis at the level of major guilds but not species.
Experimental study

For this report, data from the experimental study were divided into two time periods, before or after September 2005. Before that time, trees in the experimental plantations were too small to provide substantial habitat for forest fauna, and there was very little visible difference between the experimental treatments. Analysis of variance was then used to assess differences between experimental treatments for data post September 2005. The two groups of sites from the Delatite Arm were excluded from this analysis for two reasons. Firstly, they had been planted later than the other three groups, and had not developed to the same extent. Secondly, there had been a large amount of natural shrub regeneration in those sites, tending to obscure the experimental treatments as mentioned above.

More complex analysis had been intended, e.g. using the early data and examining trends over time. However, it was judged that this was unlikely to be productive until the experimental sites have grown and developed further.

Retrospective study

Data were analysed to determine effects of the three levels of the broad habitat variable (open farmland, plantation or native forest). This was done by tabulating mean relative abundance for each species or group, and developing generalised linear models for major guilds with the relative abundance of the guild as dependent variable and broad habitat as an explanatory variable. More complex models were developed for major bird guilds, using suites of habitat and context variables.

Data from day-time bird counts were analysed by generalised linear modelling. The mean abundance of selected major groups was the dependent variable in each case, and the basic habitat groups were treated as a categorical explanatory variable with three levels (cleared farmland, plantation or native forest). Region was considered as another categorical variable, with two levels (north-east or south-west), along with a range of variables such as elevation and landform. This analysis was conducted across all sites for the two major bird groups relating to the main habitats used by each species, i.e. forest or woodland birds and open-country birds.

Data from the 58 plantation sites were then analysed by generalised linear modelling, with various combinations of habitat and landscape explanatory variables. The main habitat variables considered for inclusion in these models were landform, plantation size-class or shape, numbers of retained hollow-bearing trees (dead or alive), and total numbers of retained old trees (dead or alive). The main landscape variables considered were elevation (metres above sea level), area of plantation within 100m, and proportion of native forest, treeless country or wetland at any one of the four spatial scales. Modelled climatic variables (mean temperature and annual rainfall) were also considered for inclusion. A correlation matrix was generated for candidate explanatory variables, and any pairs correlated more closely than r = 0.70 were not included together in subsequent models.

Standard diagnostic tests were applied to the models (notably plotting residuals against mean values) and appropriate transformations were applied where necessary to meet the assumptions of the analysis. This involved taking square roots of abundance data for many groups of species. Scarcer groups and species were modelled on a presence-absence basis using logistic regression. Models were selected for publication on the basis of variance explained and parsimony. The Akaike Information Statistic was used to select between models with different numbers of variables.
Results

Experimental Study

Birds and mammals

Despite the drought and various setbacks (e.g. the need to replant shrubs), the experimental sites developed well enough to provide habitat for a range of forest birds within the time-frame of the study (Table 2). Native mammals were less well represented, except for bats which were present at most sites and three large ground-dwelling species (Eastern Grey Kangaroo *Macropus giganteus*, Black Wallaby *Wallabia bicolor* and Common Wombat *Vombatus ursinus*), which were observed occasionally. Based on scats and signs, the latter three species were particularly common at the Delatite Arm, along with introduced Sambar Deer *Cervus unicolor*. Introduced European Rabbits *Oryctolagus cuniculus* and Brown Hares *Lepus europaeus* were sparsely distributed, and Red Foxes *Vulpes vulpes* and Feral Cats *Felis catus* were widespread in very low numbers. None of these mammal species was encountered often enough to warrant formal analysis with respect to the experimental treatments.

Table 2. Numbers of birds and mammals observed on experimental sites (4 experimental plantation treatments and benchmarks in forest & farmland) in north-east Victoria, 2005-07.

Data show mean values across three groups of sites over four visits from October 2005 to July 2007, the values being animals per area-search count (10 minutes, 1 ha). The experimental treatments are eucalypt plantations that were established in 2003-04. The control was eucalypts only; strips were three separate rows of shrubs; belt was three rows of shrubs together, and block was a central block of shrubs.

<table>
<thead>
<tr>
<th>Treatment:</th>
<th>farmland</th>
<th>control</th>
<th>strips</th>
<th>belt</th>
<th>block</th>
<th>forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest birds</td>
<td>0.40</td>
<td>4.95</td>
<td>5.00</td>
<td>5.92</td>
<td>5.87</td>
<td>14.31</td>
</tr>
<tr>
<td>Open-country birds</td>
<td>6.90</td>
<td>0.25</td>
<td>0.93</td>
<td>0.62</td>
<td>0.53</td>
<td>5.19</td>
</tr>
<tr>
<td>Water birds</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
<td>0.08</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total birds</td>
<td>7.30</td>
<td>5.25</td>
<td>5.93</td>
<td>6.62</td>
<td>6.40</td>
<td>19.50</td>
</tr>
<tr>
<td>Aerial insectivorous birds</td>
<td>0.00</td>
<td>0.05</td>
<td>0.33</td>
<td>0.08</td>
<td>0.07</td>
<td>0.44</td>
</tr>
<tr>
<td>Bark-foraging insectivorous birds</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.94</td>
</tr>
<tr>
<td>Canopy-foraging insectivorous birds</td>
<td>0.00</td>
<td>1.10</td>
<td>1.60</td>
<td>1.77</td>
<td>0.93</td>
<td>2.69</td>
</tr>
<tr>
<td>Insectivorous birds that forage from damp ground below shrubs</td>
<td>0.00</td>
<td>0.25</td>
<td>0.00</td>
<td>0.00</td>
<td>0.13</td>
<td>0.31</td>
</tr>
<tr>
<td>Frugivorous birds</td>
<td>0.00</td>
<td>0.10</td>
<td>0.80</td>
<td>0.62</td>
<td>0.33</td>
<td>0.19</td>
</tr>
<tr>
<td>Nectarivorous birds</td>
<td>0.20</td>
<td>0.90</td>
<td>0.53</td>
<td>0.85</td>
<td>0.87</td>
<td>5.50</td>
</tr>
<tr>
<td>Insectivorous birds that forage from open ground, sometimes far from cover</td>
<td>6.70</td>
<td>0.15</td>
<td>0.13</td>
<td>0.62</td>
<td>0.27</td>
<td>3.56</td>
</tr>
<tr>
<td>Insectivorous birds that forage from open ground among trees</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.23</td>
<td>2.27</td>
<td>2.38</td>
</tr>
<tr>
<td>Seed-eating birds that take food close to ground</td>
<td>0.20</td>
<td>0.30</td>
<td>0.47</td>
<td>0.00</td>
<td>0.27</td>
<td>1.00</td>
</tr>
<tr>
<td>Seed-eating birds that take food in trees and at all levels</td>
<td>0.00</td>
<td>0.30</td>
<td>0.07</td>
<td>0.54</td>
<td>0.20</td>
<td>0.44</td>
</tr>
<tr>
<td>Insectivorous birds that forage from tall shrubs</td>
<td>0.00</td>
<td>0.40</td>
<td>0.20</td>
<td>0.00</td>
<td>0.60</td>
<td>0.69</td>
</tr>
<tr>
<td>Carnivorous birds</td>
<td>0.20</td>
<td>0.25</td>
<td>0.60</td>
<td>0.54</td>
<td>0.20</td>
<td>0.75</td>
</tr>
<tr>
<td>Introduced birds (overlaps with groups above)</td>
<td>5.50</td>
<td>0.00</td>
<td>0.07</td>
<td>0.00</td>
<td>0.20</td>
<td>0.19</td>
</tr>
<tr>
<td>Native birds (overlaps with groups above)</td>
<td>1.80</td>
<td>5.25</td>
<td>5.87</td>
<td>6.62</td>
<td>6.20</td>
<td>19.31</td>
</tr>
<tr>
<td>Introduced mammals</td>
<td>0.10</td>
<td>0.18</td>
<td>0.19</td>
<td>0.06</td>
<td>0.13</td>
<td>0.06</td>
</tr>
<tr>
<td>Native mammals</td>
<td>0.00</td>
<td>0.08</td>
<td>0.16</td>
<td>0.63</td>
<td>0.31</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Relative abundances of forest birds differed substantially between the five groups of sites, but showed little consistent variation between treatments, and there was no significant difference between treatments (p>0.05). Mean values were marginally higher for the experimental treatments with shrubs than for the eucalypts-only control sites (Table 2).

Some observations of individual species are worth noting. For example, Weebills *Smicrornis brevirostris* usually forage for insects among eucalypt foliage, but in spring 2005 many were seen foraging among planted eucalypts and shrubs in one of the experimental sites, perhaps benefiting from the combined planting. But this did not translate into a significantly higher abundance in any one treatment. Some species that preferentially forage in shrubs rather than eucalypts, e.g. Yellow Thornbills *Acanthiza nana*, were often encountered in sites where shrubs had been planted, but data were too sparse for formal analysis.

At the three groups of sites in farmland (i.e. excluding the Delatite Arm), forest birds were significantly more common in plantations than open farmland, and less common than in remnant forest (p<0.05). Comparisons between these three broad habitats are considered further in relation to the retrospective study.

**Establishment costs**

Establishment costs for each group of experimental plantations (4-5 ha) ranged from $3660 to $7640, including up to $4000 for fencing. Provision of understorey shrubs cost $200 per group of sites, providing shrubs for three 1 ha sites in each case. This compared with $1400 for the larger number of eucalypt seedlings at each group of sites. The cost of understorey shrubs was incurred twice at the group of sites where replanting proved necessary. No further additional costs of the shrub treatments were identified during the course of the study. Shrub treatments may have positive or negative effects on growth of eucalypts, but it is considered premature to assess such effects until the trees have grown taller.

**Retrospective Study of Plantations in north-east and central-west Victoria**

**Diurnal birds in relation to broad habitat**

Forest birds as a group were substantially more abundant in eucalypt plantations than cleared farmland, and marginally less abundant than in native forest (Figure 4). These differences were highly significant (p<0.001). Open-country birds were more abundant in cleared farmland than either plantations or native forest (Figure 4, p<0.001), with no significant difference between the latter habitats (p>0.05).

Data for particular bird species (Appendix 1) or groups of species (Table 3) showed marked differences in responses at the level of species or feeding guild. Some species showed little difference in abundance between plantations and native forest (based on our sample of sites studied) whereas others showed marked differences. Feeding guilds proved to be a useful basis for summarising these trends, as follows.

Aerial insectivores were more common over cleared farmland than other habitats, and in this study were found to be making little use of plantations or retained forest (Table 3).

Birds that feed from open ground were generally at least as abundant in plantations as native forest: this applied both to the group that feed only among tree cover, and to the more catholic group of species that may range far from cover (Table 3). The latter group was even more common in cleared farmland. The former group was significantly more common in plantations than in native forest (p<0.001), and may have benefited substantially from plantation establishment.
Birds that feed from the eucalypt canopy or from tall shrubs were both similarly abundant in eucalypt plantations and native forest (Table 3). These birds were rare in cleared farmland, where they were only observed on the edge of other habitats with perennial vegetation.

Insectivores that forage from bark on tree-trunks were recorded occasionally in eucalypt plantations (in sites adjacent to native forest), but were very uncommon compared with native forest (Table 3). Birds in this group were sometimes seen foraging from the bark of planted eucalypts, but they also favoured retained old trees where these were available.

Nectarivores were less common in eucalypt plantations than in native forest, and essentially absent from cleared farmland (Table 3). Intermediate levels of abundance were also found in plantations for carnivores, and insectivores that feed from damp ground or low shrubs (Table 3). Many individual species from all guilds showed similar patterns, being observed most often in remnant forest, less often in eucalypt plantations and least often in cleared farmland (Appendix 1).

Seed-eaters that take seeds from the ground or low vegetation were more common in cleared farmland than in plantations or native forest. However, they regularly used both plantations and native forest for shelter, e.g. during the warmer parts of the day. Some species also fed extensively in both plantations and native forest. There was little difference in abundance of this group between plantations and native forest (Table 3).
Seed-eaters that specialise at taking seeds and other food from the tree or shrub layers made little use of cleared farmland sites during the study, although they do forage extensively in farmland at times (pers. obs.). They were fairly common in remnant forest and even more common in eucalypt plantations (Table 3). The latter effect was driven mainly by a single species, the Crimson Rosella (Appendix 1), which often fed from a wide range of food plants in plantations. The sole other common species in the guild, the Gang-gang Cockatoo, was only seen in remnant forest during the study (Appendix 1).

Table 3. Mean abundances of selected bird guilds in cleared farmland, plantations and native forest at 105 retrospective sites in north-east and central-west Victoria, 2003-06. Values shown are birds per 100 counts (area-search of 10 minutes, 1 ha). Standard errors are also shown.

<table>
<thead>
<tr>
<th>Individuals per 100 counts</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
<th>SE</th>
<th>SE</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cleared</td>
<td>Plantation</td>
<td>Forest</td>
<td>Cleared</td>
<td>Plantation</td>
<td>Forest</td>
</tr>
<tr>
<td><strong>Habitat groups</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest &amp; woodland birds</td>
<td>145</td>
<td>889</td>
<td>1019</td>
<td>6.4</td>
<td>4.0</td>
<td>11.5</td>
</tr>
<tr>
<td>Open-country birds</td>
<td>366</td>
<td>154</td>
<td>187</td>
<td>7.5</td>
<td>2.8</td>
<td>9.0</td>
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<tr>
<td>Water birds</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Feeding guilds (insectivores)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerial insectivores</td>
<td>85</td>
<td>6</td>
<td>9</td>
<td>10.2</td>
<td>2.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Bark-foraging insectivores</td>
<td>0</td>
<td>6</td>
<td>67</td>
<td>0.0</td>
<td>0.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Canopy-foraging insectivores</td>
<td>5</td>
<td>220</td>
<td>207</td>
<td>1.4</td>
<td>2.3</td>
<td>6.0</td>
</tr>
<tr>
<td>Insectivores feeding from damp ground or low shrubs</td>
<td>9</td>
<td>28</td>
<td>90</td>
<td>1.7</td>
<td>1.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Insectivores feeding from open ground, sometimes far from cover</td>
<td>225</td>
<td>95</td>
<td>67</td>
<td>6.7</td>
<td>2.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Insectivores feeding from open ground among trees</td>
<td>18</td>
<td>225</td>
<td>196</td>
<td>2.1</td>
<td>3.5</td>
<td>7.9</td>
</tr>
<tr>
<td>Insectivores feeding from tall shrubs</td>
<td>0</td>
<td>127</td>
<td>104</td>
<td>0.0</td>
<td>2.0</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Feeding guilds (other)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frugivores</td>
<td>0</td>
<td>31</td>
<td>17</td>
<td>0</td>
<td>3.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Nectarivores</td>
<td>9</td>
<td>110</td>
<td>203</td>
<td>1.7</td>
<td>1.7</td>
<td>7.7</td>
</tr>
<tr>
<td>Carnivores</td>
<td>2</td>
<td>33</td>
<td>70</td>
<td>1.1</td>
<td>1.6</td>
<td>4.2</td>
</tr>
<tr>
<td>Birds that eat seeds, taken close to ground</td>
<td>134</td>
<td>56</td>
<td>59</td>
<td>6.0</td>
<td>2.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Birds that eat seeds and galls etc., taken at all levels</td>
<td>3</td>
<td>64</td>
<td>43</td>
<td>1.6</td>
<td>2.6</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Nesting guilds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birds nesting in large or medium hollows in trees</td>
<td>71</td>
<td>122</td>
<td>130</td>
<td>4.4</td>
<td>3.0</td>
<td>5.7</td>
</tr>
<tr>
<td>Birds nesting in small hollows in trees</td>
<td>46</td>
<td>10</td>
<td>82</td>
<td>5.0</td>
<td>0.9</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Migrant guilds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birds that are summer visitors</td>
<td>59</td>
<td>114</td>
<td>95</td>
<td>5.0</td>
<td>1.5</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Status guilds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birds introduced to Australia</td>
<td>27</td>
<td>12</td>
<td>11</td>
<td>2.8</td>
<td>1.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Uncommon birds (&lt;850 records in Emison et al. 1987)</td>
<td>5</td>
<td>44</td>
<td>62</td>
<td>1.9</td>
<td>2.4</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Frugivores were also more common in eucalypt plantations than native forest during the study (Table 3), and again the effect was driven mainly by one common species, the Silvereye (Appendix 1). It was seen feeding on a range of food, including insects among the eucalypt foliage and fruits of introduced Blackberry *Rubus fruticosus* in the understorey.

Some other bird groups or species deserve brief comment. Small hollow-nesters were scarce in plantations. One species in the group (Striated Pardalote, a canopy-gleaning insectivore) visited plantations mainly in winter (when they were not nesting and hence did not need hollows). Another species (White-throated Treecreeper, a bark-foraging insectivore) was very common in nearby native forest where they fed mainly from rough-barked eucalypts, and used hollows for nesting and roosting. In contrast, large hollow-nesters were as abundant in plantations as in native forest (Table 3). They were dominated by seed-eating parrots and cockatoos, which were often seen flying long distances in the rural landscape and hence were able to access feeding habitats far from hollow-bearing trees on which they depend for nest-sites. Flocks of cockatoos were sometimes found using plantations for daytime shelter, foraging in nearby farmland and presumably nesting in large hollow-bearing trees nearby.

Introduced birds were as scarce in eucalypt plantations as in native forest, and these species were found mainly in cleared farmland. Noisy Miners (an aggressive native species that behaves as an unwelcome invader in some environments) were found locally in remnant native forest but rarely in plantations during this study (Appendix 1). Both these groups were later found to be more prevalent in old planted shelterbelts in the open agricultural landscape of south-western Victoria.

Supplementary studies in south-western Victoria and South Australia provided broadly similar results, along with some different perspectives, especially in relation to context variables. These are described in separate sections for each individual study below.

**Models of relationships between bird abundance and habitat and landscape variables (plantation sites only)**

The selected models explained up to 53.6% of variance (attachment E). The most useful explanatory variables proved to be habitat features at the site (retained trees, hollow-bearing trees, grass cover, etc.), followed by general landscape variables such as elevation, rainfall and size or shape of plantation. Other context variables (proportions of cleared land, plantations or native forest within various radii of each site) made little or no contribution to any of the models generated.

Forest and woodland birds appeared to respond positively to elevation, numbers of retained trees, and numbers of hollow-bearing dead trees (attachment E). Plantation size, shape, landform and context variables made no further significant contribution.

Open-country birds appeared to be more common in plantations at low than high elevations, and on flats or lower slopes rather than on mid or upper slopes (attachment E). They appeared to respond positively to grass cover within the plantations. They were least common in large plantations and most common in plantations of 5-10 ha or 10-20 ha in size (attachment E).

Insectivores that feed from open ground (sometimes far from cover) formed a major component of the group above. They appeared to respond positively to grass cover, and were more common on flats or lower slopes than on mid or upper slopes (attachment E). They showed the same response to plantation size as the broader group of open-country birds. In contrast, insectivores that feed from open ground among trees appeared to respond positively to elevation and also to the cover of small branches left from thinning operations (attachment E).

Birds that take seeds and other food (e.g. galls) at all levels were dominated by a single species, the Crimson Rosella *Platycercus elegans*. They appeared to respond positively to the numbers of living and dead retained trees within the plantations, and negatively to the cover of small shrubs (attachment E).
Positive relationships with numbers of retained hollow-bearing trees were also found for small hollow nesters (attachment E).

Most other models developed were weak, explaining little variance (attachment E).

**Mammals observed during day-time area-searches**

Small groups of Eastern Grey Kangaroos were found sheltering in both plantations and native forest. Other mammal species and their scats or signs were observed too infrequently to comment on their relative abundance in these habitats. Echidnas, Common Wombats, Black Wallabies and introduced European Rabbits, Brown Hares and Red Foxes were all recorded from plantation sites. Brown Hares were observed more often than European Rabbits in this study, and all records came from plantations and open farmland, not from native forest.

**Mammals and nocturnal birds observed at night**

Data from spotlighting and call-back surveys showed that arboreal mammals (Koala, possums and gliders) were extremely scarce in plantations (Table 4 and Table 5 respectively). Nevertheless, four species were recorded making some use of plantations: many of the observations were of animals seen off the marked transects or outside the formal survey periods. In the central west, Koalas were encountered as commonly in plantations as in native forest. Common Brushtail Possums were also found in plantations at a number of sites. Mountain Brushtail Possums were found in one eucalypt plantation site in a high rainfall area close to native forest in north-east Victoria. Common Ringtail Possums were found at a few plantation sites, in very low numbers. Sugar Gliders were observed only in forest sites during this study, although they are known to occupy planted sites elsewhere (e.g. Tower Hill, Suckling and Macfarlane 1983). Greater Gliders and Yellow-bellied Gliders were only observed in extensive forest sites.

Eastern Grey Kangaroos were seen more often in plantations than native forest at night (Table 5), and were often seen feeding in nearby open farmland. Black Wallabies were seen as often in plantations as native forest, whereas Common Wombats were encountered more often in native forest (Table 5).

Table 4. Numbers of nocturnal mammals and birds observed per ten standard sessions of playing owl calls in cleared farmland, eucalypt plantations and native forest in north-east and central-west Victoria, 2004-06. This table includes all individuals seen or heard on-site during playback. Additional species observed off-site included Yellow-bellied Glider *Petaurus australis*, Sugar Glider *P. breviceps*, Koala *Phascolarctos cinereus*, Red Fox *Vulpes vulpes*, Barking Owl *Ninox connivens*, Powerful Owl *N. strenua*, Masked Owl *Tyto novaehollandiae* and Australian Owlet-nightjar *Aegotheles cristatus*, as well as many Southern Boobooks. The owls and arboreal mammals were all in remnant forest near the playback sites, and some were outside the count period.

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific name</th>
<th>Open farmland</th>
<th>Eucalypt plantation</th>
<th>Native forest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bats</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-striped Freetail Bat</td>
<td><em>Tadarida australis</em></td>
<td>0</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Other small bats</td>
<td></td>
<td>0</td>
<td>1.9</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Nocturnal birds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern Boobook</td>
<td><em>Ninox boobook</em></td>
<td>0</td>
<td>0.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Tawny Frogmouth</td>
<td><em>Podargus strigoides</em></td>
<td>0</td>
<td>1.3</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 5. Mean numbers of mammals and birds observed per 10 standard spotlight surveys in cleared farmland, eucalypt plantations and native forest in north-east and central-west Victoria, 2004-06.

<table>
<thead>
<tr>
<th>Species or group</th>
<th>Scientific name</th>
<th>Open farmland</th>
<th>Eucalypt plantation</th>
<th>Native forest $</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arboreal mammals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Brushtail Possum</td>
<td><em>Trichosurus vulpecula</em></td>
<td>0 #</td>
<td>1.8</td>
<td>13.8</td>
</tr>
<tr>
<td>Mountain Brushtail Possum (Bobuck)</td>
<td><em>Trichosurus caninus</em></td>
<td>0</td>
<td>0 ##</td>
<td>3.8</td>
</tr>
<tr>
<td>Common Ringtail Possum</td>
<td><em>Pseudocheirus peregrinus</em></td>
<td>0 #</td>
<td>0.5</td>
<td>5.2</td>
</tr>
<tr>
<td>Greater Glider</td>
<td><em>Petauroides volans</em></td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Yellow-bellied Glider</td>
<td><em>Petaurus australis</em></td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Sugar Glider</td>
<td><em>Petaurus breviceps</em></td>
<td>0</td>
<td>0 ##</td>
<td>0.5</td>
</tr>
<tr>
<td>Koala</td>
<td><em>Phascolarctos cinereus</em></td>
<td>0</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Bats</strong></td>
<td></td>
<td>0.6</td>
<td>0.3</td>
<td>1.9</td>
</tr>
<tr>
<td>White-striped Freetail Bat</td>
<td><em>Tadarida australis</em></td>
<td>0.6</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Other small bat</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Ground-dwelling large native mammals</strong></td>
<td></td>
<td>0.6</td>
<td>3.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Common Wombat</td>
<td><em>Vombatus ursinus</em></td>
<td>0</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Black Wallaby</td>
<td><em>Wallabia bicolor</em></td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td><em>Macropus giganteus</em></td>
<td>0</td>
<td>2.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Unidentified macropod</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Introduced mammals</strong></td>
<td></td>
<td>3.0</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Red Fox</td>
<td><em>Vulpes vulpes</em></td>
<td>0.5</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>European Rabbit</td>
<td><em>Oryctolagus cuniculus</em></td>
<td>1.9</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Brown Hare</td>
<td><em>Lepus europaeus</em></td>
<td>0.6</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Sambar Deer</td>
<td><em>Cervus unicolor</em></td>
<td>0</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Nocturnal birds</strong></td>
<td></td>
<td>0</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Southern Boobook</td>
<td><em>Ninox boobook</em></td>
<td>0</td>
<td>0 ##</td>
<td>1.0</td>
</tr>
<tr>
<td>Australian Owlet-nightjar</td>
<td><em>Aegotheles cristatus</em></td>
<td>0</td>
<td>0.2</td>
<td>0</td>
</tr>
</tbody>
</table>

$ All of these species and some others (notably Barking Owl *Ninox connivens* and Masked Owl *Tyto novaehollandiae*) were observed in remnant forest in the study region close to sites.

# This excludes a record of 3 Common Ringtail Possums in retained trees on the edge of a cleared site.

## Mountain Brushtail Possums were recorded in a eucalypt plantation close to one of the sites, adjacent to native forest. Sugar Gliders have been observed in non-commercial plantations elsewhere, but not in this study. Southern Boobooks were occasionally found by day, roosting in eucalypt plantations.

**Bats**

Bat calls were recorded by ultrasonic bat detectors at almost every site (Table 6). Forest sites produced more calls per night than plantations, and there were more calls per night from plantations than open farmland. At least 15 species were identified, and all appeared to be making use of plantation sites for feeding (Table 6). The most commonly identified species in plantations were Long-eared Bats *Nyctophilus geoffroyi* or *N. gouldi*, and Little Forest Bats *Vespadelus vulturnus*.

Bats were observed at many sites during spotlighting surveys (Table 5), with the calls of White-striped Freetail Bats *Tadarida australis* often heard: this is the only local species whose call is audible to humans.
Table 6. Bat calls detected or identified in farmland, eucalypt plantations and native forest in north-east and central-west Victoria, 2004-06. Data on species are calls identified per site (2 nights detection), using automated species-recognition software. Further checking of specific identifications is planned as part of continuing software development. Note that species with distinctive calls may be over-represented in the sample of calls identified.

<table>
<thead>
<tr>
<th>Broad habitat:</th>
<th>Farm</th>
<th>Plantion</th>
<th>Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average calls detected per night</td>
<td>58.71</td>
<td>113.72</td>
<td>182.62</td>
</tr>
<tr>
<td>Total calls identified per site</td>
<td>31.84</td>
<td>30.86</td>
<td>50.50</td>
</tr>
<tr>
<td>Gould's Wattled Bat</td>
<td>Chalinolobus gouldii</td>
<td>1.50</td>
<td>2.29</td>
</tr>
<tr>
<td>Gould’s Wattled Bat or Inland Broad-nosed Bat</td>
<td>Chalinolobus gouldii / Scotorepens balstoni</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>Gould’s Wattled Bat or Southern Free-tailed Bat (long penis form)</td>
<td>Chalinolobus gouldii / Mormopterus (lp)</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Chocolate Wattled Bat</td>
<td>Chalinolobus morio</td>
<td>0.80</td>
<td>1.73</td>
</tr>
<tr>
<td>Chocolate Wattled Bat or Little Forest Bat</td>
<td>Chalinolobus morio / Vespadelus vulturnus</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Chocolate Wattled Bat or Common Bent-wing Bat</td>
<td>Chalinolobus morio / Miniopterus schreibersii</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>Eastern False Pipistrelle</td>
<td>Falistrellus tasmaniensis</td>
<td>0.09</td>
<td>0.48</td>
</tr>
<tr>
<td>Eastern False Pipistrelle or Eastern Broad-nosed Bat</td>
<td>Falistrellus tasmaniensis / Scotorepens orion</td>
<td>0.05</td>
<td>0.18</td>
</tr>
<tr>
<td>Common Bent-wing Bat</td>
<td>Miniopterus schreibersii</td>
<td>0.55</td>
<td>0.96</td>
</tr>
<tr>
<td>Common Bent-wing Bat or Little Forest Bat</td>
<td>Miniopterus schreibersii / Vespadelus vulturnus</td>
<td>0.59</td>
<td>0.62</td>
</tr>
<tr>
<td>Southern Free-tailed Bat (long penis form)</td>
<td>Mormopterus sp.(lp)</td>
<td>1.86</td>
<td>1.44</td>
</tr>
<tr>
<td>Eastern Free-tailed Bat</td>
<td>Mormopterus sp.(sp2)</td>
<td>0.23</td>
<td>0.04</td>
</tr>
<tr>
<td>Eastern Free-tailed Bat or Inland Broad-nosed Bat</td>
<td>Mormopterus sp.(sp2) / Scotorepens balstoni</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Large-footed Myotis</td>
<td>Myotis macropus</td>
<td>0.34</td>
<td>0.47</td>
</tr>
<tr>
<td>Large-footed Myotis or Long-eared Bat sp.</td>
<td>Myotis macropus / Nyctophilus gouldii/geoffroyi</td>
<td>0.09</td>
<td>0.33</td>
</tr>
<tr>
<td>Long-eared Bat sp.#</td>
<td>N.geoffroyi/gouldi</td>
<td>4.02</td>
<td>5.31</td>
</tr>
<tr>
<td>Long-eared Bat sp. or Southern Forest Bat (low frequency call form)</td>
<td>Nyctophilus gouldi / Vespadelus regulus (LF)</td>
<td>0.09</td>
<td>0.35</td>
</tr>
<tr>
<td>Inland Broad-nosed Bat</td>
<td>Scotorepens balstoni</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>Eastern Broad-nosed Bat</td>
<td>Scotorepens orion</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>(Yellow-bellied Sheathtail Bat ??)##</td>
<td>Saccolaimus flaviventris</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>White-striped Free-tailed Bat</td>
<td>Tadarida australis</td>
<td>14.82</td>
<td>0.92</td>
</tr>
<tr>
<td>Large Forest Bat</td>
<td>Vespadelus darlingtoni</td>
<td>0.64</td>
<td>1.76</td>
</tr>
<tr>
<td>Large Forest Bat or Southern Forest Bat (low frequency call form)</td>
<td>Vespadelus darlingtoni / regulus (LF)</td>
<td>1.00</td>
<td>4.13</td>
</tr>
<tr>
<td>Southern Forest Bat (high frequency call form)</td>
<td>Vespadelus regulus (HF)</td>
<td>0.61</td>
<td>2.94</td>
</tr>
<tr>
<td>Southern Forest Bat (low frequency call form)</td>
<td>Vespadelus regulus (LF)</td>
<td>0.00</td>
<td>0.35</td>
</tr>
<tr>
<td>Southern Forest Bat (low frequency call form) or Little Forest Bat</td>
<td>Vespadelus regulus (LF) / vulturnus</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Southern Forest Bat (low frequency call form) or Common Bent-wing Bat</td>
<td>Vespadelus regulus (LF) / Miniopterus schreibersii</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Little Forest Bat</td>
<td>Vespadelus vulturnus</td>
<td>4.02</td>
<td>5.79</td>
</tr>
</tbody>
</table>

# Calls of Lesser Long-eared Bat Nyctophilus geoffroyi and Gould’s Long-eared Bat N. gouldi cannot be distinguished with current technology.
## Yellow-bellied Sheathtail Bats Saccolaimus flaviventris are rare visitors to Victoria (Menkhorst 1995) and this identification is considered very provisional pending closer examination of the call signatures.
Mammals detected from hair-tubes

Five native mammal species (Brush-tailed Phascogale *Phascogale tapoatafa*, Agile Antechinus *Antechinus agilis*, Common Wombat *Vombatus ursinus*, brushtail possum *Trichosurus sp.*, and Black Wallaby *Wallabia bicolor*), and one introduced species (House Mouse *Mus musculus*) were identified from hair-tube samples (Table 7). Hair from the brushtail possums could not be distinguished between the two possible species (Common Brushtail *T. vulpecula* and Mountain Brushtail *V. caninus*), both of which were recorded from different sites during spotlighting. Introduced predators were also detected, but could not be identified to species level. Brush-tailed Phascogales were detected at one forest site in north-east Victoria. Agile Antechinus was detected at five forest sites and two plantation sites, and House Mouse was recorded at two plantation sites.

Table 7. Mammals identified from hair-tube samples from farmland, eucalypt plantations and native forest in north-east and central-west Victoria, 2004-06. Samples were collected from study sites in eucalypt plantations and remnant forest patches in north-east and central-west Victoria, 2005-06.

<table>
<thead>
<tr>
<th>Species name</th>
<th>Scientific name</th>
<th>Plantations (n=58)</th>
<th>Forest (n=17)</th>
<th>% Proportion of sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brush-tailed Phascogale</td>
<td><em>Phascogale tapoatafa</em></td>
<td>0</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Agile Antechinus</td>
<td><em>Antechinus agilis</em></td>
<td>5.2</td>
<td>29.4</td>
<td></td>
</tr>
<tr>
<td>Common Wombat</td>
<td><em>Vombatus ursinus</em></td>
<td>6.9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Brushtail Possum</td>
<td><em>Trichosurus sp.</em></td>
<td>15.5</td>
<td>29.4</td>
<td></td>
</tr>
<tr>
<td>Black Wallaby</td>
<td><em>Wallabia bicolor</em></td>
<td>5.2</td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td>House Mouse</td>
<td><em>Mus musculus</em></td>
<td>3.4</td>
<td>0</td>
<td></td>
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<tr>
<td>unidentified rodent</td>
<td></td>
<td>1.7</td>
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<tr>
<td>Introduced predator (feral</td>
<td><em>Felis catus</em> or</td>
<td>10.3</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>cat or fox)</td>
<td><em>Vulpes vulpes</em></td>
<td></td>
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</table>

# In addition to the records above, a probable record of Koala *Phascolarctos cinereus* came from one of the plantation sites. The records of unidentified rodents from plantation sites were considered to be probable House Mouse *Mus musculus* and *Rattus* sp. respectively.

Retrospective or Benchmark Studies elsewhere (Wimmera, Volcanic Plains near Lismore, Werribee Plains, Bacchus Marsh and the Green Triangle of south-western Victoria and south-eastern South Australia)

Progress or final reports on some of these studies are attached (attachments A-D). The following are some of the main new points that emerge:

- Old plantations can be very attractive for a wide range of nectar-feeding honeyeaters and lorikeets. Several species that usually inhabit mallee or arid regions were found in blocks of plantations in the Wimmera, e.g. White-fronted Honeyeater *Phylidonyris albifrons* (attachment A).
- Blocks of old plantations in the Wimmera supported high populations of forest birds, whereas linear shelterbelt plantations were mainly dominated by open-country bird species.
- Old plantations can provide abundant supplies of hollows and coarse woody debris. This was especially evident in the Lismore study, where stands of Sugar Gum aged 60-80 years contained more hollows than remnant forest, and attracted numerous hollow-dependent birds, bats and Common Brushtail Possums (attachment B).
- Despite the abundance of hollows, treecreepers were absent from most of the old plantations examined, just as they had been from most young plantations examined in our initial work.
This supports the suggestion that their rarity or absence from plantations relates to their liking for rough-barked eucalypts, not just to lack of hollows.

- Notwithstanding the comment above, small numbers of Brown Treecreepers *Climacteris picumnus* were found in old plantations in the Wimmera, foraging from coarse woody debris on the ground as well as from trunks of old planted trees.

- When plantations are established in intensive agricultural areas with little remaining forest, they will support higher proportions of open-country birds, introduced birds and invasive native birds (e.g. Noisy Miners) than found in our initial work. This is mainly because of the context, but also because of the long narrow geometry of shelterbelt plantations. Such plantations can play an important role in providing habitat for native open-country birds, most of which rely on tree or shrub cover for shelter, roosting and nesting.

- Cover of tall shrubs was distinctly lacking from most of the old shelterbelt plantations examined. Some of them contained a cover of low shrubs but species that inhabit shrub layers were generally scarce. This contrasts with results of our initial work, which showed that some birds that inhabit shrub layers were common in young commercial plantations, using the young eucalypts as if they were shrub thickets.

- The studies near Bacchus Marsh showed little difference in bird populations between commercial and Landcare plantations of equivalent young age (attachment C). This reinforces the idea that the main difference between these two types of plantation lies in their future management: commercial plantations will be harvested when relatively young while Landcare plantations may be allowed to grow old.

- The studies in the Green Triangle have confirmed most of our other results, and highlighted some major differences between the fauna communities of eucalypt and pine plantations (attachment D). The continuing work on embedded remnants is expected to deliver important new information, testing the hypothesis that plantations may serve a valuable role in protecting valuable patches of remnant forest.

### Use of plantations by rare, declining or threatened fauna species

Anecdotal information has been collected suggesting that many rare, declining or threatened species will make use of plantations in some circumstances. Usually this involved plantations established for conservation purposes, rather than commercial plantations. However, we have a report of the endangered Squirrel Glider *Petaurus norfolcensis* being seen in commercial irrigated eucalypt plantations of River Red Gum *Eucalyptus camaldulensis* near Shepparton (D. Stackpole, pers. comm.). The location was close to a creek with mature River Red Gums, which constitutes a more typical habitat and the likely source of hollows for this hollow-dependent species. Other anecdotal records refer to Chestnut-rumped Heathwrens *Hylacola pyrrhopygia* in farm plantations near Wodonga (D. Tonkinson pers. comm.) and Brolgas *Grus rubicunda* nesting in a wetland surrounded by Blue Gum plantations in south-western Victoria.

In our own work, we found at least two declining woodland bird species that may have benefited locally from plantation establishment. Brown Treecreepers were mentioned above, and were found feeding in old Sugar Gum plantations near Wail in the Wimmera. Speckled Warblers *Chthonicola sagittata* were found at the White Elephant Reserve near Bacchus Marsh, which was substantially revegetated in the 1950s after previous clearing. The Speckled Warblers were using patches of remnant vegetation, but aerial photographs of the reserve in the early 1950s (R. Hartland pers. comm.) show that it was much too exposed at the time to be likely to support this species. Speckled Warblers have also been seen in extensive non-commercial eucalypt plantations in the You Yangs, between Bacchus Marsh and Geelong (pers. obs.), and landholders have reported the species using Landcare plantations on their properties. Several species that are not as rare, but are believed to be declining, were encountered on plantations during the study: examples include Scarlet Robin *Petroica multicolor* and Buff-rumped Thornbill *Acanthiza reguloides*. Parallel work by Kavanagh et al. (2007) also showed that eucalypt plantations can provide habitat for declining woodland birds in north-east Victoria and southern New South Wales.
The current study produced records of a number of fauna species that are listed as threatened in Victoria, including Barking Owl, Powerful Owl and Masked Owl. However, these were recorded in remnant forest and not in plantations.

Some threatened species have benefited from deliberate revegetation work to restore habitat, but this differs from the sort of plantation that is the main subject of our study. Grey-crowned Babblers *Pomatostomus temporalis* are an example, with extensive habitat restoration work undertaken near Violet Town in north-east Victoria (D. Robinson pers. comm.) for this species which is endangered in Victoria.
Discussion

The study shows that plantations of all sorts can provide habitat for native birds and mammals, including species associated with forests, woodlands and open country. Similar conclusions were reached by Hobbs et al. (2003, working in south-western Australia), Law and Chidel (2002, 2006, working in NSW) and Kavanagh et al. (2007, working in north-east Victoria and NSW). Our initial work concluded that their value for birds will depend mainly on on-site habitat variables rather than context variables (Loyn et al. 2007), whereas Kavanagh et al. (2007) identified a stronger role of context variables. The difference may owe much to the narrow range of context variables considered in our initial work in north-east and central-west Victoria. When we extended our work to more open landscapes in south-western Victoria, landscape variables came into their own: plantations in these situations were more important for open-country species, and less important for forest and woodland species, than the plantations considered in our initial work.

The two studies also differed in their conclusions about plantation size. Our work suggested a relatively minor role of this variable, although we did not stratify sites by size and hence our data had limited power to examine that variable. We did find that open-country birds preferred plantations larger than 5 ha (a threshold to provide the necessary cover) and smaller than 20 ha (above which much of the plantation would have been well separated from the open country that sustains these species). Kavanagh et al. (2007) found that many species responded positively to patch size, in similar fashion to the response of forest and woodland birds to patch size of remnant forest (Loyn 1987; Barrett et al. 1990).

The experimental study of shrub configurations did not reveal any significant effects of the experimental treatments. This is partly because the plantations were still young (2-4 years) and growth had been slowed by the drought, and the plantations are likely to support more fauna when they have developed further over the next few years. That will be the time to reassess the fauna populations, perhaps more intensively than we have done so far, and hopefully make more definitive statements about any differences between shrub treatments. This will be valuable, as no other studies appear to have investigated this aspect. But in the meantime, the retrospective component of the study has shed a different light on the need for these shrub treatments. Young eucalypt plantations have a shrubby growth form and it emerge that many shrub-foraging bird species used them as if they were shrub thickets. The bird species missing or rare from young eucalypt plantations were not shrub-foragers but small hollow nesters (not surprisingly, as there were no hollows unless old trees had been retained) and especially one group of small hollow-nesters, the treecreepers. Treecreepers generally choose to forage from rough-barked eucalypts such as stringybarks or box species in preference to smooth-barked gums or the few deeply furrowed rough-barked species that are sometimes planted commercially (Swamp Yate and Red Ironbark Eucalyptus tricarpa). Commercial plantations cannot be expected to provide habitat for these species unless changes are made both to the mix of species planted and to the strategies employed for retaining old trees, growing selected trees to old age or providing artificial hollows (nest-boxes).

Large hollow-nesting birds made substantial use of plantations in our study, reflecting their mobility in the landscape and hence their capacity to access hollows at some distance from the plantations or other habitats where they were feeding. Nevertheless, our models showed that their numbers were positively related to the numbers of old trees retained within the plantation, and clearly these and other hollow-dependent species will benefit from such retention.

Hollow-dependent arboreal mammals (possums and gliders) were also notable by their rarity in young plantations, where they were mainly found close to remnant forest. It is possible that some plantations in farmland were too far from forest to be colonised by these species, even if the habitat was suitable. Common Ringtail Possums can build their own nests (dreys) in shrub thickets, but in many areas they need hollows for daytime shelter. Similarly, Common Brushtail Possums readily shelter in buildings, and in New Zealand they will shelter in burrows made by European Rabbits: however, in most parts of Australia away from the built environment they essentially depend on hollows in trees. Plantation
managers may be unwilling to encourage possums, because they include eucalypt foliage in their diet (as does the Koala, which does not use hollows). However, there seems to be no reason not to encourage Sugar Gliders or Brush-tailed Phascogales, with insects and nectar forming a substantial part of their diet in both cases. This would have to involve provision of hollows (in retained trees or nest-boxes) and attention to connectivity so that these species could colonise new habitat provided in plantations.

Our supplementary studies in old plantations in south-west Victoria provide an important new perspective on various questions, including the contentious issue of hollow management. Shelterbelts of Sugar Gums aged 60-80 years contained abundant hollows, and supported high populations of hollow-dependent fauna. The larger hollow-dependent species such as Common Brushtail Possums were still more numerous in stands aged over 100 years, but stands aged 60-80 years appeared to have adequate hollows for many of these species. Some of the literature on hollows has suggested a longer time-scale for useful hollow formation, in the order of 100-200 years (e.g. Mackowski 1984; Wormington and Lamb 1999; Gibbons et al. 2002; Whitford 2002). This may be true in some situations, but the present evidence suggests that useful hollows will form within 60-80 years if not sooner in shelterbelts of Sugar Gum. This may be partly influenced by the evident propensity of the species to form hollows, but it may also be influenced by the exposure of these stands, rendering them susceptible to wind damage that can initiate a chain of processes leading to hollow formation (L. Veering pers. comm.).

**Implications: developing appropriate designs for plantations to contribute to biodiversity conservation objectives**

Using data from all our studies above, and those from our colleagues, the following general guidelines can be offered to help make current and future plantations achieve enhanced outcomes for biodiversity conservation, at the same time as meeting a range of commercial and conservation objectives. This represents a substantial opportunity that is likely to increase with the recent and expected growth of plantation establishment for managed investment schemes and carbon-trading.

**Position in landscape in relation to remnant forest**

There are two theoretical reasons why new plantations should be located close to existing patches of remnant forest (Figure 5) (where there is a choice), in order to enhance their contribution to biodiversity conservation. Firstly, such plantations are more likely to be colonised by a wide range of forest fauna, while plantations that are remote from remnant forest may be colonised more slowly or not at all by some species. Secondly, such plantations may serve a useful role in protecting adjacent patches of remnant forest from a range of threatening processes. These processes include excessive grazing by stock (common when small forest patches remain unfenced in pasture, attracting sheep and cattle to shelter among the trees), invasion by aggressive Noisy Miners *Manorina melanochepala*, and forms of dieback resulting from those degradations. Dieback can be a product of reduced predation on insects when Noisy Miners expel small insectivorous birds (Dow 1977; Loyn 1987; Grey et al. 1997, 1998). Our study shows that commercial plantations are not usually colonised by Noisy Miners, supporting the idea that they can help buffer remnant forest patches. Evidence from Gippsland shows that species may be lost from small patches of remnant forest at a greater rate when they are exposed in farmland than when they are in landscapes featuring many new eucalypt plantations (MacHunter et al. 2006): this hypothesis is being investigated further.
Figure 5. Plantations may be able to perform a useful role in protecting edges of adjacent forest

Where plantations are established far from remnant forest, they can still perform a positive role, but the role will be different. They may become very useful in providing habitat for open-country species and some highly mobile forest and woodland bird and bat species, enabling them to occupy parts of the landscape that were previously not available to them. An example concerns Flame Robins *Petroica phoenicea*, which we found to use plantations both for feeding and roosting while they were spending the winter season on the plains. Much of their feeding was done in open paddocks, but the presence of plantations was clearly a positive factor enabling them to use the general area.

A possible negative factor should be mentioned in locating plantations close to valuable existing habitats. Plantations use water, and can have substantial and complex impacts on the local hydrology. If a particular habitat is sensitive to hydrological change (e.g. a wetland), it would seem unwise to establish plantations in close proximity. This was not an aspect we examined in this study, and we have heard conflicting reports about changes to wetlands embedded in plantations.

The main message from all the above is that an integrated approach is needed to planning the landscape, with plantations being one element that regional planners should consider in helping meet biodiversity conservation objectives.

**Position in landscape in relation to landform**

Plantations in gullies are more likely to attract high populations of birds and mammals than plantations on ridges, in line with expectations for native forest (Loyn *et al.* 1980; Mac Nally *et al.*, 2000; Palmer and Bennett, 2006). However, some species will prefer ridges, so it is important to make planning decisions with a good knowledge of the habitats that are represented, over-represented or under-represented in a particular landscape. It will be counter-productive to establish new plantations on parts of the landscape that were never wooded, especially if they contain valuable treeless habitats such as native grassland.
Size

Kavanagh et al. (2007) concluded that large plantations were likely to be better for forest or woodland birds than small plantations. This relationship was less clear in our study, but we did conclude that open-country birds would benefit from having plantations established above a certain threshold (5-10 ha) but below a higher value (~20 ha) where much of the plantation was physically removed from adjacent farmland. Hobbs et al. (2003) found that some species were more likely to be found close to the plantation edge (and hence would benefit from many small plantations) while other species showed a tendency to avoid edges (and hence would benefit from fewer large plantations). We did not stratify sites by plantation size or distance from edge in the results reported here. However, we have done that in the Green Triangle and expect to be able to make further contributions to this discussion.

Shape

Our results revealed little effect of plantation shape for young plantations. Most of the old plantations available for study were linear shelterbelts, but some old plantation blocks were examined in the Wimmera, and a marked contrast was evident. The plantation blocks supported high populations of forest and woodland birds, and the fauna was dominated by forest and woodland species. In contrast, the linear shelterbelts in the Volcanic Plains and the Werribee Plains supported much lower populations of forest and woodland species and were heavily dominated by open-country species, including some aggressive honeyeaters such as Noisy Miners. The message is clear: if plantations are established with the intention of allowing them to grow old, with the aim of providing habitat for forest and woodland fauna species, they should be established as blocks not linear strips.

Of course, there may be other reasons for establishing linear strips, including the common aims of providing windbreaks and shade or shelter for stock. These ecosystem services will be provided more efficiently by linear plantations, along with others such as providing shelter, roosting and nesting habitat for birds and bats that feed in open country. But many ecosystem services will be provided more efficiently by blocks, including habitat for forest and woodland fauna. Blocks will also provide less competition for resources (moisture and sunlight) with adjacent pasture or crops, as there will be less edge.

Connectivity and harvesting pattern

Many people question the wisdom of providing habitat for wildlife in plantations when the habitat will only be ephemeral, especially when commercial plantations are managed on short rotations. This is less of a problem for mobile species such as birds and bats than it is for more sedentary species such as mammals, reptiles or frogs. In this study we assessed the use of plantation by species that had succeeded in colonising them, so the story we tell already takes this into account. But there is more to be learned on the subject. One of the fauna groups that proved particularly scarce in plantations was the arboreal mammals (apart from Common Brushtail Possums and Koalas, which often roam far across cleared land). Most of the other arboreal mammals seen were close to native forest. It may be very hard for gliders and other arboreal mammals to access new habitat in plantations unless it is close to existing habitat in remnant forest.

When small plantations are harvested, their resident fauna will either move away or die, unless part of the plantation can be left unharvested for a few years. Movement in and out of small plantations will be facilitated (for the less mobile species) if they are adjacent to networks of interconnected existing habitat. With large plantations, the issue can be addressed by staggering planting and harvesting schedules so that they are dispersed in space and time. In this way, alternative habitat at a suitable stage of development will always be accessible to animals inhabiting a coupe that is scheduled for harvesting. As far as the population is concerned, it may not matter whether the resident adults make the move, or the new habitat is colonised by their dispersing progeny. Adults of some species such as Greater Gliders Petauroides volans are known to be very reluctant to move from established territories even when the habitat is destroyed (Tyndale-Biscoe and Calaby 1975), although the species is well capable of colonising new habitat over time, such as forest regenerating from wildfire. (Note that Greater Gliders are not known to forage in young regrowth, and are unlikely to occur in commercial eucalypt plantations.)
No species will be able to colonise plantations unless two conditions are met: firstly the plantations must provide suitable habitat, and secondly they must be accessible to source populations. Locating plantations close to remnant forest is the main strategy for meeting the second condition.

In the longer term, there may be opportunities for using plantations to improve connectivity between habitat patches in the landscape. For example, strips of forest could be planted to connect existing patches of remnant forest within large plantations or farmland. If these connections were to be left unharvested, they could be planted with indigenous species that might not be used in parts of the plantation estate where commercial management was the priority.

**Rotation times**

Long rotations are unlikely to be economically sensible in commercial plantations, though this depends on growth rates and intended products (e.g. 10-15 years for pulpwood, 25-30 years for sawlogs and 15 years staggered coppice for firewood). But some plantations are established for mixtures of purposes, including provision of ecosystem services such as windbreaks, shelter for stock or biodiversity conservation. On large farm properties or extensive plantation estates it may be feasible to manage some plantations on long rotations, perhaps with proportions of the trees harvested at different times and allowed to coppice for production of firewood. If rotations exceed 60-80 years in selected stands there may be a biodiversity dividend in terms of hollow formation, based on our observations with old Sugar Gum plantations.

**Tree species**

Most of the tree species planted for commercial purposes are smooth-barked gums (Blue Gum, River Red Gum, Sugar Gum, etc.). These do not provide good habitat for treecreepers, especially in the time-frame of a commercial rotation. It could be expected that many species of bark-dwelling invertebrate and perhaps some arboreal mammals would be similarly disadvantaged. Some rough-barked species are planted locally (e.g. Swamp Yate and Red Ironbark) but even they seem less useful for bark-foraging birds than the stringybark and box species that dominate the natural vegetation over much of south-eastern Australia. If habitat restoration is an important primary or secondary aim of plantation establishment, it will be important to include a range of tree species, preferably reflecting the natural occurrence of species in the original vegetation. Where plantations are managed mainly for commercial purposes, it should be recognised that some fauna species (with treecreepers and arboreal mammals being good examples) will rely on remnant forest for their regional conservation.

Tree species diversity also has major implications for the seasonal supply of nectar. Most of the commercially grown tree species are good nectar producers, and may attract large flocks of mobile honeyeaters when they flower: some such as Sugar Gum also attract flocks of lorikeets. This was well illustrated through our study. But plantations of a single species cannot produce sustained supplies of nectar at all seasons. A diversity of nectar-producing trees is needed in the landscape to support year-round populations of those species. Mammals such as Sugar Gliders can rely on a wide range of food sources other than nectar, but could well be disadvantaged by the limited season of nectar production in single-species tree plantations.

**Shrubs**

Shrubs are often seen as a key habitat element missing from commercial plantations. Many bird and mammal species inhabit shrub layers, and some show strong preferences for foraging in particular shrub species. For example, Yellow Thornbills favour wattles such as Black Wattle *Acacia mearnsii*, and wattles of this form (tall shrub or small tree) are attractive to many bird species in native forests (Loyn 1985) and also to Sugar Gliders. It is highly likely that the habitat value of plantations would be improved by including tall and low shrubs in the species mix. Nevertheless, our experimental plantations did not provide supporting evidence, within the four years from plantation establishment.
Cover of low shrubs emerged as a positive variable in some of the models developed in the retrospective study (attachment E).

Shrub-foraging birds did prove to be scarce in the old plantations we examined, including the old shelterbelts in the Volcanic Plains and the Werribee Plains. If shrub layers could be added to those old plantations, it is likely that their value for forest and woodland fauna could be improved. But that is not a simple task, because most shrub species have much shorter life-spans than the trees. The ideal solution would be to establish a self-perpetuating understorey, with shrubs maturing and reproducing below the eucalypt canopy. This may happen naturally in some cases, but not in others where fire or other disturbance is needed to promote effective regeneration.

Perhaps the best way of producing a natural shrub understorey is to encourage natural regeneration. This will be cheaper than planting, and may include more appropriate mixtures of local species. However, we recognise that shrubs may compete with trees and present fire hazards and logistical difficulties, especially when plantations are managed intensively. But if compromise positions can be identified locally (e.g. leaving natural or planted understorey in selected rows, belts or blocks that remain unharvested) they may be of value.

**Hollows**

Tree hollows were missing from all the young plantations examined, except in a few cases where original old trees had been retained. This was reflected in low abundances of arboreal mammals, bats and small hollow-dependent birds in our studies. Large hollow-dependent birds were not as adversely affected, because they were highly mobile and able to access hollows elsewhere in the broader landscape.

However, the old plantations we examined proved to contain abundant hollows, and correspondingly high populations of hollow-dependent fauna. This was evident with Sugar Gums even in the 60-80 year age-class, often considered too young to produce useful hollows.

Hollows will clearly not form within the usual commercial rotations of 10-30 years. Hence conservation of hollow-dependent fauna will need to be based mainly on protection and recruitment of hollow-bearing trees outside those commercial plantations. Protection of hollow-bearing trees where they exist within plantations also deserves high priority. Production of new hollows through specially designed plantations may be a more realistic proposition than would have been thought if previous estimates of times to hollow formation (100-200 years) had been taken as universally true.

Another option would be to provide artificial hollows (nest-boxes) within the plantations. This could have benefits for production by attracting insectivorous species of bird, bat or arboreal mammal. Note that some hollow-dependent birds can be very effective at controlling insect outbreaks in some situations: this can be the case even when they are not classed as insectivores, as with Crimson Rosellas *Platycercus elegans* and Eastern Rosellas *P. eximius* feeding on lerps (Loyn et al. 1983).

**Parasitic plants**

Several plant species are favoured by fauna but were notable by their absence from most of the plantation sites we examined. Mistletoes are one example, and they are a major source of nectar and fruit for honeyeaters and Mistletoebirds *Dicaeaum hirundinaceum*. Mistletoes were common in the old plantations we examined in the Wimmera, and in Landcare plantations of Silver Wattles *Acacia dealbata* and other species we examined beside the Yarra River in Melbourne (pers. obs.). Mistletoes on eucalypts are seen as undesirable for commercial production, but there may be ways of encouraging growth of mistletoes on non-commercial species and more generally in non-commercial plantations. The semi-parasitic Cherry Ballart *Exocarpos cupressifolius* may be in a similar category: it is a valuable source of fruit for birds and mammals, and appears hard to establish in plantations. Some special efforts may be warranted to improve representation of species of this sort in selected plantations where biodiversity conservation is seen as an important objective.
Recommendations

Our main recommendation is that biodiversity should be considered by conservation planners and land managers in making decisions about plantation establishment in the landscape. We have shown that commercial plantations can and do perform a dual role: they provide an economic product, but even without targeted management they also provide habitat for a wide range of fauna species. There is scope for enhancing their contribution, especially if this is considered early at the planning stage. There are good reasons why such enhancements should be considered in some situations, especially where public investment is involved or biodiversity conservation is an accepted objective. Following from this recommendation, there will be a continuing need to convey information such as the results of this study to policy makers, rural planners and plantation managers, so that they make best use of the plantations that will continue to be established.

Our second set of recommendations concerns the detail of how to enhance their value for biodiversity conservation. Most of these were presented above under Implications. In order of priority, we suggest:

- Retaining patches of remnant forest and individual old trees
- Encouraging new plantations to be located close to remnant forest
- Encouraging new plantations to be located in parts of the landscape where there is a need for restoration of wooded habitats
- Planning planting and harvesting cycles to produce or retain as much connectivity as possible in the broader landscape
- Planting blocks not strips where possible, if it is intended to encourage forest or woodland fauna species
- Including some rough-barked stringybark or box species where possible
- Allowing natural or planted understorey to develop in parts of the plantation, e.g. selected rows, blocks or belts
- Encouraging selected special plant species, including mistletoes and Cherry Ballart, where possible
- Adding artificial hollows in the form of nest-boxes

Our third set of recommendations is that we still need more information to help improve plantation planning and management, and to inform public policy on the issues. The following further studies would help provide such information, building on current work:

- Study of embedded patches of remnant forest and the role of plantations in protecting them (Aspects of this are under way in the Green Triangle.)
- Meta-analysis of all aspects of the present study (planned for 2008)
- Intensive assessment of the experimental sites established in this study, when the plantation trees have developed fuller canopy cover (perhaps in 2009/10)
- Further studies on the retrospective sites to assess their development over time, to assess their response to any breaking of the drought, and to determine more about how selected animal species actually use the plantations for feeding, nesting, roosting, etc.
- Studies of vegetation and invertebrates in some of the retrospective sites
- Studies of nest boxes placed at different densities and spatial arrangements in extensive plantations. (This would also have application for native forest management.)
References


Appendix 1

Bird species observed on-site during 220 timed area-searches (10 minutes, 1 ha) in north-east and central-west Victoria, south-eastern Australia, in spring-summer and winter 2003-05. Also shown are the mean abundances of each species in cleared land (25 sites), eucalypt plantations (58 sites) and remnant native forest (22 sites), expressed as birds observed per 100 counts. Also shown are the guilds to which each species was assigned for further analysis. The habitat group has four levels (F=forest or woodland bird; G=generalist; O=open-country bird; W=water bird). The feeding guild has single levels for frugivores (F), nectarivores (N), carnivores (V, taking vertebrates as a major part of their diet) and water birds (W), and two levels for seed-eaters (SG=mainly takes seeds close to the ground, and ST=takes seeds and other food at many levels, often high in trees). Insectivores are the most diverse component of the fauna, and are considered as seven guilds, depending on whether they feed mainly from open air (A), bark (B), eucalypt canopy (C), damp ground below cover (DG), open ground, sometimes far from cover (OG), open ground among trees (OT), tall shrubs (TS) or low understorey (U). The groups DG and U were combined in this study (as birds feeding from understorey or the damp ground below shrub cover). The nesting guild distinguishes species that nest mainly in burrows in the ground (B), on the ground surface (G), in large or medium sized tree hollows (LH), in small tree hollows (SH), in open hollows or ledges on trees or buildings (L), as brood parasites in other birds’ nests (BP) or in normal nests on branches of trees or shrubs (N). The migrant guild distinguishes summer migrants (S, predictably rare or absent from these regions for a period each winter), winter migrants (W, vice versa) and species that do not show such marked migratory patterns in the region (N). The status guild distinguishes species introduced to Australia (I), uncommon native species (U, <850 records in Emison et al. 1987) and other native species (N).

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<th>Scientific name</th>
<th>Mean individual birds per 100 counts</th>
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